ESD-TR-76-162, Vol. III

MTR-3066, Vol. III

MAC AIR CARGO DATA ENTRY:
3. INITIAL TESTING OF ON-LINE TERMINAL, DIGITAL RECORDER, AND CHECKSHEET

AUGUST 1976

Prepared for

DEPUTY FOR COMMAND AND MANAGEMENT SYSTEMS
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Hanscom Air Force Base, Bedford, Massachusetts

Project No. 515B

Prepared by
THE MITRE CORPORATION
Bedford, Massachusetts

Contract No. F19628-76-C-0001

Approved for public release, distribution unlimited

REVIEW AND APPROVAL

This technical report has been reviewed and is approved for publication.

THOMAS F. BASHARA, GS-12
Project Engineer

ROBERT S. PHILLIPS, Lt Col, USAF
MAC Liaison Office

FOR THE COMMANDER

FRANK J. EMMA, Colonel, USAF
Director, Information Systems
Technology Applications Office
Deputy for Command & Management Systems

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ESD-TR-76-162-Vol. III	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): MAC AIR CARGO DATA ENTRY: 3. INITIAL TESTING OF ON-LINE TERMINAL, DIGITAL RECORDER, AND CHECKSHEET.	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER: MTR-3066-Vol. III
7. AUTHOR(s): S. L. Smith	8. CONTRACT OR GRANT NUMBER(s): F19628-76-C-0001
9. PERFORMING ORGANIZATION NAME AND ADDRESS: The MITRE Corporation, Box 208, Bedford, MA 01730	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Project No. 515B
11. CONTROLLING OFFICE NAME AND ADDRESS: Deputy for Command and Management Systems, Electronic Systems Division, AFSC, Hanscom Air Force Base, Bedford, MA 01731	12. REPORT DATE: AUGUST 1976
	13. NUMBER OF PAGES: 154
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DATA ENTRY
EVALUATION
ON-LINE COMPUTER TERMINAL

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A program evaluating the application of data capture techniques to the entry of shipping data at MAC air cargo terminals is in progress. As a part of this program six airmen from the truck dock of the MAC air cargo terminal at Dover AFB participated at MITRE in tests comparing three alternative modes of data entry: an on-line keypad/display, a digital recorder, and manual checksheets. Data items were entered from

(over)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

235050

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. Abstract (continued)

photographed shipping labels simulating truck loads of cargo varying in shipment-to-piece ratio and availability of advance shipment information. Performance measures included data entry time required for each test load, for characteristic entry sequences, and for the input of individual data items. Accuracy of performance was measured in terms of the frequency of different entry errors in data content and format, and detection/correction of errors in advance data. Recorded evaluations by the MAC test operators confirmed a strong preference for the on-line mode for potential use in truck dock data entry. A follow-on program of laboratory and field testing is recommended.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

ACKNOWLEDGMENT

This report has been prepared by The MITRE Corporation under Project 515B. The contract is sponsored by the Electronic Systems Division, Air Force Systems Command, Hanscom Air Force Base, Massachusetts.

The initial testing of data entry techniques reported here was carried out with the help of six airmen from the truck dock of the MAC air cargo terminal at Dover Air Force Base: Sgt. James Nolan, Eddie Garcia, Kerry Kennedy, Sewell Laughrun, Jim Rathbun, and Jeffrey Tinsley. These men worked effectively as test operators in the evaluation of alternative data entry modes. Their participation was arranged with the cooperation of Colonel Ruel J. Neeley, USAF, Commander of the 436 Aerial Port Squadron at Dover.

Several people at MITRE contributed significantly to this test program. Warren E. Anderson designed and implemented the computer software providing sequence control for the on-line keypad/display terminal, and served as observer for test sessions involving that device. He was also responsible for software mediating computer storage and processing of all shipment data, print out of advance shipment data in checksheet form, and computer processing of test records. Joanne B. Czulada developed the software for computer storage and preliminary screening of records produced by the digital recorder. She also served as observer for test sessions using the checksheet mode of data entry. Mary Jane Ashmore assisted in analysis of transaction time records.

TABLE OF CONTENTS

TABLE OF CONTENTS (Concluded)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Concluded)

SECTION I

INTRODUCTION

The Military Airlift Command (MAC) is responsible for air movement of DoD cargo throughout the world. This cargo consists of thousands of different shipments and separate pieces. Cargo selected for air movement is essential military material requiring records to be kept concerning its disposition while moving through the air transport system. Thus the handling of air cargo is accompanied by a heavy burden of data handling as well. It is vital that this data processing be made as efficient as possible, so that record keeping will not slow cargo movement. In the MAC Integrated Management System (MACIMS) program, various ways are being considered to improve air cargo data processing.

Preliminary analysis indicates that data processing at MAC's air cargo terminals can be improved by facilitating data entry at the truck docks. Here at the truck dock, cargo destined for export first comes into the air transport system. As each piece of cargo is unloaded, its shipping label must be examined to determine proper disposition, and pertinent data recorded in some way for subsequent processing. Several alternative modes have been considered for improving data entry at the truck dock, as discussed in the first volume of this report series[1].

One potential mode of data entry would involve image capture of shipping label data at the truck dock, either by conventional photography or by video recording techniques. Such an approach offers potential advantages in truck dock use. A complete set of data about each piece of cargo could be recorded in the few seconds it might take to photograph its shipping label. To explore the feasibility of photographing shipping label data in the truck dock environment, several MITRE personnel tested that technique earlier this year, at MAC's mechanized air cargo terminal at Dover Air Force Base, Delaware. The results of that visit were summarized in the second volume of this report series[2].

An obvious disadvantage of image capture techniques, of course, is that imaged data would have to be processed in some way and transcribed into digital form, before becoming available for reference within the air transport system. Other modes of data entry at the truck dock may prove more promising. It might be possible, for example, to provide a member of an unloading crew with some kind of keyboard/display, which he could use to input data over a direct, on-line connection to a computer. Alternatively, he might record shipping data in some way, perhaps by keying items into a digital recorder or simply writing them on a checksheet, with subsequent data input to the computer delayed until truck unloading has been completed.

The final evaluation of any data entry mode can only be made by measuring its effectiveness in full-scale, day-to-day use at the truck dock. But such full-scale evaluation can be expensive, and it is not practical to test all possible data entry modes in that way. Some preliminary screening of alternative modes must be done first, in successive stages of analysis, initial laboratory testing, and follow-on field testing, so that only those modes which prove likely candidates will be considered for full-scale operational evaluation.

Some of the more promising modes of data entry were identified on the basis of preliminary analysis[1]. It was decided to conduct a program of initial testing at MITRE to compare three methods of accomplishing the data entry job. The three alternatives chosen for initial testing were those suggested above - use of an on-line keypad/display, a digital recorder, or manual checksheets. The present report documents the results of this initial test program.

A detailed description of the test design and procedures used is presented in Section II of this report. Testing was conducted using facilities in MITRE's Data Handling Applications Center (abbreviated DHAC in the remainder of this report). Performance was measured for the several candidate input modes, as the test operators entered data from photographed shipping labels simulating truck loads of cargo. The simulated loads used for testing varied in shipment-to-piece ratio and in the availability of advance shipment data, in order to permit estimation of the effects of these two load factors on data entry performance.

Performance was measured in terms of both speed and accuracy. Section III of this report presents an analysis of the time required for data entry, as influenced by the input mode used, by composition of the test loads, and by session to session changes in performance as test operators became more familiar with their tasks. This analysis of data entry speed is reported in terms of overall time required to complete a test load, the time required to complete characteristic sequences of data entry, and the time required for individual data input transactions. Also included in Section III is an analysis of keying activity for the two data entry modes requiring keyboard inputs.

Accuracy of data entry is discussed in Section IV of this report. Error rates are analyzed to determine the effect of data entry mode, load factors, and individual differences among the test operators. Errors are categorized by type, including a distinction between errors of data content and errors of data format. In addition to analysis of entry errors committed by the test operators, Section IV also presents an analysis of operator performance in detecting and correcting errors during review of pre-stored advance shipment data.

Although performance measures can provide an objective basis for the comparative evaluation of different data entry modes, it was also considered important to record the opinions of the test operators themselves. These men, with firsthand experience in the actual unloading job at the MAC truck docks, were asked to evaluate the different data entry modes they had used in the laboratory in terms of their potential application in the real job. The results of that operator evaluation are presented in Section V of this report.

Much valuable information was obtained in this initial test program, and its overall results should provide a useful guide in developing improved techniques for MAC air cargo data entry. Some follow-on laboratory testing will be required, however, along with a subsequent program of on-the-job field testing, before a full-scale system can be recommended for operational use. Section VI of this report presents recommendations for such a follow-on test program.

Certain specific aspects of the initial test program merit more detailed discussion than could conveniently be included in the body of this report. Several special topics are discussed at greater length in a series of Appendices. Appendix A describes the capabilities and technical characteristics of the two data entry devices tested here - the on-line terminal and the digital recorder. Appendix B describes the operational logic of the interactive software providing sequence control for the on-line terminal. Appendix C discusses certain deficiencies noted in the MITRE-designed keyboard for the digital recorder and proposes an improved design for future use. Appendix D discusses the detailed format of the checksheets used for testing and includes a sample set of checksheets. Appendix E provides an extended analysis of format errors in use of the digital recorder. Appendix F describes the questionnaire formats used in operator evaluation of the different data entry modes tested, and provides a sample set of those questionnaires.

SECTION II

TEST DESIGN

During the period 12-22 May, 1975, six men from the 436 Aerial Port Squadron, Dover Air Force Base, participated as test operators in an initial evaluation of alternative data entry techniques for potential future use at the truck docks of MAC air cargo terminals. This test program was conducted at the Data Handling Applications Center, The MITRE Corporation, Bedford, Massachusetts.

Test operators worked to record data from facsimile shipping labels photographed at Dover AFB from truck-delivered cargo in early April. That is to say, the operators did not actually have to handle real packages, but simply entered the data from a pack of photographed labels, plus tag identifier and disposition code for each "piece". Simulated truck loads used during testing each consisted of the labels from 48 pieces of cargo.

Different test loads were used to examine the effect of different load factors. Half of the loads represented a high shipment-to-piece ratio (36 shipments, S/P=.75) and half a low ratio (12 shipments, S/P=.25). Half of the test loads simulated a high level (.75) of advance shipment information available, and half an unusually low level (.25).

Three modes of data entry were tested: 1) an on-line terminal, a handheld keypad/display device which the operators used to enter data in direct interaction with a computer, with computer control of the input sequence and computer prompting for correction of detected input errors; 2) a digital recorder, involving key entry to create magnetic tape records of digital data which were subsequently input to a computer for processing and storage; 3) a checksheet, or rather a pack of checksheets, on which the operators wrote down the necessary data for each test load.

Each operator worked for a day with each of the three data entry modes, in four sessions each day using different test loads, providing an overall total of 72 test sessions. Performance measures consisted of the time required to complete each session, the time required for a variety of specific data entry transactions within each session, a count of data entry errors of different kinds, and a measure of the operators' success in detecting and correcting errors in the pre-stored data for each test load.

At the end of the daily test sessions, each operator was asked to write an evaluation of the particular data entry mode he had just used, recording his judgments on a question sheet formatted for that purpose. At the end of three days of testing, each operator was asked to evaluate all three data entry modes in comparison with one another.

The data entry task, the modes of data entry, and the procedures used for testing, are described in greater detail in the remainder of this section.

THE DATA ENTRY TASK

In testing data entry modes there must be some data to be entered. Photographed shipping labels were used to provide such data, grouped into simulated test loads which varied in shipment-to-piece ratio and in the availability of advance shipment data. Errors and omissions were included in the advance data to test error detection performance.

Shipping Labels

To create the corpus of shipment data needed for testing, MITRE personnel spent two days at MAC's mechanized air cargo terminal at Dover Air Force Base, photographing several hundred shipping labels from pieces of truck-delivered cargo destined for air transport overseas. The results of that photographic expedition have been described in volume two of this report series[2]. The photographic negatives were enlarged to produce prints of approximately true size, thus providing fair facsimile of the labels themselves, one of which is illustrated in Figure 1.

The standard military shipment label, DD Form 1387, contains 12 fields of data. First is the transportation control number (TCN), a group of 17 symbols which uniquely identifies each shipment. The TCN is followed by further data about the shipment, including required delivery date (RDD), an optional project code, priority, consignor (the FROM field), aerial ports of embarkation (POE) and debarkation (POD), and the consignee. The bottom line indicates the total pieces of cargo in the shipment and the number, weight and cube of the specific piece bearing this label.

For shipments comprised of more than one piece of cargo, the TCN and the general shipment data would be the same from one label to the next. Only the piece-specific data would differ. For a multi-piece shipment, it should be possible to shorten the data entry task

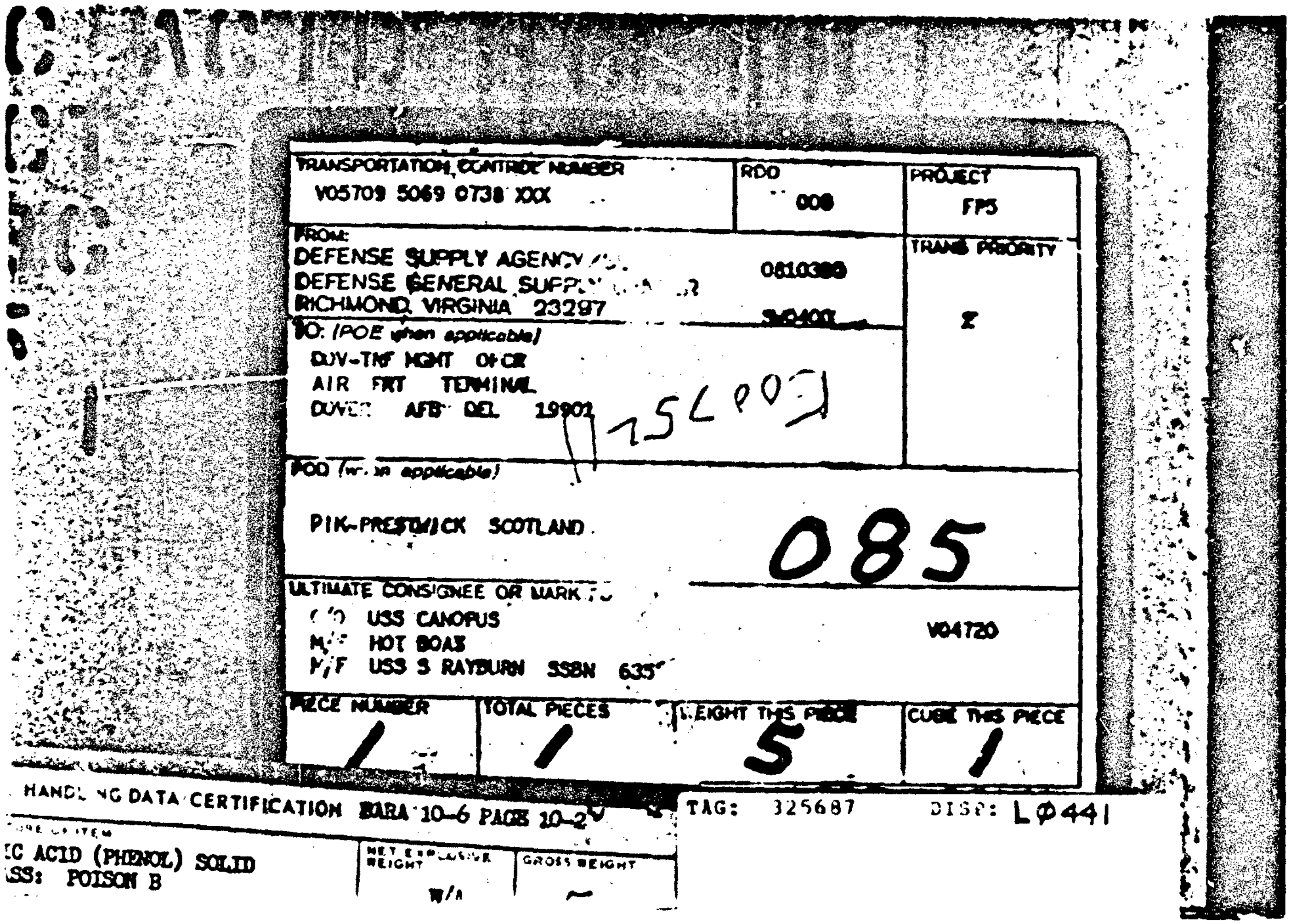


Figure 1. Photographed Shipping Label with Tag Identifier and Disposition Code Added

somewhat, by entering a full set of data for the first piece unloaded, but then simply entering a shipment identifier and the piece-specific data for each subsequent piece from that shipment. Such shortcut procedures were in fact used in this test program.

In actual air terminal operations, not all data items on the shipping label would be considered equally important. Probably the TCN, priority and POD are the most important items for efficient cargo handling, whereas the other items of shipment data are used for more general record keeping purposes. In this initial test program, however, no attempt was made to draw such distinctions. It was assumed that all label data had to be entered. Timing measures were taken separately for different portions of the data entry task, as will be noted later, so that the test results can be interpolated to predict performance for a real task involving entry of only partial data.

Actually, the operators in this test program were required to enter two extra data items for each piece of cargo, in addition to the shipping label data. At the lower right of each photographed shipping label was attached a special adhesive tag displaying a computer-printed tag number, uniquely identifying the piece, and a disposition code, both of which were included in the data entry task. This special tag can be seen in Figure 1. In this illustration the disposition code (DISP) is a 5-symbol group identifying a cart in which the piece of cargo is assumed to have been placed.

In actual cargo handling, the operator at the truck dock would have to decide the appropriate disposition for each piece. In this laboratory test situation, the label for every piece had already been assigned a disposition. That is to say, the test operators did not have to handle real cargo or make decisions about it. They simply entered data about each piece of simulated cargo based on the facsimile label and tag information.

The following list indicates in more detail just what items comprised the data entry task.

TCN	14A/N (alphanumeric) symbols. The last 3 symbols of the real TCN's were omitted since they are always XXX except when changed to denote partial and split shipments.
INDEX	2N, a simple alternative to the TCN, designating a shipment from the load list of advance shipment data.

Use of an index to shortcut TCN entry is discussed later in this report.

RDD	3N, generally the Julian notation for required delivery date, although occasionally some other code group appears. Operators were instructed not to try to convert conventional calendar dates which appeared on some labels, but simply to omit them.
PROJECT	3A/N, a code sometimes included for accounting purposes, but often omitted.
PRIORITY	1N, either 1, 2, 3, or 9.
FROM	6A/N consignor code. Operators were not asked to enter names and addresses of suppliers, but simply the 6-symbol agency code when it appeared.
TO	3A code designating port of embarkation, in this case always DOV since the labels used were all photographed at Dover.
POD	3A code designating port of debarkation, the overseas destination for each piece of cargo. For some labels which happened to omit the POD, the appropriate code was printed onto the photograph so that the operator did not have to figure it out.
CONSIGNEE	6A/N code designating the receiving agency. No names or addresses were entered here, but only the 6-symbol code if it appeared.
PIECE	1N, designating the piece number. In actual transport operations this number might occasionally have two digits or even more for larger shipments.
TOTAL	1N, designating the total number of pieces in the shipment. In this test program, the largest shipments simulated contained 8 pieces.
WEIGHT	1N to 4N, designating the piece weight in pounds.
CUBE	1N to 3N, designating piece size in cubic feet.
TAG	6N, representing what is thought to be an adequate length code to identify each piece uniquely during its movement within the air transport system. Tag codes

were assigned in sequence to each piece in a test load, simulating the order of unloading at a truck dock, but with one break included at an arbitrary point in that sequence for each load.

DISP — 1A or 3A or 5A/N, representing codes for the assumed disposition of each piece of cargo. Pieces for local distribution (L) or requiring special handling (S) were assigned single-letter codes. Pieces heavy enough to require direct forklift to the pre-pallet storage areas were coded by their 3-letter POD. Smaller pieces were assigned 5-symbol codes simulating the numbers of carts in which they were assumed to have been placed. These disposition codes were invented for purposes of testing; some other code scheme might well prove better in actual cargo handling operations.

During testing, all of these data items did not have to be entered for every piece. Where data items were missing from the label they were perforce omitted in data entry. For a shipment where advance data were made available, those data items did not have to be entered unless found to be wrong in comparison with the label. The minimum data entry required would be for a label representing a single-piece shipment with correct advance data: in that case, shipment weight and cube would match the piece weight and cube, so the only data entry required would be the TCN (or INDEX) shipment designator followed by the tag and dispostion codes for the piece. For multi-piece shipments with correct advance data, the task required entry of piece-specific data as well, i.e., piece number, weight and cube.

Test Loads

To prepare the data base needed to support the test program, the photographed shipping labels were grouped into 12 stacks with 48 different labels in each. These stacks simulated the truck loads of arriving cargo whose data would be entered during 12 test sessions. That is to say, as a test operator moved from one data entry mode to another, from one session to the next, he found a new, different "load" of data waiting to be entered. If he had to enter the same load data session after session, he might come to have that set of data memorized by the end of the test series. Certainly it would come to seem more and more familiar.

But if different test loads are to be used, by different operators using different means of data entry, then it is important that the test loads either be equivalent in respect to task difficulty, or that they differ in factors which are measured and taken into account. In the design of this test program both approaches were employed.

The 12 test loads were equivalent in size, each containing the labels from 48 pieces of cargo. It was estimated that the data from 48 labels would take something less than an hour to enter, which seemed about right for test purposes. The ordering of labels within each stack of 48 was completely random. For a multi-piece shipment, the several labels for the different pieces could be mixed anywhere in the stack, just as if a van load of cargo had gotten jumbled up en route to the truck dock and had to be unloaded in random order. In actual operations, of course, vans are sometimes packed more neatly, with some effort made to keep all pieces of each shipment reasonably close together. Thus the test situation was designed to represent a worst case for data entry.

The test loads were also made equivalent in terms of the image quality of their photographed labels. Image quality of the photographs taken at Dover was generally good, but varied from excellent to poor for particular labels[2]. Labels were assigned to different test loads in such a way that each load included 37-39 labels of excellent or good legibility, and 9-11 labels of fair or poor quality, i.e., labels which were blurred carbon copies or perhaps smudged with dirt and hard to read.

The 12 test loads differed in two factors controlled in the experimental design. Loads were constructed so as to represent two levels of shipment-to-piece ratio, and all loads were presented during the test series under two conditions simulating high and low levels of availability of advance shipment data.

Shipment-to-Piece Ratio

Presumably, it should be easier to enter the data for one shipment of four pieces than for four shipments of one piece each. For the multi-piece shipment, the complete set of general shipment data would only have to be entered once, after which only a subset of piece-specific data would be entered for each additional piece in that shipment. Thus an important factor influencing the difficulty of the data entry task should prove to be the shipment-to-piece ratio in each load. The more multi-piece shipments in a load, then the lower the S/P ratio, the more data items on the shipping label can be omitted on the average, and the easier the data entry task

During the photographic expedition to Dover, the observed S/P ratio for truck-delivered cargo was approximately .50, representing an average of about two pieces per shipment. The distribution of shipment size was quite skewed, with many shipments having only a single piece and a few shipments having multiple pieces[2]. It was decided to construct test loads at both a higher and a lower S/P ratio, bracketing the observed mean, to measure the effect of this load factor on data entry performance.

Six of the 12 test loads were constructed to represent an S/P ratio of .75, where the 48 labelled pieces came from 36 different shipments. The other six test loads were constructed with an S/P of .25, where the 48 pieces comprised only 12 different shipments. The number of shipments of different sizes in these "high" and "low" test loads is shown in Table 2-1. Some of the shipments of larger size were created artificially, by replicating a photographed label several times and marking different piece numbers on each copy, to construct test loads with the desired S/P ratios.

Table 2-1

Variation in Shipment Size for Test Loads with High and Low S/P Ratios

Shipment Size (Number of Pieces)	Number of Shipments in Load S/P High (.75)	S/P Low (.25)
1	30	2
2	2	2
3	2	2
4	2	2
6		2
8		2

Advance Shipment Data

Once the 12 test loads of different shipment-to-piece ratio had been constructed, the shipping label, tag and disposition data for the 48 pieces in each load were keypunched and stored on disk in the DHAC computer. Thus a complete set of data for each load was available for comparison with data entered subsequently by the test operators, to determine how accurately they performed the data entry task under different test conditions.

For each test load, the computer was programmed to print out two sets of checksheets, one set displaying the pre-stored shipping label data for one-quarter of the shipments (and one-quarter of the pieces) in the load, and the other set displaying pre-stored data for the remaining three-quarters. These checksheets were given to the operators during testing to provide either a low level (.25) of advance shipment data or a high level (.75), respectively. The partitioning of shipments used to simulate these low and high levels of advance shipment data is indicated in Table 2-2 for test loads of high and low S/P ratio.

Table 2-2

Availability of Advance Shipment Data

Shipment Size (Number of Pieces)	Number of Shipments in Load with Advance Data Available — S/P High (.75) Advance Data Low (.25)	S/P High (.75) Advance Data High (.75)	S/P Low (.25) Advance Data Low (.25)	S/P Low (.25) Advance Data High (.75)
1	7	23	1	1
2	1	1		2
3	1	1	1	1
4		2		2
6				2
8			1	1

The format used for the advance data printout is illustrated by the sample set of checksheets presented in Appendix D. Advance data for each shipment in the load were displayed on a separate page, with the items arranged in a format corresponding to the layout of a shipping label to facilitate comparision during review of advance data by the test operators. It should be noted that tag and disposition were not included in the advance data, since these would be determined during the unloading of actual cargo, and that piece-specific data were included only for single-piece shipments where such data are known in advance.

The advance data printed out for each load contained some errors. Some of those had been introduced deliberately in order to test the ability of test operators to detect and correct errors in their review of the advance data. It turned out that still other errors were introduced accidentally during the keypunching of shipping label data for computer storage. In general, errors in the advance data consisted of two types, missing data items and wrong items. The subsequent analysis of test operator performance compared error detection for both types of error.

The two levels of advance shipment data used in this initial test program simulated situations which might actually be encountered in truck dock unloading operations. A high level of advance data represents the usual case. Indeed the proportion of shipments with advance data will often exceed the .75 level tested here. A low level of advance data would represent a truck load of cargo which arrives with inadequate advance documentation. It was expected that this factor, the availability of advance data, would have a significant effect on data entry performance, and that expectation was confirmed in testing.

MODES OF DATA ENTRY

Three modes of data entry were compared in this initial test program: a portable on-line terminal consisting of a handheld keypad with visual display; a digital recorder, permitting data entry to be performed as an off-line task; and the manual printing of data entries on specially formatted checksheets. The characteristics of these three input modes, as used for the data entry task, are described in the following paragraphs.

On-Line Terminal

As used here, the word "terminal" refers to a device connected to a computer, permitting direct, on-line interaction during performance of the data entry task. The word is not intended to refer to any larger facility such as an air cargo terminal. A photograph of a test operator working with the on-line terminal is shown in Figure 2. The on-line terminal was connected to the computer presently being used in MITRE's Data Handling Applications Center, a NOVA 800 minicomputer manufactured by Data General Corporation.

A close view of the keypad/display for the on-line terminal is shown in Figure 3. This device is manufactured by Termiflex Corporation, Nashua, New Hampshire, and is often called simply "the termiflex". The terminal itself weighs only 1.5 pounds. Its display can present two lines of 10 symbols each. Its keyboard has an alphanumeric cluster similar to that which has become standard on Touch-Tone® telephones, plus some extra control keys below and to the left. A more detailed description of this device is provided in Appendix A to this report.

The terminal is designed to be held in the left hand, with the right hand used for keying data entries. Numeric data can be keyed in a straightforward manner. Alphabetic entries require depression

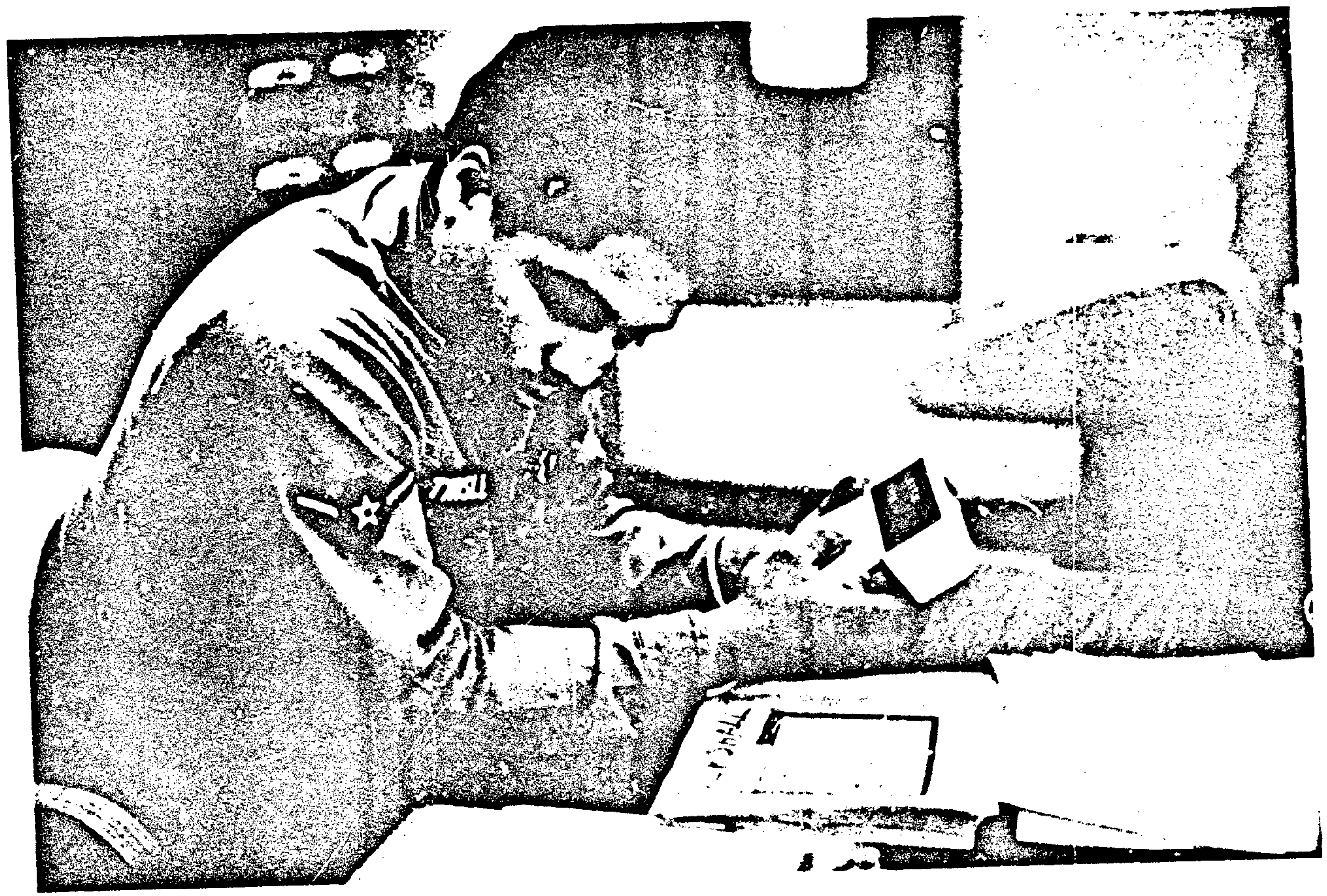


Figure 2. Test Operator Using Handheld On-Line Terminal

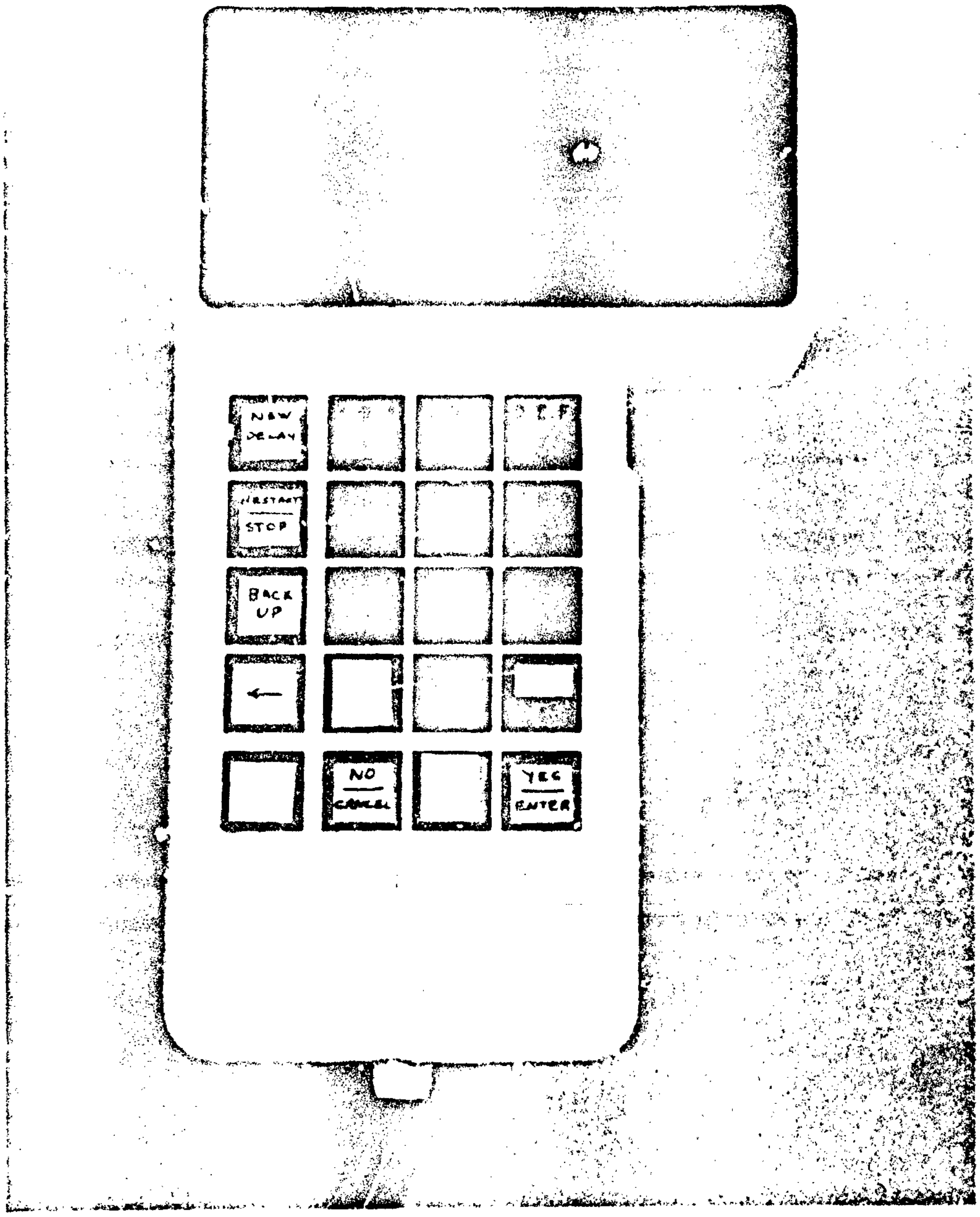


Figure 3. Close View of Handheld Keypad/Display

of one of three shift keys on the side of the termiflex, by fingers of the left hand, to designate which of three letters is intended when the right hand presses a key on the face of the device. This requirement for simultaneously combined action from fingers of the two hands seems awkward on first use of the device, particularly in the key entry of mixed alphanumeric data.

Key entries appear on the bottom line of the associated display, at the position denoted by a cursor symbol, which is not visible in Figure 3. When the bottom display line is full, i.e. when 10 symbols have been entered, it moves upward displacing the old top line from view. Further data entry is displayed in the new bottom line. In use of the termiflex for the task of entering cargo data, the data items were entered one at a time, each in a single display line except for the truncated, 14-symbol TCN which required two lines of display.

Since this device was used on-line, the computer could be programmed to interpret any selected key entry as calling some particular function needed in sequence control. It can be seen in Figure 3 that six special control keys were assigned such programmed functions:

- YES/ENTER — to signal the end of a data entry, or to answer affirmatively a computer-posed question.
- NO/CANCEL — to cancel a garbled data entry currently being input, or to respond negatively to a question.
- BACKSPACE — (labelled ←) to cancel the last symbol in a current data entry.
- BACKUP — to cancel the current entry and return to the last previous step in the data entry sequence.
- RESTART/STOP — to interrupt the data entry sequence to enter a revised TCN, or to stop the sequence.
- NEW DELAY — to divert from the data entry sequence temporarily to define a new delay parameter for transient advisory displays, as discussed below.

Since the termiflex was used on-line, the computer could control the contents of the display. This capability was exploited in several ways when programming sequence control for the data entry task. As a simple example, when the operator keyed BACKSPACE, the computer regenerated the entire two-line display minus its last symbol. The resultant visual effect was to see the display blink as the cursor apparently moved backward one space to erase the last symbol.

During the data entry sequence the computer wrote "prompts" to the termiflex display. Figure 3 shows the prompt for entry of a TCN. When entry of a data item was completed using the ENTER key, the computer checked the input item against stored criteria for validating data. If an entry seemed correct, with proper number of symbols, type of symbols, etc., then the computer displayed the appropriate prompt for the next item to be entered. Thus the data entry task proceeded as a sequence of discrete transactions.

If the computer detected an error in the format of a data entry, it was programmed to "beep" an auditory signal inside the termiflex, to display a transient error message for a set interval of time, and then to display a prompt for the re-entry of that data item. In certain instances two transient error messages would appear in succession, to provide guidance in alternative means of error correction. The time interval chosen for the display of such messages was set under computer control, and could be changed arbitrarily by using the NEW DELAY key to initiate a short on-line transaction to enter whatever interval is desired. During testing, an interval of 1.5 seconds was used during each operator's first session with the on-line terminal. This interval was shortened to .5 seconds for subsequent sessions.

If the operator himself detected an error during data entry, he could use the BACKSPACE key to correct it. If he became confused, he could use the CANCEL key to abort the transaction. The computer simply regenerated the prompt for the data item, without any intervening error messages. If he wanted to change some previous data entry, he could use the BACKUP key, which caused the computer to step backward through the data entry sequence one item at a time. If the operator decided at any point that he had to revise his entry for a TCN, he could use the RESTART key to abort the current data entry sequence and start over again. Such options permit flexibility in the use of an on-line terminal. They may seldom be used but are helpful when needed.

Aside from these implicit options, always available to him, the operator could be offered an explicit choice by the computer. At the end of data entry for each piece of cargo, he was asked if there were data for another piece to be entered. He would use the YES key to request continuation of the data entry sequence, and finally the NO key to signal the end of a load. For shipments with advance data available, the control sequence required the operator to review the data item by item, to confirm correct items and change incorrect ones, for the first piece "unloaded" for that shipment. For a new TCN, he simply entered the necessary shipment data for the first piece. For subsequent pieces, in both cases, the operator was given a choice as to whether he wished to review the stored shipment data, and he used the YES or NO keys to indicate his decision.

Other niceties of program control of the interactive data entry sequence included computer anticipation of highly probable inputs. In entry of port of embarkation, for example, the computer prompt read POE=DOV? The operator could approve this "guess" with a single keystroke, rather than having to key the three letter code. For piece identification the computer predicted the next tag to be entered by adding 1 to the last, assuming that pieces are tagged in their order of "unloading". That is to say, if the last piece entered had the tag 325687, the tag prompt for the next piece would read TAG=325688? The operator could confirm this prediction with a single keystroke unless he had just reached that point in the test load where a break in the tag sequence had been inserted.

The control program mediating on-line data entry (and also performance recording, as discussed later) was completely checked out in shakedown runs prior to testing. No program flaws appeared during actual testing. A more detailed outline of the sequence control logic used for the on-line terminal is presented in Appendix B to this report, along with suggestions for improvement based on problems observed during testing.

It should be noted that for each test load the operator of the on-line terminal was given a set of checksheets displaying the advance data available for that load, as described later in this report. He did not need to refer to these checksheets, however, because the computer displayed advance data item by item for review at his terminal. He could simplify his data entry task somewhat by referring to an index which accompanied the checksheets, listing by TCN all shipments with advance data. If a piece of cargo came from a shipment on that list, the operator could simply enter the shipment's two-digit index number instead of the full TCN. Each "new" shipment in the load was automatically assigned an index by the computer. If the operator bothered to note this new index, by writing its TCN on the index list, he could use this index when entering data for subsequent pieces of that shipment.

Digital Recorder

By "digital recorder" is meant a device which permits key entry of data off-line to create a digital record, perhaps on magnetic tape, which can subsequently be played back and transmitted for computer storage. (A keypunch would serve the same function, but keypunch equipment is more cumbersome and more expensive.) The digital recorder used in this initial test program is called the Source 2001 portable data terminal by its manufacturer, MSI Data Corporation, Costa Mesa, California. A photograph of the digital recorder being used by a test operator is shown in Figure 4. A more detailed description of the capabilities of this device is presented in Appendix A to this report.

Previous research at MITRE had provided some measures of data entry time and errors using the digital recorder, and had indicated that this device might prove suitable for air cargo data entry (Sutherland, 1974). It was decided to undertake further testing of the digital recorder under conditions which simulate more realistically the truck dock data entry task.

A MITRE-designed keyboard previously used with the digital recorder was refurbished for use in the present study. A close view of this special keyboard is shown in Figure 5. The keyboard was held in one hand by a pistol grip fastened to its bottom (not visible in the photo), and key entries were made with the other hand. Different groups of keys were coded by color. The alphabetic keys on the left were blue. The numeric keys on the right were green. The special line indicator keys, above and to the left of the numeric cluster, were red.

In practice, this keyboard layout did not prove optimum for the data entry task. The problem is one of format control. In a data entry sequence using the on-line terminal, the computer can prompt the entry of each data item and so "knows" what the item is. The operator of a digital recorder does not enjoy this advantage. As he enters a sequence of data items he must strike extra keys to indicate which item will be entered next. The most straightforward keyboard design would provide one specially-labelled indicator key for each type of data item to be entered. The keyboard actually used did not have enough extra keys available for that purpose.

The expedient used in this initial test program was to categorize the different data items on a shipping label into several "lines", and then use the spare keys on the keyboard to indicate which line of data was to be entered next. To mark the boundaries of the several data fields within each line, it was necessary that the operators key an ENTER button after each data item. This line entry logic was explained to each operator during his first test session using the digital recorder, with the aid of the special instructional display reproduced in Figure 6. That display remained

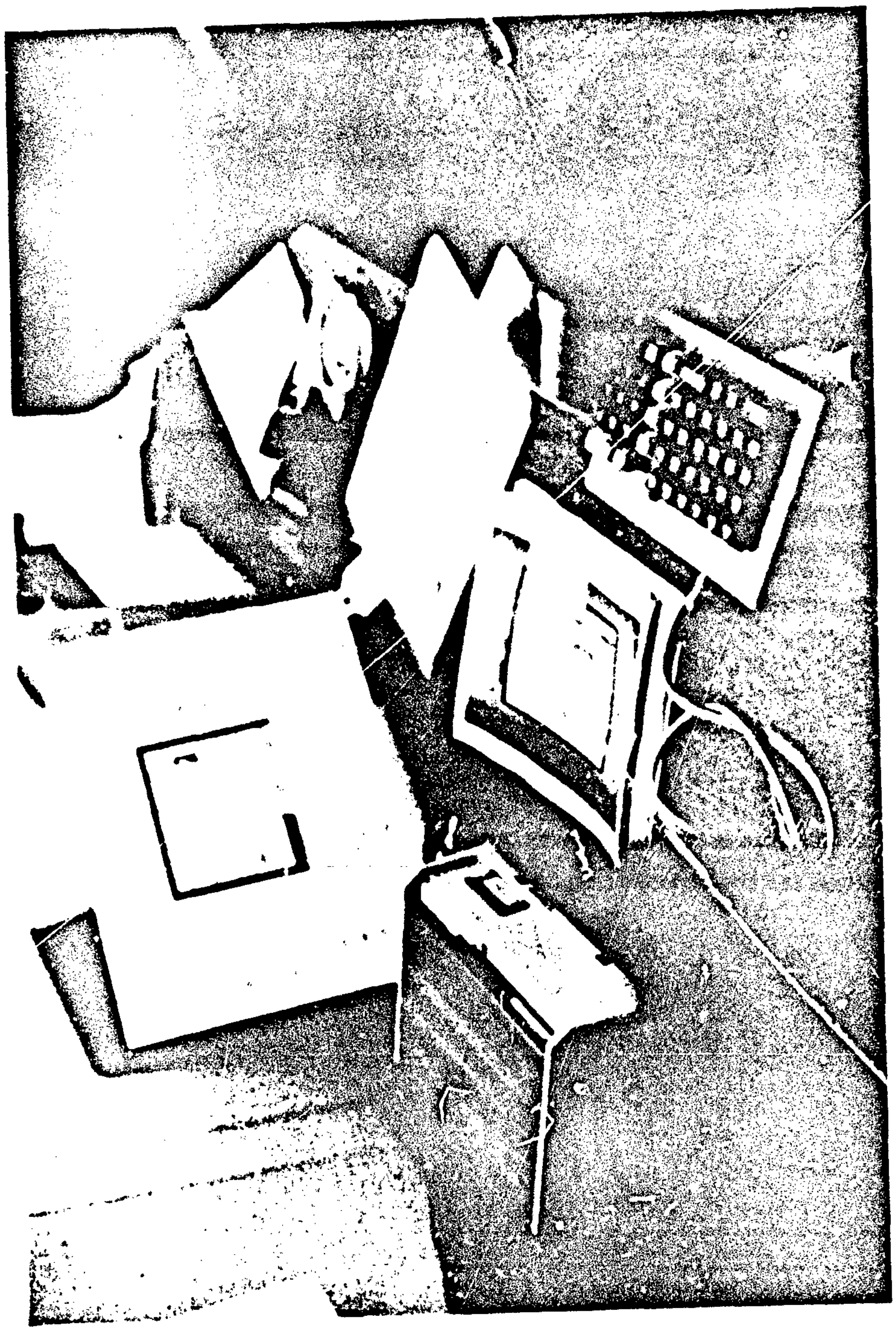


Figure 4. Test Operator Using Digital Recorder

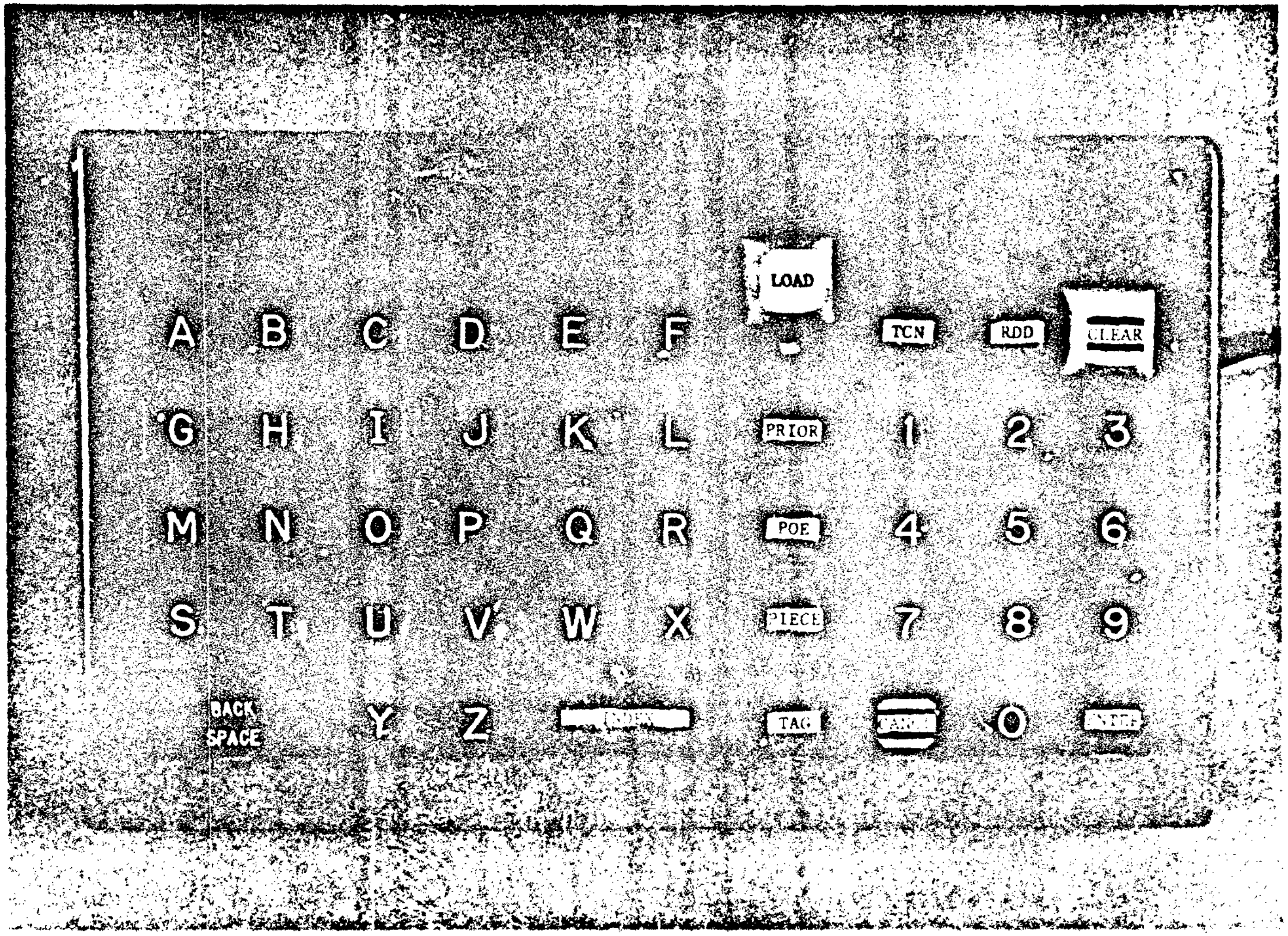


Figure 5. Close View of Special Keyboard for Digital Recorder

Line 1

Push TCN

Then enter 14-symbol TCN, ignoring the last 3 letters, usually XXX

or simply enter 2-digit index code, if one has been defined

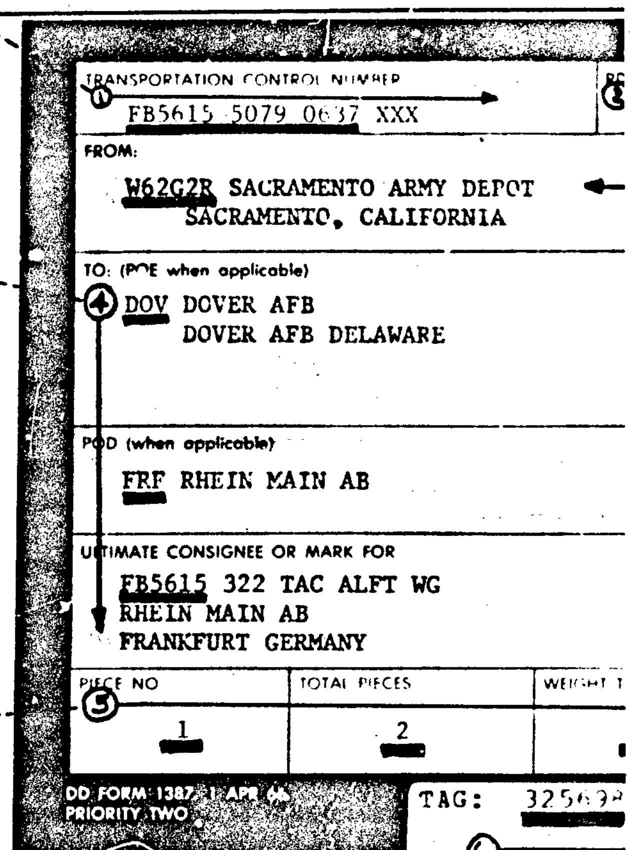
Push ENTER

To index a new, multi-piece TCN:

Push INDEX

Then enter 2-digit index code

Push ENTER



Line 4

Push POE

Then enter 3-letter POE code ("TO")

Push ENTER

Then enter 3-letter POD code

Push ENTER

Then enter 6-symbol CONSIGNEE code, if there is one

Push ENTER

Line 5

Push PIECE

Then enter PIECE NO.

Push ENTER

Then enter TOTAL PIECES

Push ENTER

Then enter WEIGHT

Push ENTER

Then enter CUBE

Push ENTER

Line 6

Push TAG

Then enter 6-digit TAG code

Push ENTER

Then enter DISPosition code, 5-symbol maximum

Push ENTER

Figure 6. Data Entry Sequ

piece TCN:

ex code

Line 2

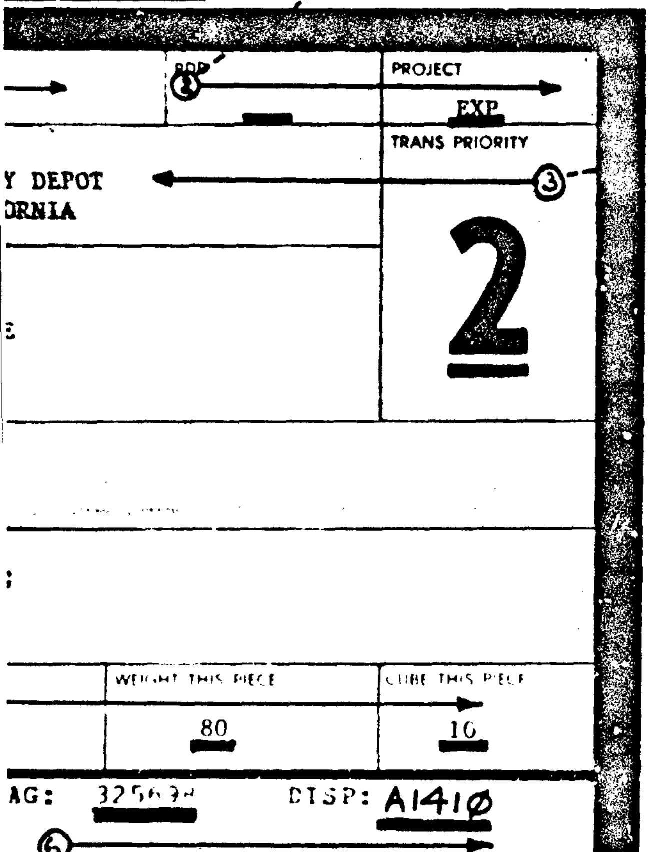
Push RDD

Then enter 3-symbol RDD, if there is one

Push ENTER

Then enter 3-symbol PROJECT code, if there is one

Push ENTER



Line 3

Push PRIOR

Then enter 1-digit PRIORITY

Push ENTER

Then enter 6-symbol consignor code ("FROM"), if there is one

Push ENTER

NOTE:

General shipment data **(yellow fields)** can be omitted for TCN's where the advance data record is correct, or where shipment data has already been entered for another piece. In those cases, simply enter the TCN (or index) and then the PIECE and TAG data.

le

e, 5-symbol maximum

ta Entry Sequence for Digital Recorder

available to serve as a ready reference throughout all sessions using the digital recorder, and can be discerned in Figure 6.

Just as there was no on-line sequence control provided by a computer to the user of the digital recorder, neither was there any on-line feedback from computer checking of data entry errors. The operator himself had to stay alert to notice errors as he made them. The keyboard was configured to provide similar means of error correction to those used with the on-line terminal. The BACKSPACE key permitted correction, i.e., erasure and re-entry, of particular characters. A CANCL key permitted erasure of the data field currently being entered. A backup capability of sorts was provided by using double-keying of a line indicator to begin re-entry of all data items in a line, or to correct a TCN. Operators were reminded of these error correction procedures by a supplementary reference display, reproduced in Figure 7.

Aside from producing a record of key inputs on magnetic tape, this particular digital recorder also generates a printed record on a strip of paper. At any time, the 23 symbols most recently entered can be viewed (with some difficulty) through a small display window in the front of the recorder device. Test operators using the digital recorder seldom looked at this paper display, usually being content simply to re-enter data if they became confused and doubtful. On several occasions during the test sessions the strip printer was not operating properly, which may have contributed to the operators' reluctance to rely on its display.

It should be noted that for each test load the operator of the digital recorder was given a set of checksheets displaying the advance data available for that load, as described later in this report. He could refer to these sheets to determine whether corrections to advance data needed to be recorded. He did <u>not</u> need to record data items which were already correct in the advance shipment information. Thus by reviewing checksheet data the operator could shorten his data entry task. He could also refer to the index accompanying the checksheets to designate shipments by a short index number rather than by TCN, just as he could when using the on-line terminal. For a new shipment, he could assign an index number himself if he wished, using the appropriate keying sequence noted in Figure 6.

Anticipating the results of this study, which are discussed in later sections of this report, the logic governing the data entry sequence and the procedures for error correction both seemed to pose problems to users of the digital recorder. Evidence to support that conclusion was derived from an analysis of format errors made using

Error Correction using the Digital Recorder

- To unlock keys after a double strike, push CLEAR

- To go back and correct a wrong keystroke, push BACK SPACE as many times as necessary, then re-key the data from that point.

- To cancel whatever you have keyed in the current data field, push CANCL and then re-key the data.

- To make changes outside the current data field, push the appropriate <u>line</u> indicator (<u>red button</u>) <u>twice</u>, then re-key the entire line of data.

Figure 7. Error Correction Procedures for Digital Recorder

this device, summarized in Appendix E, and tends to contradict the operators' expressed evaluation of all data entry modes as easy to learn. If the digital recorder is to be considered for actual use in this data entry job, it will be necessary to redesign its keyboard and consequently the logic of data input. Suggestions for an improved keyboard layout are presented in Appendix C to this report.

Manual Checksheets

The third mode of data entry which was tested did not require any equipment at all, except for pencil and paper. The paper consisted of a set of specially formatted checksheets on which the operator could print the necessary data for each piece of cargo in a test load. Figure 9 shows a test operator working with a set of checksheets.

The checksheets were printed out by the NOVA computer, from the stored data base of shipping label information, in advance of the test sessions. For each test load, two sets of checksheets were available, one providing a low level of advance shipment data and the other a high level. The test operator was given whichever set was appropriate, depending upon his particular test schedule. A sample set of checksheets is presented in Appendix D to this report.

The checksheets displayed advance data one shipment to a page, with data items arranged to correspond to the format of a shipping label for convenient comparison. Operators were instructed to write in any missing data items, including piece-specific data and possible omissions from the advance shipment data, and to cross out and write over any items which were wrong in the advance data. For "new" shipments all data items had to be written in, and blank checksheets were provided for that purpose.

Each set of checksheets began with a cover sheet which listed the TCN's for those shipments with advance data, along with a two-digit index number associated with each TCN. These index numbers were displayed prominently on the checksheets and so could be used by the operator to speed his search through the pack looking for the checksheet for a particular shipment. For new shipments, the test operators were encouraged to add TCN's to the index list if they wished to do so. Often they did index new shipments, particularly multiple-piece shipments whose checksheets would have to be accessed several times during a test session.

Aside from the use of checksheets for data entry, sets of checksheets were also provided as supplementary reference material

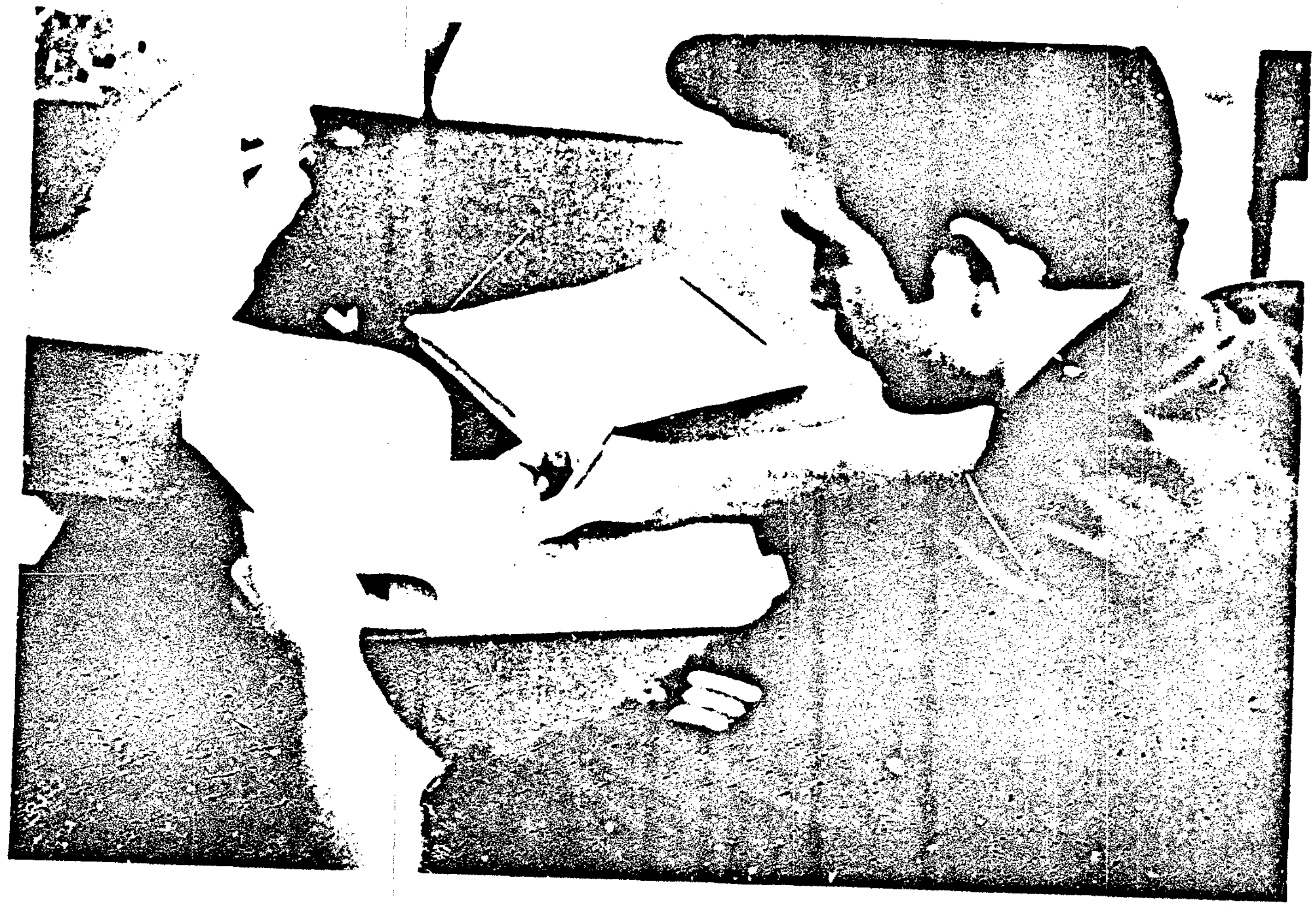


Figure 8. Test Operator Working with Checksheets

to test operators working with the on-line terminal and with the digital recorder, as noted earlier in the descriptions of those two data entry modes. The operator of the on-line terminal used only the index list attached to the checksheets, to permit shortcut entry of index number rather than TCN to designate shipments having advance data. The operator of the digital recorder used the index list in the same way, and referred to the checksheets as necessary to review the correctness of advance data. In neither of those two modes did the operator have to write data onto the checksheets. Neither of those modes require that checksheets of advance data be used, but the checksheets (or at least a load index list) may prove a helpful reference when available.

TEST PROCEDURES

Having defined the data entry task to be performed, and the modes of data entry to be tested, the remaining aspects of test design have to do with the selection and training of operators, the sched ling and conduct of test sessions, and the observation, measurement and evaluation of performance. The procedures used in this initial test program are described in the following paragraphs.

Test Operators

Six men from the 436 Aerial Port Squadron, Dover Air Force Base, were recruited to participate as test operators. These men were drawn from the unloading crews currently working the truck dock at the Dover air cargo terminal. As a group they may be considered a representative sample of MAC personnel assigned to this job, including men with different degrees of experience in cargo handling, ranging from a few months to several years. None of these men had any particular prior experience in data entry, and none of them now perform any specialized clerical tasks at the truck dock. These men all have normal vision and nc manual impairment.

This initial test program was conducted at the ESD/MITRE Data Handling Applications Center in Bedford, Massachusetts. For convenience in scheduling, test operators were invited to this laboratory facility in groups of three, each group working there for several days, the first group on 13-15 May 1975 and a second group on 20-22 May.

Each group of test operators was welcomed to the DHAC with a short briefing for general orientation. They were told something of the continuing effort to upgrade MAC data processing and the perceived need to improve data entry at the truck docks. They were given a short summary description of the three data entry modes to be tested. They were told that the purpose of this initial testing was to determine whether any of these data entry modes look good enough to warrant subsequent field testing. They were told that performance measures would be taken of the speed and accuracy of data entry, and that they would be asked to make their own evaluation of each data entry mode. They were assured that it was the device or mode which was being tested and not themselves, and that anonymity would be preserved in any subsequent reporting of individual performance.

Sample photographs of shipping labels were distributed to the test operators to remind them of the data format, and the various items comprising general shipment data and specific piece data were reviewed. The concept of pre-stored data simulating availability of advance shipment information was discussed, and also the differences in shipment-to-piece ratio which can occur from load to load. It was explained that test loads would vary in both of these factors, and so the operators should not be surprised if the data entry task proved easier for one load than another.

A work schedule was posted showing each of the test operators which data entry mode he would use for each of the several days of testing. Test operators were then introduced to the three MITRE observers who would work with them during the test sessions, and the first session was begun. No attempt was made to familiarize operators with a data entry mode in any period of hands-on use prior to testing. All training was conducted on the job, so that any problems encountered could be observed and learning measured in terms of changes in job performance.

Scheduling

Each operator worked four sessions using a particular data entry mode in each day of testing. Each session involved data entry for a different test load, with either a high or low shipment-to-piece ratio, combined with either a high or low availability of advance shipment data. The daily sequence in which the operators used the three data entry modes was counterbalanced so that potential order effects would not bias the subsequent analysis of performance comparing modes. As an example, if there were a tendency for operators to learn general aspects of the job and work better from day to day, giving their best performance with whatever mode is used last, then to permit a fair comparison of different data entry modes it would be important that different operators use them in different order. Similarly, the sequence in which the operators worked with different types of test loads, from session to session, was randomized so that the effects of learning how to use a data entry mode would not introduce any consistent bias in the subsequent analysis of load factors. The resulting schedule of test sessions which embodied these constraints is summarized in Table 2-3.

Table 2-3

Test Scheduling of Data Entry Mode and Load Factors

Day:	1				2				3			
Session:	1	2	3	4	1	2	3	4	1	2	3	4
Test Operator:												
C	OT				DR				CS			
	LL	HH	LH	HL	HH	HL	LL	LH	LL	LH	HH	HL
B	DR				CS				OT			
	LH	LL	HL	HH	LH	HL	LL	HH	HL	LH	HH	LL
A	CS				OT				DR			
	HL	HH	LH	LL	HH	LL	HL	LH	HL	HH	LH	LL
E	OT				CS				DR			
	LH	HL	LL	HH	HL	LL	HH	LH	LH	LL	HH	HL
D	CS				DR				OT			
	LH	HL	LL	HH	LL	LH	HL	HH	HH	LL	LH	HL
F	DR				OT				CS			
	HL	HH	LH	LL	LL	HH	HL	LH	HH	LH	HL	LL

Note: For each test operator, designated here by letters A through F, the first row indicates the data entry mode used on each test day: OT = on-line terminal; DR = digital recorder; CS = checksheet. The second row indicates characteristics of the test load used in each session: HL = high S/P ratio and a low level of advance shipment data; LH = low S/P and high advance data; etc.

The test schedule was contrived in such a way that on any day each of the three operators in a group was using a different mode of data entry. This was necessary because only one on-line terminal and one digital recorder were available for use in the DHAC, and because the computer program provided control for only one on-line device at a time.

Test Environment

No attempt was made to simulate the truck dock environment in this initial test program. As noted earlier, the test operators did not have to handle real cargo, nor make decisions about its disposition. They were given no waybills to check. They simply entered or recorded data from a stack of photographed shipping labels.

Test operators did not have to move about, from one piece of cargo to another, dodging forklifts and other workers, nor did they have to carry any of the data entry gear they were using. Instead, they worked comfortably seated at tables. They did not have to strain to read labels in the dimly lit interior of a van. In the laboratory a high ambient illumination was provided by overhead fluorescent lights.

On the other hand, there was no special attempt made to preserve a quiet laboratory environment during testing. Test operators worked in the same room, at three locations separated by only 6 or 7 meters, and could hear and observe each other at work if they wished to do so. Other users of the laboratory were sometimes present. Visitors occasionally wandered about, chatting in the background. Phones rang, and other machine noises, particularly the high speed printer, were obtrusive.

There was no time pressure on the test operators to complete the unloading of a truck, or to keep up with other members of a work crew. Each man worked individually, at his own pace. The test operators were obviously motivated to work well, however, and all were diligent in their task performance. Although they were encouraged to take a break after each test session, these self-regulated rest periods seldom extended for more than 5 or 10 minutes.

The steady rate of work resulted primarily from the conscientious attitude of the test operators. Other contributing factors were implicit competition among three operators working simultaneously, and a desire to finish early. Each afternoon when all members of a test group had completed their scheduled test sessions, they were given an opportunity to explore other data processing capabilities available in the DHAC, including demonstrations of electronic display stations, voice input equipment, bar-code wand reader, and optical character reader.

Despite such interesting "extracurricular" activities, and the general amenities of a laboratory setting, the test environment was in one significant way more demanding than the actual data entry job would be. At the truck dock, data entry would be performed as a sporadic task, with occasional intervals of waiting for the next piece of cargo to be unloaded and brought into view. In the test environment, the label for the next piece of simulated cargo was always waiting in the stack of photographs, so that the data entry task required continuous concentration of attention. There is little doubt that the operators were tired at the end of each day's test sessions.

Observers

Each MAC operator worked at all times with a MITRE observer, a different person for each data entry mode. The role of these observers was somewhat broader than the name suggests. The observers were responsible for training test operators as well as recording performance, and also served as MITRE hosts, answering questions, providing escort to the cafeteria, etc. They acted more as friendly assistants than as taskmasters.

During the first test session of each day, the observers instructed the operators in use of the data entry modes, offering general advice and step by step guidance as required. Each data entry mode had its own special features which influenced how the task was performed. Operators learned the necessary procedures while entering data for the first few pieces in the test load, and thereafter worked on their own. Throughout the first test session with each new operator the observers would volunteer comments if they saw some mistake being made, and were prepared to answer questions at any time. During subsequent test sessions the observers generally did not comment on operator performance, except in answer to specific questions.

The observers each kept a log during every test session, noting any apparent errors made by the operators and any points of seeming confusion or difficulty with data entry procedures. Observers were responsible for recording the beginning and end times for each test session. For the two modes of off-line data entry, the observers were also expected to record the time required for various different types of data entry sequences, using a stopwatch. For the on-line terminal, the times of all transactions were recorded automatically by the computer. No attempt was made to conceal these data recording activities from the test operators. The operators were encouraged to work quickly and accurately, and they understood that their performance was being measured in both respects.

Performance Measurement

Measures of data entry speed included the overall time required to complete each session, i.e., for a 48-piece test load, and the time consumed by different types of data entry sequences. Session time was recorded by the observer in minutes. Sequence times were recorded in seconds. The observers used a specially formatted record sheet to note the type of each data entry sequence as well as the time required. Sequence types included entry of shipment and piece data for a "new" TCN, review of advance shipment data and entry of piece data for an "old" TCN, and entry of piece data only for a TCN whose shipment data had already been entered or reviewed.

Within a data entry sequence, the observers of the two off-line modes were sometimes able to record the time required for individual transactions, e.g., the time consumed in scanning an index list, in finding the particular page in a pack of checksheets, in reviewing shipment data, in keying a TCN, etc. For the on-line terminal, the controlling computer kept a time record for every operator input. This record was stored on disk for later analysis, and also printed out at the end of each test session. It was thought that such transaction analysis could prove useful in the future when test results might have to be interpolated to predict performance if the data items to be entered in the actual job setting were some subset of those used in this initial test program.

A record was preserved of all data entries, of course, and for the on-line terminal and the digital recorder a count was subsequently made of the frequency of all keystrokes, for data entry itself and for the various function keys used to control data entry. It was expected that such records would help the interpretation of any measured differences in data entry time in the use of those two devices. The data records were preserved in digital form on disk and also were printed out for visual inspection.

Accuracy of data entry for the on-line terminal was determined by programming the computer to compare records of data actually entered with a true record already stored for each test load. As a result of this comparison, it was possible to note those discrepancies which indicated either errors in entering new data or failure to detect errors in reviewing advance data.

For the digital recorder, the measurement of accuracy was not quite so simple, since it was possible for the test operators to make errors of format as well as errors in data content. The operator of the digital recorder had to push special function keys to indicate that the next symbol group he entered would be a TCN, or a POD, or a consignee code, or whatever. If he made an error using these function keys, it made the resulting digital record difficult to interpret. When the computer assembled a data file from the digital record, a correct data entry might be associated with a wrong item, even with a wrong shipment, because of such format errors.

To try to cope with this problem, the digital records generated by the test operators were submitted to computer analysis to create an initial data file for each session, which was then printed out for inspection. A number of common format errors were noted which had resulted in garbled data. The analysis program was revised to cope with some of the most damaging format errors, and then used again to create a new data file. Those refined data files, still containing some unavailable residual losses due to format errors, were then compared with the complete true records for each test load to determine data entry errors, just as described above for the on-line terminal.

For the checksheet mode of data entry, it was not possible to develop a sensible measure of accuracy in the context of this initial test program, since the data items written on a checksheet are not yet in digital form. Use of a checksheet implies a subsequent process of key entry which would itself be subject to error. Although the test operators were cautioned to write legibly, casual inspection of the resulting checksheets raises some question as to whether their data could in fact be transcribed accurately.

It is planned to test that question by having MITRE operators enter data working alternatively from the scrawled checksheets generated in initial testing, and from the shipment labels themselves. The results of that follow-on study will not be available until later this year. Any data errors detected in that follow-on study will be examined to determine whether they should be attributed to faulty recording on the checksheet or faulty transcription, although as a practical matter it is the <u>combined</u> error rate which would be important.

Although the commission of data recording errors using the checksheets cannot be assessed here, it was possible to measure the operators' success in detecting errors in advance shipment data. All checksheets generated during this initial test program were scanned to determine how many of the known errors in advance data had been noticed and corrected by the test operators, and those results are documented in this report.

Operator Evaluation

In addition to measuring data entry performance, it was also considered important that the test operators themselves be given an opportunity to evaluate the data entry modes. At the conclusion of each day's test sessions, all operators were asked to fill out a questionnaire designed to record their opinions of the particular data entry modes they had used that day. At the completion of all test sessions, on the third day of testing, the operators were asked to fill out a final questionnaire in which they made a comparative evaluation of the three data entry modes they had used. Copies of these two questionnaires, for mode evaluation and mode comparison, are included in Appendix F to this report.

SECTION III

RESULTS - SPEED OF DATA ENTRY

If a data entry task at the truck dock is superimposed on the primary job of unloading cargo, it is important to ensure that data handling does not delay and interfere with cargo handling. Thus for any data input mode being considered, an important measure is speed of data entry at the truck dock. Measures of data entry speed obtained in this initial test program are discussed in this section of the report.

Speed of data entry is discussed here first in terms of the overall time per <u>session</u>, i.e., the time required to complete a 48-piece test load. Then data entry is analyzed in terms of the time required to complete characteristic <u>sequences</u> of inputs for pieces of cargo with and without advance shipment information. Finally, this section provides an analysis of the time required for specific <u>transactions</u>, in which speed of data entry is examined for the individual items on a shipping label.

Because the time required is strongly dependent on the amount of data to be entered, this discussion of data entry speed is also accompanied by an analysis of transaction keying for the two input modes involving use of keyboard devices - the on-line terminal and the digital recorder.

SESSION TIME

MITRE observers recorded time at the beginning and end of each of the 72 test sessions, to the nearest minute. Those session times are listed in Table 3-1. Presented in this form, it is difficult to discern the relative influence of the several experimental variables because of their overlapping effects. Aggregate statistics derived from this table will be presented in the paragraphs that follow, in discussing each of the relevant factors involved.

Statistical significance of differences in data entry speed attributable to different test conditions was examined through analysis of variance of session times, using standard computer software developed for that purpose[3]. The analysis of effects of data entry mode, shipment-to-piece ratio, and level of advance shipment information, is summarized in Table 3-2. A similar analysis, in which session times were re-ordered to examine learning effects by day and by session, is summarized in Table 3-3.

Table 3-1

Session Time for 48-Piece Test Loads
under All Test Conditions

Test Operator	Load Factors	On-Line Terminal Day-Session	On-Line Terminal Time	Digital Recorder Day-Session	Digital Recorder Time	Checksheet Day-Session	Checksheet Time
A	HL	2-3	58 min.	3-1	75 min.	1-1	73 min.
	HH	-1	65	-2	46	-2	45
	LL	-2	42	-4	34	-4	37
	LH	-4	31	-3	28	-3	32
B	HL	3-1	53	1-3	49	2-2	40
	HH	-3	35	-4	38	-4	32
	LL	-4	32	-2	34	-3	20
	LH	-2	26	-1	59	-1	21
C	HL	1-4	60	2-2	60	3-4	42
	HH	-2	60	-1	62	-3	39
	LL	-1	74	-3	42	-1	35
	LH	-3	33	-4	37	-2	26
D	HL	3-4	50	2-3	44	1-2	38
	HH	-1	41	-4	36	-4	28
	LL	-2	32	-1	48	-3	23
	LH	-3	27	-2	29	-1	23
E	HL	1-2	52	3-4	48	2-1	45
	HH	-4	46	-3	45	-3	33
	LL	-3	43	-2	37	-2	27
	LH	-1	51	-1	47	-4	19
F	HL	2-3	68	1-1	96	3-3	46
	HH	-2	51	-2	56	-1	36
	LL	-1	64	-4	45	-4	31
	LH	-4	35	-3	42	-2	29

Note: For load factors, HL indicates a high S/P ratio (.75) and a low level of advance shipment information (.25); LH indicates a low S/P ratio (.25) and a high level of advance information (.75); etc.

Table 3-2

Analysis of Variance of Session Time as Influenced by Data Entry Mode, Shipment-to-Piece Ratio, and Level of Advance Shipment Data

Source of Variance	d.f.	Mean Square	F
Operators (O)	5	463.5	-
Conditions	11		
Mode (M)	2	1,404.5	14.8*
S/P Ratio (R)	1	3,556.1	37.6*
Advance Data (A)	1	1,404.5	14.8*
M x R	2	2.93	.03
M x A	2	30.5	.32
R x A	1	162.0	1.71
M x R x A	2	159.5	1.68
Operators x Conditions	55	94.7	
O x M	10	111.1	
O x R	5	143.2	
O x A	5	83.3	
O x M x R	10	85.7	
O x M x A	10	77.6	
O x R x A	5	129.7	
Residual	10	68.1	

*$p < .001$

Table 3-3

Analysis of Variance of Session Time as Influenced by Day of Testing, and Session within Day

Source of Variance	d.f.	Mean Square	F
Operators (O)	5	463.5	-
Conditions	11		
Day (D)	2	462.9	2.99
Session (S)	3	961.7	6.22**
D x S	6	202.0	1.31
Operators x Conditions	55	154.6	
O x D	10	299.5	
O x S	15	125.7	
Residual	30	120.7	

**$p < .005$

Statements of statistical significance in the following paragraphs are based on these two analyses.

Effect of Data Entry Mode

The use of different modes of data entry resulted in differences in the length of test sessions, i.e., the time required to complete data entry for a 48-piece test load. Average session times for the three modes tested are listed in Table 3-4. The checksheet was the fastest, with the other two modes about the same in overall speed of data entry. The analysis of session times summarized in Table 3-2 indicates no significant interaction effect between data entry mode and any other test variable.

Table 3-4

Average Session Time for Three Data Entry Modes

Data Entry Mode	Mean Session Time
On-Line Terminal	47.5 min.
Digital Recorder	47.4
Checksheet	34.2

In actual operations, of course, handwritten data on the checksheets would have to be transcribed in some way to digital form, perhaps by keypunching, thus adding to the total time required for data entry. What is important is that all three modes seem fast enough for use at the truck docks, indicating that data entry could keep pace with truck unloading. That conclusion will be discussed further at the end of this section, after all results on speed of data entry have been reported.

Effect of Load Factors

Session time was also influenced by load factors, as one would expect based on common sense. For loads with a high level of advance shipment data, fewer new data items have to be entered, and so data entry is faster. For loads with many multi-piece shipments (low shipment-to-piece ratio), fewer data items have to be entered because general shipment data can be omitted for all but one piece in each shipment; and again data entry is faster. These effects are illustrated in Table 3-5, which presents session times for the different combined load factors - high and low S/P ratio, and high and low levels of advance shipment information - averaged over all three data entry modes. The analysis of session times summarized in Table 3-2 confirms significant effects attributable to both of these load factors, but indicates no significant interaction effect between them.

Table 3-5

Average Session Time for Different Test Loads

Load Factors		
S/P Ratio	Advance Data	Mean Session Time
High (.75)	Low (.25)	55.9 min.
High	High (.75)	44.1
Low (.25)	Low.	38.9
Low	High	33.1

Learning Effects

Differences in average session time from day to day, summarized in Table 3-6, were not great. Although there seems to have been a tendency for the test operators to work somewhat more quickly from one day to the next, the analysis of session times presented in Table 3-3 indicates that this apparent difference does not quite achieve statistical significance ($p>.05$).

Table 3-6

Average Session Time from One Test Day to Another

Day	Mean Session Time
1	47.8 min.
2	42.0
3	39.2

The kinds of learning which might result in day to day performance changes are speculative. The operators might gradually become accustomed to shipping label formats and the general requirements of the data entry task; but shipping labels were already familiar to them. The operators might gradually become used to the general test environment and learn to concentrate their attention in meeting task demands; but the test environment although novel was not particularly stressful.

More notable differences in time were observed from session to session within each day of testing, as summarized in Table 3-7. It can be seen that the first test session of the day went fairly slowly in comparison with succeeding sessions, as test operators learned the procedures for the particular data entry mode they were using. It seems evident that most of this mode-specific learning was accomplished within the first test session, since little further improvement in speed can be observed for data entry in subsequent sessions.

Table 3-7

Average Time for Repeated Sessions
Using the Same Data Entry Mode

Session	Mean Session Time
1	53.8 min.
2	41.1
3	3[illegible]
4	37.8

A special analysis of session time was conducted to determine whether there was any interaction between session and data entry mode. No significant interaction effect was found. One might suppose that the two modes involving keyboard data entry could show greater learning effects from session to session than the checksheet mode which only involves use of paper and pencil. The results do in fact match that expectation, as can be seen in Figure 9 where average data entry time is plotted against session separately for the three data entry modes. The decrease in time from the first to second session does seem more marked for the on-line terminal and digital recorder than for the checksheet mode. But because the

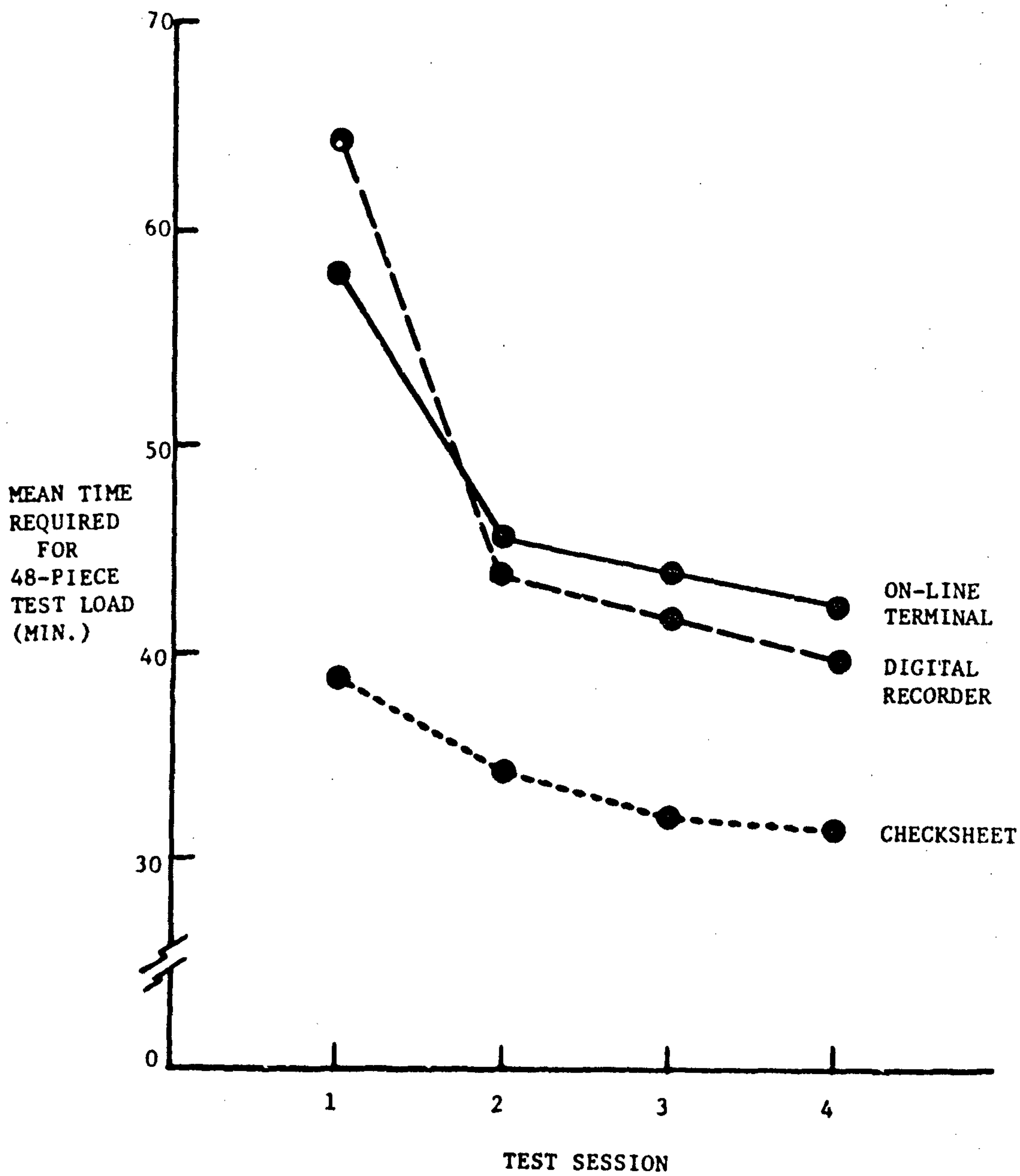


Figure 9. Data Entry Time as a Function of Test Session for Three Input Modes

checksheet is generally faster, the proportional reduction in data entry time is similar for all three modes, thus accounting for the failure to confirm an interaction effect in variance analysis. Even the simple checksheet mode provided an opportunity for learning, if only to learn better how to shuffle paper.

Individual Differences

As in any test involving human performance, there were individual differences among the test operators. Average session times for these six individuals are listed in Table 3-8. It can be seen that the fastest operator took about 30 percent less time than the slowest. (The fastest operator is not necessarily the best man for the job, however, unless he is accurate as well.) Since the test design involved repeated measurements from each operator, there can be no valid test of the statistical significance of individual differences in performance, but these appear to be of about the same magnitude as differences in data entry speed attributable to the controlled test variables.

Table 3-8

Individual Differences in Speed among Six Test Operators

Test Operator	Mean Session Time
A	47.1 min.
B	36.6
C	47.5
D	34.9
E	41.9
F	49.9

Keystrokes

To some extent it is possible to account for differences in data entry speed in terms of different demands of the data entry task under the various test conditions. Task demands could be estimated by counting data entries, or perhaps by counting keystrokes. For the two modes of data entry which produced digital records, it was possible to program the DHAC computer to scan those records for each test session and count automatically the number of keystrokes of various kinds which were used to accomplish the data entry task. Thus there is available a direct and convenient statistic reflecting the amount of data entered for test loads of different kinds.

The average number of keystrokes per session for test loads combining different load factors is shown in Table 3-9, listed separately for the on-line terminal and the digital recorder to permit comparison of those two data entry modes. It can be seen in this table that those test loads which resulted in shorter session times did in fact require substantially less data input.

Table 3-9

Average Keystrokes per Session for Different Test Loads Using On-line Terminal and Digital Recorder

Load Factors		Data Entry Mode	
S/P Ratio	Advance Data	On-Line Terminal	Digital Recorder
High (.75)	Low (.25)	1,939	2,445
High	High (.75)	1,325	1,663
Low (.25)	Low	1,297	1,777
Low	High	1,086	1,567

A comparison of performance measures for different test loads in Tables 3-5 and 3-9 certainly indicates a rough correspondence between time required and data entered. But this correspondence does not exist between the two data entry modes, which were equivalent in time required (Table 3-4) but involved quite different levels of keying activity. In effect, users of the digital recorder were required to make more keystrokes to accomplish the job, but made them more quickly. Users of the on-line termimal were presumably constrained to a more deliberate pace in the item-by-item sequence of interaction with the computer. The net result for these two modes of data entry proved to be equivalent session times achieved in different ways.

An overall count of keystrokes, of course, is not an exact measure of data entered. Some keystrokes are needed for signalling associated with the control of entry format, and for error correction, as well as for data entry. A more detailed analysis of keying activity for the on-line terminal is summarized in Table 3-10 and for the digital recorder in Table 3-11. These tables show the average number of keystrokes used for data entry, format control and error correction, for different test loads.

Comparing keystroke counts for the two entry modes, it may be seen that the digital recorder required on the average about 400 more strokes for data entry than the on-line terminal. This difference can be accounted for entirely in terms of the different data entry procedures used in this initial test program. The user of the on-line terminal generally did not have to enter data for POE and TAG, instead simply confirming computer-displayed values for those two data items, whereas the user of the digital recorder had to enter all items completely.

Comparing the two data entry modes in terms of keystrokes required for format control, it can be seen that the overall proportion was fairly similar for the on-line terminal and digital recorder, 38 and 32 percent respectively. This "overhead" for format control could be reduced for the digital recorder by redesign of its keyboard to permit individual item entry rather than line entry of groups of items, as recommended in Appendix C, with savings of perhaps 300 keystrokes per test load.

To assist in comparing the two data entry modes in terms of keystrokes required for error correction, a further analysis of error correction keying is presented in Table 3-12. Here it can be seen that BACKSPACE was by far the most common procedure employed for error correction in both modes. Considering the tremendous number of total keystrokes recorded in this initial test program, the relatively slight proportion of keying required for error correction is evidence of conscientious effort by the test operators to maintain accuracy of input in both modes of data entry.

INPUT SEQUENCE TIME

The overall time per session gives only a rough picture of the time required for data entry. A more detailed view would take into account the various different kinds of data entry sequences which were included in this initial test program. Three sequences can be usefully distinguished:

1. The first piece of cargo from a "new" shipment, whose TCN cannot be found on the index list, for which the test operator must

Table 3-10

Analysis of On-Line Terminal Keying for Different Test Loads

Load Factors		Keystrokes for					
		Data Entry		Format Control (ENTER, YES/NO)		Error Correction	
S/P Ratio	Advance Data	Mean	%	Mean	%	Mean	%
High (.75)	Low (.25)	1,311	68	605	31	23	1
High	High (.75)	709	54	605	45	11	1
Low (.25)	Low	817	63	465	36	15	1
Low	High	635	58	438	41	13	1
	Overall:	868	61	528	38	15	1

Table 3-11

Analysis of Digital Recorder Keying for Different Test Loads

Load Factors		Keystrokes for Data Entry		Keystrokes for Format Control (ENTER, Indicators)		Keystrokes for Error Correction	
S/P Ratio	Advance Data	Mean	%	Mean	%	Mean	%
High (.75)	Low (.25)	1,722	70	713	29	10	1
High	High (.75)	1,148	69	508	31	7	0
Low (.25)	Low	1,182	67	587	33	8	0
Low	High	1,023	65	538	35	6	0
	Overall:	1,269	68	587	32	8	0

Table 3-12

Keystrokes Used for Different Error Correction Procedures

Data Entry Mode	Total Keystrokes	BACKSPACE	CANCEL	Other
On-Line Terminal	35,883	287	25	47 (BACKUP) 6 (RESTART)
Digital Recorder	44,707	168	10	4 (CLEAR) (also 67 line re-entries)

enter the full TCN, and all general shipment data as well as piece-specific data.

2. The first piece of cargo from a shipment with advance data, whose TCN is on the index list, for which the operator can enter the short index designator, and review general shipment data, usually without having to enter any changes, before entering the necessary piece-specific data.

3. Any extra piece of cargo in a shipment whose general data have already been entered and/or reviewed, for which the operator need enter only the index designator and the piece-specific data.

On logical grounds one would expect that the time required for data entry would decrease from one kind of sequence to the next, and this indeed proves to be the case. The average times required for these three different data entry sequences are listed in Table 3-13, for the three modes of data entry used in this initial test program. Table 3-13 also includes average time required for two portions of each sequence, the first part involving shipment identification plus entry and/or review of general shipment data, and the second part involving simply the entry of piece-specific data which is common to all three sequences. Table 3-13 also provides for each sequence and data entry mode a parenthetic indication of the fastest time recorded in this initial test program.

Several additional comments will aid interpretation of these tabulated performance measures. It should be noted that this table does not necessarily permit fair comparisons among data entry modes. As an example, from these tabulated figures one might suppose that the on-line terminal was somewhat slower to use than the digital recorder, but the comparison of overall session times has shown those two devices to be equivalent in speed. The seemingly anomalous results in Table 3-13 can be accounted for by several specific differences in the test conditions. For the on-line terminal time recording was automatic, with the time interval for one sequence beginning the instant the previous sequence had been completed. Time recording for the digital recorder was manual, with the observer starting his stopwatch only when the operator began work on a new sequence, which could account for 1-2 seconds of the difference in measured sequence time between these two modes. Moreover, the observer of the digital recorder occasionally failed to complete his time recording, when he was distracted by offering advice to the operator or answering questions, so that time records were sometimes lost for that subset of "trouble trials" which may have required somewhat longer times to complete. By contrast, computer recording of times at the on-line terminal was not

Table 3-13

Average (and Shortest) Times Required for Different Data Entry Sequences

Data Entry Sequence	On-Line Terminal	Digital Recorder	Checksheet
"New" shipment; mean time =	108.1 sec.	90.0 sec.	73.4 sec.
Enter TCN and general data	87.2	71.3	59.5
Enter piece-specific data	20.9	18.7	13.9
(Fastest time =)	(57)	(50)	(46)
Shipment with advance data, mean =	51.6	47.4	33.3
Enter index, review advance data	34.3	32.9	22.9
Enter piece-specific data	17.3	14.5	10.4
(Fastest time =)	(28)	(23)	(17)
Extra pieces in a shipment, mean =	33.3	26.6	20.9
Find and enter index	13.5	9.3	8.3
Enter piece-specific data	19.8	17.3	12.6
(Fastest time =)	(16)	(15)	(9)

influenced by whether its operator was having difficulties; the only times eliminated in subsequent analysis of the computer record were for those few instances in which the operator elected to RESTART a data entry sequence.

On the other hand, Table 3-13 does permit a fair comparison within each data entry mode of the times required for different entry sequences. As an example, for all three modes it can be seen that the sequence involving entry of complete shipment data takes more than twice as long as the sequence in which advance shipment data can be reviewed instead. This finding suggests that if all shipment data are needed for processing at an air cargo terminal, there are practical benefits in permitting review and confirmation of advance data when available, rather than requiring an operator to enter all data directly from shipping labels.

It can be seen that for a given data entry mode the entry of piece-specific data takes approximately the same time in all three sequences listed in Table 3-13. An exception might be noted for the sequence involving review of advance data. For a single-piece shipment the advance data would include a WT and CUBE correct for that piece, so that those two data items (considered here piece-specific for multi-piece shipments) could be simply confirmed during the data review rather than entered. As a consequence, the average entry time for piece-specific data was measured to be somewhat faster for sequences involving data review.

Average values, of course, do not tell everything about performance. As one might suppose, the time required to complete a data entry sequence was somewhat variable as the operators accomplished their job more quickly for some pieces of cargo than for others. This kind of performance variability is probably influenced by a number of factors, including such things as differences in label legibility as well as fluctuating attention on the part of the test operators. For the on-line terminal, frequency distributions of sequence times were developed on the basis of machine analysis of computer records. Probably the most useful way of examining such distributions is in terms of the cumulative frequency with which data entry is accomplished within an increasing time limit. Such cumulative distribution curves are illustrated in Figure 10 for the three kinds of data entry sequences under discussion.

The curves in Figure 10 all indicate skewed distributions of sequence entry time, lacking that symmetric ogival form which characterizes a balanced "normal" distribution. In effect, in such a task it is not possible to balance the occasional instances of

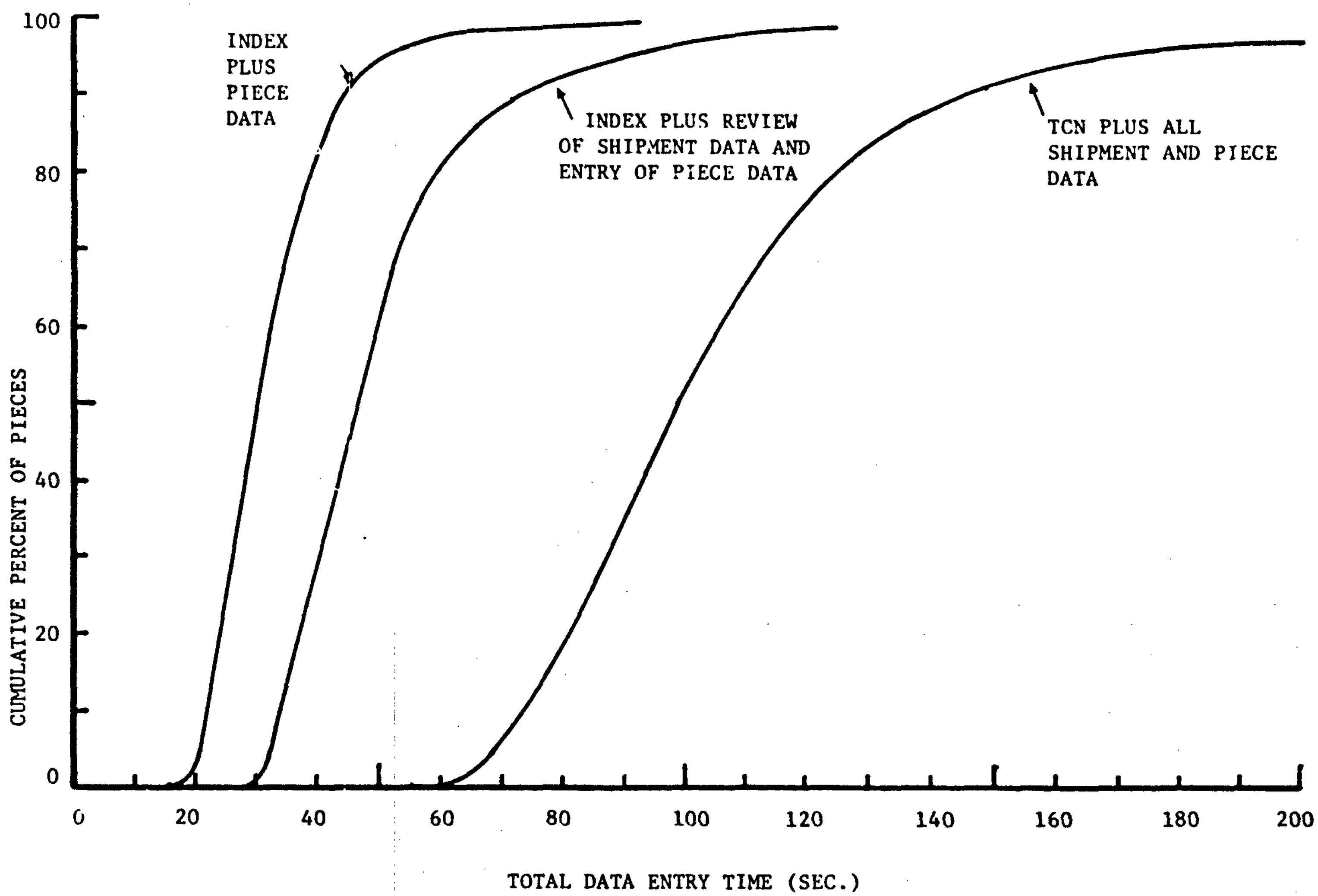


Figure 10. Cumulative Distribution of Time Required for Different Data Entry Sequences Using the On-Line Terminal

very long entry times with an equal number of unusually short times. Given such skewed distributions, the mean value is not necessarily a characteristic value. For all three data entry sequences considered here, more than 60 percent of entries were accomplished in less than the average times reported in Table 3-13. That is to say, the median entry times were lower than the means in all three cases.

With distribution curves such as those shown in Figure 10, it is possible to predict expected performance within any selected time limit. Consider the rightmost curve, for sequences involving complete entry of all data for a new shipment. If one wished to know what proportion of entries were accomplished in two minutes or less, to pick an arbitrary example, this distribution curve permits an estimate of 75 percent. The curves permit estimation in reverse with equal ease. As an example, for entry only of piece-specific data for extra pieces in a shipment, what is the time limit within which 90 percent of those entries can be accomplished? The leftmost curve in Figure 10 permits an estimate of 45 seconds.

Once an actual data entry task has been defined to support air cargo terminal operations, perhaps a task involving entry of some critical subset of shipping label data items, then similar distribution curves could be developed on the basis of field testing to predict operator performance on the job. Such testing should be conducted for the on-line terminal and for any other modes of data entry considered as feasible alternatives for use on the truck dock.

TRANSACTION TIMING

Data entry sequences considered at a finer level of detail are comprised of the discrete transactions by which individual data items are entered or reviewed. For the two off-line modes of data entry it was difficult to record the timing of separate transactions, although observer notes occasionally included timing for different portions of a data entry sequence. For the on-line terminal, however, the controlling computer was programmed to record the time of every operator input, and so a subsequent analysis at the transaction level could be undertaken.

There are several ways of looking at the results of transaction analysis. Table 3-14 lists the number of keystrokes and the time required for different transactions of data entry or review, averaged over all load conditions experienced by users of the on-line terminal. The keystroke count includes keying needed for sequence control as well as for data entry, so that keying the six-digit TAG, for example, required 7.0 strokes on the average (i.e.,

Table 3-14

Average Keystrokes and Time Required for Different Data Transactions Using the On-Line Terminal

Data Item	Data Entry: Mean Keystrokes	Data Entry: Mean Time Required	Data Review: Mean Keystrokes	Data Review: Mean Time Required
TCN/INDEX	6.1	17.8 sec.	-	-
RDD	2.1	10.7	1.0	4.3 sec.
PROJECT	1.7	2.9	1.0	2.3
PRIORITY	2.1	2.7	1.0	1.8
FROM (Consignor)	4.9	9.3	1.0	2.9
TO (POE)	4.0	7.0	1.0	1.8
POD	4.1	7.4	1.0	1.6
CONSIGNEE	4.5	8.1	1.0	3.4
PIECE	2.0	3.9	1.0	2.3
TOTAL	2.0	3.4	1.0	1.9
WT	3.5	3.4	1.0	1.4
CUBE	2.5	2.5	1.0	1.5
TAG	7.0	9.6	1.0	3.1
DISP	5.2	7.1	-	-

six digits plus ENTER). These counts also include any keying needed for error correction, including BACKSPACE, so that some of the averages are slightly higher than the minimum requirement: e.g., 2.1 rather than 2.0 for PRIORITY, 4.1 rather than 4.0 for POD. For the "optional" items of RDD, PROJECT, FROM and CONSIGNEE, the average keystroke counts included occasional entry of blank items and so appear lower than the figures logically expected. For TCN/INDEX the average of 6.1 keystrokes includes frequent transactions of entering a 2-3 stroke INDEX as well as entries of TCN which would require 15 strokes (or more if errors were made and corrected).

The transaction timing figures in Table 3-14 are generally related to the number of keystrokes involved, as one would expect. It is clear that data review, with just one confirming keystroke per item, is faster than data entry, as discovered earlier in the analysis of sequence timing. It should be noted, however, that these tabulated transaction times actually represent the intervals between one ENTER input and the next. Consequently, the average time figures include any time required for thinking, checking, reading displayed prompts, etc., as well as keying time itself. The mechanics of button pushing probably require no more than one second per stroke. None of the transaction times in Table 3-14 approach that keying speed except for the entry of WT and CUBE which are both short numeric items.

A different way to look at transaction records is shown in Table 3-15. Here, an analysis of data entry and data review transactions is presented separately for test conditions involving different load factors. (The "Other" category in this table represents the time spent at that choice point in the control sequence offering optional review of previously entered shipment data.) Instead of showing average keying and time required per item, this table lists the proportion of total keying or total time required to enter or review each data item. These numbers were calculated directly from the test records for each load type, and were not derived from the overall averages in Table 3-14.

When different data transactions are considered in terms of their proportional demands, certain aspects of the data entry task can be discerned more clearly. One can see, for example, how the burden of the job shifts from data review to data entry for loads with a lower level of advance shipment information, and that this shift is somewhat different for loads with different shipment-to-piece ratios.

Table 3-15

Proportion of Keystrokes and Time Required for Different Data Transactions Using the On-Line Terminal for Different Test Loads

	Mean Number of Transactions				Percent of Total Keying				Percent of Total Time			
Load Factors:	HL	HH	LL	LH	HL	HH	LL	LH	HL	HH	LL	LH
Data Entry												
TCN/INDEX	51	48	49	48	26	21	19	15	32	34	30	27
RDD	33	25	13	7	4	3	2	1	9	7	8	4
PROJECT	35	25	15	8	4	3	2	1	3	2	2	1
PRIORITY	28	10	10	4	3	2	2	1	2	1	1	0
FROM (Consignor)	31	16	12	6	9	5	5	2	8	4	5	2
TO (POE)	0	0	0	0	0	0	0	0	0	0	0	0
POD	28	10	9	4	6	3	3	2	5	3	3	2
CONSIGNEE	30	17	10	6	7	4	4	2	7	4	3	2
PIECE	18	18	46	46	2	3	7	9	2	2	7	8
TOTAL	28	9	9	3	3	1	1	1	2	1	1	1
WT	42	26	47	48	7	7	13	16	4	3	6	8
CUBE	41	25	47	48	5	5	9	11	3	2	4	6
TAG	2	2	3	2	1	1	1	1	0	1	1	1
DISP	49	49	49	48	13	19	20	24	10	12	12	17
Totals:	416	280	319	278	90	77	88	86	87	76	83	79
Data Review												
RDD	5	14	4	[illegible]	0	1	0	1	1	2	1	1
PROJECT	2	13	2	5	0	1	0	1	0	1	0	1
PRIORITY	10	28	8	10	1	2	1	1	0	2	0	1
FROM (Consignor)	8	22	6	8	0	2	0	1	1	2	1	1
TO (POE)	37	37	17	14	2	3	1	1	2	2	1	1
POD	10	28	7	11	0	2	1	1	0	1	0	1
CONSIGNEE	7	21	7	8	0	2	1	1	1	2	1	1
PIECE	30	31	3	2	2	2	0	0	2	2	1	0
TOTAL	10	28	8	10	0	2	1	1	0	2	1	1
WT	7	23	1	1	0	2	0	0	0	1	0	0
CUBE	7	23	1	1	0	2	0	0	0	1	0	0
TAG	47	48	48	47	3	4	4	4	4	5	5	7
Totals:	180	316	112	124	8	25	9	12	11	23	11	15
Other	12	12	36	36	1	1	3	3	1	2	5	6
Overall Totals:	608	608	467	438								

Note: For load factors, HL indicates a high S/P ratio (.75) and a low level of advance shipment information (.25); LH indicates a low S/P ratio (.25) and a high level of advance information (.75); etc.

At this detailed level of transaction analysis it is possible to use the numbers in Table 3-15 to predict the effects on performance time of reconfiguring the data entry task in different ways. As an example, suppose that in the actual data entry job at the truck dock it was not necessary to enter or review the "optional" data items of RDD, PROJECT, FROM and CONSIGNEE. Suppose further that the TO (POE) item could be omitted on the assumption that it would be the same for all export cargo at a given air terminal. Suppose finally that the identifying TAG on each piece of cargo did not have to be keyed but instead could be "wanded" for automatic input from a machine-readable label. From the numbers in Table 3-15 it can be estimated that the net effect of all of these changes would be to reduce keying by 15 to 28 percent, depending upon load factors, and the time required for the job by 21 to 34 percent.

Examining the numbers in Table 3-15 it is evident that the single most time consuming transaction in this job is entry of the TCN or INDEX, which by itself required 27 to 34 percent of the total time, depending on load factors. If the technique of indexing had not been used to shortcut shipment identification, so that a full TCN had to be entered for every piece of cargo, then this one type of transaction would account for an even greater proportion of the total data entry time. This observation implies that the single greatest contribution to increased efficiency of data entry on this job would be to make the TCN itself machine-readable, so that the operator does not have to key it, but instead can input this long symbol string by the easier method of "wanding" it. Perhaps the TCN could be expanded to include a piece indicator, and this combined identification used instead of the extra TAG postulated for each piece of cargo simulated in this initial test program. If so, the hardest data entry transaction measured in this initial test program might become the easiest at the truck dock.

DATA AVAILABILITY

If truck unloading could proceed without pause, with no rest breaks for the work crew and assuming continuous availability of forklift equipment to move heavy cargo, the time required might average about one minute per piece. In actual operations at the truck docks this estimated rate is seldom achieved, since a number of practical problems can introduce periodic delays in the unloading process. Accepting this postulated one-minute-per-piece average as a desirable goal nonetheless, the results of this initial test program look encouraging. In terms of session time, it was found that all three data entry modes permitted data input at an overall average rate of less than one minute per piece (Table 3-4).

It is true that several aspects of test performance tend to counter this encouraging result. For the most difficult test loads (high S/P ratio, low advance information) data entry was somewhat slower than one minute per piece on average (Table 3-5). Also, some individual operators worked more slowly in early sessions even with relatively easy test loads (Table 3-1). Furthermore, the timing of data entry sequences indicates that the entry of complete data for a new shipment always took longer than one minute for the on-line terminal in this test situation (Figure 10) and so conceivably could impose some delay on unloading at the truck dock.

In this initial test program, speed of data entry was measured for a job which required the operators to enter or review all items from a shipping label at least once for each shipment. In actual data entry operations at the truck dock, it is possible that the job could be redefined to require entry only of some smaller subset of critical items, as suggested above in the analysis of transaction timing. If so, actual data entry performance would probably be faster than that measured in this initial testing, and one data entry operator working along in parallel with an unloading crew should have little trouble keeping pace. If the data entry task were reduced to a minimal set of data items, it would appear that data handling need not slow cargo handling whichever mode of data entry were to be used.

If data entry modes are effectively equivalent in providing adequate speed of data entry at the truck dock, then other kinds of measures are needed to determine which is the preferred mode. One such measure, of course, would be accuracy of data entry, as discussed in the next section of this report. Another measure which may prove important in overall system operations is the availability of entered data for further processing. The three input modes examined in this initial test program imply considerable differences in data availability.

Data inputs made using an on-line terminal are immediately available for further processing. If a piece of cargo has been sent from the truck dock to a particular pallet pit or storage area, that fact would be known immediately in the general data processing system used to support air cargo terminal operations.

Data inputs entered via a digital recorder would not be available for further processing until truck unloading is completed. At that point, the digital tape record could be read into the general computer system in a matter of only a few minutes. In the meantime, however, the first pieces unloaded from a truck may wait at a pallet pit for an hour or more before their data records are transmitted to the computer.

For the checksheet mode of data entry, the potential de: between data recording and data availability is longer still. e a tru has been unloaded, its cksheet records must be trans bed into digital form before they are available for computer proce ng. That transcription process may be performed by skilled operators working under relatively good conditions in a data handling center, but even assuming continuous availability of personnel (probably unrealistic) this job would take time, perhaps another 30 to 60 minutes per load. In follow-on testing at MITRE it is planned to measure performance of operators entering checksheet data into a computer, in order to permit better estimation of just how long that process would take.

The importance of delays in data availability can be evaluated only in the context of a broader analysis of data handling and its effects on air cargo terminal operations. It is recommended that such a broader analysis of system performance be undertaken, with emphasis on determining what are acceptable delays in data availability following data entry at the truck dock. By comparing performance requirements established in that analysis with performance capabilities confirmed by testing, it should be possible to decide under what circumstances the digital recorder and checksheet modes can be used as effective alternatives to on-line data entry.

SECTION IV

RESULTS - ACCURACY OF DATA ENTRY

Fast data input can be considered useful only when data entries are made accurately. If data entries are often wrong, or perhaps accidentally omitted, then the data entry task has been performed poorly. Faulty data input can result from equipment malfunctioning or from operator error. Whichever the cause, some modes of data entry may prove more accurate than others.

The question of equipment failure can be dealt with briefly. The on-line terminal worked well throughout this initial test program. No flaws in terminal or computer functioning were detected. For the checksheet mode of data entry, there was no equipment to malfunction. Sometimes pencils broke, but they were replaced as needed.

For the digital recorder, however, some difficulties were encountered in hardware functioning. In careful scrutiny of the digital records produced by this data entry mode, a number of record gaps were detected, which were caused by failures in "stepping" the magnetic tape cassette. Over the 24 test sessions, a total of 41 tape gaps occurred, varying in size from just one character lost to a sequence of several hundred missing characters. In the laboratory setting, it was possible to retrieve the missing data by a time-consuming process of manual re-keying from the parallel data record produced by the paper strip printer on the digital recorder. In any actual data entry operation, such record gaps would be undetected until too late to repair. These 41 tape gaps would have resulted in complete data loss for 113 pieces, partial data loss for 13 more pieces, and wrong data recorded for 10 pieces, out of the total of 1152 piece records entered.

Such data loss obviously represents an unacceptable hazard. If digital recorders are considered for operational use, some means must be found to ensure more reliable performance. In this initial test program, most of the tape gaps occurred when using cassettes which were in some way incompatible with the digital recorder. When the manufacturer's own cassettes were used, such gaps occurred only rarely. It should be noted that several thousand similar recorders are being used commercially, apparently without serious problems.

The question of operator error is more complicated, and will be discussed at length in the remainder of this section. The topics to be considered include: the frequency and nature of format errors made by the test operators; errors of content in data entry; and operator performance in the detection and correction of errors, either errors made during data entry or errors in the pre-stored advance shipment data.

FORMAT ERRORS

Suppose that an operator makes a mistake and transposes two characters when entering a TCN. Such an error in content would probably not be detectable in a data processing system. But suppose that the operator forgets to enter any TCN at all, or enters a TCN with too few or perhaps too many characters. Such errors could be detected in data processing because they violate rules which define the required data entry format.

For the on-line terminal, data processing follows immediately on data entry, so that format errors cannot be made. Put more accurately, when an error in format <u>is</u> made, it is detected by whatever data validation procedures have been included in the on-line computer software, and the nature of the error is signalled to the operator so that he can correct it before proceeding to the next item in the data entry sequence. A format error can be made, but it must be corrected before the data entry sequence can be continued.

Format errors are defined in terms of the data validation checks which are applied. For the on-line terminal, data checks and associated error messages used in this initial test program can be determined from review of the control sequence outlined in Appendix B. Other modes of data entry could involve other kinds of format errors, as discussed below for the digital recorder.

When an on-line data entry sequence is fairly straightforward, as in this test situation, the incidence of format errors will tend to be low. Errors will occasionally be made, but since each one is brought immediately to the operator's attention he will learn to avoid them. All transaction records generated while testing the on-line terminal were analyzed to determine the frequency of format errors, i.e., instances in which operators were required by the computer to re-enter a data item. Only 59 format errors were found, as summarized in Table 4-1.

That result should be considered in terms of the total data entry job accomplished in this initial test program. Six operators each worked in four sessions, entering data for 48 pieces per session, with 3-14 data items per piece depending upon whether data items are pre-stored for review or must be entered from the label.

Table 4-1

Data Format Errors in Use of the On-Line Terminal

	Type of Format Error				
Data Item	Blank	Too Short	Too Long	Other	Total
TCN/INDEX	2	19	0	1 (Note 2)	22
Other Items:					
RDD	- (Note 1)	0	5	-	5
PROJECT	-	0	0	-	0
PRIORITY	0	-	-	5 (Note 3)	5
FROM (Consignor)	-	7	3	-	10
TO (POE)	0	-	-	0	0
POD	4	-	-	0	4
CONSIGNEE	-	0	1	-	1
PIECE	2	-	-	0	2
TOTAL	1	-	-	0	1
WT	2	-	-	0	2
CUBE	1	-	-	0	1
TAG	1	1	0	0	2
DISP	1	-	3	-	4
Totals:	14	27	12	6	59

Notes: 1. "-" indicates that no data check was made.

2. Attempted entry of an unassigned INDEX.

3. All five instances represent attempts to enter FROM data when asked to enter PRIORITY.

This represents an aggregate total of approximately 8000 data items entered. Thus the 59 format errors observed represent only a very small proportion, less than one percent, of all data entries.

There are not enough format errors listed in Table 4-1 to reveal any consistent pattern of mistakes, except for the apparent tendency to shorten rather than lengthen entry of the TCN. A 14-symbol TCN constitutes a data string which exceeds the immediate memory span of most people. Thus entry of the TCN requires glancing back and forth from label to keypad. In the process, some symbols occasionally get lost.

For the digital recorder, the general situation is quite different. There is no on-line computer to detect format errors of the type described above. Such errors might be detected in subsequent computer processing of digital records, but they are irretrievable in the sense that they could not then be corrected.

A more significant problem in use of the digital recorder is that there is no on-line control of the data entry sequence. An on-line terminal asks its user for each data item, and thus the controlling computer "knows" what item is being entered. The user of the digital recorder must remember to signal which data item he is entering next, using whatever special indicator keys are provided for that purpose. If he forgets to include that signal, or if he makes a mistake and records the wrong signal, a correct data entry may be lost or garbled in subsequent data processing of the digital record.

Such format errors in signalling the <u>sequence</u> of data entry may have disastrous effects on the accuracy of data records. Simple omission of a single key stroke could lose the complete data record for a piece of cargo and produce wrong data entries for the preceding piece. Care must be taken in equipment design, in operator training, and in the logic used for analyzing digital records, to reduce the likelihood of such format errors and minimize their consequences insofar as possible.

Digital records generated during this initial test program were scanned to determine the nature and frequency of format errors. A total of 183 errors were detected, involving improper data entry procedures of various different kinds. Of these 183 errors, 24 were minor in nature and would have no consequences in subsequent data processing. The remaining 159 format errors, using a straightforward method for computer processing of the digital records, would have the effect of losing all data for 76 pieces, creating wrong data records for 85 pieces, adding false data records for 3 imaginary pieces, losing data for 98 miscellaneous items and recording wrong data for 94 other items. A more detailed discussion of format errors using the digital recorder is presented in Appendix E to this report.

The computer software used to analyze digital records was revised in various ways to try to make it "smart" enough to correct some of the more serious format errors. To consider one example, occasionally a test operator using the digital recorder would forget to key the special indicator when beginning to enter the TCN for a new piece of cargo. The effect of that simple error in any straightforward data analysis scheme would be to overlay subsequent data entries as "corrections" to data items just entered for the immediately preceding piece, thus storing a complete set of wrong data for that piece and losing any record of the new piece. To try to remedy this situation, the data analysis software was revised to include a search for each piece to determine whether the entry of disposition code (properly, the last data item) was directly followed by a long string of symbols (assumed to be a new TCN) in which case a TCN indicator was inserted before data analysis continued. Other kinds of format errors were corrected in other ways. A description of various correction routines is included in Appendix E.

Using this improved data analysis software, a number of format errors in the digital records still remained uncorrected, and indeed uncorrectable. The net result was 89 uncorrected format errors (including 6 introduced by the "correction" routines) resulting in complete data loss for 14 pieces, wrong data records for 21 pieces, 7 false records, and lost or wrong data for 131 other individual data items. The effects of these residual format errors are listed in greater detail in Table 4-2. It is obvious that there are limits to how well machine analysis can counteract operator error.

For the checksheet mode of data entry, analysis of accuracy poses a problem. The data items written on a checksheet may contain errors, and still further errors may be introduced in the process of transcribing written checksheet data into digital form. Data items may have been recorded correctly but illegibly, as suggested by the sample checksheets illustrated in Appendix D. For the checksheet mode, any sensible analysis of accuracy must take into account such potential problems of data transcription.

There is little point in looking at the checksheets and trying to guess what the error rate of data transcription would be. That must be measured empirically. A follow-on study is now being designed to measure the speed and accuracy of data transcription

Table 4-2

Consequences of Format Errors in Use of the Digital Recorder

Data Item	Number Lost	Number Wrong
TCN/INDEX	14 piece records	21 piece records (Note 2)
Other Items:		
RDD	0 items (Note 3)	7 items
PROJECT	4	0
PRIORITY	3	0
FROM (Consignor)	14	0
TO (POE)	2	7
POD	2	11
CONSIGNEE	4	8
PIECE	5	1
TOTAL	0	3
WT	5	7
CUBE	9	2
TAG	6	14
DISP	12	5
Totals:	66 other items	65 other items

Notes: 1. After computer correction of digital records, 89 residual format errors remained, some of which had multiple consequences.

2. 9 TCN's were too short as entered and 3 too long.

3. Lost or wrong data records caused by faulty entry of TCN are not included in the remainder of this tabulation, which represents the effects of miscellaneous other format errors.

from the checksheets generated in this initial test program, and results of that study will be reported when available. Meanwhile, in this analysis of initial test results no attempt has been made to estimate the accuracy of checksheet records, either in terms of format errors or errors in data content.

ERRORS IN DATA CONTENT

Some errors cannot be detected by discrepancies in data format and cannot be attributed to faulty data entry procedures, but result from other simpler kinds of mistakes. An operator may misread a data item when transcribing from a shipping label, or he may see the item correctly but hit a wrong key when entering the data. If his mistake does not invalidate the format of the item entered, the error cannot be detected by machine analysis. The operator may not notice a data item on the shipping label, perhaps a consignee code, and so neglect to enter it. If that item is not required by format conventions, then its absence will not be noticed in any machine analysis of the data record. Errors of these kinds, which do not violate format rules, are referred to here simply as errors in data content.

To discover such content errors in the data record is potentially a difficult task. In this initial test program, the technique used to identify content errors involved several steps. First, a true record of all shipping label data was stored in the DHAC computer. When testing was completed, the computer was programmed to compare each digital data record actually input by an operator with the true record for that test load. The results of that comparison were then printed out with any discrepancies flagged to call attention to them. These printed records were then scanned to determine what content errors of different kinds had occurred and what was their effect on the accuracy of the final data records produced during testing.

For the on-line terminal, the input data could be examined directly in this fashion. For the digital recorder, it was necessary first to process the data record through several screening routines designed to compensate for certain format errors, as described above and in Appendix E, before the final records could be scanned for content errors. For the checksheet mode, the data had not been entered in digital form, and so no such machine analysis of content errors was feasible. As argued earlier, any sensible analysis of checksheet errors must await a follow-on study in which checksheet data are transcribed to digital form, and resulting errors can be assessed to determine which should be attributed to faulty data entry and which to mistakes in data transcription.

Insofar as errors in data content are concerned, the present analysis permits comparisons only between the on-line terminal and the digital recorder. A summary of content errors for these two modes of data entry is presented in Table 4-3, showing the number of errors made for different items on the shipping label. For the on-line terminal, 102 content errors were noted, 34 involving wrong entries for TCN or INDEX, plus 56 other items entered wrongly and 12 items omitted altogether. For the digital recorder, 134 content errors were noted, distributed as shown in the table.

Errors of omission, resulting in missing items, must presumably be attributed simply to inattentiveness on the part of the test operators, momentary lapses in their generally effective level of performance. It is only the optional data items (PROJECT, CONSIGNEE, etc.) which are included here. Omission of a <u>required</u> data item was classified earlier as a format error rather than an error in data content, since such omissions could be detected in subsequent processing of the data record.

Errors involving wrong data content may result from more complicated causes. A categorization of such wrong entries is presented in Table 4-4. The most common category, of course, is the substitution error, in which one symbol is wrongly entered in place of another. Substitution errors accounted for more than 80 percent of wrong data content in both the on-line terminal and digital recorder entry modes. More than half of these substitution errors involved confounding of Ø (zero) and O (the letter), presumably a perceptual problem. Many other substitution errors involve adjacent numbers (1 for 2, 2 for 3, 7 for 8, etc.) or adjacent letters, which may reflect keying errors.

Other types of errors producing wrong data can be identified: transposition, where two symbols are entered in reverse order; omission, where a symbol has been lost in data entry; additions, where an extra symbol has been entered; displacement, where one data field is accidentally entered for another (e.g., CUBE instead of DISP); etc. Such mistakes are quite infrequent for conscientious operators, and are usually accepted as representing an inescapable residual level of human error.

The confounding of Ø and O, however, is a common mistake which is induced by the circumstances of this data entry task. Most shipping labels are typed or printed in such a way that those two symbols look identical and can be distinguished only on the basis of

Table 4-3

A Comparative Count of Errors in Data Contenι

Data Item	On-Line Terminal Missing	On-Line Terminal Wrong	Digital Recorder Missing	Digital Recorder Wrong
TCN/INDEX	- (Note 1)	34 (Note 2)	-	28 (Note 4)
Other Items:				
RDD	0	1	0	0
PROJECT	0	9	1	14
PRIORITY	-	0	-	1
FROM (Consignor)	4	4	11	16
TO (POE)	-	0	-	1
POD	-	1	-	0
CONSIGNEE	8	11	15	16
PIECE	-	2 (Note 3)	-	5 (Note 5)
TOTAL	-	0	-	0
WT	-	2	-	5
CUBE	-	1	-	4
TAG	-	2	-	4
DISP	-	23	-	13
Totals:	12	90	27	107

Notes:

1. "-" indicates items whose absence would be termed a format error rather than an error in data content.
2. Resulting in 2 piece records lost, 42 wrong.
3. Resulting in 2 piece records lost, 2 wrong.
4. Resulting in 4 piece records lost, 36 wrong.
5. Resulting in 5 piece records lost.

Table 4-4

Error Categorization for Wrong Data Items

	On-Line Terminal		Digital Recorder	
	TCN/INDEX	Other Items	TCN/INDEX	Other Items
Substitution errors	31	42	25	64
Ø/O	9	8	6	11
O/Ø	13	7	13	25
Other	9	27	6	28
Transposition errors	1	0	2	3
Omissions (too short)	-	5	-	3
Additions (too long)	-	1	-	3
All other types	2	8	1	6
Totals:	34	56	28	79

meager contextual clues. It is somewhat surprising to note that none of the test operators ever asked for guidance in this regard, perhaps having (unjustified) confidence that they could guess which symbol was intended on the shipping label. But the consequences of a wrong guess in any straightforward data processing system can be severe if the wrong symbol has been entered in a TCN, as for example keying DJØB... for a shipment whose TCN actually begins DJOB.... In this initial test program, such confusions of Ø and O accounted for 41 wrongly input TCN's, which resulted in wrong data records for 54 pieces of cargo.

Fortunately, there are several potential solutions which could entirely eliminate this particular type of error, or at least its consequences, in the entry of TCN's. One possible solution would be procedural, to require that all shipping labels be typed or printed in such a way as to distinguish between Ø and O. Because of human unreliability, that approach would probably be only partially successful. Another procedural solution would be to enforce a ban on the use of the letter O in TCN designators. That approach looks feasible but might be a bother to implement. Perhaps the best solution is one which could be accomplished in the data processing system itself. A screening routine could be devised to convert all O's into Ø's (or vice versa) in any entered TCN before comparing it with pre-stored TCN records which are converted in the same way for purposes of comparison.* Thus whichever symbol had been entered by the operator, O or Ø, a match could be found. Some such approach as this might well prove useful in actual MAC data handling operations.

Having alluded several times in the foregoing discussion to the occurrence of operator error, it may be worthwhile to examine that question more specifically. Individual differences in accuracy among the six test operators can be discerned in the summarized results presented in Table 4-5. In this table, the number of content errors (of all kinds) made by each operator is shown for each of the two data entry modes for which results have been analyzed. For purposes of comparison, a similar count of format errors made by users of the digital recorder is also included. (For the on-line terminal <u>no</u> format errors were possible in the final data records.) Statistically significant differences among individual operators are confirmed with respect to error frequency in all three categories of error. All six test operators made some errors, of course, but two of these operators (designated here D and F) seem to have been more error-prone than the others.

---

* This solution was suggested at MITRE by Warren E. Anderson.

Table 4-5

Differences in Accuracy among Test Operators

Test Operator	On-Line Terminal: Content Errors	Digital Recorder: Content Errors	Digital Recorder: Format Errors
A	9	11	5
B	16	11	9
C	11	10	15
D	26	40	19
E	16	15	5
F	24	47	30
Totals:	102	134	83
Individual Differences			
x^2	13.6	61.9	33.9
p	<.05	<.001	<.001

It is interesting that the four "careful" operators made no more errors of data content when using the digital recorder than when working with the on-line terminal, whereas the two "careless" operators made relatively more content errors with the digital recorder. In applying human engineering principles to the design of equipment, it is sometimes argued that a device which is well designed can be used better by more people and so tends to reduce variability in individual performance. If that is a sound argument, then the present results would suggest that it is the on-line terminal which was the easier device to use in this test situation. The test operators themselves generally concurred in this judgment when making thier own explicit evaluations of the different data entry modes, as discussed in Section V of this report.

Although a comparison between data entry modes has been maintained throughout the preceding discussion of input accuracy, it is probably useful to recapitulate the basic results here. Table 4-6 presents an overall summary of the frequency and consequences of data entry errors, including errors of data content for the on-line terminal, and errors of both content and format for the digital recorder. In terms of data content, error rate was quite low with consequences about the same for both devices. The primary difference between these two data entry modes is the additional damage to data records caused by format errors in using the digital recorder, errors of the kind which were corrected under computer guidance when the same operators worked with the on-line terminal.

ERROR DETECTION AND CORRECTION

Throughout their data entry task, of course, the test operators were aware of the possibility of error and took steps to correct those errors which were detected. The operators were in fact successful in correcting many errors, both errors which they made themselves during data entry and errors in pre-stored data which they detected during review of advance shipment information. These two categories of error correction are discussed in the following paragraphs.

Data Entry

Error correction was possible in all three data entry modes used in this initial test program. In working with the checksheets, the operators occasionally erased and re-wrote mistaken data entries. In the other two modes of data entry, the operators used the BACKSPACE capability and sometimes other procedures for correction

Table 4-6

Consequences of Data Entry Errors Using On-Line Terminal and Digital Recorder

	On-Line Terminal	Digital Recorder	
	Content Errors	Content Errors	Format Errors
Number of errors	102	134	83
Piece records lost	4	9	14
Piece records wrong	44	36	21
Other data items missing	12	27	66
Other data items wrong	56	79	65

of entry errors, as discussed earlier in the analysis of transaction keying presented in Section III of this report.

In terms of what can be learned, it does not seem worth the effort to scan the off-line records produced by test operators, looking for corrected entry errors, i.e., erasures on the checksheets or special symbols of various kinds in the printed outputs of the digital recorder. Such a scanning process would be tedious and itself highly subject to error. For the on-line terminal, however, it proved a relatively easy matter to program the DHAC computer to scan its records of the interactive data entry process and print out a machine analysis of which data items had been corrected using what means. The results of that analysis are summarized in Table 4-7.

It should be emphasized that the numbers in Table 4-7 count only those data entry errors which were corrected by the operators themselves, and do not include format errors which the operators were required to correct by prompting from the on-line computer. Altogether, 188 data entry errors were corrected spontaneously by the operators. Most of these corrections (88 percent) were accomplished using the BACKSPACE capability.

The relative frequency of error corrections for the various different data items entered at the on-line terminal illustrates one pattern of interest, namely, that more corrections were required entering alphabetic or mixed alphanumeric items than entering simple numeric items. A fair comparison in this regard might be that between DISP (54 errors corrected) and WT (21 corrections). A similar pattern can be discerned in the distribution of uncorrected errors shown previously in Table 4-3. Presumably the greater difficulty of alphabetic entries is related to the double-keying technique required to enter letters with this particular on-line keypad. By comparison, straight numeric entries are easier.

The overall frequency of error correction using the on-line terminal (188) compares favorably with the number of wrong entries which went uncorrected (90), indicating conscientious effort by the test operators to maintain accuracy in their data inputs. It is probable that the same effort was also applied by the operators when working with the other two data entry modes.

Data Review

In addition to entering new data, the test operators were also instructed to review all items of pre-stored shipment data and to correct those items which were discrepant with the actual shipping

Table 4-7

Self Detection and Correction of Data Entry Errors
by Operators Using the On-Line Terminal

Data Item	Number of Data Errors Corrected Using BACKSPACE	CANCEL	BACKUP
TCN/INDEX	39	5	1
Other Items:			
RDD	1		
PROJECT	4		
PRIORITY	2		
FROM (Consignor)	9		
TO (POE)	-		
POD	14	3	
CONSIGNEE	11	1	
PIECE	4		
TOTAL	1		
WT	21	2	
CUBE	5	1	
TAG	1		
DISP	54	9	
Totals:	166	21	1

label information. All errors in the pre-stored data were either known in advance or determined during subsequent analysis of data records produced during testing. Operator inputs were compared against the list of known errors in pre-stored data to determine which errors had been detected and corrected. This comparison process was performed with computer assistance for the digital data records.

Data review and correction procedures, of course, were available to the test operators in all three data entry modes. For the operators using checksheets, their error correction procedure was to cross out wrong items of pre-stored data and write in the correct item from the shipping label, and also to write in any items missing from the pre-stored data. All checksheet records were scanned to determine how many of the known wrong and missing items of pre-stored data were in fact corrected during the test sessions. Thus for this particular aspect of performance, an analysis of accuracy is available for the checksheet mode of data entry as well as for the on-line terminal and digital recorder.

The results of this analysis are presented in Table 4-8. It can be seen that detection and entry of missing items of pre-stored data was quite good in all three modes of data entry, averaging 93 percent overall. Operator performance in noticing and correcting wrong items of pre-stored data was quite good using the on-line terminal (90 percent) but somewhat poorer in the digital recorder and checksheet modes (53 and 67 percent, respectively). Chi-square analysis of error detection frequency for wrong items of pre-stored data confirms the statistical significance of this observed difference in performance among the three input modes ($\chi^2=14.9$; $p<.01$).

It seems apparent that it is easier to notice a missing item of data than a wrong item. A missing item represents a blank in the data record where there is not a blank on the shipping label. A wrong item, on the other hand, may differ from its correct (label) version by only one symbol, and so would be harder to notice. The effectiveness of the on-line terminal in correcting wrong pre-stored data can probably be attributed to its particular procedure of displaying items one by one for review, thus focussing the operator's attention at least momentarily on each item. In the other two modes of data entry, the operator had to scan the checksheet printouts to review pre-stored data. Under those circumstances, the operators' self-adopted scanning procedures were not so effective as that discipline imposed by the on-line computer. The observer for the digital recorder mode did, in fact, note several occasions in which data review seemed quite cursory.

Table 4-8

Detection and Correction of Errors in Review of Pre-Stored Data

	Pre-Stored Data Items Missing		Pre-Stored Data Items Wrong	
Data Entry Mode	Corrected	Not Corrected	Corrected	Not Corrected
On-Line Terminal	22	1	38	4
Digital Recorder	17	2	16	14
Checksheet	27	2	28	14

Perhaps it should be noted here that this superior detection of wrong pre-stored data items using the on-line terminal was not a result of any sort of data validation checks applied by the computer. All pre-stored data items were assumed to have passed data screening procedures before storage, so that no data checks were applied during the review process unless a revision was made. If a wrong item was confirmed as correct by the operator, it was retained in storage without any further checking by the sequence control software. In this initial test program, detection of wrong items in data review was the responsibility of the man, not the machine.

Correction of errors in pre-stored data was influenced in some measure by the type of data item in which the error occurred. Results to support that conclusion are summarized in Table 4-9. In this tabulation it can be seen that failures to detect errors occurred relatively more frequently for what have been termed "optional" data items than for required data items. In this initial test program, four data items were optional in the sense that sometimes they were blank and no data entry was required: RDD, PROJECT, FROM (consignor code), CONSIGNEE. These four data items account for most instances (75 percent) of failure to correct wrong or missing pre-stored data. It seems likely that the test operators habitually gave somewhat less attention to data items which did not appear consistently in the data entry task sequence.

This observation suggests that to help ensure reliable performance in a real data entry job, it would be wise to select just a subset of shipping data, a minimal number of items whose entry would be required for every piece of cargo. This suggestion for redesign of the data entry job applies primarily to use of off-line modes of data entry such as the digital recorder or the checksheet, where consistency of input is solely a responsibility of the operator. For the on-line terminal, where the computer-generated control sequence is continuously available to guide its user, the combination of man and machine can maintain performance accuracy even when the task contains sporadic elements.

Correction of errors in pre-stored data, just like all other aspects of performance, varied somewhat from one test operator to another. Differences among operators in error detection/correction are shown in Table 4-10, summed over all three data entry modes. For wrong items of pre-stored data, correction rates ranged from 33 to 92 percent, for the "worst" and "best" operators. Individual differences illustrated in Table 4-10 seem to correspond roughly to differences in error commission discussed earlier and summarized in Table 4-5, indicating that each operator was fairly consistent in his ability to maintain accuracy in these different aspects of job performance.

Table 4-9

Error Correction for Different Categories of Pre-Stored Data

	Pre-Stored Data Items Missing		Pre-Stored Data Items Wrong	
Data Item	Corrected	Not Corrected	Corrected	Not Corrected
RDD	16	2	6	0
PROJECT	15	0	9	6
PRIORITY	3	0	7	2
FROM (Consignor)	2	1	17	7
TO (POE)	-	-	3	0
POD	-	-	9	3
CONSIGNEE	10	2	14	10
PIECE	5	0	-	-
TOTAL	5	0	-	-
WT	5	0	9	3
CUBE	5	0	8	1
Totals:	66	5	82	32

Table 4-10

Differences in Error Detection/Correction among Test Operators

Test Operator	Pre-Stored Data Items Missing		Pre-Stored Data Items Wrong	
	Corrected	Not Corrected	Corrected	Not Corrected
A	16	2	17	4
B	12	0	22	3
C	14	1	13	7
D	11	2	13	7
E	7	0	12	1
F	6	0	5	10
Totals:	66	5	82	32

SECTION V

RESULTS - OPERATOR EVALUATION

At the end of each day's testing, the operators were asked to record their evaluation of the data entry mode they had just used, completing a questionnnaire designed for that purpose. At the conclusion of all three days of testing, the operators were asked to compare the three data entry modes directly, completing another questionnaire. The results of these operator evaluations are presented in this section.

MODE EVALUATION

The exact questionnaire format used for the evaluation of data entry modes at the end of each day is illustrated in Appendix F to this report. The questionnaire sequence will be followed here in reporting operator evaluation.

General Comment

The first question asked the operators to record their general reaction, to discover which aspects of their experience seemed most notable to them:

> After a day's experience using this particular input mode to enter shipping data, what is your general reaction? Which aspects of the job go well, and which poorly? What advantages does this data input mode provide? What disadvantages?

Operator responses are presented here verbatim for the three data entry modes.

On-Line Terminal

Operator A. "I like this system better. It is simple and would be a great help. It helps in keeping information straight and it is very easy to correct your mistakes. You don't have any equipment to get in your way except may be one small cord. It is a fast and very efficient system."

Operator B. "This is the best out of the three systems we tested. It is an excellent system for checking your mistakes. It could be used also when building up pallets of cargo. This system would eliminate a lot of paperwork. It is a comfortable machine to work with and it is easy to learn how to use it."

Operator C. "I think this little machine will speed the processing up and make the cargo move faster through the system. I think in my opinion that there wasn't any bad aspects towards the machine. The good aspects that I could see was it speeds up the system about twice as fast."

Operator D. "The on-line terminal device was a very good handling device but the device get's right warm in the palm of your hand, other than that I like it the best."

Operator E. "My general reaction is that the On Line Terminal is fantastic makes the job much quicker. It would cut down paper work to a dragstic measure it would allow the cargo to be moved faster no need to wait for the Matco men for wright up. In my opinion there are no disadvantages."

Operator F. "One disadvantage is that it gets hot. Correcting prestored data wasn't too good."

<u>Digital Recorder</u>

Operator A. "This device did not impress me to much. I would say it is the most complicated of the three we tested. One of the disadvantages is that you would have to carry the whole machine with you or have a desk where you can operate it from. If you did this it would mean one less man on a crew for physical work."

Operator B. "This mode becomes easier as you do it more. The more advanced documentation you have the easier it would be. It is much quicker using this machine than having to go running through a lot of different bills. If this was to be used it would need to be used in all areas of the freight system. If not then I can't really see what it would eliminate as far as checking a truck off."

Operator C. "I think this mode would be better if you didn't have to carry all of it with when you were working. I think it would be good because you could always go back to the tapes if you ever had any trouble. This mode provides faster movement of cargo."

Operator D. "Your hand gets tired from holding it. Other than that I liked it."

Operator E. "My reaction as before with the other modes is the same with the digital recorder. All aspects of the job go well. It allows the paper work two be written up much faster then the one presently being used."

Operator F. "I see no disadvantages other than it size and it advantages is speed."

Checksheet

Operator A. "It is an easy method to learn and use. No one should have any trouble with this method. I really couldn't judge on the advantages and disadvantages of this type of system. Over all it is a very simple system."

Operator B. "As in all modes of input, the more advanced information you have the easier it is. It is pretty easy to check for mistakes this way. The biggest advantage is that all your work would be combined in one checksheet rather than with a lot of different bills. It doesn't get in your way. A person would have no worries about damaging a piece of expensive equipment."

Operator C. "I think this checksheet is good but I don't think it would be as good as the other two machines. The way it is layed out makes is go well and fast. The advantages is that is makes the system easyer and quicker."

Operator D. "I had a little trouble finding some of the numbers but I liked the checksheet as it was. The trouble I had was with the Ø the line through the zero is what gave me the trouble. At a quick glance it looked like an 8 not a zero."

Operator E. "Again this method used in my opinion is faster and better than the one presently being used. It would allow all personnel to be used instead of Matco write ups. It also again very simple to be trained on 10 minutes."

Operator F. "To much paper work, other than that it works well."

What conclusions can be drawn from these comments? The general response seems favorable to all three modes. Several drawbacks are cited, but these are usually characterized as minor in comparison with the recognized advantages of each data entry technique. It is evident that as the operators used different modes of data entry, from day to day, they began to draw comparisons between one mode and another. In that process, the on-line terminal seems the mode regarded most favorably.

Overall Rating

The next question asked the operators to rate their overall evaluation of the data entry mode:

Check one of the boxes on the right to indicate your overall evaluation of this input mode for the task of entering shipment data.

	Excellent	Good	Adequate	Fair/Poor	Poor	Mean Rating
On-Line Terminal (OT)	6					4.0
Digital Recorder (DR)	1	2	3			2.7
Checksheet (CS)	1	4	1			3.0

This tabulation shows the number of operators who chose each rating. The on-line terminal is confirmed as the most popular mode, with a unanimous "excellent" rating. If a numeric value of 4 is assigned for each "excellent" rating, 3 for "good", 2 for "adequate", 1 for "fair", and 0 for "poor", then an average numeric rating for each input mode can be derived: 4.0 for the on-line terminal, 2.7 for the digital recorder, and 3.0 for the checksheet. These derived numeric ratings are included here and in subsequent tabulations.

Specific Performance Ratings

The next question asked the operators to rate specific aspects of task performance:

Check to indicate your evaluation of this input mode in performing specific aspects of the data entry job.

		Excellent	Good	Adequate	Fair/Poor	Poor	Mean Rating
Entering the TCN designator	OT	5	1				3.8
	DR	1	4	1			3.0
	CS	1	3	2			2.8
Entering general shipment data	OT	4	2				3.7
	DR	2	3	1			3.2
	CS	2	3	1			3.2
Reviewing pre-stored shipment data	OT	6					4.0
	DR	2	1	2	1		2.7
	CS	2	2	2			3.0
Entering specific piece data	OT	6					4.0
	DR	2	2	2			3.0
	CS	3	2	1			3.3

		Excellent	Good	Adequate	Fair/Poor	Poor	Mean Rating
Detecting errors in pre-stored data.......	OT	4	1	1			3.5
	DR	2	2	1		1	2.7
	CS	2	4				3.3
Correcting errors made during data entry..	OT	5	1				3.8
	DR	1	4	1			3.0
	CS	2	4				3.3

The on-line terminal is rated comparatively well in all aspects except detection of errors in advance (pre-stored) shipment data. The test operators, of course, did not have available to them the performance results described earlier in this report which confirmed that the on-line terminal was clearly the best mode in terms of detecting wrong items of pre-stored data.

If the ratings listed above for specific aspects of performance are averaged, the resulting aggregate ratings again confirm a preference for the on-line terminal (3.8) in comparison with the digital recorder (2.9) and the checksheet (3.2). These derived aggregates correspond closely to the overall ratings assigned by the test operators in the previous question, and indicate a reasonable consistency in operator responses.

Comments on Learning/Training

Next, the operators were asked for comments on learning to use the data entry mode they had just experienced:

> What are your general impressions of your experience in learning how to use this input mode? Which aspects were difficult? How could your training have been improved?

On-Line Terminal

Operator A. "Over all it is the best system I have seen yet. There are know aspects which are difficult."

Operator B. "It isn't a difficult mode of input to learn. Anyone could learn to use it in a day's experience."

Operator C. "What really impressed me was the way you could always go back to something and refer to it and save time by that."

Operator D. "The device wasn't to hard to learn how to use and I had a little difficulty hitting the correct button. I don't think that my training could have been improved."

Operator E. "There were no difficult aspects of learning how to operate. It just takes about ten minutes to learn and get use to it. The training period was conducted in an excellent fasion."

Operator F. "it was easy"

Digital Recorder

Operator A. "My impression is that it would be unpracticle in my field of work. Over all it is easy to operate and doesn't take long to learn how to operate it."

Operator B. "It takes time to get used to it. Nothing was very difficult. It is easy to learn how to use it. The best way to train someone on this machine is the way I learned. You can learn more quickly by doing it first hand and learning by your mistakes."

Operator C. "I thought it was difficult to learn the key board because of so many keys. I it is better for a guy to have someone tell him what the keys are for then more less learn on his own just like did I think that is the best way of training someone."

Operator D. "I thought it was very easy at the end of it but I did have some trouble getting use to it."

Operator E. "There were no difficulty in learning total training time was fantastic. So was the training."

Operator F. "it was easy to learn"

Checksheet

Operator A. "My impression is that this is a quick and easy input mode."

Operator B. "It was easy for me because I work with boxes with these labels all the time. I'm used to looking at all the writing and I can check it fairly easy. Someone who is inexperienced would have a more difficult time at first. As in anything, the more you do it the easier it gets."

Operator C. "It was very easy to learn how to use. I didn't find any that were difficult. I think training was good."

Operator D. "The only difficulty I had was look at a quick glance the numbers were a little close."

Operator E. "It was very simple to learn how to use this specific input mode. The training again was conducted superbly."

Operator F. "it was easy to learn and use"

The generally positive comments reported here probably reflect several factors - the high morale of the operator groups, their pride in accomplishment, and a desire to compliment the MITRE observers who had provided their training and guidance.

Rating of Learning Ease

The next question asked the operators to rate ease of learning:

Indicate your evaluation of this input mode in terms of how easy it is for a beginner to learn to use it.

	Very Difficult		Moderately Difficult		Easy	Mean Rating
OT	1				5	3.7
DR					6	4.0
CS			1		5	3.8

It may be seen here that few of the operators were willing to admit any learning difficulty, even when some specific difficulties were noted in their previous comments. It is interesting that no poor ratings were given the digital recorder, which in the opinion of MITRE observers was in fact a difficult data entry mode to learn. Presumably the operators themselves remained largely unaware of their frequent format errors in using that device, errors which reflected in some degree a failure to learn skilled performance, as well as simple lapses of attention.

Interest Rating

The next question asked the operators to rate their interest in the job:

> Considering your experience with this input mode, rate your interest in the job today.

	High Interest		Moderate Interest		Low Interest	Mean Rating
OT	6					4.0
DR	4				2	3.3
CS	2				4	2.7

The high interest rating for the on-line terminal probably reflects a "pinball" effect - the novelty of this initial exposure of the operators to direct interaction with a computer. By contrast, the simple paper shuffling of the checksheet mode was rated the least interesting; and the digital recorder, an unresponsive device, received an intermediate interest rating.

Performance Rating

The next question asked the operators to rate their performance, as a consistency check on similar ratings made ealier:

> Considering speed and accuracy of data processing, and any other factors you think important, how would you rate your performance using this input mode?

	Excellent	Good	Adequate	Fair/Poor	Poor	Mean Rating
OT	1	5				3.2
DR	1	2	3			2.7
CS	1	2	3			2.7

Again, the on-line terminal received more favorable ratings. It may be noted that the performance ratings here seem somewhat lower than ratings given in response to similar questions earlier in the questionnaire. The key is probably the qualifier "<u>your</u> performance". The operators may have been influenced by considerations of modesty in rating their own performance of the data entry task, in contrast to earlier questions which were phrased to request a more detached rating of mode capability.

Equipment Rating

The next question asked the operators to evaluate the equipment used, i.e., the physical implementation of each mode:

How would you rate the physical equipment used in this input mode?

	Excellent	Good	Adequate	Fair/Poor	Poor	Mean Rating
OT	3	3				3.5
DR	3	2		1		3.2
CS	1	1	4			2.5

Again there is the suggestion of a "pinball" effect, with higher ratings given the two data entry modes actually involving hardware devices. That is to say, it is probable that the operators were influenced by the novelty of equipment used, rather than the adequacy of mode implementation considered in relation to task requirements.

Other Comments

A final question gave the operators a chance to note any further observations on topics not already covered in the questionnaire:

What other comments can you make concerning the equipment, or any other aspect of the test situation?

On-Line Terminal

Operator A. "I think it is a very good system."

Operator B. "This mode seems excellent to me. I would highly recommend it's use in any freight terminal."

Operator C. "It is a very modern and fast way to get the job done."

Operator D. (None)

Operator E. "The heat emitted by hand commuter can be cut down some. But overall I am amased with this equipment."

Operator F. "Try to cool it down it gets to hot in your hand."

Digital Recorder

Operator A. {None}

Operator B. "It wouldn't take any great length of time in teaching someone to use this machine. It would be easier than trying to train someone all the different types of paperwork there is."

Operator C. "I think in my own opinion that this should be looked into farther in making the machines more compack."

Operator D. "I think it would be easay if the handheld device were placed on a stand for when you are sitting down."

Operator E. "The handle on this mode should be made bigger."

Operator F. "Make it smaller."

Checksheet

Operator A. {None}

Operator B. "The good thing about this mode is that the checkers won't have any expensive piece of equipment with them and it wouldn't get in their way or get damaged. Also, everything is just copied off the label which makes it easier. All the paperwork can be kept on one clipboard."

Operator C. {None}

Operator D. {None}

Operator E. {None}

Operator F. "I hate it, too much paper work."

Because of the way in which this question was worded, and because it followed immediately the question asking for equipment rating, most of the additional comments elicited had to do with matters of hardware design. Some operators offered no final comments, as noted, which suggests that they felt their evaluation had already been covered adequately in previous questions.

MODE COMPARISON

The exact questionnaire format used for the direct comparison of all three data entry modes is illustrated in Appendix F to this report. The questionnaire sequence will be followed here in reporting the operators' comparative evaluation of modes.

Performance Comparison

The first question asked the operators for ratings of ten different aspects of task performance, on a scale from 0 to 100, comparing the three data entry modes. Mean ratings are presented in Table 5-1, which follows closely the questionnaire format.

Table 5-1

Mean Ratings for Different Aspects of Task Performance in Comparing Data Entry Modes

Performance Aspect	On-Line Terminal	Digital Recorder	Checksheet
Entering the TCN designator	93	72	76
Entering general shipment data	95	78	78
Reviewing pre-stored shipment data	96	68	81
Entering specific piece data	93	83	78
Detecting errors in pre-stored data	74	67	70
Correcting errors made during data entry	93	88	82
Ease of learning to use input mode	95	87	90
Interest in data entry job	95	84	85
Performance level achieved in one day's use	90	88	88
Physical equipment used with this input mode	98	73	69
Overall Mean	92	79	80

As one might expect, these comparative ratings are quite similar to those made by the operators when evaluating the data entry modes separately. A product moment correlation between these 30 mean ratings and the derived mean values of corresponding ratings made in the separate mode evaluation is statistically significant ($r=.65$, $p<.005$), indicating consistency in operator judgement. Again a preference for the on-line terminal is apparent, although all three data entry modes are rated well.

Practical Usefulness

The next question asked the operators to assess the practical usefulness of the three data entry modes:

> Considering your overall experience, do you believe any of the three input modes tested here could be used effectively in the actual work situation at the truck docks? If YES, which modes do you think could be used?

All six operators indicated that the on-line terminal could be used on the truck dock. Only two operators considered the digital recorder acceptable for use on the job. Three of the operators judged the checksheet an acceptable data entry technique. This pattern of response is clearly consistent with the performance ratings reported above, confirming a preference for the on-line terminal.

Operator Characteristics

The next question asked the operators their opinion as to what kind of man would be best suited to the data entry job:

> Suppose that one of your unloading crew must be responsible for entering shipment data in the actual work situation, using whatever input mode is available. How would you choose which man should be responsible for this data entry job? What characteristics should he have to handle the job well?

Operator A. "More than likely rank or say one has a light duty excuse or is driving a fork lift. It reall doesn't matter any one could handle the job. Some one who is not childish and would use the insturment as a tool and not a toy."

Operator B. "Mostly a person who would be conscious of what he is doing. Someone who could do it fairly easy and with as few mistakes as possible."

Operator C. "He should be trained on how the input mode operates. I would choose the man that is interested the most."

Operator D. "The man who check's the truck should be the person who uses the input mode. Each mode were not to difficult to learn so any person should be able to use them."

Operator E. "He must first be responsible enough to handle the machine and willing to check and recheck all data that he has and put in that which he does not have."

Operator F. "he would have to be awake"

The purpose of this question was to elicit some reflection of the operators' view of the requirements of the data entry job. It seems apparent that they regard the data handling job as important, one requiring responsible performance and careful attention to detail.

<u>Job Satisfaction</u>

The next question asked the operators to indicate whether this is the sort of job <u>they</u> would like to do:

> Considering your experience over several days of testing, how willing would you be to handle such a data entry job in your real work situation?

Interesting job, glad to do it..............	5
Tough job, do it if I had to................	
Share the job with others, do it sometimes...	3
Would prefer not to do it..................	
Definitely not the job for me...............	

Five operators indicated that the data entry task was sufficiently interesting that they would be willing to do it in their actual work setting, although two of these operators also checked the "sharing" alternative. The sixth operator indicated that he would prefer to share such a job with others. These positive responses probably reflect the generally high morale induced by the test environment. A more extended program of field testing would be required to confirm acceptability of the data entry task as a real job.

Other Comments

A final question gave the operators a chance to volunteer any last words on the subject:

> Whatever further comments you can make concerning the data entry job, the various input modes, and the test procedures will be most welcome.

Operator A. (None)

Operator B. "The on-line terminal would make a lot of people more interested in the job. It is much better tan using pencils and paperwork, which becomes boring very easy."

Operator C. "I think in my own opinion that the input mode I would like to work with most is the online terminal."

Operator D. (None)

Operator E. "The handle on the digital recorder should have a larger handle. And the on line terminal should be able to be stored by haveing it able to hook apart or together some where along the caple thus preventing unnecessary damage."

Operator F. (None)

When the operators had completed this final questionnaire, they were asked to participate in a short debriefing session where an attempt was made to elicit any additional comments and to clarify if necessary their written evaluations. In particular, each group of operators was asked to explain their stated preference for the on-line terminal in face of the fact that on each day of testing they had all seen the man using the manual checksheets finish first. Their comments in response to this challenge restated the theme apparent in their questionnaire answers, namely that the checksheet mode involves too much paper shuffling.

It may be inferred, although the idea was never made explicit by the operators themselves, that shuffling paper imposes a continuous burden of attention. That is to say, in completing a checksheet the operator must decide everything for himself and keep careful track of what he is doing. In using the on-line terminal, the computer can provide much of this guidance, and the operator can simply accomplish the data entry sequence as a series of simple transactions requiring less continuous concentration of his attention.

SECTION VI

RECOMMENDATIONS

The overall results of this initial test program look encouraging. Test operators were able to achieve generally good levels of performance with all three data entry modes, with no prior training in data handling procedures. The operators themselves were unanimous in recommending the on-line terminal for actual use in truck dock data entry, and several operators recommended the digital recorder and checksheet for potential use at the truck dock, as documented in Section V of this report. On the basis of the positive results of this initial testing, it is appropriate here to consider what are the next steps to take toward eventual implementation of improved data handling in the air transport system.

Although many questions can be explored in laboratory testing of the kind described in this report, final recommendations for system implementation can be made with confidence only after prototype data handling methods have been tested under operational conditions. It is recommended, therefore, that the on-line terminal undergo field testing at a MAC truck dock to assess its usefulness for the data entry task. A proposed plan for such field testing is currently being developed and will be reported later this year.

In this initial test program the on-line terminal permitted adequate speed of data entry for all but the most difficult test loads. In field testing the on-line terminal, the time required for data entry using this device could be decreased in several ways. First, the actual data entry job should be analyzed to determine just what is the minimum set of data items which must be entered in the real job, presumably some subset of the items used in initial testing. Second, some means should be found to create a machine-readable tag to be affixed to each piece of cargo unloaded at the truck dock, combining the TCN shipment identification with an additional code for each separate piece within a shipment. Both of these recommendations were discussed earlier in Section III of this report.

Accuracy of data entry using the on-line terminal can be improved over the levels achieved in this initial test program. Given a definition of the actual data entry job to be accomplished, the computer software for sequence control of the on-line terminal should be redesigned prior to field testing, to incorporate the specific improvements recommended in Appendix B to this report.

Computer processing of data inputs should include special routines to avoid confounding of O and Ø in keyed entries for TCN, as recommended in Section IV. If any significant portion of the actual job includes items available as advance shipment data, then provision should be made in field testing to permit optional data review as well as data entry, as recommended in Sections III and IV, since data review proved both fast and accurate in this initial testing.

With regard to the digital recorder, the picture is somewhat different. This mode of data entry permitted adequate speed in initial testing, but the absence of on-line sequence control placed higher demands on the test operators, some of whom were not able to maintain a high level of accuracy. A general account of this problem was provided in Section IV of this report, and a more detailed analysis of factors contributing to format errors is provided in Appendix E. The digital recorder cannot be recommended for field testing unless changes are made in its keyboard design and data entry procedures.

One possible approach to improving performance using the digital recorder would be to redesign its keyboard, following the recommendations presented in Appendix C, to simplify the logic of data inputs. If such a keyboard redesign is undertaken, it should be optimized for the actual data entry task to be performed at the truck dock. Then the improved keyboard and data recording procedures should be evaluated in further laboratory tests to confirm acceptable accuracy of data inputs before the digital recorder can be recommended for truck dock use.

There is another possible approach to improving off-line digital data recording which has not been discussed elsewhere in this report. One might reconfigure the Termiflex keypad/display device so that it could be used "off-line" to store data inputs on disk under control of a local microcomputer. Such disk records could be read into the primary data processing system at any convenient time rather than requiring piece-by-piece interaction with an on-line terminal. But the microcomputer could provide sequence control assistance, with displayed prompts to the operator on an immediate basis as needed, thus compensating for the major deficiency in the digital recorder. Use of the same Termiflex device for data input, either on-line or off-line, would help ensure reliable operator performance in his job, and hence increase the credibility of off-line recording as a potential backup to on-line data entry.

Further analysis is needed to estimate the comparative cost and the expected performance capabilities which could be achieved by redesigning the digital recorder or by reconfiguring a Termiflex for off-line use. Depending upon the results of that analysis, one or the other approach may eventually be recommended for field testing as a backup alternative to the on-line terminal, for potential use in work settings where on-line data processing is not available.

With regard to the checksheet, several significant questions remain unanswered. In this initial test program, the checksheet was demonstrated to be the fastest mode of data entry for potential use at the truck dock. But no measures are yet available for the accuracy of data entry using this mode, as discussed in Section IV of this report. A program of follow-on testing should be undertaken to determine how well the checksheet records generated in this initial test program can be transcribed into digital form, both in terms of the time required and the accuracy of the final digital records.

Such follow-on testing will soon begin at MITRE. Clerical personnel will work at on-line display stations using a keyboard to enter data from handwritten checksheets. Results of that follow-on test program will be reported as available.

Whatever the results in terms of data accuracy, it seems certain that both these methods of data transcription would involve significant delays in effective data availability subsequent to cargo unloading at the truck dock, as discussed in Section III of this report. It is recommended that a broader analysis of system requirements be undertaken to determine the impact of delays in data availability resulting from such transcription processes. Such an analysis may eventually disqualify the checksheet as a useful alternative to other modes of data entry at the truck dock.

Pending the results of such analysis, and the results of follow-on testing of transcription speed and accuracy, it would be premature to recommend the checksheet for field testing at this time. The checksheet was the least preferred mode of the operators in this initial test program, as discussed in Section V, and some significant evidence of its effectiveness must be confirmed in follow-on testing before checksheets could be recommended as a backup for on-line or off-line key entry in operational use.

REFERENCES

1. Smith, S. L., MAC Air Cargo Data Entry: 1. Preliminary Analysis of Alternative Modes, ESD-TR-76-162, Vol. I, August 1976.

2. Smith, S. L., MAC Air Cargo Data Entry: 2. Photography of Shipping Labels, ESD-TR-76-162, Vol. II, August 1976.

3. Dixon, W. J., ed., "BMDØ2V Analysis of Variance for Factorial Design," BMD Biomedical Computer Programs, University of California Press, Berkeley, CA, 1967.

APPENDIX A

KEY ENTRY DEVICES

In this initial test program, the Termiflex on-line terminal and the Source 2001 digital recorder were selected simply on the basis of their convenient availability in MITRE's Data Handling Applications Center. Perhaps other equipment would have served equally well for test purposes. The particular devices tested here should each be considered as representative of a broader class of commercially available equipment. Neither device was especially designed for MAC air cargo data handling, but both have found successful application in similar record keeping tasks. The following paragraphs provide a more complete description of the capabilities of these devices than was presented in the body of this report. The information was derived from technical brochures published by the respective manufacturers.

TERMIFLEX HT/2

The on-line terminal tested here is designated the Termiflex HT/2 by its manufacturer, Termiflex Corporation, 17 Airport Road, Nashua, New Hampshire 03060. The HT/2 is connected to the DHAC NOVA computer via an early version of the manufacturer's PS/1A power supply. The HT/2 is also designed for use in conjunction with an acoustic coupler, power supply, and carrying case, designated the TC/1 Termicoupler.

Dimensions of the handheld terminal are approximately 5 x 11 x 18 cm. Dimensions of the power supply are 8 x 12 x 24 cm. The terminal weighs approximately 0.7 kg (1.5 lb). The power supply weighs 2.7 kg.

Power requirement for the HT/2 terminal is 15 watts (+5V @ 2A, -5V @ .3A, +12V @ .1A, -12V @ .1A, and -9V @ .2A). The PS/1A power supply operates with 105 to 130VAC, 50/60 Hz @ 0.5A. It is interfaced directly to the NOVA with an RS232C interface, usually operated at 120 characters per second.

Communication speed from the terminal is selectable at 10, 15, 30 or 120 characters per second. Selectable parameters include line adjust; odd, even, mark or space parity; half or full duplex transmission; and choice of either upper or lower case characters for normal transmission.

The HT/2 provides a two-line display of 10 characters each, permitting full alphanumerics with both upper and lower case. Character size is about 5 x 7 mm formed by a 5 x 7 LED dot matrix refreshed more than 80 lines per second. The display includes an incoming data indication, and alternative cursor symbols indicating next character position, case, control mode, special shift operation, and clear to send.

The HT/2 keyboard, illustrated in Figure 3, includes a 20-key pad on the face, plus three special shift keys on its right side, permitting generation of all 128 ASCII characters plus break. The keyboard features multi-key lockout, and lock/unlock for case. As used in this initial testing, some of the special control keys, shown in the left column and bottom row of Figure 3, were interpreted by on-line computer software as signalling various different special functions required in the data entry sequence, as described more fully in Appendix B to this report.

The HT/2 features a control switch for line/off/local operation, an audible "bell" code, and audible indication of improper keyboard operation. The HT/2 also includes a 1000-character memory which permits scrolling to view previous displays, controlled by a thumbwheel on the left side of the terminal. This scroll memory capability was not used in initial testing, and probably would not be needed for actual data entry at the MAC truck docks.

Current Termiflex equipment specifications state that it will operate over a temperature range of 0° to 50°C (32° to 120°F), under relative humidities ranging from 5 to 95 percent. This equipment is listed under Government Services Administration Contract GS-00C-00510, with current price of the HT/2 set at $1570, the TC/1 priced at $580, and the PS/1A at $160 for single unit purchases.

SOURCE 2001

The digital recorder tested here is designated the Source 2001 Portable Data Terminal by its manufacturer, MSI Data Corporation, 1381 Fischer Avenue, Costa Mesa, California 92627. To transmit recorded data by telephone, the Source 2001 is plugged into another device, the Source 2300 Communication Module, which permits acoustic coupling to a telephone handset. Transmission speed is 1200 bits per second, but allows effectively 40 characters per second to be transmitted.

Dimensions of the Source 2001 recorder are approximately 9 x 18 x 26 cm. The recorder weighs 3.6 kg (8 lb) including a self-contained battery pack and an optional strip printer. Power is supplied by a rechargeable 12.5V nickel cadmium battery, or the recorder can be operated from a standard 110V AC power source.

The recorder is designed using solid-state integrated circuits, with erase and read/write recording heads, and single-track, digital self-timing recording. Data are recorded in ASCII code on a removable tape cassette (Phillips type). Cassette capacity is 50,000 characters per side, which far exceeds what would be required even for a large truck load of cargo. Playback speed is 15 characters per second.

Functional controls for the recorder include record, rewind, play, and off. Operator and equipment errors are signalled by a red light, an audible tone, and keyboard lockout.

The optional strip printer uses 36 meter (120 ft) rolls of 8 mm pressure-sensitive paper tape. A dot matrix print method is used, producing a character height of about 6 mm. Functional controls for the printer include on/off, forward/reverse scan, and step. An alternative option for the Source 2001, not available on the device tested here, is an LED display.

The keyboard usually provided with the Source 2001 contains keys only for digits 0-9, +, -, =, period, clear, ID, and two user-specified keys. In this initial test program, it should be noted that the digital recorder was provided with a special keyboard, illustrated in Figure 5, designed and built at MITRE to provide a full alphanumeric capability. As it turned out, this MITRE keyboard proved deficient in several respects. Improvements to its design, to optimize its use for this particular data entry application, are recommended in Appendix C to this report.

The Source 2001 digital recorder is no longer available as a production model, although reconditioned units can be obtained. It has been replaced by an improved model designated the Source 2100, which offers a slightly faster transmission rate and a somewhat larger optional display (12 characters rather than 10). Technical details of the Source 2100 can be obtained from its manufacturer, MSI Data Corporation.

APPENDIX B

SEQUENCE CONTROL FOR THE ON-LINE TERMINAL

To illustrate the nature of the interactive sequence controlling use of the on-line terminal, the following pages tabulate the basic displays which appeared at different stages of the data entry process. This tabulation provides an arbitrary reference number for each display, assigned for convenience in this discussion, along with a facsimile of the display itself, plus occasional annotation.

The display window of this on-line terminal is small, just two rows of 10 symbols each. The interactive sequence was designed to maximize use of that limited display, by breaking the entire data entry task into simple, discrete transactions, and by compressing displayed messages required for operator guidance into as few words as possible.

The displays used fell roughly into three categories - questions, prompts, and transient advisories - and are shown thus in this tabulation. Questions offered the operator a choice in the interactive sequence (e.g., whether to review previously reviewed shipment data, display 120), or asked him to confirm the correctness of previously entered data. Prompts signalled the operator that he could key new data onto the display, or correct previously entered data. Transient advisories appeared as needed to alert the operator to detected errors in entered data, or to remind him of the next step in the data entry sequence.

For convenience of discussion, the total data entry job can be considered as accomplishing several different tasks. The first task involves load identification, illustrated in displays Ø10-Ø59. These displays were included only for purposes of demonstration, to show how this task might be accomplished in actual truck dock operations. These displays were used by the observer to initiate a test session, but were not used by the operators.

The second general task involved shipment identification, illustrated in displays 112-129, which represented the first actual task of data entry during testing. An operator began his job by entering a TCN for the first piece of cargo to identify its shipment, in display 112. Alternatively, he could enter a two-digit index code, as explained earlier in the body of this report. Various computer checks were applied to his input, as indicated by displays 113-115. If a new TCN was entered, the computer would assign it an index, in display 117, which the operator could note for future use if he wished to do so.

(A deficiency in the control program is apparent at this point. There should be greater feedback linking TCN's to indices, and vice versa. Imagine that the operator makes a mistake in reading his index list, and keys the wrong index. Using the present program he might not notice his error, and so proceed to enter the right data for the wrong shipment. It would help if for <u>whichever</u> shipment designator the operator entered, either TCN or index, the computer would respond with a display of the <u>other</u> designator, to give him a chance to check it. In that way, perhaps the convenience of index codes could be preserved without their pitfalls.)

In this program, sequence control branches depending on what shipment has been designated. For the first piece of a shipment with advance data, the operator is required as his next task to <u>review</u> all shipment data, in display 118 followed by display 210 (or 211 if RDD is blank). For the first piece of a "new" shipment the operator is required to <u>enter</u> such data, in display 119 followed by display 211. In either case, for subsequent pieces in the same shipment the operator is given a choice whether or not to review general shipment data, in display 120. Generally he would choose <u>not</u> to review shipment data again (the review option was selected 8 percent of the time, in only 46 instances out of 579 choices), and so would proceed directly to enter piece-specific data, in display 129 followed by display 312.

The task of reviewing or entering general shipment data was mediated by the sequence beginning with display 210 or 211. If a data item already had a value, whether pre-stored from advance shipment data or entered previously on-line, the sequence control presented that value for review, in displays 210, 220, 230, etc. If the operator confirmed the displayed value by keying YES, the review sequence continued to the next item. If he keyed NO, then the sequence shifted to the matching data entry display - 212, 222, 232, etc.

Various computer checks were applied to each data entry. If the entry seemed improper, a transient error message was shown, as illustrated in displays 213, 223, 233, etc., after which the same data entry display was shown again. The error messages were designed to be as informative as possible, within their brief limitations. A scanning of the error messages listed here will indicate the kinds of data checks which were included in this initial test program. More specific checks could be designed for actual use in truck dock data entry.

When a data entry passed the computer checks correctly, program control moved on to the next item in the sequence, showing either the next review display or the next data entry display as appropriate. If the operator himself decided that a previous entry might be wrong, he could use the general BACKUP option to move backward through the sequence, step by step, seeing either the review display for each item or a data entry display for blank items.

Review/entry of general shipment data was followed by entry of piece-specific data, in display 289 followed by display 310 or 312. Entry of PIECE number illustrates that potential data checks are not limited to comparison against fixed criteria, but can also be made contingent on other data entries. In this example, if the PIECE entry exceeds the value already entered for TOTAL, the operator is required to review TOTAL, in displays 314 and 315, followed by display 280. A broader example of this sort is provided by the error check for TAG entries which will not permit the operator to duplicate any TAG already assigned to another piece of cargo.

The review display for TAG (display 340) was unusual in that the computer was programmed to anticipate data entries, on the assumption that the real operator would assign tag identifiers in sequence to pieces as they are unloaded. The only other example of this kind was the review display for POE ("TO"), display 250.

The tabulated display sequence indicates a program flaw at the conclusion of the entry of piece-specific data. Since it was assumed that the disposition of individual pieces of cargo could not be known in advance, no review display for DISP was provided. If an operator had just entered a DISP and then realized it was wrong, he could not BACKUP to correct it. Future versions of this program should provide a display 350 to permit review of DISP entries, and following DISP entry some display from which BACKUP is possible.

When the operator completed the entry of piece-specific data, program control cycled back to the task of identifying the shipment for the next piece of cargo, display 359 followed by display 112. This cycling continued throughout a test session until data for all pieces had been entered, at which point the operator would signal STOP.

The STOP input initiated a final bookkeeping sequence, illustrated in displays 400 through 442, which was used by the observer to terminate the test session. The test operator, his job done, simply handed the terminal to his observer who dealt with these final chores.

Throughout the control program, the interactive sequence was designed, insofar as possible, to be foolproof against mistaken operator inputs. That is to say, the operator could enter wrong <u>data</u>, within the limits of the programmed data checks, but he could not enter wrong sequence commands which might "confuse" the control program. At branching nodes of the program, represented by the question displays, the operator could input only YES or NO. Any other input was rejected, with the exception of implicit options such as BACKUP. (The actual incidence of wrong replies to YES/NO questions was less than one percent, only 41 instances out of a total of 4915 responses, generally representing an impulsive attempt to correct a wrong data item directly rather than first signalling that it was wrong.)

This rejection of random inputs was programmed with a nicety which seems in retrospect to have been wasted effort. Every question was programmed to have an alternative display format, so that whenever the operator responded inappropriately a <u>different</u> version of the same display would appear. For example, display 230 might first read "PRIORITY=2?", but after a wrong response would reappear in altered form as "PRIORITY=2 YES/NO?" (Because of their redundancy, such alternate display forms, display 231 in this example, have <u>not</u> been included in the tabulation of displays presented here.)

The purpose of this particular design tactic was to ensure that for every operator action (input) there would be some visible reaction (changed display output) from the computer, an elementary design rule fo interactive sequences of this sort. It probably would suffice just as well, however, simply to program each question display so that it reappears accompanied by an auditory signal whenever a wrong input is made. That simpler expedient is recommended for future versions of this program.

The sequence control program for this initial testing would probably have to be revised in other ways for actual use on the truck dock. For test purposes, the task required entry of all data items from the shipping label. In actual operations, it is possible that some of these items could be omitted from the entry sequence, so that only a subset representing the most critical data would have to be entered.

In actual use, still other kinds of changes will prove desirable. The distinction between general shipment data and piece-specific data need not be maintained in the control program. Such transitional guidance displays as 118-129 and 289 should be omitted as unnecessary to the operator. PIECE should be entered before

TOTAL, reversing displays 282 and 312, so that the entry sequence for those items corresponds to their order in the shipping label format. The review display for PIECE, display 310, should be eliminated, since the occasional appearance of that display tended to confuse the test operators, interrupting their regular data input sequence.

Several changes should also be made to the keypad used with the on-line terminal. Labelling the BACKSPACE key simply with a left-arrow proved too cryptic. That key should be given some sort of name, such as ERASE. The CANCEL key should be eliminated, since it was seldom used properly. The on-line sequence to modify the timing of transitional displays should be eliminated, and the key used to initiate that sequence should be modified in function to provide a simple flip-flop between fast (.5 sec) or slow (1.5 sec) time intervals.

Display Number	Questions (Yes/No)	Data Entry Prompts	Transient Advisories	Notes
Introductory Load Identification				A displayed question mark (?) is used throughout to denote that a YES or NO input is required.
Ø1Ø	READY TO UNLOAD?.			
Ø12		DOCK: .		A displayed colon (:) denotes that some data input may be required.
Ø13			* ENTER 1-2 DIGITS	
Ø22		CARRIER: .		The period (.) is used here to indicate displayed cursor position.
Ø32		TRUCK: .		The asterisk (*) is used here to indicate displays which are accompanied by an auditory signal ("beep"), mostly error messages.
Ø42		GBL: .		
Ø43			* ENTER 8 SYMBOLS	
Ø52		NEXT GBL: .		Ø52 repeats itself until the operator signals STOP.
Ø53			* ENTER 8 SYMBOLS	
Ø59			ENTER STOP IF DONE	Ø59 is a simple advisory rather than an error message. The "beep" is omitted.

Display Number	Questions (Yes/No)	Data Entry Prompts	Transient Advisories	Notes
Shipment identification				A few error messages must be output as a sequence of displays, in order to explain available options. The plus (+) is used here to indicate the second display in the sequence.
112		ENTER TCN:.		
113			* ENTER 14 SYMBOLS	
114			+ OR 2-DIGIT INDEX	An underline is used here to indicate a variable display element. The underline was not actually displayed.
115			* INDEX <u>NN</u> NOT FOUND	
117			* NEW INDEX= <u>NN</u>	Although 117 is not an error message, the "beep" is used to call attention to its appearance. It was displayed for twice the time interval used for error messages.
118			MUST CHECK TCN DATA	
119			NOW ENTER TCN DATA	
120	CHECK TCN DATA?.			
129			NOW ENTER PC DATA	

Review/entry of shipment data

Display Number	Questions (Yes/No)	Data Entry Prompts	Transient Advisories	Notes
210	RDD=XXX?.			This series of displays permits sequential review, or entry, of data items appearing on a shipping label. Where advance data are available, or data have already been entered, the items are displayed in query form for confirmation. Where no data have been entered, the blank items are displayed as prompts for data entry.
212		RDD: .		
213			* ENTER 3 SYMBOLS	
220	PROJECT= XXX?.			
222		PROJECT: .		
223			* ENTER 3 SYMBOLS	
230	PRIORITY=N ?.			The data validation checks for all of these items are rudimentary, as can be seen from the advisory error messages. More complicated checks could be programmed if needed.
232		PRIORITY: .		
233			* ENTER 1,2, 3 OR 9	
240	FROM= XXXXXX?.			
242		FROM: .		
243			* ENTER 6 SYMBOLS	
250	TO=AAA?.			This question was exceptional in that POE was displayed when there had been no previous entry of POE. If all truck cargo arriving at a terminal did in fact have the same POE code, then this entry could be eliminated.
252		TO: .		
253			* ENTER 3 LETTERS	
260	POD=AAA?.			
262		POD: .		
263			* ENTER 3 LETTERS	More complicated checks could be made here, to ensure that entered POD matches a possible destination.
270	CONSIGNEE= XXXXXX?.			
272		CONSIGNEE: .		
273			* ENTER 6 SYMBOL	
280	TOTAL PCS= NNNN?.			During testing, the actual total never exceeded 8, but the variable display element is shown here as being potentially larger.
282		TOTAL PCS: .		
283			* 4 DIGITS MAXIMUM	
289			NOW ENTER PC DATA	

Display Number	Questions (Yes/No)	Data Entry Prompts	Transient Advisories	Notes
Review/entry of piece-specific data				
310	PIECE=1?.			This question was asked only when a TOTAL of 1 had been entered. It proved confusing to the test operators and should be eliminated in future versions of the program.
312		PIECE: .		
313			• 4 DIGITS MAXIMUM	
314			• NNNN LOOKS TOO LARGE	
315			• MUST CHECK TOTAL	Branch to 280.
320	WEIGHT= NNNNN?.			
322		WEIGHT: .		Advance data on weight and cube could be reviewed only for single piece shipments.
323			• 5 DIGITS MAXIMUM	
330	CUBE= NNNN?.			
332		CUBE: .		
333			• 4 DIGITS MAXIMUM	
340	TAG=NNNNNN ?.			In this question the displayed TAG was 1 higher than the last TAG entered, assuming that the operator assigned tag numbers in sequence.
342		TAG: .		
343			• ENTER 6 DIGITS	
344			• NNNNNN HAS BEEN USED	
352		DISP: .		A flaw in the program: since no disposition data were pre-stored, a review question was omitted, and it was not possible to BACKUP to correct a wrong entry for DISP.
353			• 5 SYMBOLS MAXIMUM	
359			ENTER STOP IF DONE	Branch to 112.

Display Number	Questions (Yes/No)	Data Entry Prompts	Transient Advisories	Notes
Final bookkeeping sequence				
400	UNLOAD DONE?.			
402	***	NOTIFY OBSERVER		This advisory, not transient, was included for test purposes. It was accompanied by 3 "beeps", which alerted the observer to make the remaining entries needed to complete the test session.
410	LIST LOAD?.			
420	PRINT FILE?.			
430	START NEXT LOAD?.			
432		LOAD: _		
440	SIGNOFF?.			
442		SIGNED OFF AT NN:NN		

APPENDIX C

IMPROVED PROCEDURES FOR DIGITAL RECORDING

In the body of this report, several problems were noted with regard to the format control logic for data entry, and the procedures for error correction, associated with use of the digital recorder in this initial test program. A more detailed analysis of errors of entry format, presented in Appendix E, suggests that some of these problems are probably associated not with the general concept of digital recording as a data entry mode, but rather with deficiencies in the particular implementation chosen for testing. That is to say, some of these problems could be effectively eliminated by an improved keyboard design permitting simpler procedures for data entry:

Observed Problem	Possible Solution
Operators may forget to push TCN key before entering TCN or index.	Make the TCN key more prominent in size and position.
Operators may confuse data items grouped in a "line".	Provide a separate key to indicate each data item.
Operators may forget to key ENTER.	Omit ENTER if individual field indicators are used.
Operators may hit indicator keys by mistake when keying data.	Provide an extra margin of space between indicator keys and data keys.
Operators may get confused using BACKSPACE key.	BACKSPACE would be used less often if re-entry of individual data items were easy.
Operators may misuse CANCEL key.	CANCEL would not be needed if data items could be re-entered easily.
Operators may forget to key indicator twice to signal line re-entry.	Item re-entry need not require double keying of indicator.
Operators may forget to key TCN twice to re-enter TCN.	A special key is needed for unambiguous correction of a wrongly input TCN.

Observed Problem	Possible Solution
Operators may forget to assign an index when beginning data entry for a new multi-piece shipment.	Index assignment should be an optional, discrete action at the end of each data entry session.

A keyboard layout incorporating these suggested improvements is diagrammed in Figure C-1. Here keys are arranged in relation to their intended function, with indicator keys and other special keys around the margins of the keyboard. Data entry for each piece of cargo would begin with the large TCN/INDEX key at the top left. The indicator keys for items of general shipment data are arrayed across the top and down the left side of the keyboard, corresponding approximately to the format of those items on a shipping label. Similarly, the indicator keys for specific piece data are at the bottom of this keyboard, just as those data items are displayed at the bottom of a shipping label. Special keys required for error correction are grouped at the top right of this proposed keyboard.

Although not indicated in the diagram, the various special keys could be color coded according to their function. Indicator keys for TCN, TAG and DISP, representing the minimum data items to be entered for any piece, might be red. Indicator keys for piece-specific data, i.e., PIECE, TOTAL, WT, CUBE, might be orange, since these represent items which must usually be entered. Indicator keys for general shipment data items might be yellow. Keys used for error corrections might be blue. At the least, the large TCN key should be made a different color from the other keys in its vicinity, in order to add perceptual salience.

It should be noted that this proposed keyboard is designed to facilitate the data entry task as it was performed in this initial test program, i.e., entry of a complete set of shipping label data, beginning with TCN. In actual truck dock data entry, it is possible that the task could be simplified to include only portions of the shipment data, and it is possible that the entry sequence would begin with the TAG identifier for each piece of cargo. If the task were changed in these ways, the proposed keyboard design should be modified accordingly.

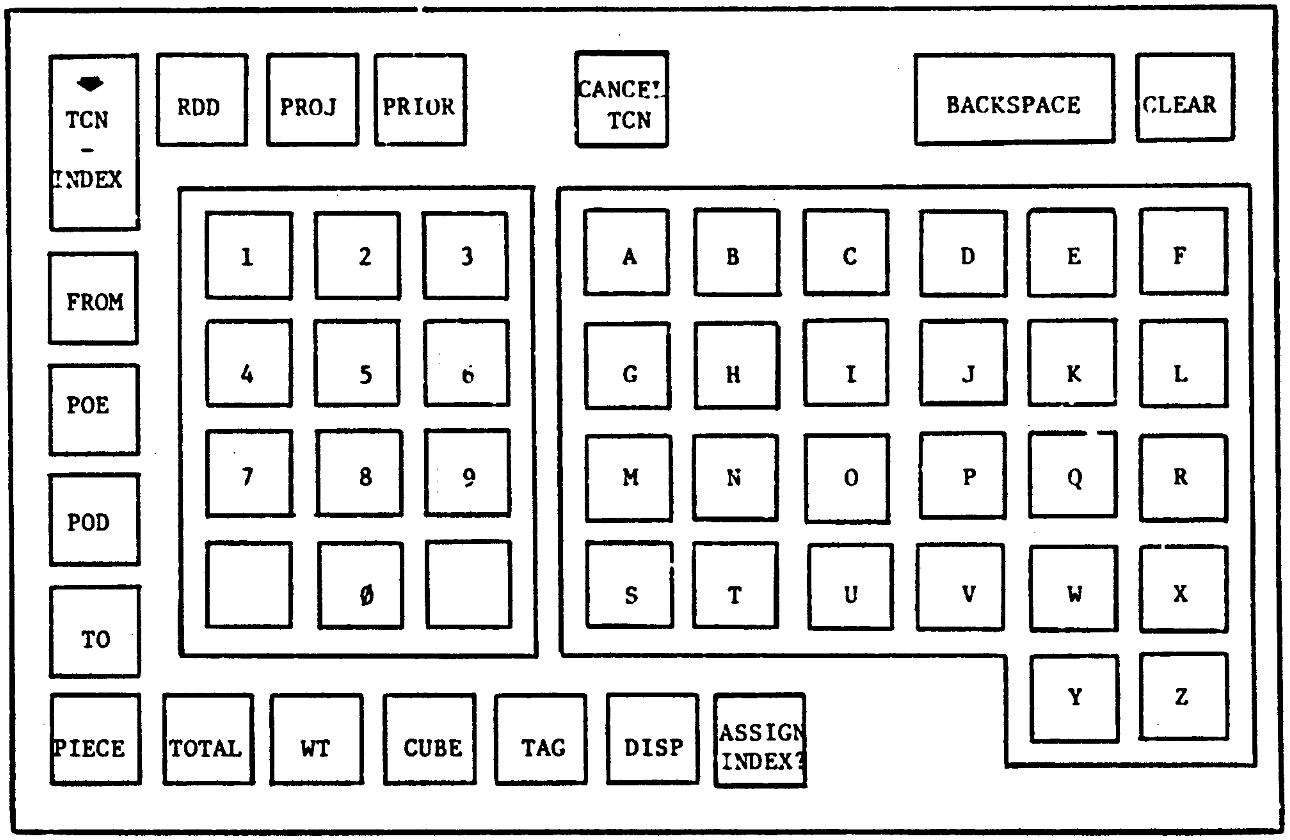


Figure C-1. Improved Keyboard Layout for Digital Recorder

APPENDIX D

SAMPLE CHECKSHEETS

The following pages illustrate one complete set of checksheets used in this initial test program. The checksheets in this sample set provide a high level of advance data for a test load of low shipment-to-piece ratio. Printouts of advance data are included for 9 shipments of the total of 12 shipments in this load. The set of checksheets begins with a cover sheet indexing these 9 shipments arranged "alphabetically" by TCN. Succeeding pages, each showing a prominent index number, display the advance data for each shipment.

The items comprising the general data for each shipment are arranged in a format corresponding to the actual layout of shipping labels, to facilitate comparison; missing items are denoted by an empty field of dots. Lines for piece-specific data are displayed below the outlined label format, with the number of these lines corresponding to the number of pieces known to be in the shipment.

In the checksheet mode of data entry, the test operators were instructed to review advance data items for accuracy and completeness, and to write in any necessary changes. For purposes of testing, the information actually shown on a shipping label was assumed to be correct, and advance data items were to be changed as necessary to match the label. In the sample checksheets shown here, it can be seen that correction to advance data was made for the shipment indexed 3 (wrong consignor code), and an addition made for shipment 9 (missing project code).

In using the checksheet mode of data entry, the test operators had to write in the necessary piece-specific data for all shipments. For shipments with no advance data available, the general data also had to be written onto the checksheet, copied from the shipping label. Blank checksheets were included for that purpose, and three of these are shown at the end of the sample set illustrated here.

Test operators were instrucuted to write legibly, and reminded frequently during the test series that their checksheets would be used later by other people in transcribing the written data to digital form. Examination of the resulting checksheets, however, raises some question as to how accurately such data transcription could be performed. The sample sheets illustrated here represent reasonably legible writing in comparison with some others produced in this initial test program.

The general layout of the checksheets seemed satisfactory in testing, and could probably be recommended as a desirable format for practical use. The layout of the cover sheet index list could be improved. In retrospect it seems a mistake to have listed TCN's alphabetically. The most distinctive feature of a TCN tends to be its last group of four symbols. The preceding symbol groups, representing codes for initiating agency and date, tend to be similar, sometimes identical, from one shipment to another. During the data entry task, test operators were observed scanning the last column of symbol groups on the index list, looking for a match with the next TCN to be entered. Such scanning would be faster if the list of TCN's were rearranged so that these last groups of symbols were in numeric order. Such a rearrangement would also reduce the possibility of error in identifying the proper TCN in an occasional instance where the last group of symbols in one TCN is the same as that in another, since these two TCN's would be displayed together in the index listing.

L22A

INDEX	TCN	INDEX	TCN
1	A50762 3054 4943	22	
2	A50775 4676 5128	23	
3	F04497 4150 0776	24	
4	F05620 5056 0316	25	
5	F50711 2528 6332	26	
6	F50723 0764 7975	27	
7	N62770 4266 2011	28	
8	82603A 5072 X030	29	
9	V04720 5067 0451	30	
10	AT117750840001	31	
11	AK455950069532	32	
12	5IOF02 5039 00Q	33	
13		34	
14		35	
15		36	
16		37	
17		38	
18		39	
19		40	
20		41	
21		42	

A58762 3854 4943 899 ...

...... 2

DOV

OSN

......

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	2	40	3	355136	K1471
2	2	70	5	355043	K1431

1

1

A58775 4676 5128 188 ...

A15MMG 2

DOV

OSN

AT4177

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	4	.130.	.8.	325121	.0.5.N
2	4	.130.	.8.	325050	.0.5.N
3	4	.138.	.8.	325120	.0.5.N
4	4	.130.	.8.	345055	.0.5.N

2

2

FB4497 4150 8778 888 ...
Swe[illegible]
~~[illegible]~~ 3

DOV

DOV

FB4497

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	4	7	1	325108	60141
2	4	15	1	325044	60141
3	4	15	1	325046	60141
4	4	15	1	325059	60141

3

3

F35620 5086 0316 ... ...

GK0001 2

DOV

FRF

F85620

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	6	.254	.18	325110	.SRF
2	6	.254	.18	325122	.SRF
3	6	.254	.18	325052	SRF
4	6	.254	1.8.	325054	SRF
5	6	.254	1.8.	325107	SRF
6	6	.254	.18.	325113	.SRF

4 4

F50711 2528 0332 101 ...

FB7000 2

DOV

TOJ

......

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	3	245	15	335114	705
2	3	50	5	335125	50260
3	3	50	5	335045	50260

8 5

F58723 8764 7975 184 ...

2

FB4487

DOV

FRF

FB9620

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	8	199	15	325058	SRF
2	8	199	15	325052	SRF
3	8	199	15	325053	SRF
4	8	199	15	325132	SRF
5	8	199	15	325048	SRF
6	8	199	15	325051	SRF
7	8	199	15	325119	SRF
8	8	199	15	325114	SRF

8

8

N62770 4266 2011 269 EK2

SN3100 2

DOV

CRK

N62770

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	6	.40	.1.	325118	60170
2	6	.40	.1.	325105	60170
3	6	.40	.1.	325112	60170
4	6	.40	.1.	325111	60170
5	6	.40	.1.	325049	60170
6	6	.40	.1.	325123	60170

7

7

82603A 5072 X030 ... TEB
JH1706 1
DOV
OSN
AT4147

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	1	72	7	325128	151131

8

8

V04720 5067 0451 ... F.50
SW3500 2
DOV
PIK
V04720

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	2	46	3	325052	N1761
2	2	68	3	325130	N1761

9

9

BT4627 0024 0021	094	...
B24 275		1
B2U		
BSN		
BT4177		

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	8	37	1	325[illegible]	B0220
2	8	37	1	325129	B0220
3	8	37	1	325112	B0220
4	8	37	1	325106	B0220
5	8	37	1	325104	B0220
6	8	37	1	325123	B0220
7	8	37	1	325047	K1431
8	8	37	1	325115	K1431
9	....	.....	....	......	.....
10	....	.....	....	......	.....

10

AK4SF7 0026785 42 ... OPL
4325614 1
DQU
FRF
AK4559

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	3	75	1.5	325060	N0461
2	3	75	.15	325134	N0461
3	3	46	2	325127	N0461
4					
5					
6					
7					
8					
9					
10					

11

810PP2 5023 0003

[illegible] 1

[illegible]

[illegible]

[illegible]

PIECE	OF	WEIGHT	CUBE	TAG	DISP
1	1	152	1.1	325121	SPK
2					
3					
4					
5					
6					
7					
8					
9					
10					

12

APPENDIX E

FORMAT ERRORS IN USING THE DIGITAL RECORDER

As observed in the body of this report (Section IV), use of a digital recorder for data entry can result in a variety of format errors of different kinds. Some format errors can be detected as logical discrepancies between a data item actually entered and the formal requirements for that item - a TCN with too few symbols, or perhaps an undefined entr of "6" for PRIORITY. Such errors of improper data format can occur in any mode of data entry. Other format errors result from mistakes in the sequencing of data inputs, as for example a failure to indicate which data item is being entered next. Such errors of entry format are easily made when using a digital recorder, and difficult to correct in subsequent analysis of digital records. That problem is the subject of this Appendix.

Digital records generated during this initial test program were scrutinized to determine what kind of format errors occurred. Altogether some 30 specific types of error were identified in ten general categories. Some kinds of error had to do with data format and some with entry format, as those terms were used above. Errors in entry format reflected failures to remember or use properly the indicator keys; trouble with the concept of line entry, along with use of the ENTER key to separate data items within a line; and operator confusion about error correction procedures. Some kinds of error were serious in their consequences. Other errors made no difference in the final record but merely involved unnecessary effort for the operator. Some of the more serious errors could be detected and corrected to some degree in computer processing of digital records. Others could not.

A general categorization of error types is presented below, along with comments on the consequences of each type of error, and what means might be taken to prevent it if possible, or to detect and correct it otherwise.

Errors of Data Format

Two categories of error have to do with faulty format of the data entered. Errors of data format would be detected and corrected immediately using an on-line terminal, but cannot be corrected in the record produced by the digital recorder.

1. Missing data. The operators sometimes forgot to enter a data item which was required. The consequences of this error can vary considerably. If the operator fails to enter an item of shipment or piece data, then it may be only that item which is lost from the final data record. If he forgets to enter a TCN or INDEX to identify the shipment, however, then the consequences are more serious. Data items for the new piece would be overlaid as supposed corrections to corresponding data items for the last previous piece, creating wrong data for the previous record, losing the new record altogether, and possibly losing other records as well depending upon how carefully the operator enters data for multi-piece shipments. These errors cannot be corrected by computer analysis. The operator must be trained to enter all necessary data, although it is clear that even a well-trained operator will occasionally become distracted and forget an item. The key designating input of the TCN, initiating the data entry sequence, should be made prominent in some way, to try to ensure that the operator will not forget that one especially critical item.

2. Wrong data. The operators sometimes entered data items wrongly, perhaps entering a symbol string that was too long or too short or recognizably deficient in matching some other formally defined requirement. The consequences of this error again vary depending upon whether just a single data item is faulty, or whether a wrong TCN has invalidated the entire data record for a piece of cargo. These errors can be detected in subsequent computer analysis of the data record, but cannot be corrected when an off-line device such as the digital recorder has been used for data entry. The only solution to this problem is to try to prevent such errors by selecting responsible operators and training them in the importance of careful data entry. Even then, some persistent level of errors must be expected.

Misuse of Indicator Keys

The remaining categories of error have to do with errors in entry format. Such format errors would be impossible for the user of an on-line terminal. For the digital recorder, errors of entry format would vary with the keyboard design and the associated logic of the data entry sequence.

3. Missing indicators. The operators sometimes forgot to hit an indicator key to identify the next data items to be entered. In this initial test program, indicator keys were used to signal a "line" of data items. The consequence of omitting an indicator was to string the new data items at the end of the previous line; but in subsequent processing that previous line was truncated to its proper

length, so that new items were lost. When the indicator for a TCN entry is forgotten, the situation is more serious, as mentioned in the body of this report. If the new TCN is not recognized as such in subsequent computer processing, then all new data entries will be accepted as supposed corrections to the corresponding data items in the record for the previously entered piece. In that process, the previous record becomes completely wrong, and the new record is completely lost. Several preventive measures appear possible. One approach would be to revise the keyboard so that every data entry must be preceded by its own indicator, as recommended in Appendix C. For the operator, such a keying logic would strengthen the habit of hitting an indicator key before every data entry. In subsequent computer analysis of data records, the consequence of a forgotten indicator would be loss of just one data item rather than a "line" of items. (The line concept should be abandonned in any case because it was confusing to the operators, as noted below.) The indicator key for TCN entry should be made especially prominent, to reduce the likelihood that it will be forgotten. Since the consequences of its omission are so severe, the computer software used to analyze recorded data should include some sort of preliminary screening routine to detect omission of TCN indicators and insert them as needed. In this initial test program, a routine was devised to scan the data record immediately following entry of disposition code (properly, the last item entered for each piece) to determine whether a long unidentified string of symbols appeared, in which case that string was assumed to represent a new TCN and an indicator was inserted before it. This routine corrected many omissions properly, but in a few instances caused errors of its own. Its net effect was clearly beneficial. A similar screening routine was devised to insert indicators before the line of data items containing TAG and DISP.

4. Wrong indicators. The operators sometimes hit an indicator key accidentally, or hit a wrong indicator key. If the operator does not notice this error, some data loss may occur by premature truncation of line entries. If the TCN indicator has been keyed by mistake, this can cause more extensive loss from the data record being prepared: the next data item entered will be considered as a new TCN and subsequent data items in the record will be associated with that spurious TCN. Computer analysis software may detect such errors but cannot correct them. A keyboard expanded to eliminate the need for line entry would reduce the consequences of wrong indicator keying. The TCN indicator key in particular should be positioned so as to minimize the likelihood of its accidental use. It is important also that if the operator himself notices wrong indicator keying he be given the means to correct his error. In this initial test program, the operators sometimes tried to use

BACKSPACE or CANCL keys for that purpose. As it happens, the original data analysis software did not anticipate this problem and did not permit such erasure of indicator entries. The software was subsequently revised to deal appropriately with operator corrections of that sort.

Errors in Line Entry

The concept of entering groups of data items in a single "line", along with the consequent need to use the ENTER key to separate items within a line, proved a source of some confusion to the operators in this initial test program. The line concept and its techniques of implementation require the operators to remember a number of things: to use appropriate line indicators, to enter items within a line in a fixed order, marking them with the ENTER key, to re-key an entire line of items when correcting one of them, etc. When memory fails, as it sometimes does, the operator may make errors in the format of line data entries. Errors of this kind would not occur using a keyboard on which each individual data entry could be signalled using a separate indicator key, following a keyboard design such as that recommended in Appendix C. Using such an improved keyboard, data items could be entered in any order, blank items could be omitted, wrong items corrected individually, with no confusion in concept or data entry technique caused by item grouping into lines. With the line entry logic actually used in this initial test program, however, a number of format errors were observed.

5. Displaced data. One operator on several occasions keyed a data item in the wrong line, at the beginning, with the result that this item was lost and all other items in that line were displaced and recorded wrongly. There is no reasonable means of correcting an error of this kind in subsequent computer processing. These errors apparently resulted from simple lapses of attention, since that operator usually entered the same data items correctly.

6. Blank items. Several operators when correcting a data item at the end of a line (e.g., CONSIGNEE) sometimes entered blanks for the preceding items, rather than re-entering all items in the line as they had been instructed to do. In straightforward computer processing of the data record, this lapse in entry format would result in loss of the blanked items. The data analysis software was modified so that blank entries could not erase pre-stored items of advance shipment data, which represents a solution of sorts. On the other hand, operators sometimes forgot to make even blank entries for preceding items, which resulted in displaced data. A better solution would be to abandon line entry altogether. As a somewhat

different indication of the potential confusion caused by blank items in a line entry format, one operator actually entered a line of blanks (denoting no RDD and no PROJECT) on several occasions, an unnecessary data entry which had no effect on the final data record but simply represented wasted effort.

7. Missing ENTER's. Operators sometimes forgot to key ENTER when needed to signal separation of data items in the middle of a line, which resulted in loss of the next item, possibly a wrong entry for the preceding item, and probably wrong entries for any following items. There is no feasible correction routine which can be applied in subsequent data analysis. Sometimes the ENTER key is not forgotten, but some other key is hit accidentally in its stead. The results are the same unless the key hit accidentally is an indicator key, in which case the confusion is compounded as in the type 4 error described earlier. Sometimes the ENTER key has been used properly but then is accidentally erased from the record by subsequent use of BACKSPACE in an attempt to correct the next following data entry. The resulting data loss is the same. One operator frequently forgot to key ENTER at the conclusion of a line entry. Although these omissions violated his instructions, it happens that they proved harmless in that they had no effect on subsequent processing of his data record.

8. Wrong ENTER's. Operators sometimes accidentally hit the ENTER key when they should not. If ENTER is struck too soon when keying a TCN, for example, that entry would be truncated in subsequent processing of the data record, so that shipment identification would be recorded wrongly for that piece of cargo, and possibly for other subsequent pieces as well in the case where an index was assigned to a multi-piece shipment as part of the data entry sequence. If the extra ENTER is internal to some other data item, then that item will be truncated and stored wrongly, and subsequent data items may be displaced to produce wrong records using the line entry logic. Hitting an ENTER key twice by mistake will also have the effect of displacing subsequent data items in a line to produce wrong records. If an extra ENTER begins a line of data entries, then all data items in that line would be displaced in the record in a straightforward data analysis. In this instance, however, a special routine can be devised to repair the error, namely to pre-screen data records and remove initial blank entries from a line. In this initial test program, such a routine was included in screening data records, to remove extra ENTER's at the beginning of data lines (except for the RDD line), which corrected most errors of this kind. If the extra ENTER's are at the end of a line, which occasionally happened, then no harm is done in subsequent analysis of the data record. A further problem with the

use of ENTER was occasionally observed: one operator sometimes keyed line entries so quickly that the ENTER key was <u>transposed</u> in position with the data item it was to mark, thus resulting in both an extra ENTER and a missing ENTER in the same line. There is no cure for this sort of carelessness if the line concept of grouped data entries is retained.

<u>Mistakes in Error Correction</u>

As described in the body of this report, the test operators had available to them several means of correcting data entry errors if those errors were detected as they were made. Error correction procedures included use of BACKSPACE or CANCL to erase single symbols or data fields respectively, or double keying a line indicator to re-enter a line of data. All three of these procedures are potentially subject to misuse, i.e., they can cause errors as well as correct them. BACKSPACE can be used to erase wrong symbols, or to eliminate wrong indicators or ENTER's (correcting error types 4 and 8 above). But careless use of BACKSPACE can cause missing indicators or ENTER's in the data record (error types 3 and 7). That seems an unavoidable risk if a BACKSPACE capability is provided, and BACKSPACE <u>is</u> a useful capability when used correctly. The other modes of error correction seem to offer more hazard than help.

9. <u>Misuse of CANCL</u>. For all operators, there seemed some degree of confusion between the use of the BACKSPACE and CANCL keys. CANCL was seldom used, and then sometimes improperly. In one instance an operator was observed to use CANCL repetitively, under the momentary misapprehension that it was the BACKSPACE key, with the result that he eliminated several preceding <u>items</u> from the data record rather than several wrong symbols as he had intended. It is recommended that a CANCL function not be included in any revised keyboard, except for a special key to cancel a wrongly input TCN as recommended below. If data items are entered separately, each with its own indicator, then a CANCL key would offer little advantage in any case. Corrections to any individual entry could be made easily, either by BACKSPACE or by re-entry of the data item.

10. <u>Misuse of double indicators</u>. In this initial test program the technique of double keying indicators to correct line entries was devised for one purpose only, to permit unambiguous correction of a wrong TCN entry in the data record. Double keying indicators for lines of shipment data was not really necessary, since the logic of subsequent data analysis was such that any new line of data would properly replace the old, whether a single- or a double-keyed indicator was used. The operators were not told this, however,

since it was considered important that they develop a consistent habit of double keying indicators when making line corrections. Although double keying was not really needed for correcting shipment data, double keying was essential for proper correction of TCN's. When used properly, double keying of the TCN indicator is a satisfactory technique for signalling that a correction must be made to the last previous TCN in the data record. But the hazards of misuse are severe. When trying to correct a wrongly input TCN, the operator may forget to begin his correction with a double stroke of the TCN indicator. The consequences in subsequent analysis of the data record are various: the previous wrong TCN remains uncorrected, with or without associated shipment data; and the new correct TCN may be dissociated from its data depending upon when in the data entry sequence the re-entry of TCN was attempted. Even worse is the situation where an operator accidentally keys the indicator twice when starting to enter a new TCN: the new TCN replaces the last previous TCN in the data record, the new shipment data replaces corresponding items in the old; and old items not replaced will persist wrongly in the new record. The most sensible solution to these problems is to abandon the double keying technique altogether, and to include on the keyboard a new key used specifically to cancel a wrongly entered TCN. Such a key is incorporated in the improved keyboard design recommended in Appendix C. Perhaps that key can be given some notable color to help ensure its proper use on the occasions when it is needed.

Frequency of Format Errors

Having catalogued these ten general types of format errors, the next step is to consider their frequency and consequences. A summary of the relative frequency of format errors of different types is presented in Table E-1. Altogether, 183 format errors were noted. Of these, 24 were harmless in their consequences and have been omitted from this tabulation. Of the 159 errors remaining, 76 were corrected by software routines used to screen the data records in preparation for subsequent analysis. These screening routines introduced 6 new errors, so that a net total of 89 format errors remained.

Table E-1 indicates the consequences of those residual format errors: data records completely lost for 14 pieces of cargo, completely wrong for 21 other pieces, 7 false records added, plus lost data for 66 miscellaneous items in other piece records, and wrong data stored for 65 items. These data losses would have been much higher if no screening procedures had been used, as indicated by the parenthetic numbers shown in the table.

Table 7-1

Format Errors Using the Digital Recorder

Error Type	Error frequency (Note 1): Test Operator A	B	C	D	E	F	Total	Total after data screening	Consequences (Note 3): Piece record lost	Piece record wrong	False record added	Miscellaneous data items lost	Miscellaneous data items wrong
1. Missing data	1	4	2	0	0	4	11	11	7	0	0	16	10
2. Wrong data	2	0	5	5	0	14	26	26	3	15	1	1	11
3. Missing indicators	1	2	2	33	0	19	57	10	1 (55)	1 (51)	1 (?)	1? (31)	2
4. Wrong indicators	3	0	2	0	0	3	8	7	1 (2)	0	1 (2)	6	4
5. Displaced data	0	0	0	7	1	0	8	8	0	0	0	6	27
6. Blank items	2	2	1	0	1	0	6	2	0	0	0	2 (9)	2
7. Missing ENTER's	0	0	1	3	2	1	7	7	0	0	0	7	5
8. Wrong ENTER's	0	1	3	15	2	4	25	14	0	4	4 (0)	3 (17)	10 (30)
9. Misuse of CANCL	0	0		0	1	0	2	2	0	1	0	2	0
10. Misuse of double indicators	0	1	0	1	0	7	9	2	2 (9)	0 (14)	0	0	0
Overall	11	10	18	70	7	43	159	89 (Note 2)	14 (76)	21 (95)	7 (3)	66 (93)	65 (94)

Notes:

1. 28 harmless format errors are omitted from this tabulation.
2. This total includes 6 new errors which were introduced by the data screening procedures.
3. Parenthetic numbers indicate different consequences if no data screening procedures had been applied.

The incidence of data format errors (37 errors of types 1 and 2 above) was somewhat lower then the comparable figure when these operators were using the on-line terminal (59 errors, as shown in Table 4-1). This finding suggests that the users of the digital recorder were trying to be careful, since they could not rely on a computer to monitor their data entries and flag obvious errors. Their conscientious performance, however, was not sufficient to prevent the frequent occurrence of entry format errors. Some redesign of the equipment and the job would be required in order to reduce the considerable data loss resulting from errors of entry format.

An improved keyboard for the digital recorder, such as the design recommended in Appendix C, would simplify the logic of the data entry sequence by eliminating the need to enter lines of data items grouped together. By simplifying the data entry task in this way, it is probable that most errors of entry format (error types 5-10 above) could be eliminated completely.

Even with an improved keyboard, however, some errors of entry format must be expected, namely the omission or misuse of item indicators (error types 3 and 4 above). Examining the frequency of such errors as shown in Table E-1, it is evident that errors of omission (type 3) are much more common than errors of commission (type 4). Although keyboard redesign might improve performance somewhat, it is probable that omission of data indicators would remain a persistent problem in a real data entry job just as it was in this laboratory situation. If so, then some sort of data screening routines to insert missing indicators will be useful in processing real data records just as they were needed in this initial test program.

Given an improved keyboard design and a simpler logic for data entry, it is possible that the digital recorder could prove adequate as an alternative (or backup) mode of data entry for use instead of an on-line terminal. Further laboratory testing would be needed to assess that possibility. If an improved method of digital recording could be developed in the laboratory, it would then have to be evaluated in field testing to confirm its real value. Patterns of error might be significantly different in real job performance.

In the laboratory setting of this initial test program the data entry task was continuous. As an operator finished entering data from one label, the next label was immediately available on top of the remaining pile. Many errors may have resulted from haste to complete the data entry task. In a real data entry job, the process of cargo handling at truck dock or pallet pit would tend to interrupt the data entry task as the operator moves from piece to piece. The pacing of data entry would be more deliberate, with a longer pause between each piece of cargo. Under those conditions, certain kinds of errors, like forgetting to key a TCN indicator, may be less frequent. Or perhaps they might be <u>more</u> frequent. Field testing will be needed to resolve that uncertainty.

In the laboratory task used in this initial test program, all data items from a shipment label had to be entered, including some items always present and other items which had to be entered only occasionally. In a real data entry job, it might be possible to regularize the task to require data entry only for a minimal subset of items always present. Under those conditions, it is possible that the operator could develop more reliable habits of data entry and make fewer format errors in the entry sequence. Again, further testing would be needed to assess that possibility.

APPENDIX F

OPERATOR EVALUATION QUESTIONNAIRES

The following pages illustrate the wo types of questionnaires used to record operatoı evluations of t.ıe several data entry modes. The first questionnaire, three pages long, was completed by each operator at the end of a day's test sessions using a particular mode. It begins with an open-ended question intended to elicit a general reaction and comments on aspects of the data entry mode which seem important to the operator. The next question asks the operator to rate his overall evaluation, on a scale which can later be quantified in comparison with other ratings.

On page two of this questionnaire the operator is asked to rate performance on different aspects of the data entry task. He is asked for spontaneous comments on his experience in learning to use the data entry mode, and then is asked to rate ease of learning.

On page three he is asked to rate his interest in the task, reflecting motivational factors. He is asked to rate data handling performance, a consistency check on earlier ratings. He is asked to rate the physical equipment used. Finally, he is asked again for general comments, to elicit any ideas which may have occurred to him while working on the questionnaire.

The second questionnaire, also three pages, was designed for a somewhat different purpose. It was used only on the third day, at the completion of <u>all</u> test sessions, to record each operator's evaluation of all three data input modes considered in comparison with one another. This questionnaire begins by asking the operator to provide a numerical rating for each mode on all aspects of the job previously considered.

On page two the operator is asked to assess the three modes in terms of their potential application to the actual data entry job. He is asked to describe desirable qualifications for a person doing the data entry job, to elicit his perceptions of what talents the job requires. He is asked to rate his own willingness to work at such a job, on a hypothetical basis.

On page three the operator is asked for the last time to offer additional comments or opinions.

MAC AIR CARGO TERMINAL DATA ENTRY - INITIAL TEST PROGRAM

Date: 5-13-75

Input Mode: On-Line Terminal   Operator: [redacted]

After a day's experience using this particular input mode to enter shipping data, what is your general reaction? Which aspects of the job go well, and which poorly? What advantages does this data input mode provide? What disadvantages?

I think this little machine will speed the processing up and make the cargo move faster through the system.

I think in my opinion that there aren't any bad aspects towards the machine. The good aspects that I could see is it speeds up the system about twice as fast.

Check one of the boxes on the right to indicate your overall evaluation of this input mode for the task of entering shipment data.

	Excellent	Good	Adequate	Fair/Poor	Poor
Check here ▶	✓				

Check to indicate your evaluation of this input mode in performing specific aspects of the data entry job.

	Excellent	Good	Adequate	Fair/Poor	Poor
Entering the TCN designator		✓			
Entering general shipment data		✓			
Reviewing pre-stored shipment data	✓				
Entering specific piece data	✓				
Detecting errors in pre-stored data		✓			
Correcting errors made during data entry		✓			

What are your general impressions of your experience in <u>learning</u> how to use this input mode? Which aspects were difficult? How could your training have been improved?

What really impressed me was the way way you could always go back to something and refer to it and save time by that

Indicate your evaluation of this input mode in terms of how easy it is for a beginner to learn to use it.

Very Difficult		Moderatly Difficult		Easy
				✓

Considering your experience with this input mode, rate your interest in the job today.

High Interest		Moderate Interest		Low Interest
✓				

Considering speed and accuracy of data processing, and any other factors you think important, how would you rate your performance using this input mode?

Excellent	Good	Adequate	Fair/Poor	Poor
	✓			

How would you rate the physical equipment used in this input mode?

Excellent	Good	Adequate	Fair/Poor	Poor
	✓			

What other comments can you make concerning the equipment, or any other aspect of the test situation?

It is a very modern and fast way to get the job done.

MAC AIR CARGO TERMINAL DATA ENTRY

INITIAL TEST PROGRAM

Date: 5-15-75

Comparison Across Input Modes   Operator: [redacted]

Now that you have tried all three input modes, you are asked to compare them in terms of how well they perform the data entry job. In the table below are listed several aspects of job performance. Please rate the three input modes on each of these aspects, on a scale from 0 to 100.

(Imagine that you are a teacher grading students. Even your best student may not deserve a grade of 100. Similarly, you may decide that the best input mode deserves a rating no higher than 80 on some aspect of the job. If you consider the second-best input mode only half as good, you would rate that at 40, and so on.)

Input Modes:

Performance Aspect	On-Line Terminal	Digital Recording	Checksheet
		Ratings	
Entering the TCN designator	80	40	40
Entering general shipment data	100	40	40
Reviewing pre-stored shipment data	100	40	80
Entering specific piece data	40	40	40
Detecting errors in pre-stored data	80	40	40
Correcting errors made during data entry	80	80	40
Ease of learning to use input mode	100	80	80
Interest in data entry job	80	40	20
Performance level achieved in one day's use	80	40	80
Physical equipment used with this input mode	100	40	20

Considering your overall experience, do you believe any of the three input modes tested here could be used effectively in the actual work situation at the truck docks? Yes.

If YES, which modes do you think could be used? The on line terminal and Digital Recording.

If NO, what are the deficiencies which you believe would handicap use of these modes in the actual work situation? ______________________________

Suppose that one of your unloading crew must be responsible for entering shipment data in the actual work situation, using whatever input mode is available. How would you choose which man should be responsible for this data entry job? What characteristics should he have to handle the job well?

He should be trained on how the input mode operates. I would choose the man that is interested the most.

Considering your experience over several days of testing, how willing would you be to handle such a data entry job in your real work situation?

Interesting job, glad to do it...............	✓
Tough job, do it if I had to.................	
Share the job with others, do it sometimes...	
Would prefer not to do it....................	
Definitely not the job for me................	

Whatever further comments you can make concerning the data entry job, the various input modes, and the test procedures will be most welcome.

I think in my own opinion that the input mode I would like to work with most is the online terminal.

If we are able to send you a summary of test results some time during the next several months, what address should we use to reach you?

[redacted] Dover AFB, Del.
19901.

And finally, thanks for your help in this test program.