DESIGN OF A TOUCH-TONE BASED MEDICAL INFORMATION SYSTEM

by

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ABSTRACT

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Submitted to the Alfred P. Sloan School of Management
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The problem studied is that of whether or not the touch-tone telephone handset is a viable terminal alternative for the development of information processing systems.

To provide a background for this project both a review of previous literature in this area and an introduction into the technical foundations underlying touch-tone technology is provided.

The information flow of the Lahey Clinic laboratory is examined in detail and problems relating to accuracy and time delays in the medical test result reporting process are identified. The touch-tone telephone is contrasted with the IBM 2260 character display device in terms of its usefulness as an I/O terminal for a communications based system designed to eliminate the reporting problems. An analysis indicates that the touch-tone handset is highly attractive from the standpoint of cost but falls short in other critical areas such as speed, visability of the interaction pattern, and complexity of the transactions it can handle.

It is suggested that the touch-tone terminal has greater marginal value in environments where I/O is minimal and where transaction complexity is low. Accordingly, its shortcomings inhibit its use under a stand-alone, total information system concept. The device appears to have its most significant role as a support tool

to a comprehensive information system. By strategically placing keyboard devices in primary locations and backing the system up with low cost touch-tone terminals at secondary points it appears that the optimum cost effective system could be developed. Further research is necessary, however, before any firm conclusions can be reached.

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A significant contribution was made to this thesis by my wife, Cathy, both through her editing and typing assistance as well as through her support during a time period of all work and no play.

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CHAPTER I

INTRODUCTION

I.1 OBJECTIVES

The objective of this thesis is to demonstrate that the touch-tone telephone handset is a viable terminal alternative for the development of information processing systems. In support of this objective are three sub-goals. The first is to establish a comprehension of the technology involved in terms of what issues must be covered to interact meaningfully with this kind of hardware. A second is to contrast touch-tone terminals with more conventional keyboard devices in terms of identifying the classes of problems for which they might prove useful. The third sub-task is to illustrate the system design process necessary to support a communication oriented information system.

It is hopeful that after the completion of these tasks that the issues raised will prove useful in reevaluating the direction of current information system trends toward the development and use of sophisticated and "Sexy" terminal devices. It is suggested that there is a subset of activities in which slow, low cost, and unsophisticated on-line terminal devices may prove to be desirable in terms of overall effectivness. It is toward identifying this spectrum that we begin.

I.2 MEDICAL INFORMATION SYSTEMS

Having selected the task of developing a medical information system it would prove useful here to define exactly what is meant by such a system. A medical information system is defined to be an organism capable of providing information processing support to medical practioners and auxiliary technical and paramedical personnel engaged in the health delivery process. These information processing requirements can be classified into two major areas:

A) Diagnostic support activities

B) Administrative support activities

Diagnostic support activities involve decision making aids for diagnostic purposes, providing medical test results, access to health data banks, computation aids, and patient data retrieval. These activities involve a reasonably high degree of interaction with highly trained medical personnel.

Administrative support activities are those tasks which provide for patient admission, discharge, and scheduling, accounting functions, payroll, billing, third party payment systems, and the development of financial information systems. These tasks differ in that interaction occurs at a somewhat lower level of medical competence, often with personnel who have little or no medical training.

We are involved with the development of an information processing system that must interface with a wide spectrum of medically oriented personnel. It is felt that touch-tone technology (the application of end-to-end signaling concepts) is in fact a highly useful and underutilized tool applicable to such systems.

I.3 RELEVANCE

Questions might be asked regarding the usefulness of demonstrating the telephone handset as a viable terminal for the development of medical information processing systems. With many highly sophisticated computer terminal devices being developed why, in fact, should one promote a simple, apparently inflexible, numerically oriented, and limited thruput device to process apparently complex alphabetical medical I/O transactions? This subject deserves a reasonable degree of attention and can be discussed in terms of five critical areas: cost, reliability, universal accessibility, underutilization of resources, and ease of use.

COST

Cost can play a significant role in the feasibility of touch-tone based information systems. Under Massachusett's Tariff the cost of the touch-tone option for the telephone handset is $2.00 per month in a commerical environment. This

can be contrasted with $75.00 - $100.00 a month for communication oriented keyboard terminal devices available with today's current state of the art.

RELIABILITY

Reliability is an important factor both in terms of inconvenience and in terms of the cost incurred to repair the malfunction. Touch-tone telephone reliability is high and the telephone company assumes all maintenance functions. More expensive terminal keyboard terminal devices such as teletypes, IBM 2741's, and IBM 2260 character displays possess intuitively lower reliability and the maintenance costs are often covered only when an optional maintenance contract is signed.

UNIVERSAL ACCESSIBILITY

Without question the telephone is the most widely available terminal device manufactured today. For a small investment an organization can utilize this instrument for a wide variety of information processing tasks.

UNDERUTILIZATION OF RESOURCES

Given the capabilities inherent in the design of touch-tone telephones and the current state of the art in communications technology, the touch-tone telephone handset is an extremely underutilized instrument when used only for voice

communications. A by-product of the voice communications capability is an extremely good low speed data communications capability, a factor which ought to be considered when designing information processing systems.

EASE OF USE

Given that the great majority of medical and paramedical personnel have a reasonable degree of familiarity with a telephone instrument the telephone can not be considered a foreign device. This would be expected to produce a favorable learning curve in the training of personnel for a system implementation.

I.4 ENVIRONMENT

The construction of this thesis takes place in the environment of the Lahey Clinic, Boston, Massachusetts. The Lahey Clinic, one of the largest outpatient clinics in the United States, currently supports a professional staff of approximately 100 physicians in addition to over 600 professional and non-professional staff members. Further information on the history and development of the Clinic may be found in Frank H. Lahey, M.D., published by the Lahey Clinic Foundation. (22)

I.5 SCOPE

The thesis is structured in the following framework:

A) Chapter I contains general introductory statements covering both the objectives and relevance of the effort.

B) Chapter II discusses previous work in the area of touch-tone based systems and its significance to this thesis and to information systems in general.

C) Chapter III provides a technical background in the area of touch-tone technology.

D) Chapter IV outlines the environment of the Lahey Clinic as it relates to the ordering of medical tests. The laboratory is examined in detail and problem areas in the reporting of test results are identified.

E) Chapter V illustrates the process necessary to design a communications based information system in an environment such as Lahey. Contrasts are made between traditional keyboard devices and touch-tone handsets as well as several different hardware systems, each capable of supporting such an information system.

F) Chapter VI will summarize what has been accomplished and suggest implications as to where touch-tone based systems may prove useful.

Having set the tone of the thesis the next step is to identify previous work in the field of touch-tone technology.

CHAPTER II

PREVIOUS WORK

The object of this chapter is to indicate previous work in the application of touch-tone based terminals to the processing of information.

In general there has not been an extensive amount of work in this field. This I believe is to be a result of four principle factors:

A) The touch-tone telephone was not introduced into commerical service until the middle of the 1960's.

B) The initial touch-tone telephone had only a ten button dial which in effect meant that no control characters were available to signify either operations or the bounds of data.

C) The limited geographic availability of touch-tone service.

D) The professional zeal inherent in the computer industry towards the development of more and more sophisticated and complex hardware devices. It is felt that this technical enthusiasm has to a great extent overlooked the touch-tone telephone handset as a viable terminal.

In an effort to structure the previous work in this area the following three classifications were selected: off-line

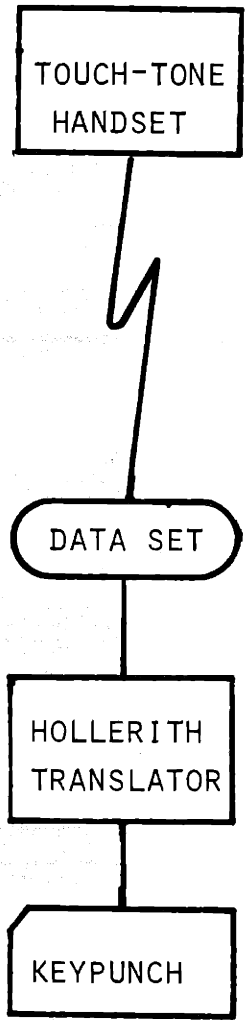
applications, on-line applications, and general research.

II.1 OFF-LINE APPLICATIONS

Off-line applications of touch-tone technology are defined as information processing systems having no direct hardware or software interface with a computer system. This implies that there is no feedback mechanism inherent in the design. In general most, if not all, off-line touch-tone based systems are configured to have a touch-tone telephone handset, connected through the telephone switching network, operating an IBM keypunch. See Figure 2-1.

There is a wide discrepency in reported error rates using off-line systems. Two implementations are representative of this. Gino's Fast Food Resturants, although they admit to an extremely high turnover rate, report a 10 percent error factor. In another report, advertising literature by the company that installed a system at High's Dairy Stores indicated an increase in accuracy from 100-125 errors per 10,000 transactions to 6-12 errors per 10,000 transactions. To make further comments on the error rates of off-line systems is difficult because the majority of companies do not compile statistics.

In general it can be said that the advantages of off-line systems are their low cost, and their ability to increase the speed of information flow. The disadvantage is the lack



OFF-LINE CONFIGURATION

FIGURE 2-1

of feedback and a questionable error rate.

II.2 ON-LINE APPLICATIONS

On-line applications of touch-tone technology are defined as information processing systems having a direct hardware and software interface with a computer system. This generally implies the existence of an audio response unit. Although little literature exists for on-line systems two major implementations are representative of progress in this area.

The Rohr Corporation has implemented a control system for job shop flow using a 360/50 with an IBM 7770 audio response unit (37), (38). The system is based around data collection stations throughout the job shop which monitor job shop work and parts flow. Reports are that the accuracy of order-location information is 40 percent better than with the former data collection system (95 percent of the work in process can be located as opposed to only 35 percent with the previous system) (38).

Another major application was operated on an experimental basis in a joint effort by the Bank Of Delaware, Storms Shoes, and AT&T. The objective was to study the practicality of customers making purchases and having their charge accounts updated through the telephone instrument. The hardware used in this system consisted of an IBM 1410 computer with a

1301 disk file and an IBM 7770 audio response unit. The pilot study was rated highly successful and the only major obstacle was the lack of a method to produce coded identification cards on a mass scale. (04)

II.3 GENERAL RESEARCH

The great majority of the literature in the field of touch-tone technology has been published in the area of what I classify as general research.

In 1966 Davidson (10) examined the issue of whether the touch-tone telephone could input alphanumeric information to a computer system. He discussed a possible rearrangement of the alphabetic characters on the touch-tone dial so as to include the letters "Q" and "Z" which do not currently appear. The basic problem with this idea of rearranging the dial layout is that this would eliminate the compatibility between the touch-tone telephone and the rotary dial telephone, a task which would appear to not be in the telephone company's best interests.

Conway and Morgan (08) discuss a rather dubious scheme of using the touch-tone telephone as a timesharing terminal. As a by-product of their work they do, however, derive a more practical method for providing alphabetic capability by using a two button sequence for each character.

Smith and Goodwin (29) have done an excellent job of

raising human engineering issues associated with touch-tone technology. Two of the more interesting ones are:

A) User controlled output - By allowing the user to control the pacing of his output, lost information, either from lapsing attention or interruptions, will be minimized.

B) Voice coding - By using more than one tone of voice, different classes of information can be presented. This is analogous to using multiple colors in a visual display device to indicate various classes, or relevant importance, of data. Example - A helpful nurse's voice provides instructions while an authoritarian doctor's voice provides critical medical information.

Two new and different terminal characteristics are also identified. These are:

A) No capacity for simultaneous display of multiple alternatives for terminal selection.

B) No capacity for remembering previous output, a limiting factor in the complexity of touch-tone terminal transactions.

The Division of Computer Research and Technology of the National Institutes of Health has undoubtedly produced

the largest volume of research in evaluating the usefulness of the touch-tone telephone handset for medical applications. The focus of their efforts has been to develop methods to give physicians and paramedical personnel low cost, fast access to up to date medical information which is not easily available through more conventional sources. Applications to date have centered around therapy computations, drug information, diagnostic assistance, literature inquiries, computer aided instruction, and hospital information processing functions. Several articles have been published as a result of these efforts. They are as follows:

Allen and Otten (01) explore the concept that the telephone is a useful tool to allow small medical organizations and individual practioners to apply computer techniques to their problems without facing high cost, difficult operating procedures, and machine unavailability. Selecting three parameters (convenience, reliability, cost) as the basis for evaluating the touch-tone terminal for medical usage they conclude that the instrument appears to be a highly useful terminal for short computer problems and inquiries.

The most interesting idea they present is the application of the callamatic telephone as a useful tool for inputting alphabetic medical terms. Additionally, four alter-

natives are suggested to alleviate the hard copy problem.

A) Use of an office dictating machine to make voice recording of all computer communications.

B) Recording of all input and output transactions on magnetic tape.

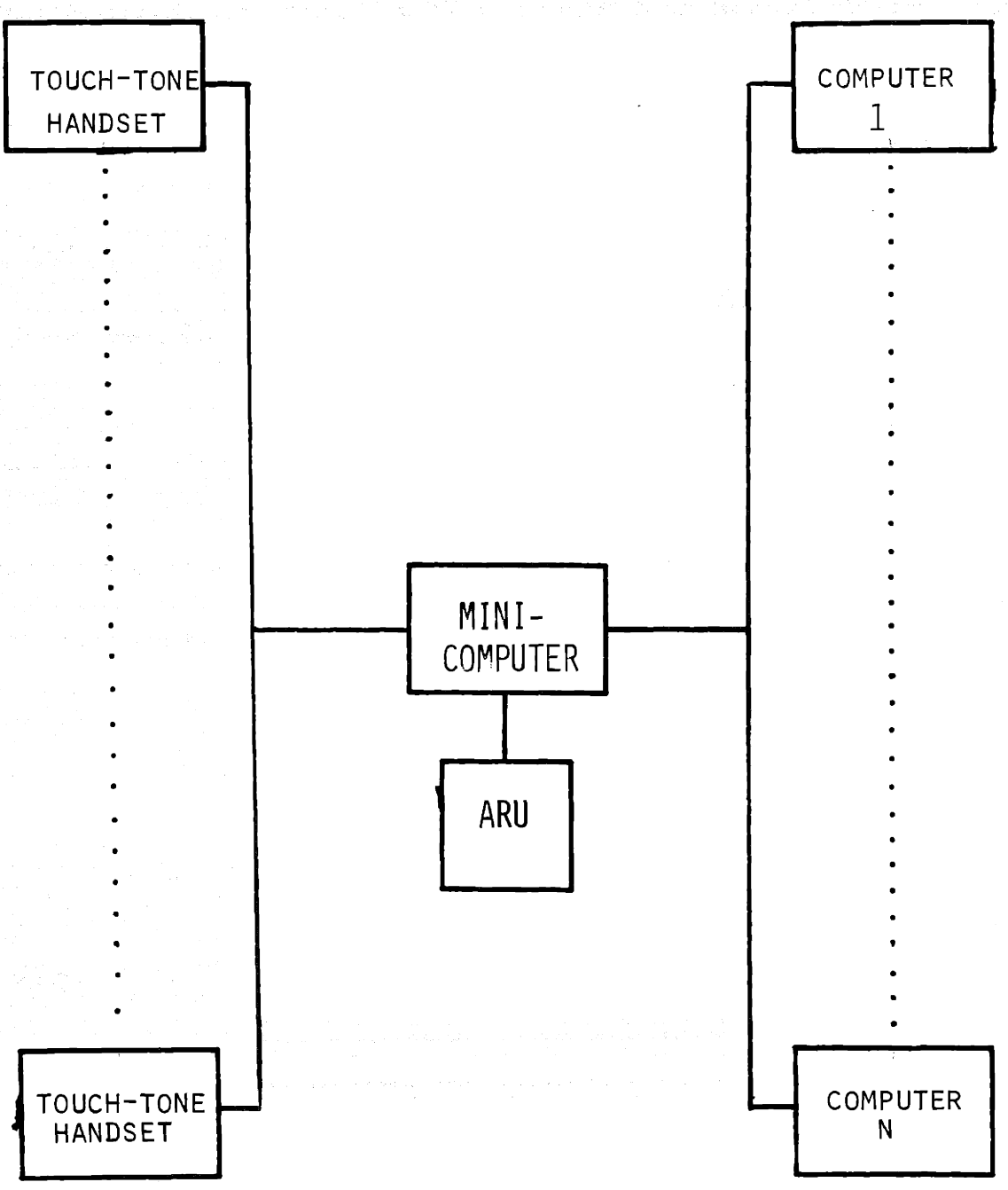
C) The routing of all output to a local facsimile copier.

D) The routing of output to a local telegraph office.

White, Allen, Otten and Swarthe (36) propose a computer network for medical data processing that can be used with touch-tone terminals. They point out that the sharing of programs is infrequent because much effort is spent programming similar medical packages for different equipment configurations. The alternative is to avoid this reprogramming by allowing access to many different machines via a single interface

The core of the system presented (See Figure 2-2) is a mini-computer interfaced to an audio response unit. By logging into this mini-computer and indicating which task or tasks one wishes to perform it in turn dials up the appropriate computer, logs the user in, and then acts as a line concentrator, providing audio response capability for interaction with computers that have no audio response units.

Otten, Allen, Plexico, and White (27) discuss an



AUDIO RESPONSE MEDICAL SYSTEM

FIGURE 2-2

experimental audio input-output system for medical information which is based upon delta modulation techniques. The system allows updating of vocabulary files from a remote telephone terminal. Speech signals are processed with an analog-to-digital converter at the rate of 10,000 samples per second. These signals are then compressed to one bit per sample and stored on a random access file.

The techniques used here were selected on the basis of a tradeoff in favor of low hardware cost versus heavy computer overhead. Although at this time delta modulation might be adequate for experimental work the computer capacity required to operate the system would rule out its use in any large application. The authors point out that their voice response system resulted from a need to provide an operational system at minimum cost and suggest that other more practical techniques are available for commerical systems. The article does provide a useful introduction to delta modulation voice generation techniques and the identification of the design parameters used in this particular application.

II.4 SUMMARY

Having identified the research environment as the major source of previous literature and thought, let us now examine the technical issues underlying touch-tone systems.

CHAPTER III

TOUCH-TONE TECHNOLOGY

Touch-tone technology is a term referring to the technical foundations underlying the use of the touch-tone telephone handset to transmit and receive data over the telephone switching network. It is assumed that these technical foundations are not usually known. The objective of this chapter is to provide this background information in order that a reasonable level of comprehension may be obtained for use in later discussions.

Touch-tone technology will be discussed in terms of three elements: terminal devices, audio response units, and communications issues. The rest of this chapter is devoted to these topics.

III.1 TERMINAL DEVICES

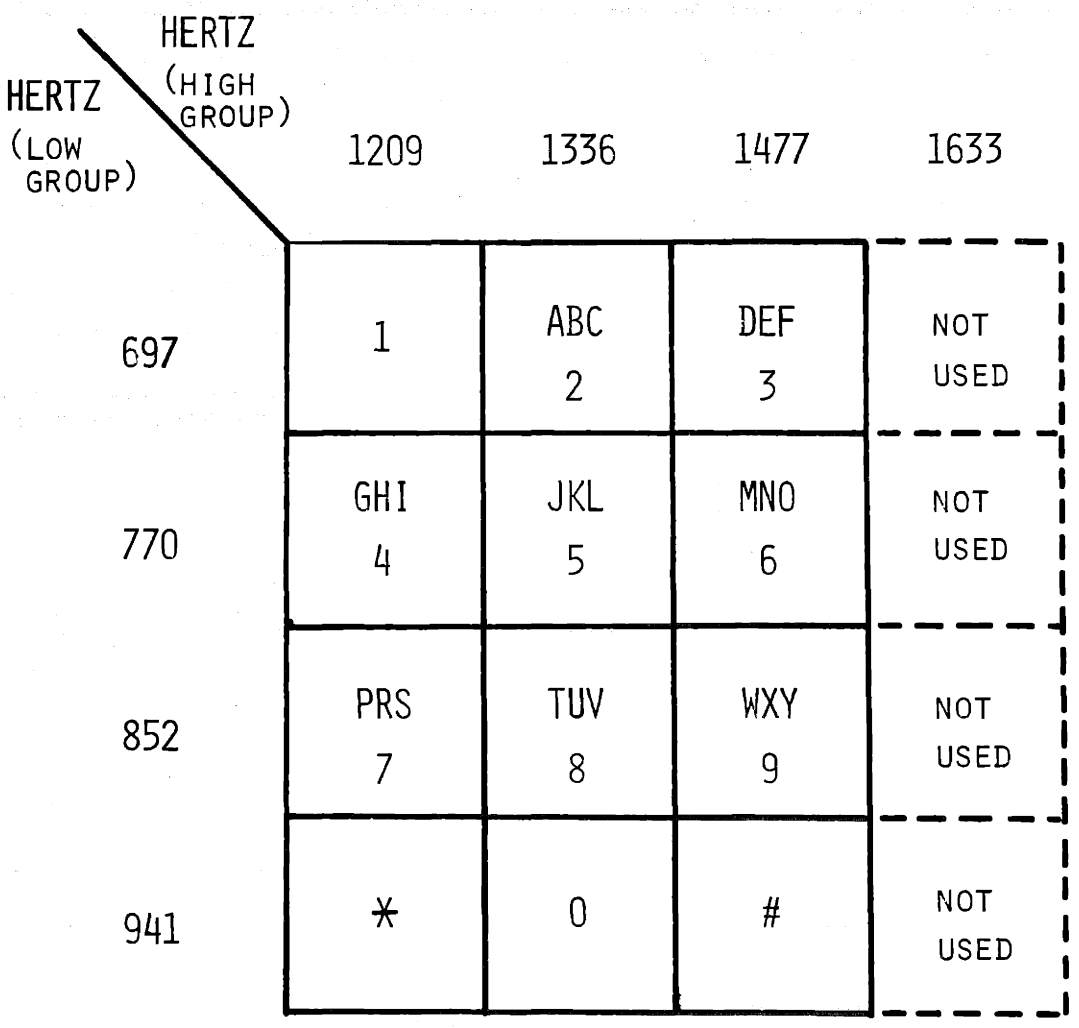
The rotary dial telephone does not prove to be practical for use in data transmission. It generates signal pulses that open and close a circuit each time a number is dialed, very similar in nature to a telegraph. Each digit is represented by a chain of pulses with the pulse chain length corresponding to the numeric value of the digit. The impracticality for data transmission lies in the difficulty in distinguishing between line noise and meaningful data. It

is not feasible to filter line signals with the degree of precision necessary to attain an acceptable degree of accuracy.

The development of the touch-tone telephone made the telephone a practical terminal for data transmission. The touch-tone differs from the rotary dial in that each digit is represented by different combinations of two discrete frequency tones out of a four by four matrix, one from a low group (measured in Hertz) and one from a high group. This matrix yields 16 possible digits or characters. A diagram of this matrix and its relation to the touch-tone dial may be seen in Figure 3-1.

The discrete frequencies chosen to produce this matrix were selected using parameters designed to minimize misinterpretation of the signals, ie. mutually exclusive of frequencies likely to be found in noise, music, or human speech. Currently 4 of these 16 frequencies are unassigned and remain available for future transmission requirements. For a detailed discussion of the parameters considered in selecting the touch-tone frequencies see Battista (05).

The frequency that is produced by the depression of a touch-tone dial button is an analog tone, similar to a musical note. These tones or signals are transmitted down the telephone line in the same manner as voice communication. This signaling convention thus allows the touch-tone tele-



TOUCH-TONE DIAL

FIGURE 3-1

phone to continue transmitting meaningful information once the telephone connection to the other party has been reached, a concept known as end-to-end signaling. With the proper device at the other end of the line to decode these frequencies the telephone circuit now has the capability to support data communication.

For general information on the touch-tone handset see Auerbach's "AT&T Touch-tone Telephone Handset Report" (03) and Hiatt (14). For an excellent and detailed technical discussion of touch-tone development and operation see Kraemer (21) and Soderberg (30).

III.1.1 BELL TELEPHONE HANDSETS

There are a wide variety of touch-tone oriented instruments offered by the Bell System in addition to a growing number of independently manufactured terminals. We will now discuss these devices. All costs referenced that relate to telephone service are based upon Massachusett's Tariffs.

TOUCH-TONE PAD

A touch-tone pad is an auxiliary unit that is peripherally attached to a rotary dial telephone for use in generating touch-tone frequencies. There are two environments applicable to the touch-tone pad. The first is where the central telephone office is not equipped to handle touch-tone initiated dialing and the second is in a geographic area

where touch-tone service is available but the internal telephone network of an organization does not have touch-tone capability. The use of a touch-tone pad involves a $5.00 installation charge plus $2.00 per month.

TOUCH-TONE HANDSET

The touch-tone handset is merely a telephone that has a three by four matrix of buttons replacing the rotary dial. Originally this handset was produced in a ten button version, minus two control characters (# and *), but all units currently being produced have a twelve button dial. The additional two buttons serve several purposes. For the telephone company the control buttons will be used to provide advanced telephone services such as automatic rerouting of telephone calls. For data transmission the buttons prove useful in providing control characters that can be distinguished from the standard numeric digits. The local central office must be equipped for touch-tone service in order to use a touch-tone handset. It carries a $5.00 installation charge plus $2.00 per month service charge. For further information on the history and development of the touch-tone handset see Kraemer and Roscoe (21). For a description of the instrument see Auerbach (03).

TOUCH-TONE CARD DIALER

The touch-tone card dialer is a touch-tone handset

with the addition of a card reading mechanism. This mechanism allows the unit to read a 14 digit plastic card at a speed approximating 10 characters per second and to translate these digits into multifrequency dialing tones. Initial tests indicate that dialing errors produced while using the card dialer option were extremely low, being on the order of .3 percent (12). Installation of the touch-tone card dialer is $5.00 and the additional monthly charge for this service is $3.50.

CARD DIALER PAD

The card dialer pad is similar to the touch-tone pad with the addition of a card reading mechanism. The installation charge is $5.00 and the monthly charge is $3.50.

CALLAMATIC

The callamatic telephone is a touch-tone telephone handset containing a magnetic tape cartridge capable of storing up to 500 16 digit numbers. Access to a given section of the tape is through a motorized alphabetic index (the entire tape may be scanned in 7 seconds), while access to a specific entity is obtained via a non-motorized calibration dial. Visual identification of a number is obtained via a paper tape, with each position on this tape corresponding to one position on the magnetic tape.

The callamatic is useful in data communication in that any information string, either alphabetic, numeric, or special symbols, may be represented on the paper tape with a corresponding numeric code recorded on the magnetic tape. This enables one to input complex information strings in an environment that at first glance appears to be compatible only with numeric data.

In order to dial a telephone number or to transmit an information string one must press a button labeled "call" and the data on magnetic tape which corresponds to the information string on paper tape is translated into multi-frequency tones. Installation charge is $15.00 while the monthly surcharge for callamatic service is $14.00.

III.1.2 HANDSET OPTIONS

Use of the touch-tone telephone handset for end-to-end signaling requires certain features built into the handset to insure error free operation. The two primary features are the polarity guard circuit matrix and the transmitter exclusion feature.

POLARITY GUARD CIRCUIT MATRIX

The polarity guard circuit matrix is electronic circuitry designed to prevent the dial oscillators from becoming inoperative when the polarity of the power supplied to the battery reverses. This may occur during a long

distance call, but normally occurs after and not during the dialing process.

TRANSMITTER EXCLUSION FEATURE

The transmitter exclusion feature is a circuit to block voice and background noise picked up by the handset microphone while the multifrequency tones are being transmitted.

III.1.3 INDEPENDENT MANUFACTURER SUPPLIED TERMINALS

There is an ever enlarging variety of independently manufactured touch-tone based terminals entering the marketplace. We will now indicate the general classes of these devices.

The largest variety of independent devices are of the portable and acsoustically coupled construction. These devices range from the standard 12 button numeric dial to alphabetic keyboard terminals. Some of these units are also equipped with optional strip printer devices to provide hard copy. The most advanced touch-tone terminal on the market automatically dials a remote telephone number, sends a terminal identification number, sends the identification number off a credit card or identification badge which is inserted in a slot, and then sends the value of a numeric digit register which can be set to any given value, all with no manual intervention. In general, these devices

do not replace a telephone but rather work in conjunction with it or operate independently of it. Offsetting the advantages of hard copy or portability are two notable disadvantages. The first is the fact that these terminals are not dual purpose in the sense that voice conversations can not occur (except the receiving of audio response messages) and secondly, the more significant issue that maintenance is not provided by the telephone company.

III.2 AUDIO RESPONSE UNITS

An audio response unit is a peripheral device, generally interfaced to a multiplexor channel (or its equivalent) of a computer which allows the formation of human voice responses as an output medium. Audio response units may be classified into two functional types: analog and digital. The chief distinction between these two methods of generating voice output involves tradeoffs regarding the size of the vocabulary, the number of simultaneous access channels, and cost. The distinction between analog and digital response units and the advantages and disadvantages of each are as follows:

III.2.1 ANALOG AUDIO RESPONSE UNITS

An analog audio response unit has a prerecorded vocabulary one word per track, on a magnetic or photographic film durm. Generally each track may be accessed in parallel

through time division multiplexing, either by placing a read head on each track (magnetic recording) or by sensing a light beam modulated by prerecorded audio and detected by silicon photo-sensitive cells (photographic film). Photographic film drums are less sensitive to wear than magnetic drums because there is no read mechanism directly touching the film.

Access to a vocabulary word is obtained under program control by sending the analog audio response unit a string of drum addresses of words comprising the response, one string for each output channel.

The two major manufacturers of analog audio response units are IBM with its 7770 audio response unit (03), (18) who use a magnetic drum and the Cognitronics Corporation which markets a line of photographic film units called "Speechmakers". An extremely good operational description of the "Speechmaker" unit (07) is published by Cognitronics and is highly recommended reading for a detailed feel of the operation of an analog audio response unit.

ADVANTAGES

The advantages of analog audio response units are:

A) The low computer overhead involved since the words do not have to be constructed and only drum addresses must be generated.

B) A large number of simultaneous output lines is possible since each output line is time division multiplexed.

C) Lower hardware cost since you do not need voice synthesis hardware for each output channel. In general it can be said that with a smaller number of output channels digital audio response units are cheaper but with a larger number of output lines audio techniques are least costly.

D) Low I/O channel utilization since the vocabulary is prerecorded and it does not have to be assembled from bit strings residing on mass storage as with digital techniques.

DISADVANTAGES

The disadvantages of analog audio response units are:

A) The size of the vocabulary is limited by the number of tracks on the analog drum. Currently the maximum vocabulary size for an analog unit is 255 words (35).

B) There is significant difficulty in modifying the vocabulary since it is prerecorded at the factory.

C) Each vocabulary word is allocated a fixed output time regardless of its length which may result in uneven spoken phrases.

III.2.2 DIGITAL AUDIO RESPONSE UNITS

A digital audio response unit has a prerecorded vocabulary in digitally coded form that is stored on some form of random access storage device, usually a drum or disk. The sequence of bits in a given word represent the timing, frequency, and energy associated with the spoken word. To generate an audio response reply one inputs to the audio response unit the digital bit string representing the word to be spoken. This bit string is used to activate a set of band filters that cover the telephone frequency band. The sum of these band filter outputs produce the audio response reply.

Digital audio response units require voice synthesis hardware for each output channel, a factor which can result in high cost with a large number of lines. The IBM 7772 audio response unit is the only major digital unit manufactured at this time (03), (19).

ADVANTAGES

The advantages of a digital audio response unit are:

A) Since the vocabulary is stored on random access storage the size of the vocabulary is limited only by the storage available. The 7772 requires approximately 2,400 bits of random access storage to store one second of audio output.

B) The vocabulary can be modified with relatively little effort since a new vocabulary word merely requires the addition of a new bit string.

C) Vocabulary entries are not restricted by fixed time unit intervals.

D) Digital audio response units are less costly for use in applications where a small number of output lines are needed.

DISADVANTAGES

The disadvantages of a digital audio response unit are:

A) The high computer overhead necessary to process the vocabulary word bit strings.

B) Heavy disk and I/O channel utilization necessary to access the bit strings from mass storage.

C) Constraints on the number of simultaneous users due to the cost of the voice synthesis hardware and the overhead associated with each output channel.

D) The requirement for mass storage in the computer configuration.

III.2.3 SUMMARY

The relative advantages and disadvantages of analog and digital audio response units have been discussed. For applications in the field of medicine it appears that the

greater flexibility inherent in the digital unit and the large medical vocabulary in use favors the use of digital audio response units in medical applications. The limitation on the number of lines that can be processed should prove to be no great problem since a relatively large number of telephone transactions can occur with a small number of lines (19).

For a decent discussion and evaluation of the major audio response units available now see Weitzman (35).

III.3 COMMUNICATIONS FACILITIES

This section will outline some of the communications facilities that may concern the designer of touch-tone based data transmission system. It will not be a comprehensive discussion of the telephone services offered by the Bell System. It will however attempt to provide a starting point for a meaningful discussion of the communications issues.

III.3.1 VOICE GRADE TELEPHONE SERVICE

The following voice grade services are available from the Bell System:

DIRECT DIALING

Direct dialing is a term applied to the use of the telephone in standard dial-up mode. Cost for the use of

this service consists of the basic service charge plus any message units or toll charges accumulated.

PRIVATE LINE SERVICE

A private or leased line allows access between two or more locations for a fixed monthly charge. Only those locations connected to the leased line have access to it. There is no access to the telephone switching network.

FOREIGN EXCHANGE SERVICE

Foreign exchange service allows the telephone company subscriber to have local exchange service in a remote city. This allows a person to dial a local exchange number in this remote city and be connected to the subscribers office facility (or computer). The cost of this service is the cost of a private line between the subscribers office and the remote city plus local exchange service costs in the remote city. There can be only one simultaneous conversation on a foreign exchange line.

WIDE AREA TELEPHONE SERVICE

Wats is an accounting arrangement allowing the subscriber to have network access to other subscribers in a geographic area for a rate which is less than normal toll charges. Wats is offered on either a measured or a full basis. Measured wats provides the first 10 hours per month of usage for a flat fee plus an additional charge for

every one-tenth of an hour over and above the first 10. Full wats provides for unlimited telephone usage per month for a fixed monthly charge. There can be only one simultaneous user on a wats line.

III.3.2 DATA SETS

Touch-tone telephone transmission of data requires a device at the other end of the telephone line to convert the multifrequency tones into digital bit strings. The device necessary to make this conversion is a data set and the units offered to subscribers by the telephone company to accomplish this task are known as Bell Systems series 400 data sets. The distinguishing features of these data sets are:

401A DATA SET

The 401A data set is a numeric only sending unit. This data set is used to generate tones for devices which do not have an internal tone generating capability. It will accept from customer supplied equipment one of 24 possible asynchronous characters (using a 2 out of 10 code) at any rate up to 20 characters per second. The cost of the 401A is $15.00 installation plus $5.00 per month.

401B DATA SET

The 401B data set is a numeric only receiving unit generally used in conjunction with the 401A. It carries an

installation charge of $50.00 and a monthly fee of $40.00.

401E DATA SET

The 401E data set is a sending unit providing one way communication of alphabetic and numeric data. It operates using a 3 out of 14 code and can transmit any one of 99 asynchronous characters. It carries a $20.00 installation charge plus a $7.00 per month service charge.

401F DATA SET

The 401F data set receives both alphabetic and numeric data. It has an installation charge of $40.00 and a monthly charge of $30.00.

401H DATA SET

The 401H data set is a alphabetic and numeric sending unit that operates with a 3 out of 14 parallel signal code. It carries a $20.00 installation fee plus $8.50 per month.

401J DATA SET

The 401J data set is a parallel tone receiver intended to be with any of the 401 type transmitters for alphabetic or numeric data. A touch-tone telephone can be used as the transmitting terminal in conjunction with the 401J receiver if the transmitter of the telephone is excluded during the data mode and the "C" group data contacts are ignored. Although the 401J data set receiver has the ability to detect

touch-tone signals, it should not be used unless this transmitter exclusion feature is on the transmitting telephone. The 401J3 version of this data set provides a voice answerback channel for use with audio response units. The data set costs $50.00 for installation and $37.50 per month.

403D DATA SET

The 403D data set is a multifrequency data receiver for use with touch-tone telephones. It uses a 2 out of 8 code and will accept any one of 16 asynchronous characters. The 403 type receiver operates with wider bandwidths than the 401J, provides echo protection, digital simulation protection, and a voice answerback channel. The Bell System recommends that this data set should be used for data transmission where the transmitter exclusion feature is not available on the transmitting telephone handset. In the state of Massachusetts installation of this data set is quoted on a special assembly basis.

III.4 SUMMARY

Having introduced the hardware and communications framework surrounding touchtone technology we will now examine the Lahey Clinic environment.

CHAPTER IV

LAHEY CLINIC ENVIRONMENT

IV.1 INTRODUCTION

This chapter outlines the Lahey Clinic environment. The first section provides a general overview of the entire Clinic from the standpoint of medical test ordering and the second section outlines the laboratory environment in a greater detail. The final section in this chapter will identify the problems that currently exist in the reporting of medical laboratory test results.

IV.1.1 MEDICAL TESTS

Medical tests are essential to the functioning of a medical facility in that they provide decision making support to physicians. It is important to perform these tests accurately and promptly in order that a doctor's time may be fully utilized.

The largest volume of tests performed fall into one of three categories: Radiology, Cardiology, and Laboratory. The focus of this thesis will center mainly on information flow associated with laboratory tests.

IV.1.2 DIFFERENCE IN TEST REPORTING

There are functional differences between the reporting

of test results in a hospital and test reporting in an outpatient clinic. The differences are as follows:

HOSPITAL TEST REPORTING

In a hospital you can schedule the flow of data. Since the majority of patients can be located at any given time (because they are generally confined to bed) medical tests can be administered at almost any time. Coupled with the fact that physicians generally make their patient visits at specific times during the day (usually once in the morning and/or once at night) it becomes a somewhat trivial task to schedule a test far enough ahead so that there is little difficulty in providing the test results for the physicians' next patient visit.

OUTPATIENT CLINIC TEST REPORTING

In an outpatient clinic a more complicated situation exists. The clinic does not have the capability to schedule a 24 hour patient day, patients are not confined to a physical location, and they visit physicians at random intervals throughout the day. A further complicating factor is that a doctor may schedule patient tests or appointments with other doctors at his discretion, thus upsetting any scheduling that may have been attempted. As a result of these factors the task of providing medical test results to physicians can become a non-trivial effort.

IV.2 CLINIC OVERVIEW

IV.2.1 TEST ORDERING

When a patient arrives at the Clinic he is provided with a list of one or more doctor appointments scheduled for that day. After the patient has seen a doctor the physician may request the patient to undergo a series of one or more medical tests. The patient then has these tests performed. It is often desirable to have the results of these tests available before the patient sees another doctor and definitely desirable to have the test results available before the patient returns for a followup visit with the doctor who ordered the tests.

If the patient's next or followup appointment occurs on the following day there is generally little difficulty in obtaining the results before the appointment. Typically the only test results which are not readily available on the following morning are those which were either administered late on the previous day or those which were sent to an out-of-house facility for testing.

If the patient's next or followup appointment occurs in the same day that the tests were given there is often considerable difficulty in obtaining test results. This difficulty is typically a function of one of four issues. They are:

A) The test has not been completed. Variables affecting

completion time are: 1) the time the specimen was taken, 2) the time the specimen entered the laboratory, 3) the lab work load, and 4) the frequency that the assays are performed.

B) A test abnormality was discovered and the specimen is being retested.

C) The test has been completed but the results can not be located.

D) The specimen was sent to an out-of-house testing facility.

IV.2.2 OBTAINING RESULTS

The Clinic nurses are responsible for obtaining test results before a patient visits a doctor on a followup visit. The suggested procedure is as follows. First they telephone the Medical Records Department to see if the test results have been officially reported. If the Medical Records Department has the results they walk to the Department to pick them up. The Medical Records Department is not allowed to provide test results over the telephone. The reason given for this is that it is felt that both the personnel is too busy to provide this service and that they are unqualified and can not be expected to accurately provide this information.

If the medical test results are not available in the

Medical Records Department the nurse has the option of either waiting, and telephoning back at a later time, or calling the medical testing facility.

If the decision is made to telephone the testing facility then personnel in the facility have the responsibility for attempting to determine the status of the tests. If the test results are not readily available then the nurse will be informed that the test results are not available. If the nurse indicates that it is extremely important that the results be obtained then the personnel in the testing facility will attempt to determine the precise status of the tests, even if it means going to the technicians work station.

IV.3 LABORATORY ENVIRONMENT

The Lahey Clinic Laboratory assumes responsibility for performing a variety of medical tests for the Clinic physicians. The exhibits in Appendix A indicate which tests are performed as well as illustrate the actual requisition forms used in the ordering of tests.

If one is to talk about the information flow in the laboratory in a meaningful way it is necessary to focus in on a subset of its operation. Accordingly, further discussion will center on the Hematology Department. We will now trace the information flow from the time a blood specimen arrives until the time a complete test result report is sent to the

Medical Records Department.

IV.3.1 HEMATOLOGY TEST ORDERING

When a patient is to be administered a blood test he is given a requisition and sent to the basement of the Clinic where the blood collection lab is located. After the blood is drawn it is placed in a tray along with the requisition. Periodically a messenger arrives to pick up the specimens and transports them to the Clinic laboratory which is located in a building adjacent to the main Clinic building.

IV.3.2 INFORMATION FLOW

When the specimens and their associated requisitions arrive in the Hematology Department of the laboratory they are given to a laboratory technician. The technician then assigns a sequential test number to the test tube(s) containing the specimen (there are usually two test tubes per patient given the current distribution of requested tests). The specimens are now marked with the requisition number as well as the sequential number.

A worksheet preprinted with the sequential numbers and all hematology tests offered (in matrix form) is prepared and the corresponding requisition numbers are written beside the sequential numbers. The technician then matches up the requisitions with the requisition numbers on the worksheet and

checks off which tests are to be performed.

The next step is to take all requisitions that have ordered the differential test group and make up a special differential report sheet. This sheet contains the sequential numbers, the requisitions number, and space for test results for all the individual tests in the test group. The differential specimen is now taken to the differential workbench along with the differential report sheet.

The worksheet is now cut into strips along the Y axis and each section of the worksheet, containing the sequential number and an indication of whether or not a given test is to be administered, is taken to the proper work station where the test is performed. The test tube specimens are then taken to the first work station. When tests for all specimens in a given batch are completed the specimen tray is taken to the next work station where more tests are given and so on until all tests have been performed. There are only two exceptions to this:

A) The ESR test requires a separate specimen, and therefore processing may occur simultaneously with other tests.

B) The differential test group requires a smear, which is also handled independently of the assembly line flow.

While the tests are being processed the requisitions are sent to the keypunch station of the laboratory. Here the requisitions are keypunched and a laboratory master card is formed. This master card contains the date, patient history number, patient name, the code number of the doctor who ordered the tests, the requisition number, and the numbers of the tests to be performed. Once this card is verified it is entered into the IBM 1130 computer.

Under program control the 1130 reads this master card and creates a disk master file which includes all the information on the card plus a bucket for each test ordered. It is by checking this master file that one can determine whether all test results for a given requisition number have been reported.

IV.3.3 HEMATOLOGY RESULT GATHERING

Hematology test results are reported directly onto the appropriate report sheet or worksheet strip. After these tests are completed the worksheet is reassembled. A visual checking of results by a technician is then performed to see if any abnormal results were reported which would indicate that a retest would be in order. If a retest is needed that particular requisition number is marked off the worksheet and transferred onto a retest worksheet. If no retest is warranted then the worksheet is sent to the keypunch station where the results are keypunched and read into the 1130.

The master file is then updated.

The worksheet containing the hematology requisitions that required retesting is not processed further until all retests for the requisition have been processed. When this occurs the worksheet is sent to the keypunch station and it is handled in the same manner as the other worksheet.

The information flow which has just been described is diagrammed in Figure 4-1.

IV.3.4 NON-HEMATOLOGY RESULT GATHERING

As a rule all laboratory tests except routine urine, bacteriology tests, miscellaneous requisitions, and special cases are reported into the 1130 by means of a result card. This card is generated by one of two methods. The first is by having the laboratory technicians indicate the test results on an 80 column card and then keypunch the results into it. This is the method used for low volume test input. The second method is used in connection with high volume chemistry tests. Here an auto analyzer is read by an IBM 1080 data acquisition system which in turn drives a 1058 keypunch.

IV.3.5 COMPUTER FACILITIES

The 1130 computer which serves the laboratory generates a series of four reports which aid in the operation of the laboratory and in the reporting of medical test results. The

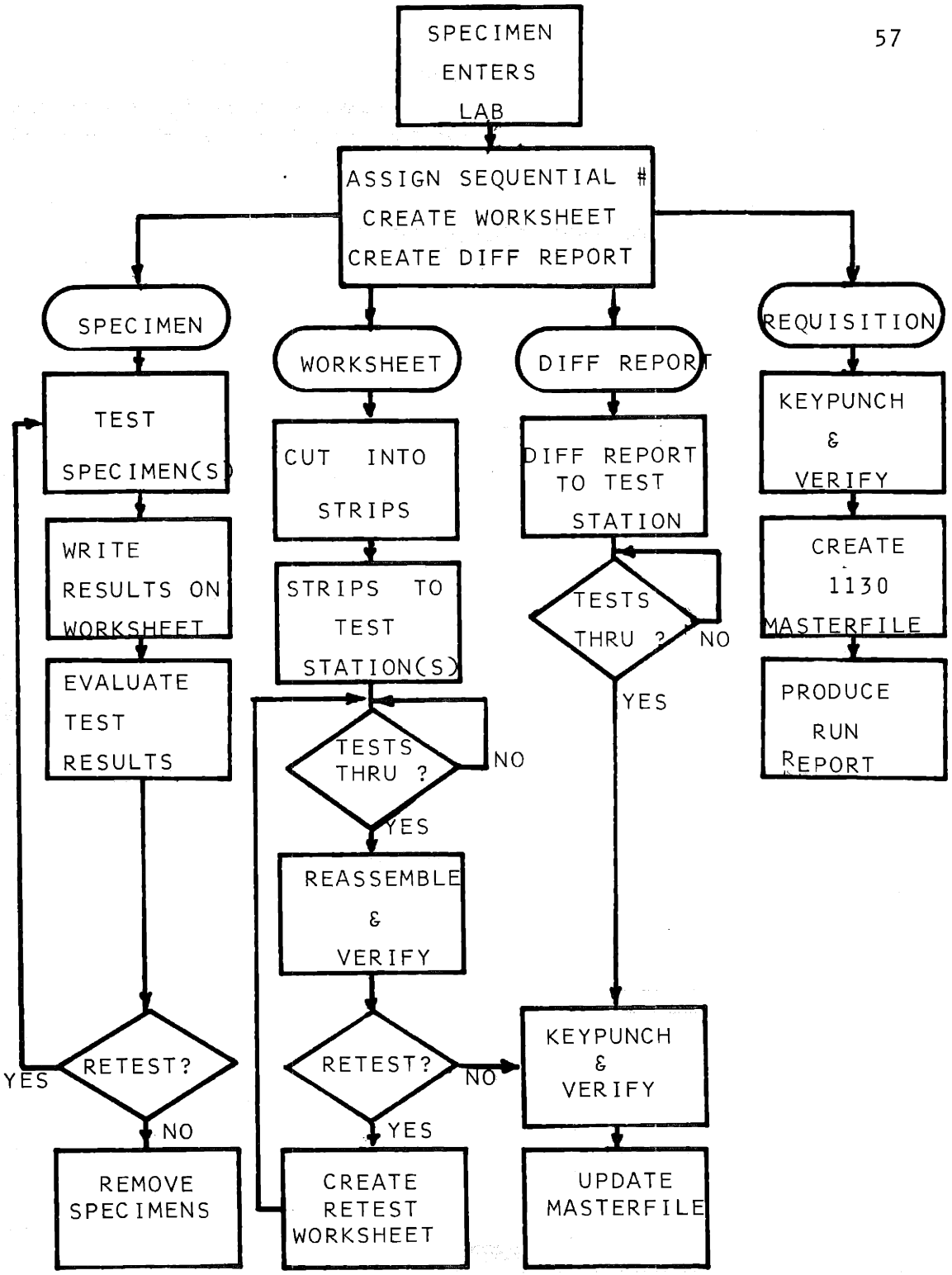


FIGURE 4-1 HEMATOLOGY INFORMATION FLOW

reports it generates are as follows.

MORNING REPORT

The morning report, produced before the start of daily operations, is a summary of the transactions from the previous day. It is a complete list of all requsitions upon which transactions occured. Both complete and incompleted requisitions are indicated and it serves as the primary source for answering telephone inquiries on test results.

COMPLETED REQUISITION REPORT

The completed requisition report contains those requisitions for which all test results have been reported. This report is produced periodically throughout the day and it is non-cumulative.

The completed requisition reports consist of two copies. One copy is filed for reference in the laboratory and the other copy is sent to the Medical Records Department for entry into the patients history folder. It is this copy which indicates to the Medical Records Department that the test results are available to the nursing stations.

RUN REPORT

The run report is a card image listing of all hematology and 1080 generated result cards which have been entered into the 1130. Since it is produced as the cards are read in the

run report contains the latest information on test results. No run reports are generated for other laboratory tests.

AFTERNOON REPORT

The afternoon report contains a summary of all transactions which have occured on the current day. This report does not replace the morning report but rather supplements it.

IV.3.6 RESULT REPORTING

As stated previously, medical test results often need to be located quickly so that the results may be available to physicians. When the results are not available in the Medical Records Department the nurse may elect to telephone the laboratory to obtain the results. Because only fully completed requisitions are sent to the Medical Records Department the results of a particular test may be available even though the entire requisition is not completed. If a high priority is assigned to obtaining these results then the nurse will generally telephone the laboratory.

The laboratory maintains two telephone lines reserved for reporting of these results. A clerk is stationed next to both a telephone and the 1130 test result reports. When a call arrives the clerk answers the telephone call, verifys that the caller wants to obtain test results, and then asks

for the patient's name, the test requisition number, and the date that the test was given. The clerk must now locate the test results.

When the clerk is on a coffee break or on a lunch break or sick a laboratory technician assumes responsibility for answering telephone inquiries as to test results. While performing this function the technician is distracted from performing her normal tasks.

IV.3.7 TELEPHONE INQUIRY STATISTICS

Telephone inquiries over a two week period were sampled and the mean number of telephone inquiries per day was 41. (See Figure 4-2) While the clerk was answering the telephone the mean telephone call hold time between 9:00 AM and 12:00 PM was 1 minute, 34 seconds per individual requisition inquiry. Between 12:01 PM and 5:00 PM the mean hold time was 1 minute, 24 seconds. The mean hold time for all telephone calls handled by the clerk was 1 minute, 31 seconds.

While the laboratory technician was answering the telephone the mean telephone hold time between 9:00 AM and 12:00 PM was 1 minute, 47 seconds per individual requisition inquiry. Between 12:01 PM and 5:00 PM the mean hold time was 3 minutes, 34 seconds. The mean hold time for all technician handled telephone calls was

DAY	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	TOTAL
1	6	7	5	2	8	2	0	2	30
2	8	6	4	6	15	5	1	0	44
3	10	9	7	7	18	18	4	3	66
4	8	7	4	5	10	4	2	1	41
5	7	4	5	5	12	5	1	2	41
6	5	7	6	4	15	3	3	0	49
7	6	4	9	3	10	6	1	0	39
8	4	2	3	5	13	6	1	0	34
9	5	6	2	6	11	4	1	0	35

TELEPHONE INQUIRY STATISTICS BY DAY AND HOUR

FIGURE 4-2

2 minutes, 34 seconds.

The variance in hold time between the clerk and the technician is explainable. The clerk and the technician are using different search heuristics. In the morning the majority of the telephone calls are seeking information on tests that were given the previous day. The clerk realizes that these results are generally complete and can be located on either the morning computer run or a completed requisition report.

In the morning the technician works under the same search guidelines. Because the vast majority of the results are on the morning report and easily locatable there is not much variance in hold times between the technician and the clerk.

In the afternoon test results are generally more difficult to locate since inquiries are usually directed towards locating test results for tests that were given in the current day. In this case test results may be unavailable for any one of five reasons:

A) The test has not been completed yet

B) The test has been completed but not sent to be keypunched

C) The test result has been keypunched but the report has not been generated from the 1130

D) The test has been sent to another facility

E) An abnormality required retesting

The clerk realizes that there is a greater probability that the test results can not be located for afternoon test requests. Accordingly, if the result is not in the morning or afternoon cumulative report folder or in a file containing the completed requisition reports the nurse will typically be told that the result is not available. It is only when the nurse indicates extreme importance will the clerk make further effort to locate the result.

The technician, (due to greater experience and a familiarity with the working environment) has a good feel for whether or not a test will be completed if she knows the time it was ordered. If her model of the environment indicates that the test results should be available she will spend a much greater effort in attempting to locate them. This greater effort produces a longer hold time for the telephone inquiries and explains the variance in the afternoon hold times between the clerk and the technician.

The technician provides a greater portion of test results per number of telephone calls than the clerk. It appears evident that there is a tradeoff between telephone time and the probability of obtaining the test results.

IV.4 AREAS OF CONCERN

After examining the effectiveness of test result reporting in the laboratory over a one month period several potential problem areas have been identified. They are as follows:

IV.4.1 CLERICAL TURNOVER

One problem revolves around the issue of employee turnover and learning curves. To properly report test results in the most timely fashion it requires a working knowledge of the laboratory operation. This can not be done with the current high turnover rate for the telephone clerk position. As a result, it is extremely important to document the report task, something which as of this date has not been done. Although there will still be a learning curve this documentation would help to eliminate a degradation in service every time a personnel turnover occurs.

IV.4.2 ACCURACY

Another potential problem area is accuracy. When there is a need for test results and they are not available in the Medical Records Department the nurse must telephone the laboratory. The result is then read to the nurse by a clerk. Although no statistics are available, this process is subject to a clerical error factor. It is interesting to note that the Medical Records Department will

not let clerks provide test result information over the telephone for exactly this reason. To overcome this situation it would be necessary to access the computer test result files and provide the information directly from this source.

IV.4.3 IN-TRANSIT DELAYS

The most significant problem affecting the efficiency of the laboratory result reporting process is in-transit delays. These delays may be observed to occur at several points in the flow.

The first in-transit delay is caused by the existence of two sources for determing the status of test results. They are the Medical Records Department and the laboratory.

The issue is that of "Buck Passing". Nurses complain that it often requires volleying between the two departments to obtain the test result status. Each department will claim that the other department has the results. This arises because the laboratory is reluctant to provide test results over the telephone if a completed requisition report has been sent to the Medical Records Department. Many times the requistion is in transit between the two departments and is unavailable.

This in-transit delay could be minimized by the implementation of either one of two steps. The first is to locate

the two departments physically next to each other. This would minimize requisition transit time. The second step would be to provide a single telephone number to obtain the status of test results. This would eliminate the volleying procedure now required.

The second type of in-transit delay occurs within the laboratory. It appears in two forms.

The first occurs between the technicians' workbench and the entry of the result cards into the 1130. The delay time in hematology, once an individual test has been completed, consists of the time necessary to reassemble the worksheet, to verify the results, to keypunch it, and to read it into the computer.

The only way to eliminate this delay time would be by automatic monitoring of testing equipment. If this were done the results could be gathered through the 1080 data acquisition system and outputted in the same manner as the automated chemistry tests.

The second form of in-transit delay in the laboratory occurs between the time the result card is read into the 1130 and the time that a completed requisition report is provided to the clerk who answers the telephone inquiries. Since the results are available in the computer but not always available to the clerk some form of accessing of the internal

files of the 1130 would be desirable.

The approach to this problem generally discussed at the laboratory is to load an inquiry program into the 1130. The major point in question with this alternative is that the 1130 does not allow foreground/background partitioning so all normal processing would have to stop during an inquiry. Because of core restrictions it is questionable whether this inquiry program could even reside in core. If not, swapping would further slow down the 1130 thruput. A secondary issue is that unless a remote terminal is available for the clerk to use there would be a tremendous amount of confusion around the 1130 console in what can be described as an already over-crowded situation.

An alternative to the inquiry process would be to produce run reports for all laboratory tests. The prinicple infeasibility of this is that the printer is the system bottleneck. Because of the lack of three-phase wiring in the laboratory the printer is only able to operate at a speed of 80 lines per minute. Further reports would then merely slow system thruput down even more.

IV.4.4 EFFECT OF TIME DELAYS

The above time delays have a derogatory effect on the process of test result reporting in four prinicple ways.

TIME VS. RESULTS

There is a tradeoff between telephone hold time and the percentage of test results that are reported for a given inquiry. This situation can be further complicated when both the telephone lines are occupied, a situation which generally adds to hold time. Under these conditions the telephone has been observed to ring for a minimum of 30 seconds before it is answered. Hold times have also ranged from a minimum of 30 seconds to a maximum of 9 minutes per single requisition inquiry. (See Figure 4-3)

NURSING TIME

The current system can be observed to underutilize a nurses time through the often lengthy process necessary to obtain a test result. Some toll on the frustration level of the nurses would also be expected from these inconveniences.

IMPLICIT PHYSICIAN TIME

Although no statistics were obtained it is estimated that the delays in reporting test results to the nursing stations cause delays in the physicians time. If this is so then the current system is underutilizing the most valuable resource the Clinic has.

IMPLICIT PATIENT TIME

Again, if delays occur in the reporting of test results

TECHNICIAN		CLERK	
MORNING	AFTERNOON	MORNING	AFTERNOON
30	60	35	35
90	90	60	70
112	195	60	90
112	332	60	90
120	334	60	135
136	395	70	
136		70	
137		120	
336		128	
		128	
		128	
		165	
		175	
		205	

SAMPLE TELEPHONE HOLD TIMES IN SECONDS

FIGURE 4-3

this has a potential effect on the patient. The effect can be realized through either longer waiting times or the necessity for the patient to return to the Clinic at a later time when test results might be available.

IV.4.5 SUMMARY

An analysis of the laboratory test reporting process identified several actual or potential problem areas. A solution for these problems will now be sought.

CHAPTER V

SYSTEM DESIGN

Having identified test result reporting problems involving clerical turnover, accuracy, and in-transit delays, an improved system is needed which will increase manpower utilization, improve response, provide good user/system compatibility, and operate at minimum cost. It is recommended that a communications based information system enabling direct computer access of test results be adapted.

There are two major hardware alternatives for developing this system:

A) A keyboard based terminal system

B) A touch-tone telephone based system

These systems will now be contrasted in an effort to determine their feasibility for use in this medical test inquiry application. The terminal selected from the keyboard class of device will be the IBM 2260 character display. It is felt that this unit is representative of the current state of the art in keyboard based terminals. The touch-tone terminal will be the standard touch-tone handset.

The major characteristics on which the terminals will be evaluated are: cost, response time, ease of alphabetic I/O, and the complexity of the interaction. These issues are now discussed.

V.1 CHARACTER DISPLAY VS. TOUCH-TONE TECHNOLOGY

Because the 2260 and the touch-tone telephone are different kinds of terminal devices certain environmental assumptions must be made in order to create a meaningful comparison. The assumptions used here are:

A) The task involves inquiry against a medical test result data base

B) The average audio response inquiry time is 60 seconds

C) The mean number of inquiries per hour is less than 100

V.1.1 2260 HARDWARE

The IBM 2260 display device selected for comparison purposes will be a model 2 (480 characters) with an alphameric option, non-destructive cursor, and extended cursor control. The 2260 requires the use of the 2848 display controller. The maximum number of 480 character display devices that can be controlled by a single 2848 is 16.

V.1.2 TOUCH-TONE HARDWARE

A system based upon touch-tone technology requires a terminal device and a verbal feedback mechanism. The terminal selected for comparison purposes will be a standard touch-tone telephone with the transmitter exclusion option. The feedback mechanism will be an IBM 7772 audio response unit. The basic response unit has a two line capacity. In order to meet the inquiry load that has been established, the 7772 will require the addition of a two line expansion option. This provides for the servicing of four lines.

V.1.3 COST COMPARISON

Cost advantages of one configuration over another is a function of the number of terminal stations desired. Figure 5-1 illustrates the cost structure at different levels of terminal requirements. All costs for the 2260 assume that it is operating in a remote mode and using the telephone switching network.

At all terminal levels the touch-tone system is cheaper. The fixed costs are $924.00 for the touch-tone configuration and $990.00 for the 2260. (See Figure 5-2 for an itemization of these costs) The variable cost per

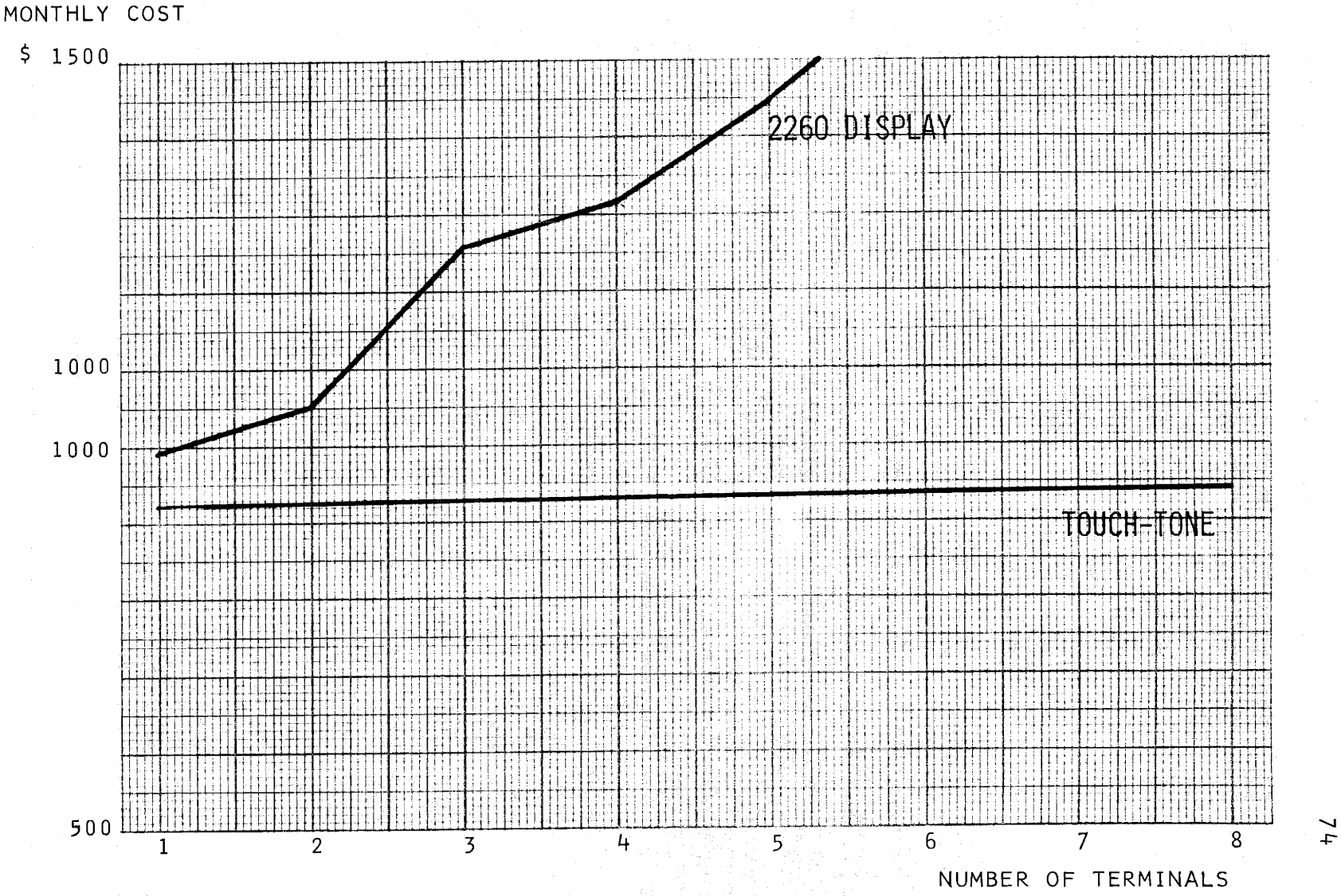


FIGURE 5-1 COST COMPARISON BETWEEN IBM 2260 AND TOUCH-TONE TERMINAL

IBM 2260 CONFIGURATION

2848	DISPLAY CONTROL	$ 390
3356	DISPLAY ADAPTER	80
5340	CURSOR CONTROLLER	10
5341	NON-DESTRUCTIVE CURSOR	5
3901	EXTENDED CURSOR CONTROL	45
2260	DISPLAY	30
3606	ALPHAMERIC OPTION	30
2701	DATA ADAPTER	300
9013	DATA SET ADAPTER	30
201B	DATA SET	- 70
	TOTAL FIXED COST FOR 1 2260 DISPLAY	$ 990

TOUCH-TONE CONFIGURATION

7772	AUDIO RESPONSE UNIT	$ 605
2	LINE EXPANSION OPTION	242
2 401J3	DATA SETS	75
	TOUCH-TONE PAD	2
	TOTAL FIXED COST FOR 1 TOUCH-TONE TERMINAL	$ 924

FIGURE 5-2 ITEMIZATION OF FIXED COSTS

terminal is $2.25 while the marginal cost per 2260 ranges from $60.00 to $140.00, depending upon which hardware modules are required. This overwhelming cost advantage of the touch-tone terminal, by a 30-70 to 1 ratio, make it highly attractive when considered from a financial point of view.

V.1.4 RESPONSE TIME

The touch-tone telephone requires approximately 73.7 seconds of nursing time to provide the test result information for a complete requisition (See Traffic Engineering Section of this chapter) while the IBM 2260 display has a rated speed (when used with a 2400 baud line) of 240 characters per second. This will fill the screen with a requisition in approximately 2 seconds.

There is a significant advantage favoring the 2260 in terms of speed but there are two factors which can not be overlooked.

A) Experience indicates that the nurse will not be able to read and comprehend this information at a rate of faster than 30 characters per second. Assuming 480 screen positions are necessary to display a formulated requisition it would require 16 seconds to obtain test result information.

B) A large portion of the inquiries only want to determine the status of the requisition. This would reduce the response ratio by an order of magnitude.

V.1.5 EASE OF ALPHABETIC I/O

The touch-tone telephone was never intended for use in inputting alphabetic information; to do so is very cumbersome. The 2260, as with most keyboard devices, is designed for alphabetic input. For this particular application, however, the alphabetic input capability is not felt to be essential since inquiry is accomplished through a numeric requisition number. Both the touch-tone telephone and the 2260 have the ability to output alphabetic information.

V.1.6 INTERACTION COMPLEXITY

As Smith and Goodwin (29) point out the telephone handset has no capability for either indicating the content of previous transactions or for representing interrelationships between data. Because of this limitation it is expected that touch-tone applications will involve output repeat requests and the number of repeat requests for an application will be a function of its complexity. Due to

the fact that the 2260 display does not suffer from these visual restrictions it is anticipated that repeat requests will be minimal and that it can service more complex interaction patterns.

V.1.7 SUMMARY

A rough comparison of the two devices has indicated several points.

A) The touch-tone telephone is of marginal value for inputting of alphabetic information while the visual display is designed for this mode of data entry.

B) The telephone provides no visual aids while the 2260 does.

C) The telephone is a limited speed output device while the 2260 display has the capability to output at much higher data rates.

D) The cost of the touch-tone based system is significantly cheaper when a large number of terminals are involved.

After contrasting the two hardware alternatives the IBM 2260 appears to dominate on most all dimensions except the issue of cost. It is because of this significant

and possible dominant cost advantage that a touch-tone based information system is worth exploring in greater detail.

To examine its feasibility further let us now propose a system, identify the system design issues, illustrate system benefits and costs, and attempt to examine in greater detail whether the touch-tone handset is in fact a viable terminal alternative for a medical test result reporting system.

V.2 OVERVIEW

The proposed design will involve the establishment of 100 terminal inquiry stations throughout the Clinic. The figure of 100 is an estimate of the number of terminals necessary to provide inquiry capability to every doctor and every nursing station in the Clinic.

The system will operate in the following manner:

When a nurse wants to obtain the results of a patient's medical tests she dials a telephone number. Instead of the call being answered by a clerk in either the Medical Records Department or the laboratory it will be answered by a computer. The computer will then request a peripherally attached audio response unit to generate

replies in the form of a spoken human voice.

The nurse will first be asked to indicate the patient's test requisition number by depressing the appropriate keys on the touch-tone dial. Once this number has been entered a reply will come back spelling the patient's name. Spelling the name back is merely a control feature to catch mistakes in keying in the requisition number. Following the spelling of the patient's name either one of two words is uttered, "complete" or "not complete". Complete means that the results are available in hard copy form in the Medical Records Department. Incomplete means that only partial results are available and that a completed requisition has not been sent to the Medical Records Department.

At this point the nurse is instructed to press one button as an authorization to proceed or a second button to reenter a corrected requisition number. If the second button is depressed the above cycle will be repeated. If the computer is authorized to proceed, the nurse is then asked to indicate which particular test result that she would like to receive. To obtain a specific test result the nurse would input a three digit code identical to the test number on the requisition. The computer will respond

with the name of the test, followed by the word "equals", followed by the numeric test result. If test results are desired for every test on the requisition the nurse may input a single code (ie. "999") and the entire series of test results will be provided. If any given test result is not available the computer will respond with "not available". If a test result requires an alphabetic phrase as well as, or in place of, a numerical result this will also be provided.

After this process the computer will then ask the nurse to indicate, by depressing the appropriate button, whether another patient's test results are desired or whether she wished to terminate the inquiry. If another patient's test results are desired the process will be repeated. If job termination is sought the computer will release the telephone line.

At any point the nurse may terminate the inquiry by merely hanging up the telephone. If 15 seconds go by after input has been requested and the nurse has taken no action the computer will hang up. This will prevent the access lines from being tied up for unnecessary long periods of time.

After the execution of any command string the nurse may indicate any one of two control functions if she

desires. These are "repeat", or "repeat and spell". Entry into one of these modes is accomplished merely by depressing predetermined control buttons. When the appropriate control buttons are depressed all spoken output generated since the last instruction was executed will be repeated in the appropriate mode. It is anticipated that this feature will minimize lost information from either interruptions or lapsing attention. A sample interaction sequence may be seen in Figure 5-3.

V.3 DESIGN ISSUES

To propose a system design it is first necessary to identify the critical elements of the design process. This section will perform that task. In addition to identifying the issues an attempt will be made to classify them in terms of their relationship to each other and to the design process as a whole.

THE ISSUES

In order to deal with touch-tone technology on a meaningful level a classification scheme must be developed so as to reflect the interrelationship of these issues as well as possibly structure some measure of priority or criticalness in terms of their importance to the implementation process.

```
"HELLO, PLEASE ENTER REQUISITION NUMBER"
123456
"S" "M" "I" "T" "H"
PAUSE
"COMPLETE"
PAUSE
"1 EQUALS AUTHORIZATION TO PROCEED, 2 EQUALS
CORRECTION"
1
"INDICATE THREE DIGIT TEST NUMBER"
370
"HEMATOCRIT EQUALS 41 PERCENT"
PAUSE
"1 EQUALS STOP, 2 EQUALS NEW REQUISITION NUMBER"
1
"GOODBY"
```

SAMPLE TOUCH-TONE INTERACTION

FIGURE 5-3

Since a structure for classification of the issues involved in touch-tone technology is historically lacking I have chosen to divide the issues into four main sub-divisions:

A) Hardware issues

B) Software issues

C) Behavioral issues

D) Communications issues

After examining several possible classification schemes the one in Figure 5-4 was chosen as the best representation of the interrelationships involved.

It would be most beneficial at this time to examine each of the four areas and discuss the issues.

V.4 HARDWARE ISSUES

The hardware issues that must be resolved in an implementation of touch-tone technology may be classified and discussed in term of two major areas:

A) Technical considerations

B) Operational considerations

V.4.1 TECHNICAL CONSIDERATIONS

Hardware technical considerations involve an evaluation of the factors influencing the selection of a computer

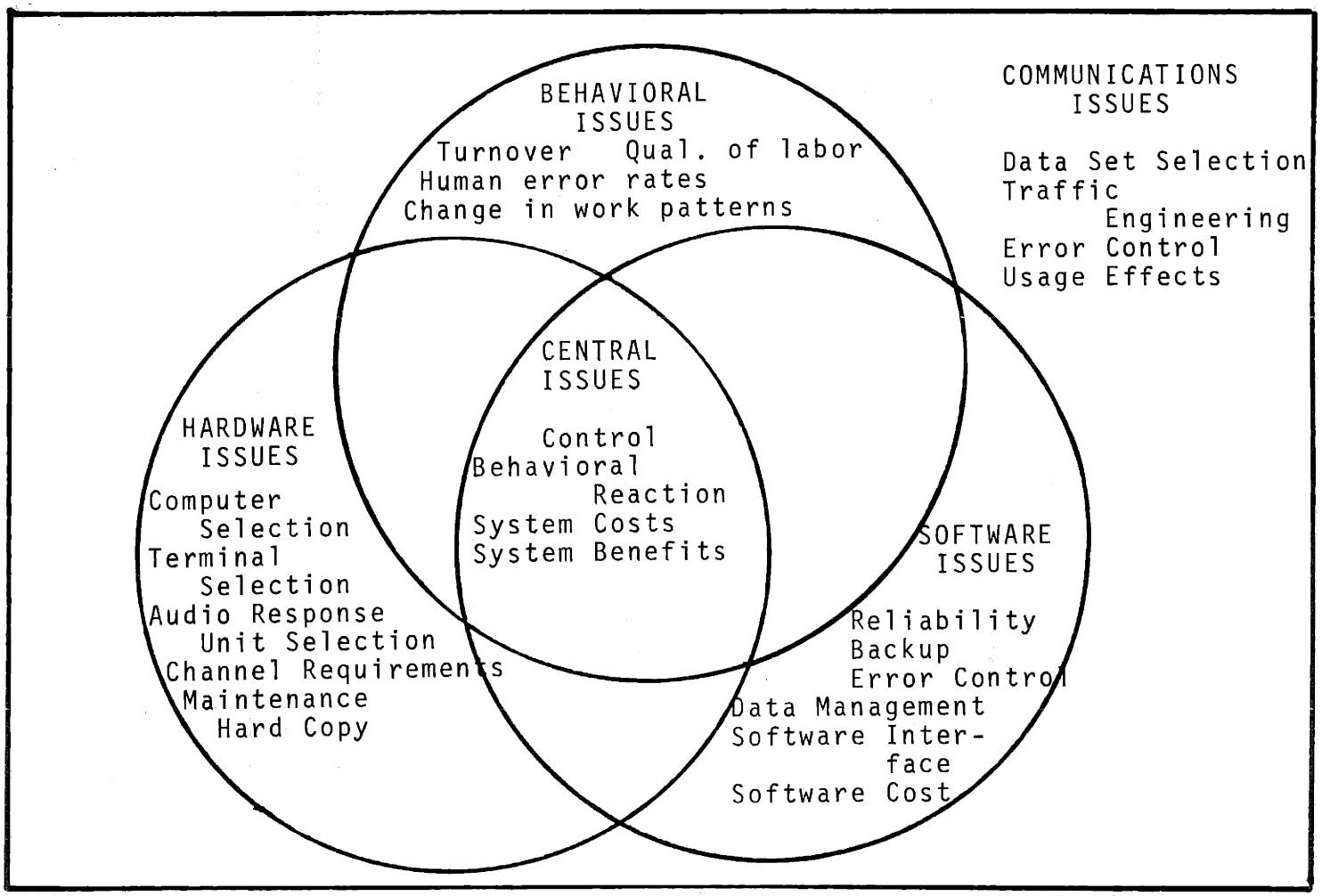


FIGURE 5-4 SYSTEM DESIGN ISSUES

configuration, terminal devices, and an audio response unit. The design alternatives are as follows:

V.4.1.1 COMPUTER CONFIGURATION

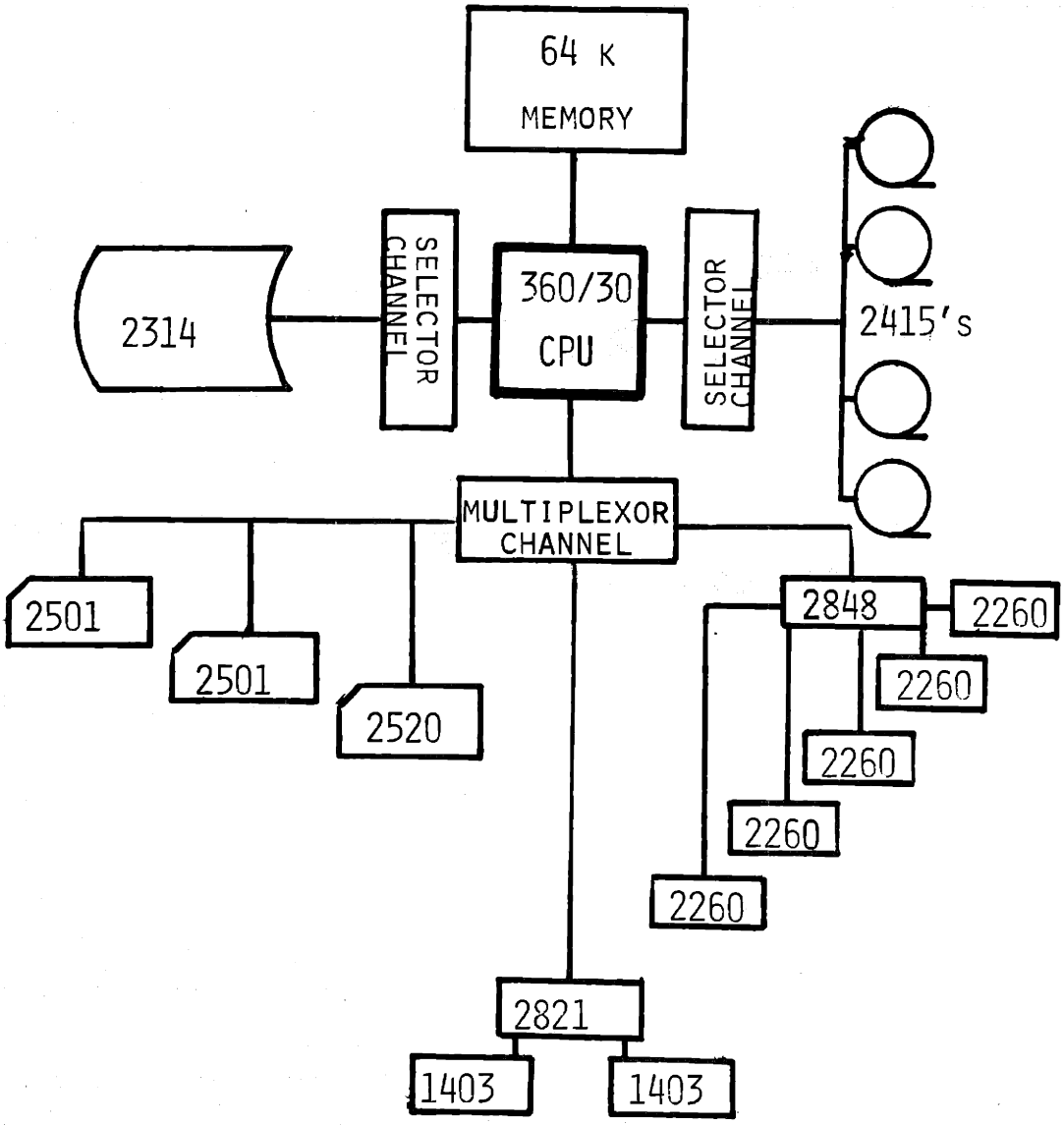
The design of the Lahey Clinic system will be based upon the assumption that the central processor is a member of the IBM 360 computer series, model 30 or larger. This is an arbitrary decision based upon several factors:

A) The Lahey Clinic has a 360/30 (See Figure 5-5) and has familiarity in working with this hardware.

B) a 360/40 is now on order

C) The Clinic's commitment to the PL/I language will limit its choice of hardware for the short run.

D) The IBM 1130 computer in the laboratory is incapable of supporting an audio response system in conjunction with its normal processing activities. It is also anticipated that the 1130 will be replaced by either one of two alternatives, the first of which is an IBM 1800 computer and the second of which is a partition in a multiprogrammed IBM 360 computer. In either of these two environments the subsequent analysis will still prove to be relevant.



LAHEY CLINIC IBM 360/30

FIGURE 5-5

V.4.1.2 TERMINAL DEVICES

There are a wide variety of touch-tone terminal devices available from the telephone company. For this particular application it is felt that the touch-tone pad is quite sufficient to handle all I/O. The reasons for this are:

A) Since no alphabetic input is required the standard 12 button keyboard provides all the necessary numeric and control keys.

B) The touch-tone telephone handset can not be used with the Clinic's 400 line PBX telephone system. There are two reasons for this:

   1) The central telephone office serving the Clinic is not equipped for touch-tone service.

   2) The minimum internal switching system capable of supporting touch-tone initiated dialing is Centrex. Centrex is not cost effective when used with less than 1,000 telephone lines.

The cost of the touch-tone pad involves a one time installation fee of $5.00 and a monthly charge of $2.00 per telephone terminal.

V.4.1.3 AUDIO RESPONSE UNITS

A discussion of audio response units must first include an analysis of both vocabulary and line requirements.

VOCABULARY

An analysis of the Lahey Clinic's Laboratory test name vocabulary reveals that it contains 217 entries. In addition 10 numeric digits are required to indicate test results along with 25 test result unit names, 26 individual alphabetic letters, and 5 special characters. This vocabulary, presented in Appendix B, contains a total of 283 vocabulary entries. Adding approximately a 50 word instructions and control vocabulary, this raises the total required vocabulary to 333 words.

LINE REQUIREMENTS

A complete analysis of line requirements for this system is contained in the Traffic Engineering Section.

AUDIO RESPONSE HARDWARE

For purposes of this Thesis the analysis of audio response units will be limited to a comparison of the IBM 7770 analog audio response unit versus the IBM 7772 digital audio response unit.

IBM 7770

The IBM 7770 audio response unit is an analog device with a maximum vocabulary size of 128 words and can handle up to 48 lines. It interfaces to the 360 via one control unit position on the multiplexor channel. The basic 7770 contains a 32 word vocabulary and can service four simultaneous users. This unit costs $55,870 ($1,165 per month rental). Each additional increment of 16 vocabulary words is an additional $4,655 ($97.00 per month) and each additional increment of four lines is $8,150 ($170.00 per month).

IBM 7772

The IBM 7772 audio response unit is a digital device, handling up to 8 lines, with a vocabulary size limited only by the amount of available random access storage. This unit also interfaces to a control unit position on the multiplexor channel. The 7772 in its basic version provides a two line capacity and costs $29,100 ($605.00 per month). Each additional increment of two lines is $11,640 ($242.00 per month).

The 7772 is supplied with approximately 1,000 frequently used American english words plus 10 words of the user's choice. Any number of additional words beyond

this are available for a one time fee of $10.00 per word.

SELECTION

The required medical vocabulary size for the test result reporting application exceeds the capacity of the IBM 7770 drum. Accordingly, the 7772 is selected as the audio response unit most appropriate for this system. (And in fact the only unit capable of supporting this large vocabulary) The cost of this response unit will be $29,000 purchase or $605.00 per month. The unit will have a two line capacity (see the Traffic Engineering Section for the decision process) with a vocabulary of approximately 333 words. There will be a one time charge of $2,170 to create the digital representation of the medical terms necessary for this application. It should be pointed out that even if the 7770 could support this large vocabulary it is almost twice as expensive as the 7772 for the line capacity this application requires.

V.4.2 OPERATIONAL CONSIDERATIONS

Hardware operational considerations relate to functional issues dealing with system operation. They involve determining channel requirements, maintenance issues, and hard copy questions.

V.4.2.1 CHANNEL REQUIREMENTS

The 7772 requires an absolute minimum of one access to the disk for each vocabulary word response it generates. The peak hour sample load of 18 calls per hour coupled with an average of 93 words of output per requisition indicate that channel loading of 1674 disk seeks per hour can be expected. Because of this, careful considerations must be given to both current and future job mixes before deciding which selector channel to place the disk storage on so as not to degrade system performance.

The 7772 interfaces to the multiplexor channel and operates in byte interleaved mode. There are no anticipated problems in overloading this channel.

V.4.2.2 MAINTENANCE

Maintenance issues must be considered for both the terminal device, the computer, and the audio response system. In the first instance the telephone company will provide all maintenance on the touch-tone pads for no additional cost. In the second case IBM provides a complete maintenance contract to provide all field support that may be required. Since there is no mixing of manufacturers' equipment there should be no major conflict as

to who is responsible for malfunctioning hardware.

V.4.2.3 HARD COPY

One of the major complaints directed against touch-tone terminals is thay they provide no hard copy. It is felt that this application does not require the presence of hard copy. The system will provide the same information, in the same form, as the current method, but in a much more efficient manner. The extension of this application, or the creation of new ones, may require hard copy. If so, the previous work chapter of this thesis should be consulted for solutions to the problem.

V.5 SOFTWARE ISSUES

The software issues to be discussed are best classified in terms of technical and operational considerations. We will now discuss the relevant issues.

V.5.1 TECHNICAL CONSIDERATIONS

Software technical considerations involve issues relating to data management, software interface problems, and software costs.

V.5.1.1 DATA MANAGEMENT

The file structure currently used to contain test results would be sufficient for the touch-tone method.

No special file structure need be set up to handle test results.

Data management support for the audio response vocabulary file is supplied by IBM. The vocabulary file utility program (program # VOC72UT) provides facilities for creating, updating, and listing the entire vocabulary.

The operational vocabulary file consists of one or more vocabulary tables with each table representing either an ordered set of data (such as digits or months) or a message whose text is predetermined. All word representations required by the user and which have not been specified for inclusion in vocabulary tables are grouped into a general purpose set called the residuum.

The number of tracks of 2314 disk storage necessary to store the vocabulary file is computed from the following formula:

TRACKS = (2.03*t)+(.10*w)+(.0002*w*(awl+101))

where:

TRACKS = number of tracks on a 2314 disk pack

t = number of vocabulary tables in the operative vocabulary file

w = number of vocabulary words in the operative vocabulary file

awl = average word length in bytes of the words in the operative vocabulary file

It is estimated that the medical test inquiry application with 333 words would need approximately 67 tracks of disk storage to store the working vocabulary file. This is a relatively insignificant amount of storage considering it is only 67/4000's the capacity of a single 2314 disk pack. For further information on vocabulary file management see IBM form C27-6924.

V.5.1.2 SOFTWARE INTERFACE

Programming support of the 7772 requires user written programs to operate in conjunction with the operating system control software. Both software support is provided to transfer inquiry into the central processor and to return the digital response message to the 7772. Evaluation of the validity of input, evaluation of the inquiry, the selection of the vocabulary words to be outputted, and their sequencing, is accomplished by user written software.

To write a word on the 7772 its digital word representation must be in core storage. Words to be spoken are accessed from the operative vocabulary file using their disk addresses. Words can be recorded in a table in the order in which they appear in a message. This allows

the addressing of any word in a message to be expressed as the address of the table plus an index value.

V.5.1.3 SOFTWARE COST

Software costs may best be discussed in terms of two components: system costs and application costs.

SYSTEM COSTS

Operation of the 7772 assumes the presence of BTAM or QTAM software. Because the Clinic is currently running its 2260 displays under the DUC package (display unit control system) in a local mode, these telecommunications modules are not residing in the operating system. BTAM requires 6 to 8K of core to implement. The DUCS module (3K of core) could then be eliminated. The net effect is to increase core requirements by approximately 3 to 5K.

APPLICATION COSTS

It is estimated that the programming of this system would take 6 man months. Including the cost of IBM schooling in data transmission techniques, salary, and overhead the system should be allocated $12,000 to cover software development costs. Because a 360/30 is available on the premises development time will be considered a free resource. If development time can not be scheduled

360/30 time can be rented for approximately $100.00 per hour.

The user program (application program) would operate most effectively in its own partition, the size of which would be a function of the object program size. If utilization is low (presuming no other large applications) then it could share a partition with another program. It is estimated that 1 CPU second of processor time is required per requisition and that a load of 18 seconds of CPU time per hour might be anticipated during a peak period.

V.5.2 OPERATIONAL CONSIDERATIONS

Software operational considerations involve issues relating to the functioning of the system. These issues are reliability, backup, and error control.

V.5.2.1 RELIABILITY

The reliability of this system will be a function of the reliability of the hardware and software used. It is not felt that reliability will be a major problem providing both proper software testing and proper preventative maintenance is supplied.

V.5.2.2 BACKUP

There are two kinds of backup problems that must be

discussed. The first is how to obtain system backup if and when the hardware or software fails. The second is how to obtain file backup if the files are destroyed.

In the first case, assuming hardware or software failure, the nurses can still obtain test result information using the same methods that are currently used. Instead of telephoning the computer she merely must telephone the laboratory where the results will be provided by a human file search. Although the results can be obtained in this manner, a degradation in service can be expected because the laboratory telephone will be overloaded.

The issue of file destruction presents a more critical problem. If the test result files are lost they can be restored as long as the result cards are available by re-reading the cards into the system. It is estimated that recovery time under this procedure would be approximately 15 minutes.

If the operative vocabulary file is destroyed it will be necessary to rebuild the file. The vocabulary file management program requires approximately a 15K partition to accomplish this task. The time necessary to rebuild the file will depend upon how fast a 15K partition becomes available but the recovery process can be speeded up by

the existence of a backup file.

To audit transactions it is recommended that each transaction input and output be recorded in digital form on magnetic tape. In this manner the tape can be re-loaded into the system and all transactions can be recovered.

V.5.2.3 ERROR CONTROL

Because of the low transmission speed of touch-tone transmission one would not expect error rates of any significant proportion which could be traced to the communications system. As mentioned in Chapter III the multifrequency tones used to represent the data were selected on the basis of their low probability of being simulated by music, the human voice, or random noise.

The important issue is to guard against the human error factor. The entering of an erroneous requisition number presents the greatest danger. If the nurse enters the wrong requisition number thinking it is the correct one then there is a possibility of the wrong test results being reported for a patient. To prevent this the name of the patient who's requisition number was entered will be spelled back. Only upon the nurses authorization to proceed will any results be given.

Other errors such as the ordering of one test result instead of another will be handled by the standardization of output responses in the form: test name equals test result. Additional errors likely to be caused either by a misunderstanding or an interruption of the nurse during a response period will be handled by allowing the user the option of seeking a repeat of previously outputted test results. If the situation warrants it the nurse can even obtain greater clarity by having any or all of the output spelled.

V.6 BEHAVIORAL ISSUES

Behavioral issues which need to be discussed are human error rates, change in work patterns, changes in the quantity of labor, and turnover.

V.6.1 HUMAN ERROR RATES

Not enough information is available at this time to predict the expected error rates for inputting information through a touch-tone telephone pad. It is anticipated that the majority of input errors will be detected either by trival software control routines or by the output formatting used. This, however, will be an important issue and should be monitored closely.

V.6.2 CHANGE IN WORK PATTERNS

The touch-tone method of reporting test results should have a favorable impact on the overall work patterns of the nurses. It may also have an impact on other personnel by allowing them easy access to information that was not previously available. For example, the physician may find it is just as easy to obtain test results himself instead of having the nurse do it. In any case the system should improve the utilization of the nurses time because long file searches will be eliminated and telephone hold time will be minimized.

V.6.3 QUANTITY OF LABOR

Although this system would eliminate the need for a full time employee to answe the telephone in the laboratory it is doubtful whether any personnel terminations would result from it. There are two reasons for this. First, the clerical work done by the clerk between telephone calls must still be done and second, the laboratory is in need of more clerical help to help process the information flow. The touch-tone system will, however, reduce the quantity of labor needed in the long run. Since the system can absorb increases in the work load new clerical

help will not have to be added.

V.6.4 TURNOVER

The touch-tone system would eliminate the learning curve problem associated with the high clerical turnover rate. Since no human intervention is needed to obtain test results clerical turnover will not affect system operation.

V.7 COMMUNICATIONS ISSUES

Communications issues that need to be discussed are best covered by classifying them into two areas: Technical considerations and operational considerations.

V.7.1 TECHNICAL CONSIDERATIONS

Communications technical considerations involve issues associated with the establishment of the proper communications hardware. They concern the selection of a data set and a traffic engineering analysis.

V.7.1.1 DATA SET

The data set to be used is the 401J3 receiver. It is designed for voice answerback and is equipped with a one way voice answerback channel. This unit can be used with either numeric oriented devices such as the touch-tone

telephone or with alphabetic terminals such as the IBM 2981 paralled tone alphanumeric keyboard (20). The 401J3 has a one time installation charge of $50.00 and a monthly charge of $37.50.

V.7.1.2 TRAFFIC ENGINEERING

Traffic engineering is necessary to determine the number of telephone lines necessary to handle the expected number of calls. The method used to determine this statistic will be the approach selected by IBM and specified in their publication number A27-2711.

A major parameter that must be determined is the holding time of an inquiry call. Hold time is a function of eight parameters: ready tone time, inquiry time, timeout delay, processing time, response time, and hangup time. The relationship is represented by the expression

HOLD TIME = RTT+IT+TD+P+R+H

where RTT = ready tone time
IT = inquiry time
TD = timeout delay
P = processing time
R = response time
H = hangup time

Ready tone time is the time delay between when the computer answers the telephone call and the authorization to begin I/O operations is given. Ready tone time is generally 2.5 seconds.

Inquiry time is the time required to key in an inquiry for the touch-tone pad. It is .4 seconds per digit.

Timeout delay is the time between the entry of the last digit and the 7772's recognition of the end of message. The default timeout delay is 5 seconds. If an end of message character is used (ie. the # or * key) then the timeout delay is .4 seconds.

Processing time is the time taken by the CPU to evaluate the inquiry and formulate the audio response message. IBM indicates the average processing time is about .2 seconds per inquiry.

Response time is the time required to output a spoken human voice reply. It is calculated on the basis of .5 seconds per word including periods of silence and pauses in the message. A sample of 35 completed requisitions indicated that the mean number of words per requisition necessary to transmit test results is 93. It is this figure that will be used for later calculation.

Hangup time is the time required by the telephone equipment to release a telephone line once the telephone receiver has been hung up. The statistic IBM suggests for use here is 5 seconds.

Assuming no mistakes in a telephone inquiry by the nurse and assuming the telephone call is to request the requisition of a single patient the following values for the hold time formula were calculated.

RTT = 2.5

IT = 4.4 (11 digits times .4)

TD = 1.2 (3 terminations times .4)

P = .6 (3 processing steps times .2)

R =65.0 (130 total words output times .5)

H = 5.

78.7 seconds average hold time for obtaining all information on a completed requisition.

Having determined the average holding time for an inquiry the next step is to determine the average traffic density in call seconds for the peak period. A sample of 9 days telephone calls indicates the peak period is between 1;00 PM and 2:00 PM (See Figure 4-2) and the average number of calls in this hour is 13. Dividing this traffic density

figure by the total seconds in the time period produces the average number of concurrent calls that will exist in the system throughout the selected time interval (19).

The average number of concurrent calls in the peak hour (ACC) is:

$$ACC = \frac{13 * 78.7}{3600} = \frac{1023}{3600} = .28$$

where: average calls/hr = 13

average hold time = 78.7

seconds/hour = 3600

Assuming that we want 96 percent of the inquiries to not experience a busy signal it is only necessary to support a two line 7772 configuration. This statistic is obtained from the grade of service versus system load table on page 25 of IBM publication A27-2711. (19) If it is desirable that less than 4 percent of the calls obtain a busy signal then it will be necessary to obtain a 7772 with a four line capacity.

The 13 call per hour inquiry rate is based only upon statistics gathered at the laboratory. A fact which can not be overlooked is that nurses are also calling the Medical Records Department in an effort to obtain the status of test results. Assuming that, in addition to

the laboratory, 15 calls per hour go to the Medical Records Department. These would now go to the computer under the touch-tone system and produce the following effect on the mean number of expected concurrent calls:

$$ACC = \frac{28 * 78.7}{3600} = \frac{2203}{3600} = .61$$

Under the increased load 85 percent of the incoming calls can still be expected to avoid a busy signal. These statistics assume that an entire average requisition is repeated over the telephone. If the only objective is to determine whether or not the requisition is complete then hold times would be significantly less and the number of calls expected to receive a busy signal would be reduced.

Since the objective is to keep the frequency of busy signals generated below the frustration level it is recommended that for the single application of medical test result inquiries that the basic two line 7772 is sufficient to service the Clinic. If other applications are desired and implemented this decision should be re-evaluated.

V.7.2 OPERATIONAL CONSIDERATIONS

Communications operational considerations involve

issues associated with the functioning of the system such as error control and usage.

V.7.2.1 ERROR CONTROL

As stated previously, expected transmission error rates are very low due to the careful selection of touch-tone frequencies. For errors that do occur minor software control routines should have no difficulty in detecting them.

V.7.2.2 USAGE

The line requirements generated in the traffic engineering section hold, given that the inquiry rate remains stable. If, however, the reporting process improves (as it would be expected to) or there is a general growth in the number of patients serviced then one should expect the number of calls to increase. If any of these situations occur, it is grounds for a traffic engineering reevaluation.

V.8 CENTRAL ISSUES

The central issues are those which effect or interact with all four of the major design issues - hardware, software, behavioral, and communications. They are control,

behavioral reaction to the system, system benefits, and system costs.

V.8.1 CONTROL

No control problems are anticipated with this design. The present system checks the validity of all test results before they are stored in the patient's master file. It is assumed that these software routines will be incorporated into the system. One other element of control that has been mentioned is the ability for easy access to test result files by anyone with a telephone and a touch-tone pad. I feel this is more of an academic issue than a practical problem. Given that the access key is the test requisition number, only someone with the patient's medical record would be able to interrogate the file in a meaningful way.

V.8.2 BEHAVIORAL REACTION

The reaction of Clinic personnel to talking with a machine instead of a human being is undetermined. I am unable to say what effect it will have. It might however, prove to be an important variable in the overall acceptance of the system. A suggestion might be to survey the attitudes of key personnel before and after an implementation

to see what effect, if any, this form of interaction has.

An additional behavioral consideration essential to proper system performance revolves around the fact that although it is technically possible to provide an audio response that is clear and audible, it is not possible to ensure correct interpretation. Nevertheless, this problem can be minimized by the use of two techniques:

A) Standardizing the message format

B) By training users to interpret the types of responses provided by the system.

V.8.3 SYSTEM COST

Cost associated with this touch-tone system are of two general types, one-time and recurring.

V.8.3.1 ONE TIME COSTS

Software Development	$12,000
Special Vocabulary at $10 per word	2,170
Data Set Installation for two data sets	100
Touch-tone Pad Installation for 100 telephones	500
Total one time costs	$14,770

V.8.3.2 RECURRING COSTS

7772 Audio Response Unit with two line capacity	605 per month
Two 401J3 Data Sets	75
100 Touch-tone pads	225
Transmitter Exclusion Option	31
Software Maintenance	150
Disk storage based upon an estimated one million bytes of utilization	66
Core utilization	?
CPU Processing Time	?
Total per month	$1,152 +

V.8.4 BENEFITS

There are many preceived benefits to this system. The majority of the benefits are qualitative ones but many have economic implications. They are:

A) Cost - The touch-tone based system is the lowest cost on-line alternative for test result inquiry. The 30-70 to 1 cost ratio makes it extremely attractive for this application.

B) Elimination of clerical turnover problem - By eliminating the clerical element, system performance can be expected to remain at a high level. The system also allows for growth in the number of transactions without causing increased personnel costs.

C) Timely Reporting - The touch-tone system will eliminate the time versus results tradeoff. The benefits here are mainly qualitative, centering on improved laboratory support of the Clinic.

D) Accuracy - By elimination of the clerical middle-man some improvement in accuracy can be expected.

E) Better utilization of nursing time - Nursing time may be expected to be better utilized by several hours per day. It will reduce volleying, multiple calls, and long search times. The major expected benefit however is qualitative - the reduction in nursing frustration and the overall improvement in service.

F) Better utilization of physician time - The system will enable faster results reporting - a qualitative factor which should promote higher doctor productivity.

G) Better utilization of patient time - Patients will be provided with better service and less wasted time since test results will be available to the physician sooner. It is expected that these benefits will be both quanitative (less forgone earnings) and qualitative (lower patient frustration).

V.9 SUMMARY

It is felt that the design presented represents the lowest cost on-line alternative for accessing test result information from the computer files. Let us now review what has been accomplished and attempt to draw implications from this experience.

CHAPTER VI

CONCLUSION

This chapter will summarize the task that has been accomplished, suggest other application areas for touch-tone technology at the Lahey Clinic, and attempt to define the role of the telephone in the development of information systems.

VI.1 SYNOPSIS

This thesis has provided the reader with an introduction into the application of touch-tone technology to the development of information systems. This was accomplished by first reviewing and evaluating the efforts of other individuals in the field. We then presented a tutorial on the foundations underlying the use of the hardware. The following chapter identified problems in the medical test result reporting process in the Lahey Clinic laboratory. Having defined these problems it was then suggested that the touch-tone telephone would be a viable terminal alternative for the development of a system to eliminate these problems. The design issues were then identified and the system design process necessary to support the application of touch-tone technology was illustrated. It is hopeful that this process will

prove useful as a model for the identification and structuring of the relevant issues involved in many other applications.

VI.2 POTENTIAL APPLICATIONS

There are a variety of applications at the Lahey Clinic which have characteristics capable of taking advantage of either off-line or on-line applications or touch-tone technology. Several of these areas will be dicusssed now.

RECORD MANAGEMENT

Sydney Martin in his thesis of An On-Line, Real Time Record Management System For A Medical Clinic (25) presents a detailed analysis of the need to locate any patient's medical record quickly and conveniently. It is suggested that touch-tone technology is a method for accomplishing this task at minimum cost. By having touch-tone pads on the desk of every physician and nurse it would be a relatively convenient process to verify the location of a patient's medical record by merely inputting the patient's medical record number on the pad.

PATIENT MONITORING

Martin (25) also suggests it would be beneficial to trace patients through the clinic in the same manner as their records. Two implicit benefits would arise:

A) Patients would have a greater chance of being

located in an emergency.

B) Statistics could be gathered enabling an analysis of clinic traffic flow, patient processing time, patient waiting time, and overall efficiency.

ORDER ENTRY

It is possible to order all clinic tests and drugs using a touch-tone telephone. To order, the nurse would enter the patient number, physician number, and items or services to be ordered. When the patient arrived at the test station or pharmacy all necessary paperwork could be completed and the patient could be serviced immediately. If this application were undertaken it is recommended that a peripherally attached Callamatic unit be used. All test and drug names could be entered on the magnetic tape and the nurse could indicate which items were to be ordered by using the corresponding alphabetic information on the paper tape instead of using the three digit test codes.

BILLING

By replacing the current Addressograph billing and patient history cards, along with the imprinters, and replacing them with touch-tone card dialers and dial cards it would be easy to automate the gathering of billing information. This would have two major benefits. First, the paperwork flow would be minimized and second, billing

information would be available in a much more timely fashion.

Although this is not an inclusive list of potential applications it does give a flavor for the kinds of applications that are compatible with touch-tone technology.

VI.3 HARDWARE SUMMARY

Condensing previous work, intuitive thoughts, and conclusions from the design process it is possible to summarize the characteristics of touch-tone technology in relation to its usefulness in the development of information systems. We will now identify these traits and classify them as to their utility.

ADVANTAGES

The following are reasons favoring the use of touch-tone technology in the development of information processing systems:

A) low cost

B) high reliability

C) no terminal maintenance costs

D) higher utilization of transmission resources

E) ease of use

F) availability of the terminals

DISADVANTAGES

The following are factors which limit the utility

of the touch-tone telephone in the development of information systems:

A) no visual aids

B) no memory capacity for recalling previous output

C) no capacity for complex output

D) no alphabetic keyboard

E) no capacity for high speed output

F) no capacity for prolonged high speed input

VI.4 SUMMARY

An analysis of the above factors indicate that the touch-tone terminal appears to be viable primarily from the standpoint of cost but suffers from the fact that it is a restricted I/O device and lacks any supporting visual aids. This has implications in that the touch-tone telephone has greater marginal value in environments where:

A) I/O is minimal

B) transaction complexity is low

With these restrictions the use of the touch-tone telephone in data communications appears to be most applicable where large numbers of terminals are desired and when short inquiry and response type interaction is prevalent. Its shortcomings will, in the short run, inhibit its use for a total information system concept. It can, however, have a significant role as a support tool to a

comprehensive, communications oriented, information system. By strategically placing keyboard devices in primary locations and backing the system up with low cost touch-tone terminals at secondary points it appears that the optimum information system, in terms of cost effectiveness, could be developed. It is this I suggest as being the proper role of the touch-tone telephone in data communications oriented systems.

An issue we must not overlook is its role in the future. It is felt that in the long run the touch-tone terminal will acquire a more important and perhaps central role in information system design. Two developments will contribute to this concept:

A) the introduction of flexible alphabetic keyboards enabling greater support for data input

B) the introduction of the Picturephone (06) will enable faster output as well as visual aids to suppliment verbal responses.

The introduction of these devices will eliminate the need for parallel hardware for information flow. At this point the telephone network will have the capability to provide a centralized and singular basis for information flow, both verbal and visual, from a single terminal source.

In conclusion, we have examined the issues relevant to the use of touch-tone technology in an information processing environment. One possible application was explored in detail and the pertinent issues were identified. The overwhelming factor favoring the implementation of touch-tone technology proves to be cost but when all dimensions are considered it is not at all clear if the touch-tone telephone is the optimum terminal. It is suggested that this area must be explored and evaluated further before any firm implementation recommendations can be made.

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APPENDIX A

Appendix A presents the different kinds of medical tests that are processed in the Lahey Clinic laboratory.

IMPRINT PATIENT'S NAME PLATE HERE

PROFILE AND AUTOMATED CHEMISTRY

TIME NEEDED:

IBM 871424

LAHEY CLINIC FOUNDATION LABORATORY

043125

	(✓)			(✓)	
PØ1		PROFILE 1	PØ2		PROFILE 2
388		HINTON	555		ALK. PHOSPHATASE
373		HEMOGLOBIN	009		A/G RATIO
370		HEMATOCRIT			TOTAL PROTEIN
850		WBC			ALBUMIN
656		ESR			GLOBULIN
840		DIFFERENTIAL	092		BILIRUBIN
338		BS–FAST HRS. P. C.	539		SGOT
765		BUN			
182		CHOLESTEROL	PØ3		PROFILE 3
770		URIC ACID			
			140		CALCIUM
SPECIAL BLOOD SUGAR			560		PHOSPHORUS
340		DEXTROL 1 HR.	555		ALK. PHOSPHATASE
342		CANDY 1 1/2 HR.	770		URIC ACID

043125

E

125

RESULTS/HISTORY

LAHEY CLINIC FOUNDATION LABORATORY

BLOOD 1 966519

8	✓		
388		HINTON	
373		HEMOGLOBIN	Gr. %
370		HEMATOCRIT	%
620		RBC	Cu. MM.
850		WBC	Cu. MM.
656		ESR	MM./Hr.
566		PLATELET COUNT	Cu. MM
634		RETICULOCYTE COUNT	%
840		DIFF.	P / BF / L / M / EOS. / BAS. / META. / MYEL. / BLAST. / AL / YL / TL / AM / YM

SMEAR

8	✓	
8		TIME NEEDED:
830		WBC ALK. PHOSPHATASE %
108		TYPE RH FACTOR
338		BS - FAST HRS. P.C. MG. %
765		BUN MG. %
228		CREATININE MG. %
182		CHOLESTEROL MG. %
180		CHOLESTEROL ESTERS
770		URIC ACID MG. %
473		LE PREP

8	✓	
140		CALCIUM MG. %
560		PHOSPHORUS MG. %
555		ALK. PHOSPHATASE B.U.
553		ACID PHOSPHATASE UNITS
740		TOTAL PROTEIN Gr. %
009		ALB. GLOB A/G
092		BILIRUBIN MG. %
124		BSP %
169		CEPHALIN FLOC.
728		THYMOL FLOC.
730		THYMOL TURB. UNITS
539		SGOT UNITS
609		SGPT UNITS
440		LDH UNITS
715		T_3 UPTAKE
593		PBI Micro. %
133		BEI Micro. %

966519 | 966519 | 966519 | 966519

8	√		Hrs.	BLOOD	URINE
340		GLUCOSE, DEXTROL - 1 HR.	0		
342		GLUCOSE CANDY - 1½ HR.	½		
344		GLUCOSE TOL. 2 HOURS	1		
346		GLUCOSE TOL. 3 HOURS	2		
348		GLUCOSE TOL. 6 HOURS	3		
415		INSULIN TOLERANCE	4		
527		ORINASE TOLERANCE	5		
			6		

RESULTS/HISTORY

8	√	TIME NEEDED:
213		COPPER
420		IRON
423		TIBC (INCL 8420)
153		CAPILLARY FRAGILITY
209		COOMBS TEST
301		FIBRINOLYSIN
597		PROTHOMBIN CONSUMPTION
553		ACID PHOSPHATASE
027		AMYLASE
463		LIPASE
458		LEUCINE AMMINO PEPT.
352		GLUCOSE 6 PHOS. DEHYD.
466		LIPID FRACT.
468		LIPID TOTAL FRACT.

LAHEY CLINIC FOUNDATION LABORATORY

BLOOD 2 113404

8	√	
670		SODIUM
574		POTASSIUM
172		CHLORIDE
196		CO_2 COMB. POWER
531		OSMOLALITY
104		BLOOD VOLUME
022		AMMONIA
116		BROMIDE
223		CREATINE
234		CREATININE CLEARANCE
452		LEAD
484		MAGNESIUM
238		CRYOGLOBULIN
480		MACROGLOBULIN
410		IMMUNO - ELECTROPHORESIS
284		ELECTROPHORESIS - PROTEIN
283		ELECTROPHORESIS - HEMOGLOBIN
900		ZINC TURBIDITY
447		LATEX FIXATION

113404 113404 113404 113404

PATIENT NAME & NO.

DATE DOCTOR

RESULTS/HISTORY

LAHEY CLINIC FOUNDATION LABORATORY

BLOOD 3 419706

TIME NEEDED:

8	V		8	V		8	V	
012		AGGLUTININS - FEBRILE / COLD	288		EOSINOPHILE COUNT	217		170H CORTICOIDS
042		ASO TITRE	100		BLEED TIME / CLOT TIME / CLOT RETR.	038		ASCORBIC ACID
381		HETEROPHILE AGGLUTINATION	190		CLOT TIME - LEE / WHITE	157		CAROTENE
383		HETEROPHILE CONFIRMATORY	192		CLOT TIME - SILICONE	310		FOLIC ACID
187		C-REACTIVE PROTEIN	599		PROTHOMBIN TIME	315		FRAGILITY - 3 HOUR
033		ANTINUCLEAR FACTOR - ANFT	305		FIBRINOGEN	317		FRAGILITY - INCUBATION
392		HISTOPLASMIN COMP. FIX.	830		WBC ALK. PHOSPHATASE	625		RED CELL SURVIVAL
734		THYROID ANTIBODY	723		THROMBOPLASTIN GENERATION	647		SCHILLING TEST
629		REITER PROTEIN COMP. FIX.	719		THIOCYANATE LEVEL	247		CULTURE - ROUTINE
750		TPI	405		I131 UPTAKE - 24 HOUR	050		BACTERIAL COLONY COUNT
074		BARBITURATE LEVEL	400		I131 SCAN - NECK	057		BACTERIAL SENSITIVITY
501		METHEMOGLOBIN	402		I131 SCAN - NECK & CHEST	067		BACTERIAL SMEAR
700		SULPHEMOGLOBIN	322		FSH			

419706 419706 419706 419706

PATIENT NAME & NO.

DATE DOCTOR

RESULTS/HISTORY

LAHEY CLINIC FOUNDATION LABORATORY

SPECIAL URINE 519278

8	V		8	V	TIME NEEDED:	8	V	
005		ACETONE	081		BENCE-JONES PROTEIN	142		CALCIUM
268		DIACETIC ACID	088		BILE	562		PHOSPHORUS
230		CREATININE	780		UROBILINOGEN 2 HOUR	145		CALCIUM INFUSION
742		TOTAL PROTEIN	783		UROBILINOGEN 24 HOUR	755		TRP
054		BACTERIAL COLONY COUNT	442		LDH	773		URIC ACID
061		BACTERIAL SENSITIVITY	366		GUINEA PIG	674		SODIUM
069		BACTERIAL SMEAR	522		OCCULT BLOOD	578		POTASSIUM
019		ALDOSTERONE	581		PREGNANEDIOL	549		pH
219		17 OH CORTICOIDS	584		PREGNANETRIOL	533		OSMOLALITY
434		17 KETOSTEROIDS	660		SEROTONIN	604		PSP
430		17 KETOGENIC STEROIDS	077		BARBITURATE LEVEL	377		HEMOSIDERIN
324		FSH	119		BROMIDE	225		CREATINE
296		ESTROGEN	259		CYSTINE	454		LEAD
161		CATECHOLAMINES	643		SALICYLATE LEVEL	486		MAGNESIUM
						494		MELANIN
						498		MERCURY
						503		METHEMOGLOBIN
						701		SULPHEMOGLOBIN
						800		VMA

519278 519278 519278 519278

RESULTS/HISTORY

TIME NEEDED:

LAHEY CLINIC FOUNDATION LABORATORY

GENERAL 1 46903

8	V		8	V	
065		BACTERIAL SMEAR	490		MALARIA SMEAR
096		BIOPSY	520		OCCULT BLOOD - STOOL
149		CALCULI	544		PAP. SMEAR-OTHER
242		CULTURE, SPUTUM ACID FAST BACILLUS	545		PAP. SMEAR CERV. /VAG.
249		CULTURE, FLUID	045		A-Z
254		CULTURE, FUNGUS	588		UCG PREGNANCY
279		D-XYLOSE ABSORP.	652		SECRETIN
291		EOSINOPHIL SMEAR - NASAL	680		SPERM COUNT
330		GASTRIC ANALYSIS DIAGNEX	693		OVA & PARASITES - STOOL
333		GASTRIC ANALYSIS ROUTINE	690		FAT QUAL. - STOOL
358		GRAM STAIN			
362		GUINEA PIG INNOC.-FLUID			
364		GUINEA PIG INNOC. - SPUTUM			

46903 46903 46903 46903

APPENDIX B

Appendix B presents a list of the required medical vocabulary words.

a
acetone
acid
aff
agglut
albumin
aldosterone
alk
amino
ammonia
amylase
an
anft
anti
ascorbic
aso
asp

b
bacterial
barbiturate
bei
bence
bile
bilirubin
biological
biopsy
bleed
block
blood
bone
bromide
bsp
buccal
bun

c
calcium
calculi
capillary
carotene
catecholamines
cell
cephalin
chloride
cholesterol
clot
co2
cold
collect
compliment
confirm
consumption
coombs
copper
corticoids
cortisol
count
creatine
creatinine
cryoglobulin
culture
cystine

d
dark
dex
diacetic
diagnex
differential

e
electro
eosin
esr
esters
estrogen

f
fat
febrile
fibrinogen
fibrinolysin
field
fixation
fluid
floc
folic
fraction
fragility
fsh
fungus

g
gast
gen
glucose
gram
guin

h
hematocrit
hemoglobin
hemosiderin
heterophile
hgb
hinton
histo

i
infus
imm
inno
insulin
iron

j
jones

k
ketogenic
ketosteroids

l
lab
latex
ldh
lead

lee
leucine
lev
lipase
lipid

m
macroglobulin
magnesium
malaria
marrow
melanin
mercury
methemoglobin

n
nas
neck
nitrogen
normals
norms
nrm

o
occult
orinase
osmolality
ova

p
pap
para
phor
phosphorus
pig
platelet
porphyrins
potassium
power
pregnanediol
pregnanetriol
prep
profile
prot
protein
prothrombin
psp

q
qual

r
ratio
rbc
reactive
red
retic
routine
rpcf

s
salicylate
scan
schilling
scretin
sens
serotonin
serum
sgot
sgpt
sicklecell
silic
smear
sodium
sperm
spinal
sputum
stain
stool
sugar
sulphemoglobin
suriv
sweat

t
test
thiocyanate
thrombopias
thymol
thyroid
time
tirc
titre
tol
total
tpi
trp
turbidity

u
uptake
uric
urine
urobilino

v
volume
vitamin

w
white

x

y

z
zinc

b.u.
f.u.
kunkel
naoh
nrm
seconds
hour
mcg