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Description and Evaluation of the MBTA Magnetic Card Fare Collection System

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16. Abstract

This report presents a system and subsystem description of the Massachusetts Bay Transportation Authority's (MBTA) magnetic card fare collection system, which was introduced on November 1, 1980. Also included is a preliminary assessment of performance of system operation based on data collected during the second and third months of operation. The objective of the magnetic card fare collection system is to allow the MBTA to continue to make monthly passes available to the public while relieving the collector of the burden of ticket-by-ticket validation. Fraudulent entry into the system is greatly reduced by requiring passengers using cards to enter through the turnstiles as token users do. Each station in the rapid transit system has a minimum of two turnstiles that have been modified to allow entry via a magnetic card as well as a token. It was determined that (1) passengers have no difficulty in using their magnetic cards to gain entry, (2) there is no noticeable difference in the time needed to pass through a turnstile with a card as compared with a token, (3) the magnetic card system has allowed the MBTA to lock the gate used with the previous paper pass system, thus forcing all passengers to use the turnstiles and thereby establishing a system which should stop fraud and increase revenues and recorded ridership, and (4) turnstiles that accept tokens can be easily retrofitted to allow entry via a magnetic card.

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PREFACE

This Final Report documents a six month program of investigation of the Massachusetts Bay Transportation Authority (MBTA) magnetic card fare collection system by the performing organization under its Ground Transportation System Support Services contract with the Transportation Systems Center, U.S. Department of Transportation, Contract No. DTRS-57-80-C-00081. Mr. Joseph S. Koziol, Code 721 of the Office of Ground Systems, Urban Systems Division was the Technical Monitor.

The work presented was drawn from documents furnished by the MBTA, interviews with MBTA personnel, and site surveys of MBTA rapid transit stations. DYNATREND acknowledges the MBTA's cooperation in providing the data necessary to describe their magnetic card fare collection system.

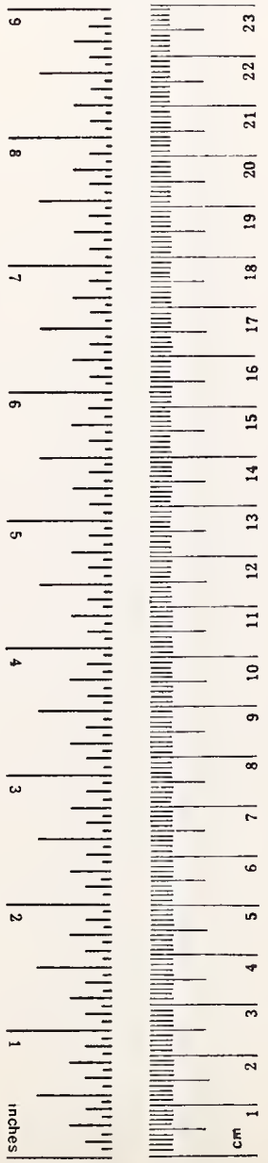
The objective of this study was to describe and assess the MBTA's new fare collection system in sufficient depth in order to allow the managers of other properties to assess the applicability of the MBTA system to their fare collection needs.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

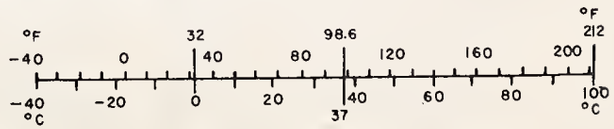
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yerds	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teespoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

On November 1, 1980, the Massachusetts Bay Transportation Authority (MBTA) introduced a magnetic card fare collection system to replace a paper pass fare collection system. The magnetic card is purchased monthly by the passengers as the paper pass was purchased and allows for an unlimited number of rides. To gain entry into the MBTA under the previous system, the passenger with the paper pass (prior to introduction of the new system) had to approach the pass gate, which at that time was open, show the pass to the collector, and receive an acknowledgement to walk through the open gate. Observation over the years by MBTA authorities indicated that a significant fraction of passengers entered the system without using a valid pass. Fraudulent entry was gained using various methods of deceit, the most common of which involved invalid or falsified passes. Fraudulent entry was particularly severe during rush hour when the collector's attention was directed to providing tokens for the turnstile users. MBTA officials took action to correct paper pass entry abuse, when estimates indicated there was a significant loss of revenue and decrease in recorded ridership.

It became apparent that a significant portion of illegal entry into the system could be stopped by closing the gate and requiring all passengers to use the turnstiles. The magnetic card fare collection system was designed to provide the MBTA passengers with the option of obtaining a monthly pass, and to establish a barrier to reduce loss of revenue and unrecorded ridership.

The major design and operating features of the magnetic card fare collection system include: (1) full compatibility with existing procedures and turnstile equipment for access and fare collection, (2) no mechanical card transporters (the cards are transported through the readheads by the passengers), (3) capability to recognize 200 categories of passengers and to selectively "lockout" any or all categories with respect to time or location, (4) capability to recognize 20 different card values and "lockout" any passenger whose card is not of sufficient value for the station, (5) capability to resolve card validation disputes with passengers, (6) provision for an "anti-passback" control

to prohibit the reuse of a valid pass at any point of entry for an adjustable period of time, (7) capability of providing a profile of card related entry, i.e., where used, time and date of use, and category of user, (8) construction of exposed hardware that is resistant to vandalism and tampering, and (9) cards with sufficient security features, so as to prevent duplication only by the most sophisticated means.

The magnetic card system is comprised of two elements: field equipment and support equipment. The principal element is the field equipment, which consists of the following subsystems: (1) magnetically encoded fare cards purchased by the passengers, which are similar in size and appearance to credit cards, (2) a readhead and housing located on top of a turnstile used to produce a train of magnetic pulses, (3) a pre-amplifier located inside the turnstile which receives by wire the electrical pulses produced magnetically and amplifies them before retransmission via wire to the controller, (4) a controller located in the collector's booth used to validate cards and send a return impulse to (5) a read recovery located in the turnstile, which amplifies the signal and activates a relay which provides the current to (6) a solenoid activated mechanical device which releases the turnstile arm and allows passenger entry. The support equipment element is composed of: (1) a card encoding machine, (2) portable controller programmers used to reprogram the controllers, (3) a master programmer which is a stationary unit used to input programs into the portable controller programmers, and (4) a portable data collection unit used to recover card data stored within the controller; the recovered data is processed by the MBTA computer to extract usage and ridership information.

The design, developmental testing, and bread boarding were done by the MBTA employees. After these phases were completed, the final packaging was contracted to Electron Inc. of San Diego, California. Presently, 168 turnstiles have been adapted to permit entry using magnetic cards and 68 controllers have been installed throughout the MBTA. The total expenditure by the MBTA has been $1.2 million. This includes procurement of system hardware plus spares, installation hardware, engineering labor, and installation labor.

Some operational data was obtained for the first two months of operation, December 1980 and January 1981. It was found that there were no delays in passenger entry. Queue lengths at both token-only and token/card turnstiles on occasion reached lengths of three to four, with these queues disappearing quickly. The system specification required a performance level of 400,000 mean cycles between failures (MCBF). Calculation of the MCBF based on two months of data indicates a value ranging between 7,631 to 8,845. This observed smaller number of cycles between failures may be due in part to the weeding out of defective components, which is not unusual during the early life of a system. A mean time of 15 minutes to repair has been reported, which is in accordance with the specification.

Preliminary assessment of the magnetic card fare collection system indicates: (1) existing turnstiles can be retrofitted to accept both tokens and magnetic card entry, (2) passengers have no difficulty in using the card system, (3) card sales have increased over paper pass sales, (4) the system performance is sufficiently high so there are no delays in entrance through the turnstiles due to equipment failure, (5) there is no noticeable difference in the time needed to pass through a turnstile using a card as compared to a token, and (6) the magnetic card system has allowed the MBTA to lock the gate used with the previous paper pass system, thus forcing all passengers to use the turnstiles, establishing a new system which should stop fraud and increase revenues and recorded ridership.

1.0 BACKGROUND

In the early 1970's, the Massachusetts Bay Transportation Authority (MBTA) introduced a fare collection system based on the use of a pre-paid monthly pass which allowed for an unlimited number of rides by the pass holder. Purchase of these passes was available to employees of companies that elected to participate in the MBTA program. The employers collected the fare from the employees which was then paid to the MBTA, and the employer received from the MBTA passes which were then distributed to their employees. In 1977 this monthly pass with unlimited rides was made available to all MBTA passengers through direct sale to the public. Incentives for the purchase of passes included (1) elimination of tokens[1] (2) reduced cost of transportation if the pass was used five days a week, every week for a month in comparison to the summed five-day-work-week cost of tokens for a month, and (3) reduced cost in automobile insurance for passengers who purchased passes for eleven months of the year.

To gain entry into the MBTA, the passenger with the paper pass would approach the pass gate, which at the time was open, show the pass to the collector, and receive an acknowledgement to walk through the open gate. The layout of a typical collector's booth, pass gate (which is closed), and turnstiles is presented in Figure 1. Observation over the years by MBTA authorities indicated that a significant fraction of passengers entered the system without using a valid pass. Fraudulent entry was gained using various methods of deceit, the most common of which involved invalid or falsified passes. Fraudulent entry was particularly severe during rush hour when the collector's attention was directed to providing tokens for the turnstile users. MBTA officials became concerned about the estimated significant loss of revenues created by illegal entry and the decrease in the number of recorded riders.

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[1]Just prior to the time of the introduction of the magnetic card fare collection system, the cost of one ride was a twenty-five cent piece which was accepted by the turnstiles. Today, the cost of a single ride is fifty cents, with entry gained by purchase of a token.

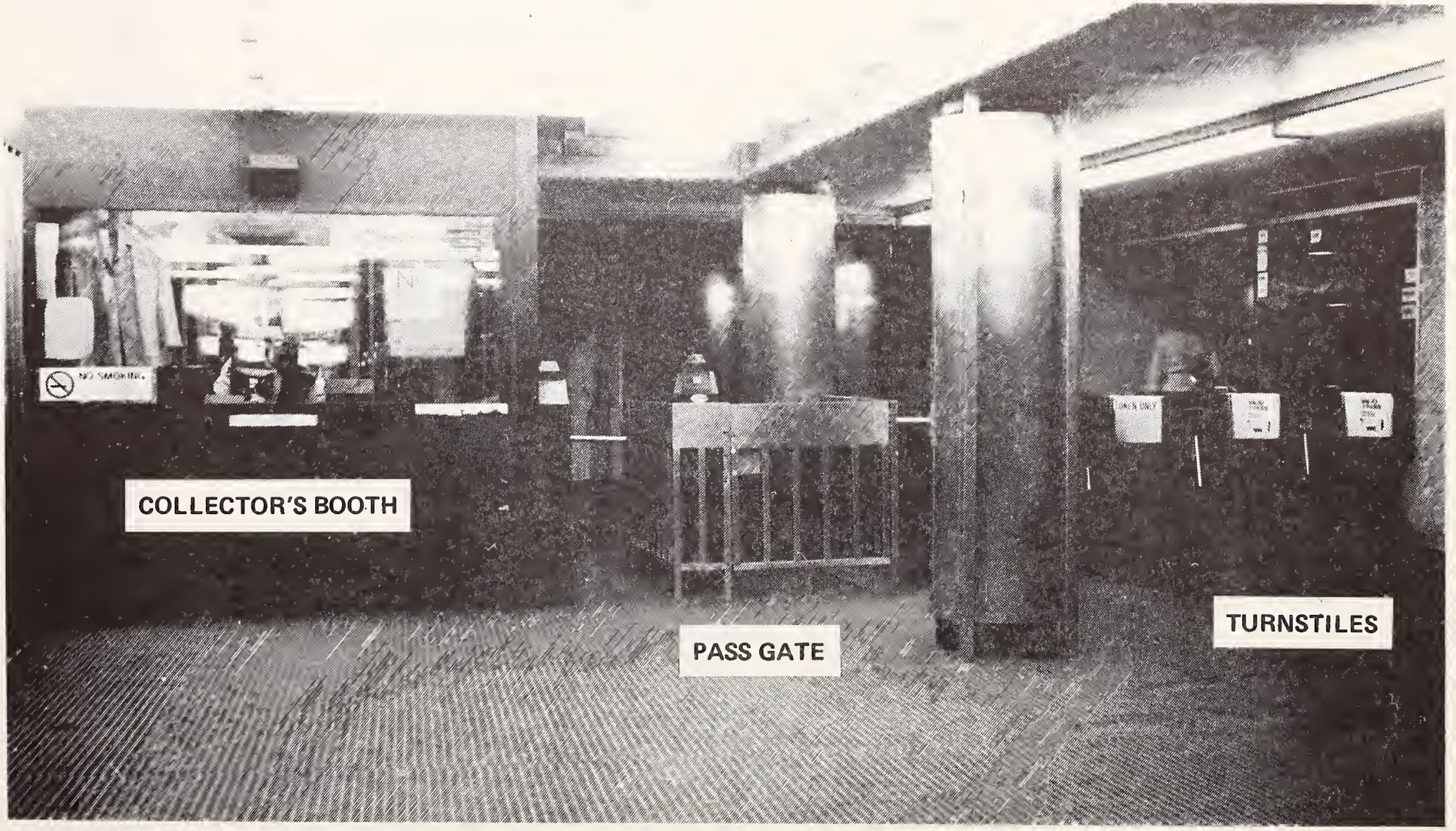

FIGURE 1. TYPICAL MBTA STATION

It became apparent that a significant portion of illegal entry into the system could be stopped by closing the gate and requiring all passengers to use the turnstiles. The magnetic card fare collection system was designed to provide the MBTA passengers with the option of obtaining a monthly pass, and to establish a barrier to reduce loss of revenue and unrecorded ridership.

The major feature of the magnetic card fare collection system is to relieve the burden of ticket-by-ticket validation, with the attendant called upon only when a problem or dispute arises. This new pass system has been designed to be consistent (after a small equipment modification) with the previously used pass and token collection system. Therefore, the passenger is not faced with a new, potentially complex, system requiring a lengthy educational process.

2.0 SYSTEM DESCRIPTION

The magnetic card fare collection system[2] installed in the rapid transit and streetcar stations was designed by MBTA employees and tailored to MBTA needs and requirements. These needs and requirements were established as a result of a fare collection requirements and alternatives analysis conducted by the MBTA. The major requirements included:

DESIGN

(1) fully compatible with existing procedures and turnstiles for access and fare collection,

(2) no mechanical transporters for card,

(3) no change in rate of passenger entry or change in passenger convenience,

(4) no change in existing card distribution procedures, and

[2]The Magnetic Card Fare Collection System was introduced on November 1, 1980.

(5) low life cycle cost, i.e., low capital cost and low maintenance costs (particularly labor).

ACCESS CONTROL

(1) capability to recognize 100 categories[3] of passengers and selectively "lock out" any or all categories of passengers at any or all points of entry and/or during designated hours,

(2) capability to "lock out" passengers on a daily, weekly, monthly, or yearly basis,

(3) provision for a "grace period"[4] during which time both expired cards or newly issued cards would be accepted,

(4) capability to recognize at least 10 different card values and "lock out" any passenger whose pass does not contain a sufficient value for the station, and

(5) capability to resolve pass disputes.

REVENUE COLLECTION

(1) provision for an "anti-passback" control to prohibit the reuse of a valid pass at a point of entry for a defined period of time, and

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[3]The choice of 100 hundred as the nominal number of categories was based on a two digit format (00 to 99). It was estimated this would be a sufficient number for present and future requirements. There are in use at the present seven categories as follows: 4 fare structure, one senior citizen, one employee, and one retiree.

[4]The "grace period" is programmable up to a maximum of plus or minus 99 days from the expiration date on the card. There is, in the controller, a hard wired provision that insures a card will be honored until 2:00 A.M. of the next day after the end of the current month listed on the card. This is to allow riders to return to their origin without being stranded with an expired card.

(2) capability of providing data which identifies passenger category, value of card, date, time, and point of entry or exit (if an additional fare is to be collected).

DATA COLLECTION

(1) outputting of stored revenue data onto compatible diskettes.

SECURITY

(1) construction of hardware that is resistant to vandalism and tampering by the public or unauthorized personnel,

(2) prevention of modification to the system except under supervisory control, and

(3) cards with sufficient data and security features, so as to prevent duplication only by the most sophisticated means.

Following examination of current systems available from suppliers, it was determined that none met the specified requirements. These findings led to the decision to design a new system. The design effort integrated both Operations, Maintenance, and Revenue Department's needs and requirements, and took into consideration the financing available for capital equipment and the future estimated costs for maintenance.

A schematic of the MBTA magnetic card fare collection system is presented in Figure 2. The magnetic card system consists of two elements: field equipment and support equipment. A brief description of all the subsystems follows.

The principal element is the field equipment, which is comprised of (1) the encoded fare card subsystem purchased by the passengers, (2) the controller subsystem, which is located in the collector's booth, and (3) the readhead and housing, pre-amplifier and read recovery circuit board, and turnstile unlatching mechanism subsystems; all of which are located on or within the

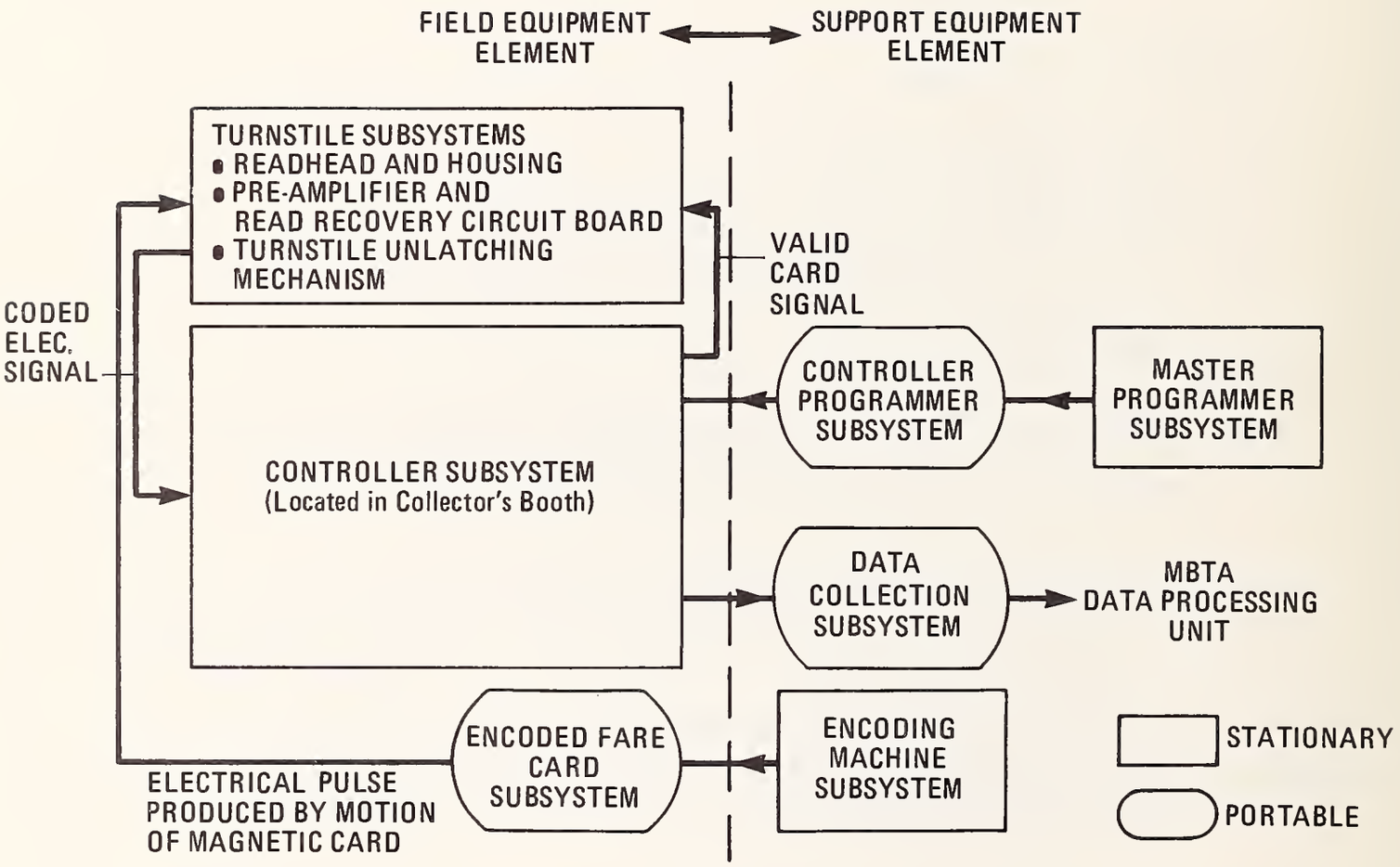

FIGURE 2. SCHEMATIC OF MBTA MAGNETIC CARD FARE COLLECTION SYSTEM

turnstile. Figure 3 shows an MBTA passenger passing a magnetically encoded fare card through the readhead housing. Note that the token slot is located just in front of the housing; this turnstile can accept both cards and tokens. The controller subsystem, which validates the card and provides the signal which unlatches the turnstile, is shown in Figure 4.

A brief description of the function of the subsystems shown in Figure 2 follows (a more complete description is given in Section 3.0):

FIELD EQUIPMENT ELEMENT

Encoded Fare Card Subsystem - a magnetically encoded card purchased monthly by passengers.

Readhead and Housing Subsystem - magnetic card reader located on top of turnstile.

Pre-Amplifier and Read Recovery Circuit Board Subsystem - amplification of magnetic signals to controller and amplification of signal from controller to unlatch turnstile.

Turnstile Unlatching Mechanism Subsystem - a solenoid actuated mechanical device that releases the turnstile arm and allows entry.

Controller Subsystem - electronic box located in collector's booth that validates cards and provides signal to allow passenger entry.

SUPPORT EQUIPMENT ELEMENT

Encoding Machine Subsystem - encodes magnetic strip on card with validation information.

Controller Programmer Subsystem - portable unit for reprogramming of controllers.

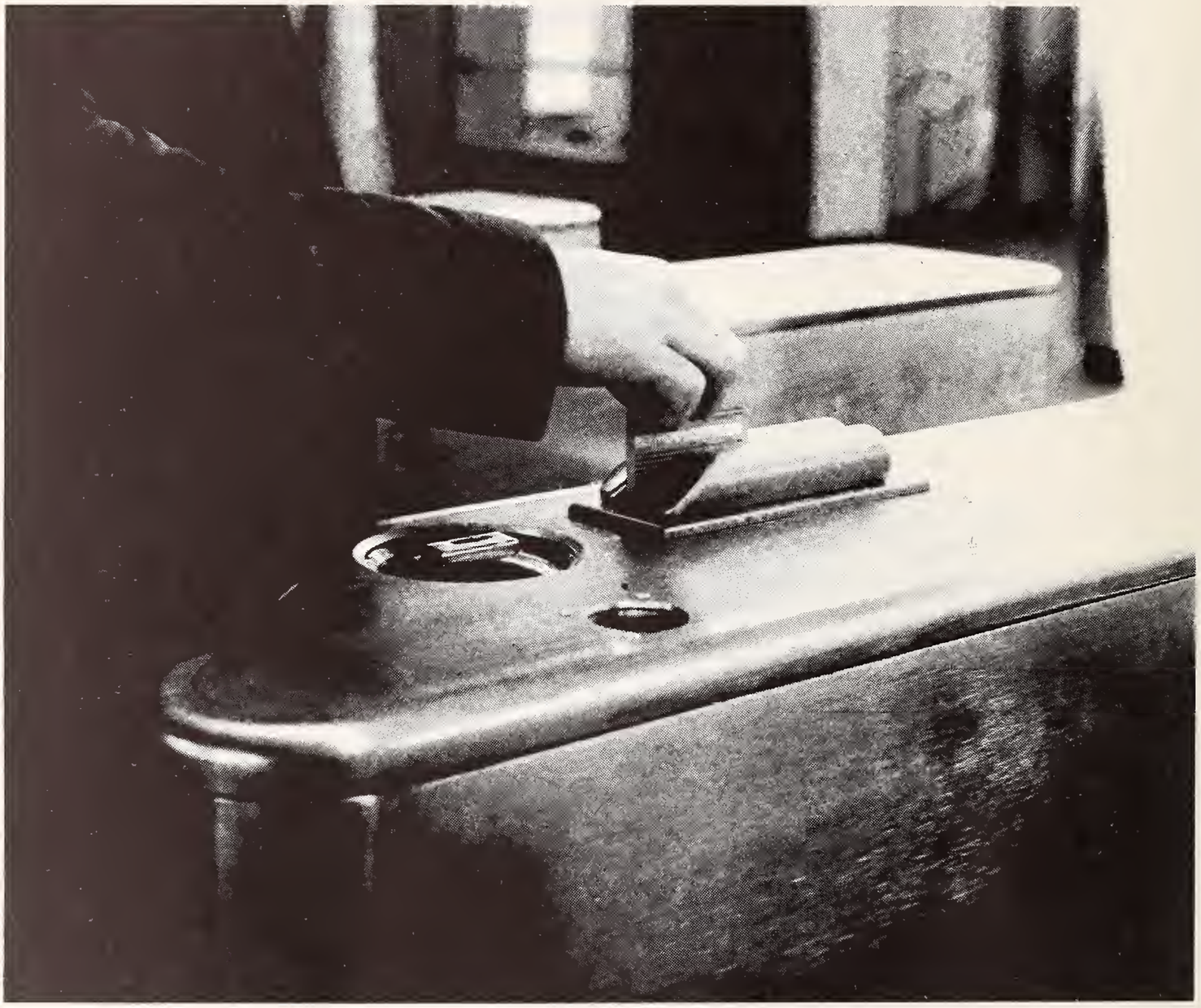

FIGURE 3. PASSENGER TRANSPORTING CARD THROUGH READHEAD

FIGURE 4. CONTROLLER (SHOWING COLLECTOR USING MANUAL VALIDATION MODE)

Master Programmer Subsystem - a stationary unit used for the reprogramming of the controller programmers.

Data Collection Unit Subsystem - used to recover card data information stored within controller.

A schematic of the field equipment element is presented in Figure 5. The following events occur between the manual read-in of the card and the unlatching of the turnstile. The elapsed time for all the events is less than two seconds. The passenger slides the card through the readhead and housing subsystem located on top of the turnstile. Magnetic flux changes generated by motion of the card are sent to a pre-amplifier circuit board[5] where the signal is shaped and amplified and sent by hardwire to the controller located within the collector's booth. The impulses are read by the controller and compared with the programmed data, and if the card is invalid the process ends. There is no signal output from the controller to make the collector aware of invalid card use. If the card is valid, an electrical signal is sent to the read recovery circuit board in the turnstile, which results in the closing of the relay contacts. Closing of the contacts activates a solenoid which unlatches the turnstile and allows passenger entry.

The turnstile subsystems consist of small modularized units which ease the problems of retrofit integration. The pre-amplifier and controller use printed circuit boards which allow for quick and easy repair. The unlatching mechanism, which responds to the electric signal from the relay and unlocks the turnstile arm, is the only mechanical unit. Installation of field equipment requires (1) a transformer (24 volts a.c.), a circuit board, and an unlatching mechanism in the existing turnstile; (2) supply of electrical energy to the turnstile; (3) placing the controller in the existing collection booth; and (4) running wires between the controller and each of the turnstiles equipped with the system. Installation of these subsystems did not require unusual skills and was accomplished by the MBTA's own work force.

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[5]Relay, pre-amplifier, and read recovery subsystems are integrated into one circuit board unit.

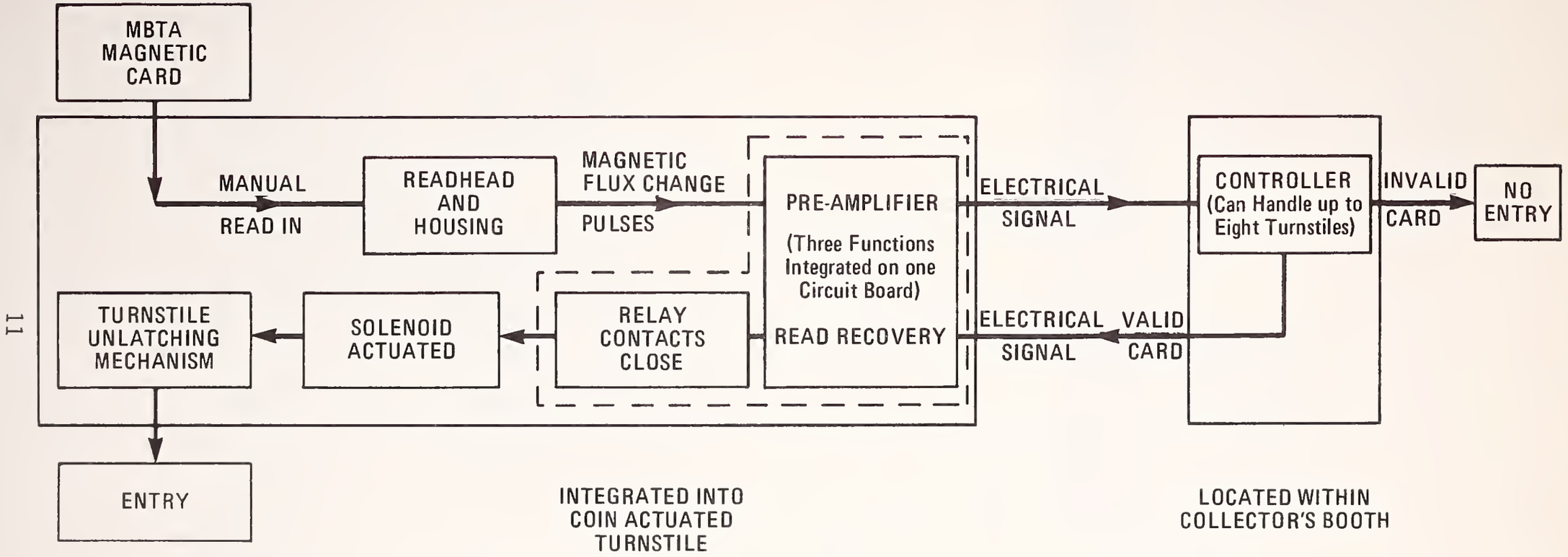


FIGURE 5. EVENT·FLOWCHART OF FIELD EQUIPMENT ELEMENT OF MBTA MAGNETIC CARD FARE COLLECTION SYSTEM

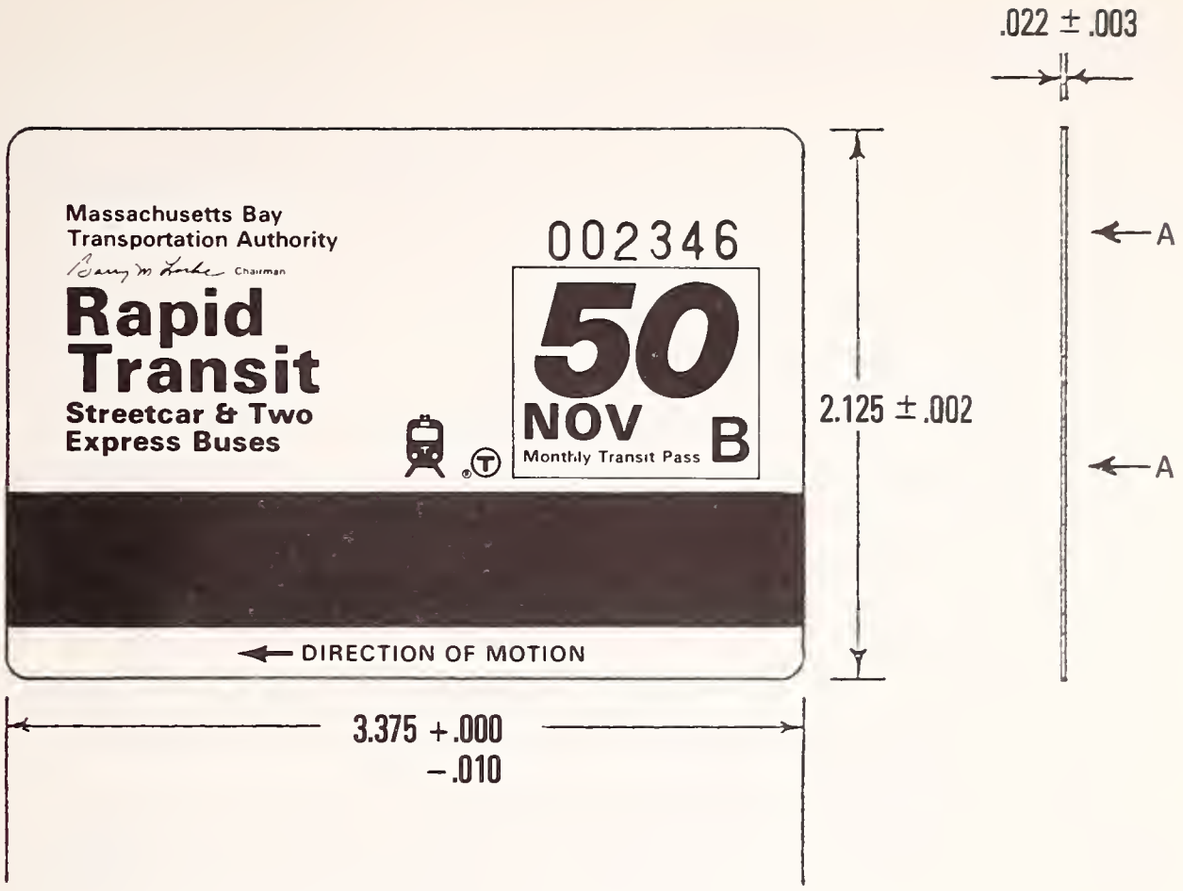
At present, 168 turnstiles have been adapted to permit entry using fare cards, and 68 controllers have been installed throughout the MBTA system. To date, the total expenditure by the MBTA has been approximately $1.2 million. This includes labor for installation, transformers, unlatching mechanisms, electrical and mechanical hardware, and the purchase of 85 controllers, 210 readheads and housings, 50 readheads (without housing), 235 pre-amplifier and read recovery circuit boards, 10 controller programmers, 100 programmer blank tapes, 1 match programmer, 5 data collection units, 1 encoding machine, 358,000 encoded cards, and one system prototype for evaluation that consisted of a readhead and housing, pre-amplifier and read recovery circuit board, and controller.

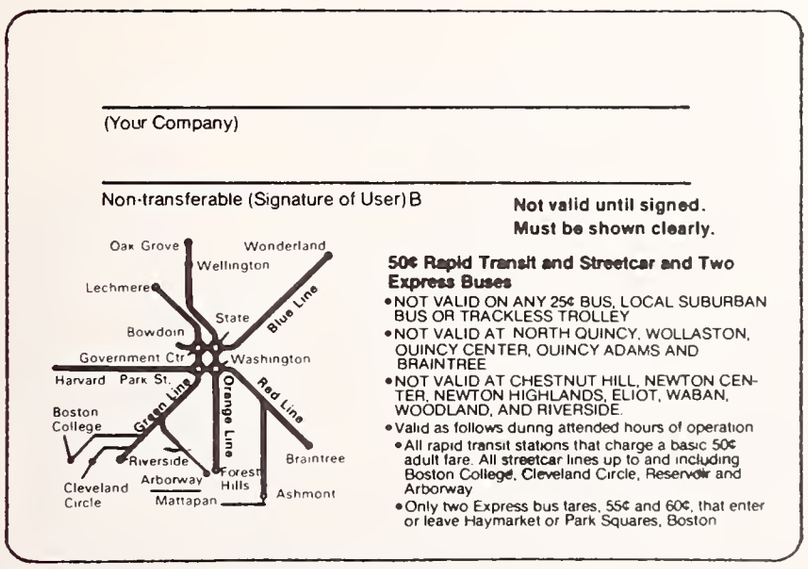
3.0 SUBSYSTEMS DESCRIPTION

This section describes in greater detail the subsystems that comprise the field equipment and supporting equipment elements of the MBTA magnetic card fare collection system.

3.1 ENCODED CARDS

The primary passenger interface with the fare collection system is the plastic pass card (see Figure 6), which contains the magnetically encoded information that permits entry into the transit system. The high energy magnetic tape used provides for greater encoded permanence and a higher degree of security than low energy tape. The card's magnetic strip, which contains the signal on a single track, is encoded with data bits in accordance with two-frequency coherent phase encoding, with data selection made by the MBTA. The magnetic materials provide readback signals that produce a code. This code must be validated by the controller. Both the card/magnetic tape and the encoded data are prepared in such a manner as to promote the utmost security, high reliability, and prevention of counterfeiting. Card design has considered features to enhance longevity, safety, and convenience. Passengers pay for and receive new cards each month, and each card contains new coded data that specifically identifies the extent of use.





VIEW A - A

Dimensions in inches

FIGURE 6. TYPICAL MBTA PASS CARD

3.2 READHEAD AND HOUSING

The encoded card is then used by the passenger to enter the station. The passenger passes the magnetic card through the slot in the readhead assembly (see Figure 7). A valid card will permit entry. The readhead is inside the housing, and the readhead is mounted on the flat surface of the Perey P.C. 97 or P.C. 109 turnstile as shown in Figure 7. The housing, manufactured from stainless steel, has been designed to be rugged and vandal proof, and to protect the readhead from most abuse. Located within the housing are the readhead and magnet. The readhead is adjustable to compensate for head wear, and is also gimballed to insure an even contact with the card as it is slid through the housing. The magnet, which can be adjusted for wear, is strong enough to erase a card that uses a standard low energy magnetic tape for the encoding of data. When the card is slid through the housing, the encoded data is "picked up" by the readhead. Encoded cards can be read at transport velocities ranging from 2.5 to 40 inches per second. The signal is then transmitted by wire to the pre-amplifier on the printed circuit board located inside the turnstile.

3.3 PRE-AMPLIFIER AND READ RECOVERY CIRCUIT BOARD

The pre-amplifier and read recovery circuit board is located within the turnstile, schematically displayed in Figure 8. Transport of an MBTA encoded card through the readhead produces a series of pulses that are sent by wire to the circuit board. These pulses are shaped and amplified and sent by wire on to the controller where they are compared with a pre-programmed code; if the pulses are in agreement with the code in the controller, a signal is then sent back via wire to the circuit board, resulting in the closing of a relay which in turn activates a solenoid controlling a mechanism that unlatches the turnstile arm. Power for the circuit board and solenoids is provided by a 24 volt a.c. transformer. After the turnstile arm swings, a microswitch is activated which powers a solenoid to a turnstile counter. There are two

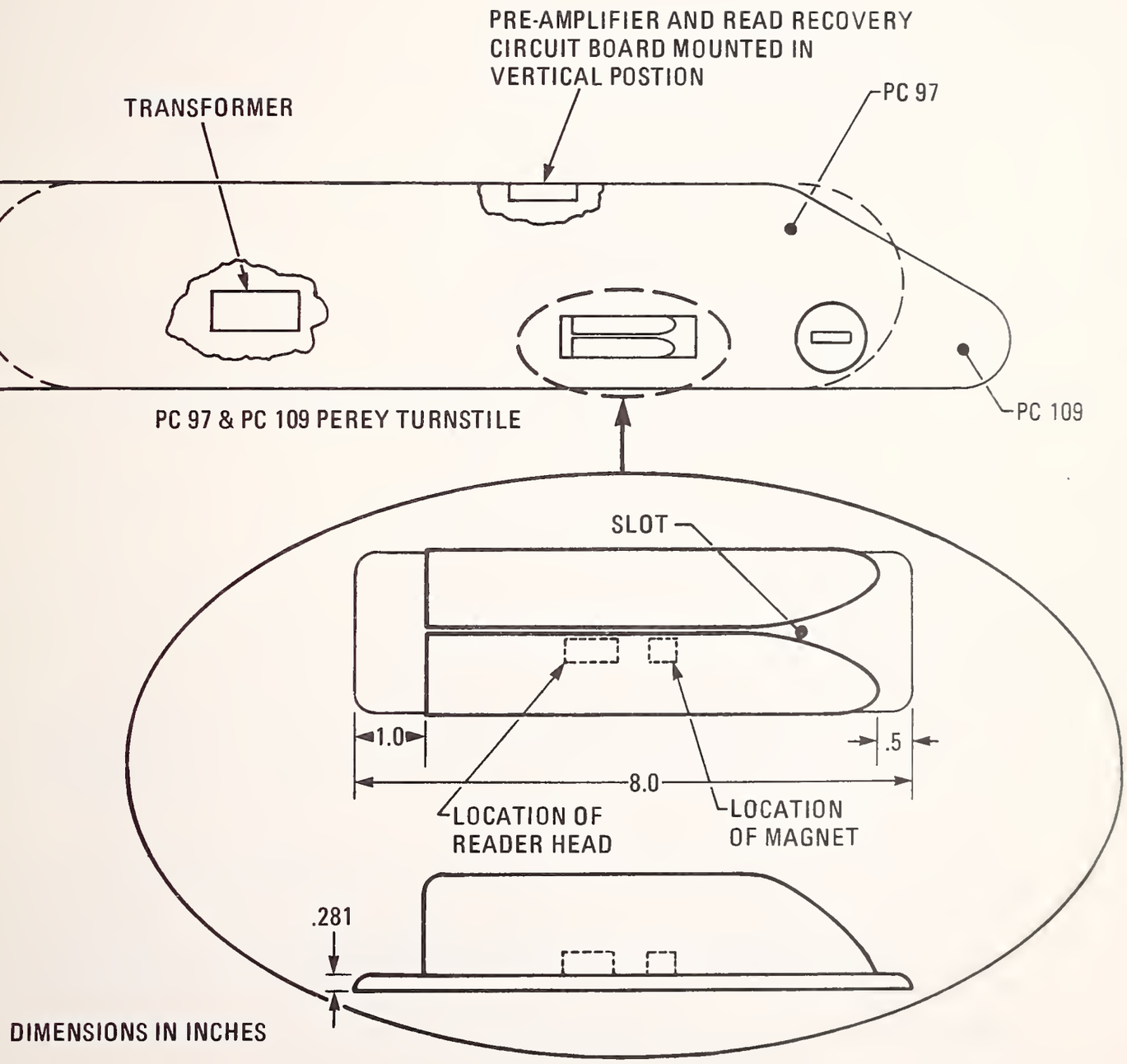


FIGURE 7. INSTALLATION OF MAGNETIC CARD FARE COLLECTION SUBSYSTEMS WITHIN TURNSTILE

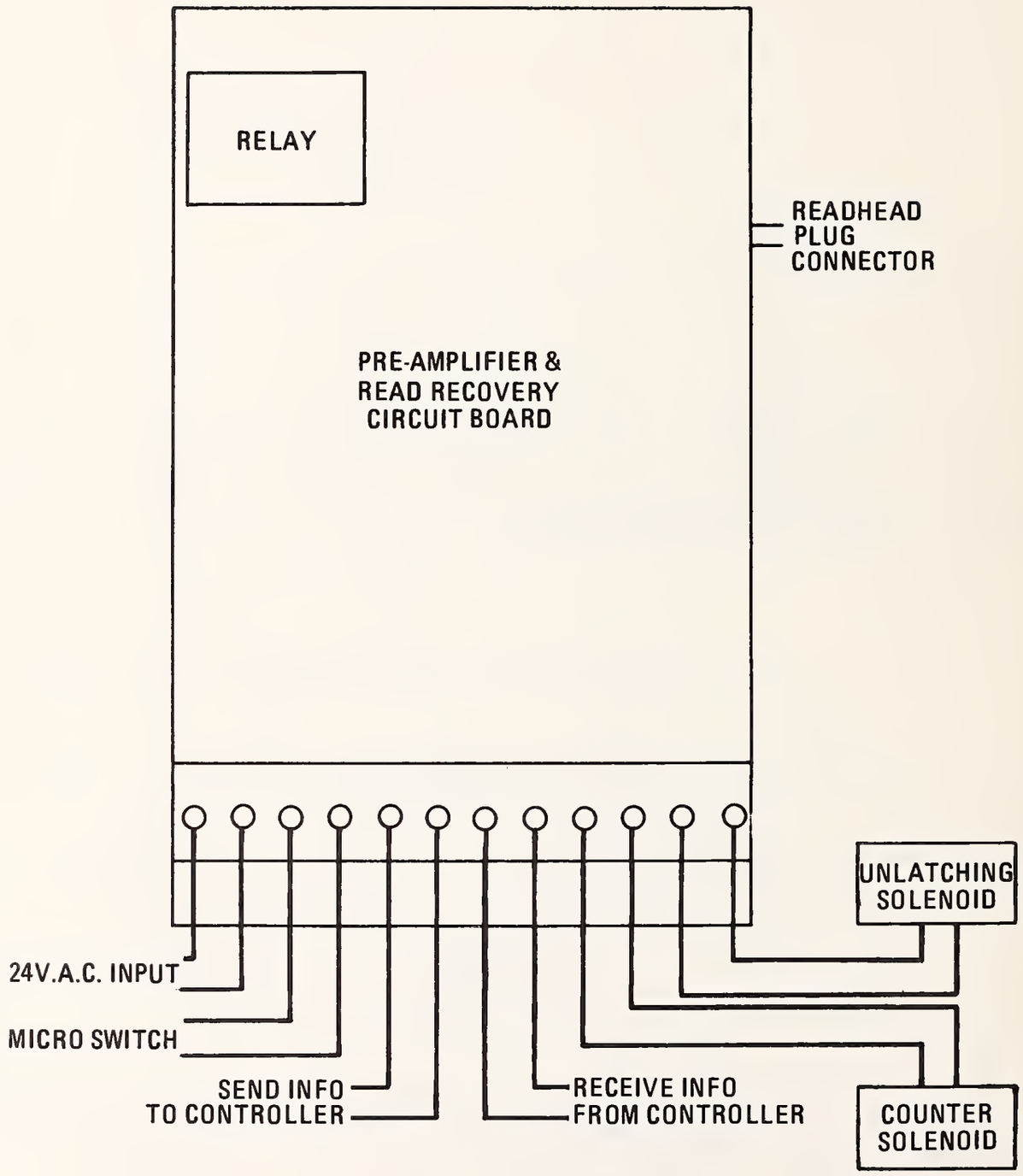


FIGURE 8. INPUT-OUTPUT FUNCTIONS PRE-AMPLIFIER AND READ RECOVERY CIRCUIT BOARD

counters at the turnstile: one counts the number of times the arm swings as a result of token or card entry, and the other the number of times the arm swings due to card entry only.

The circuit board can provide entry in the event the controller fails or a signal from the controller is not received. In the event of these circumstances occurring, the circuit board will take over the validation function and as programmed will sense and accept the signal from any MBTA card. There is no apparent external indication of controller subsystem failure that can be observed by the passengers.

3.4 TURNSTILE UNLATCHING MECHANISM

This solenoid activated mechanical assembly has been designed to unlatch the turnstile after receiving a validation signal from the relay. It works in parallel with the token actuated turnstile arm unlatching mechanism.

3.5 CONTROLLER

The controller subsystem is an electronic box which measures 12x20x15 inches in dimension and is located in the collector's booth. Its function is to receive via wires information being read from a card by a specific turnstile, and is capable of receiving, validating, and responding to inputs from up to eight turnstiles simultaneously. The controller is capable of processing data at a rate that allows more than 60 passengers to enter per minute.

To prevent a card from being used more than once over a short period of time, an anti-passback feature has been designed into the controller. It contains a memory for the short-term storage of card identifiers. After the passback time has expired, new card identification information is written over the old. This anti-passback feature has an adjustable time period of 30 seconds to 49 minutes, after which all of the stored serial information is removed from the moving stack. Certain categories of cards such as those issued to MBTA employees are not constrained by this anti-passback feature.

The controller also contains a real-time clock to restrict certain cards at a given time of day, and it is possible to record and store within the controller the time of day cards are being accepted. This feature, in conjunction with a data collection unit (see Section 3.8), would allow for determination of the time during the day when different classes of cards are being used.

The controller is programmed to accept the new magnetic cards on the first day of the month, and to reject the cards from the prior month. If warranted, a grace period can be programmed into the controller so as to allow the old card to be used for a few days in the new month or the new card to be used for a few days in the prior month, or both.

In the event a passenger does not gain entry to the system and believes the card is valid, it is possible to use the hand activated card verifier that is integrated into the controller. Figure 4 shows the card verifier being used by the collector. The collector passes the disputed card through the readhead on top of the controller and a digital light emitting diode displays a number indicating the status of the card. The causes for non-validation of the card and the collector's instructions to the passenger are presented in Table 1.

3.6 CONTROLLER PROGRAMMER

The controller programmer is a portable hand held unit that is carried from location to location to reprogram the controller. The unit operates on A.C. power and is a programmable read-only memory programmer with a cassette tape storage.

The fare collection system card and controller has been designed to identify, recognize, control, and catalog 100 categories of passengers and 10 different card values. If the program changes are small, it is possible to reprogram the controller through the use of a special encoded card.

TABLE 1. PROCEDURES FOR RESOLUTION OF CARD RELATED DISPUTES

METER READING	METER MESSAGE	ACTION REQUIRED OF COLLECTOR
00-00	Valid card	Return card to passenger and request passenger to try another passreader. If card still will not permit entrance, allow passenger to enter via pass gate. Report the defective machine or machines immediately to the dispatcher.
00-01	Under value card	Return card to passenger and explain to the passenger that the card is not valid at this station. The card is valid only at a lower fare station. Require passenger to pay regular fare to enter station. Do not accept partial payment of fare with this card.
00-02	Next month card	Return card to passenger and explain that the card is only valid for the month of purchase. Require passenger to pay regular fare.
00-03	Expired card	Hold card. Do not return to passenger. Explain that the card has expired. Require passenger to pay regular fare.
00-04	Invalid hour	This is a special pass with limited hours of access. Explain to the passenger that the card is not valid at this time and a regular fare must be paid.
00-05	Two people using pass by passing it back	Return Card to passenger. Explain that the card has been misused and regular fare must be paid. Further misuse will result in confiscation of the card.
00-06	Fraudulent	Hold card. Do not return to passenger. Require passenger to pay regular fee.

3.7 MASTER PROGRAMMER

The master programmer is a desk top unit used to generate and store the programs destined to be transferred to the controller. After the program is stored within the master programmer, the master programmer is used to reprogram the portable controller programs that are carried to the collection booths for the reprogramming of the controllers.

3.8 ENCODING MACHINE

The encoding machine is used to encode high energy magnetic tape cards, and possesses the capability of encoding 3,000 cards per hour. It has a "verify mode" to allow for a check of the validity of previously encoded cards and a "modify mode" to permit changes in a previously encoded card.

The MBTA can use the machine to produce special purpose cards, e.g., a one day pass for conventioneers. (Cards sold to the general public are encoded by a contractor to the MBTA.)

3.9 DATA COLLECTION UNIT

The magnetic card fare collection system has the capacity to recognize 100 categories of passengers and 10 different card values. The controller has been designed to store this type of information. Data collection units are portable devices used to extract this stored data from the controllers onto IBM 3740 compatible diskettes. The data on these units are eventually transferred to an MBTA central processing unit where they may be used to draw profiles on the types and numbers of card users, the times of use, and places of use.

This data collection feature has been designed into the magnetic card system, but data extraction and analysis is being conducted on a limited basis only.

4.0 SYSTEM EFFECTIVENESS

System effectiveness data was acquired through (1) discussions with MBTA operations and maintenance (O&M) personnel, (2) transmittal of limited O&M data, and (3) data obtained through direct observation of passengers entering token only and token/card turnstiles during rush hour.

The MBTA was in the process of data collection and performance assessment during the period that this same information was needed for inclusion in this report. The discussion that follows is based on the limited data that was available.

4.1 OPERABILITY

A site survey was made of three rapid transit passenger stations during the rush hour period. These stations included South Station, Washington Street, and Park Street. The objective of the survey was to assess the degree of order/confusion at the turnstiles during the rush hour.

The following was observed:

(1) the queue at mixed turnstiles[6] reached lengths on occasion of three to four people, but these queues disappeared quickly;

(2) the only observed persistent queue was at the collector's booth;

(3) some persons were seen entering by jumping over the turnstile arms;

(4) most of the passengers had their cards out and properly oriented many yards away from the turnstiles;

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[6]Turnstiles accepting tokens only or accepting both tokens and cards, i.e., mixed.

(5) the MBTA has deployed a large number of turnstile subsystems so that even though it was observed that a mixed turnstile was closed, there was no delay to entering passengers; and

(6) when on occasion a card did not work, an MBTA gateman opened the gate if the card passed visual inspection.[7]

Another indication of the operability of the magnetic card fare collection system is passenger acceptance. The MBTA reported an increase of 26% in the sales of magnetic cards over the sales of paper passes using the same months of the year for two consecutive years. This was due in part to an effective marketing plan and discount incentives as well as public acceptance of the new card.

4.2 RELIABILITY

The system specification requires a performance level of 400,000 mean cycles between failures (MCBF), i.e., the ratio of the summed magnetic card passenger entries over the entire population of installed hardware, divided by the total number of equipment failures, will not be less than 400,000. Reliability is the probability that a piece of equipment or a system will perform its intended function for a specified interval under stated conditions. MCBF is a parameter directly related to reliability. Based on data provided to DYNATREND for the period beginning December 9, 1980 to January 31, 1981, failure rates are estimated to be as follows:

[7]After the break-in period, if a card does not allow entry, then the passenger will go to the collector for a check of card validity (see Table 1). If it is determined that the card is valid but the turnstile will not open, then the collector will push a button that unlatches the gate, and the passenger will enter through the unlocked gate.

95% CHI-SQUARE CONFIDENCE INTERNAL[8]

MCBF / SUBSYSTEM	UPPER LIMIT	LOWER LIMIT
CONTROLLER	23,443	18,532
TURNSTILE	14,953	12,367
CONTROLLER AND TURNSTILE	8,845	7,631

Note that the MCBF for the controller and turnstile subsystems is considerably smaller than the requirement of 400,000. The computations for MCBF are based only on the data acquired in the second and third months of operation. During the early life of a system, it is not unusual to observe a high rate of failure due to the presence of defective parts. As these defective parts are weeded out, the system should enter a period of relative stability wherein only random-type catastrophic failures are expected.

4.3 REPAIRABILITY

Maintainability is made up of three factors (1) repairability or time to repair, (2) administrative time or time interval for preparation of orders, and (3) logistic time or time for people and parts to reach failed equipment. Information was not available for administrative and logistic times. It was reported by the MBTA that the mean time to repair (i.e., following arrival of the service person, is about 15 minutes. No data are available about the logistics time, time to acquire spare parts, administrative time, and administrative delays prior to and subsequent to actual initiation of repair. Without these times it is not possible to generate the mean maintenance time.

Preventative maintenance requirements are limited to a visual inspection of the equipment and associated wiring. Cleaning and lubricating of the mechanical portions of the turnstiles continues unchanged. A total of four

[8]There is a 95% probability that the MCBF as presented in the table will fall between the upper and lower limits indicated using the Chi-Square Test (one of many possible tests).

additional personnel have been required. Maintenance crews have been augmented by two persons, and two additional persons are needed for repair and test.

5.0 SUMMARY

This review and assessment of the MBTA magnetic card fare collection system has demonstrated the following:

(1) existing turnstiles can be simply retrofitted to accept both tokens and magnetic card entry,

(2) the controller unit located in the Collector's Booth presents no unusual problems of physical integration (which includes the wiring between the turnstiles and booth, the placement of the electronic box in the booth, and the interconnects) or specialized personnel training,

(3) hand transportation of the card by the passengers presents no difficulty and results in a significantly less complex system as compared with automatic mechanical card transport,

(4) the passengers have no difficulty in using the card system,

(5) the sales of magnetic cards have increased by 26% over paper pass[9] sales,

(6) the system availability, i.e., reliability and maintainability, and the number of magnetic card fare collection turnstiles deployed at stations is sufficiently high so that equipment failures do not result in any observable passenger delays,

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[9]Paper passes are in use on two surface lines at the present time.

(7) there is no noticeable difference in the time needed to pass through a turnstile using a card as compared to a token, and

(8) the magnetic card system has allowed the MBTA to lock the gate used with the previous paper pass system, thus forcing all passengers to use the turnstiles, establishing a new system which should stop fraud and increase revenues and recorded ridership.

REPORT OF NEW TECHNOLOGY

This report presents for the first time a detailed description and assessment of the MBTA magnetic card fare collection system. There is sufficient information to allow the owners and operators of transportation properties to determine the appropriateness of this fare collection system to their system's needs and requirements. It is expected that the favorable short term trends that were observed should continue to improve as more experience is gained in the understanding of system operation. The intention of this effort was to describe existing systems, and hence no new technology was developed.

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