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AUTOMATIC FARE COLLECTION EQUIPMENT RELIABILITY AND MAINTAINABILITY ASSESSMENT PLAN FOR URBAN RAIL TRANSIT PROPERTIES

Automated Services, Inc
1483 Chain Bridge Road
McLean VA 22101

MARCH 1981

FINAL REPORT

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16. Abstract

A generalized survey methodology for conducting assessments of automatic fare collection (AFC) equipment performance in urban rail transit properties is presented. As background for the methodology, the AFC systems at the Washington Metropolitan Area Transit Authority (WMATA) and the Bay Area Rapid Transit (BART) District are described. The discussion of the methodology covers types of data to be collected, data collection procedures, training of data collectors, timing and frequency of data collection periods, use of existing data systems, and levels of effort required for data collection. Analytic techniques and procedures are presented, including statistics to be generated, levels to which data may be aggregated, usefulness of statistics generated, and analysis and interpretation of these statistics. A suggested format for reporting and presentation of results is discussed. Finally, application of the methodology to other properties is described.

Appendix A contains the training plan utilized in implementing the methodology for an AFC equipment survey at BART. Appendix B presents the results of that survey.

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PREFACE

This project was conducted as part of the Rail Transit Fare Collection Program developed by the Transportation Systems Center. The successful completion of this project was made possible only through the cooperation and assistance of the Washington Metropolitan Area Transit Authority, the Bay Area Rapid District properties and the Transportation Systems Center, U.S. Department of Transportation, Urban Mass Transportation, Administration, Office of Technology Development and Deployment. In particular, Automated Services, Inc., wishes to acknowledge the assistance of Lloyd Johnson at WMATA, Robert Peshel at BART and Joseph Koziol at TSC.

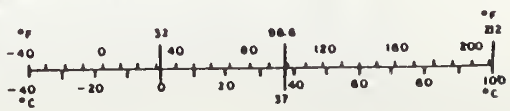
METRIC CONVERSION FACTORS

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	yards	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	teaspoons	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

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

This report represents the culmination of Automated Services' efforts, under contract to the U.S. Department of Transportation, Transportation Systems Center, to develop an Automatic Fare Collection (AFC) Data Study. The purpose of this contract was to support the Transportation Systems Center in its initial assessment of fare collection systems for their Rail Transit Fare Collection Program. In performance of this contract, Automated Services examined the Automatic Fare Collection systems and improvement programs at the Bay Area Rapid Transit (BART) District and the Washington Metropolitan Area Transit Authority (WMATA). Failure data collection and analysis efforts conducted by WMATA, were studied in detail to determine their use for application to BART.

The overall purpose of these initial activities was to acquire familiarity with the transit fare collection environment, which would provide a basis for developing a general survey and analysis methodology. This general methodology is intended to provide some standarized procedures for collecting automatic fare collection equipment performance data. The methodology can be used for a basic assessment of equipment performance, tracking performance over time, or for evaluating the effects of reliability improvement programs. An AFC survey at BART was conducted to demonstrate elements of the methodology and to refine its overall design.

Functional descriptions of AFC equipment and support systems at the WMATA and the BART are provided so the methodology developed and survey results may be seen in the context of the overall fare system. Information is presented on fare structure and fares, the number of fare collection machines in operation, patron flow paths, and equipment operation. Functional operations descriptions are sufficiently detailed so system differences between the WMATA and the BART are apparent. The responsibilities of station attendants in the operation and maintenance of the AFC systems are presented, as well as descriptions of existing data collection facilities and maintenance operations.

The assessment methodology considers two basic types of data: failure data and transaction data. Transaction data is the amount of usage of the equipment, measured in terms such as number of farecards issued by vendor or number of patrons entering or exiting a gate. Failures consist of two types; "hard" and "soft". "Hard" failures involve the services of maintenance personnel, while "soft" failures are those corrected by station attendants. Failure mode data is also required and is supplied as "Farecard jam," "Bill jam," etc. It is recommended that the distinction between "hard" and "soft" failures be maintained by all properties to provide a common base for systems evaluation.

It is emphasized that fare collection equipment does not operate continuously and experiences a wide variety of usage rates and that reliability and transactions per failure statistics are preferred since they reflect these operating conditions. A general methodology for data collection is presented, including the procedures for obtaining initial and final transaction data. The advantages of obtaining transaction data external to the equipment are presented. Typical survey forms are included, with a schedule of activities for survey team members in recording machine status, failure time and mode.

Training plan requirements to develop survey personnel data collection skills are presented. A primary requirement is a clear, brief description of expected failures and failure modes with associated hands-on experience with operating equipment. Sequence of survey activities must be specified and data forms completed with real data to assure that entry procedures and event coding are understood. Surveyors should become familiar with interior and exterior aspects of each type of machine, the location of each modular assembly, particularly the equipment data registers and maintenance indicators, to aid them in obtaining failure mode information and in understanding equipment function. To illustrate the plan development, the training program developed for use in surveying AFC equipment at BART, is included in an Appendix.

Timing and frequency of data collection depend on volume of data required to ensure a statistically sound and representative picture of equipment performance, and also on any hypotheses to be examined concerning time of equipment usage, such as a comparison of peak-hour performance vs. off-peak-hour performance.

Statistical background is provided and tables are developed to allow any property to perform two levels of analysis; confidence intervals and significance tests. The procedures and tables developed will allow management to determine how many survey observations must be made to determine the reliability of equipment groups or to detect reliability increase/decrease at a specified confidence level.

Guidance in the level of effort required in conducting AFC systems assessment is offered in discussions of survey team size, number of data collection periods required, and of summarization and analysis effort required.

A complete assessment procedure of the BART Automatic Fare Collection System, utilizing the assessment methodology developed is presented in two Appendices. Included in these Appendices are the training plan used, samples of all types of completed data collection forms and station layouts for the station's selected for participation in the survey and the survey data collection schedule.

Specific problems encountered in data collection are discussed, including interaction difficulties with property personnel having responsibilities outside of the operation of the AFC equipment.

Analysis presented includes data on the 58 AFC machines, of all types, at the three mezzanines selected for survey. Statistics displayed include total transactions, availability, reliability, mean time between failures, and transaction per failure ratios for all failures combined and for individual failure types. Similar presentations are given for each of the mezzanines surveyed to allow comparison of AFC operation across mezzanines.

SECTION I
INTRODUCTION

This document examines Automatic Fare Collection Systems (AFCS), improvement programs, and Data Collection Methods and Requirements at the Washington Metropolitan Area Transit Authority (WMATA) and the Bay Area Rapid Transit (BART) District. Under contract to the U.S. Department of Transportation, Transportation Systems Center (TSC), Automated Services, Inc. prepared this report to accompany the Rail Transit Fare Collection Program developed by TSC. An important part of the project includes failure data collection & analysis efforts that were conducted by WMATA. This material was studied in detail to determine any possible applications to BART for improvements to the system.

The Automatic Fare Collection Systems at WMATA and BART were primarily examined to gain familiarity with the transit fare collection environment. The knowledge acquired from this examination provided a basis for developing a general survey and analysis methodology. The overall purpose for providing a general methodology is to make some standardized procedures available in collecting performance data for automatic fare collection equipment. In collecting AFC equipment performance data, the general methodology can be used in making basic assessments of equipment performance, tracking performance over a period of time, or in analyzing the effects of reliability improvement programs. The AFC survey at BART was conducted to demonstrate these elements and to refine the overall design of the methodology.

The sections of this report describe the details of the methodology, analytic techniques and procedures, reporting of results, and applications to other properties.

SECTION II
AUTOMATIC FARE COLLECTION
SYSTEM DESCRIPTIONS

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

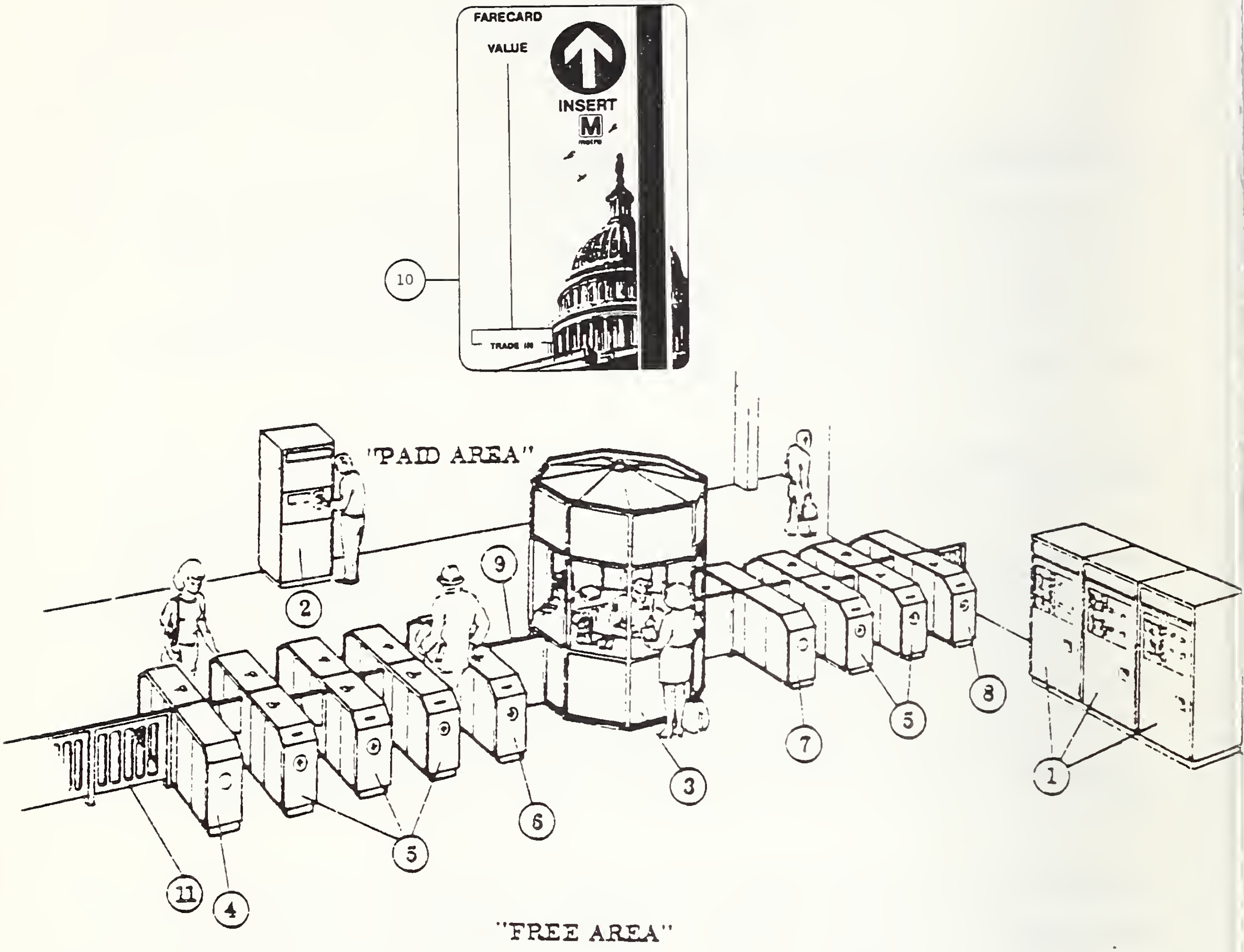
The Washington Metropolitan Area Transit Authority (WMATA) Automatic Fare Collection System (AFCS) is described in terms of Fare Structure, Patron Flow, Composite System Description, Individual Equipment Descriptions, System Maintenance, Mezzanine Attendant Interactions and system associated Data Storage and Retrieval systems.

General AFCS Description.

WMATA has a dual fare structure, a mileage-based fare during peak hours and a flat fare during off-peak hours. During peak hours the base fare is $0.45, which represents the first three miles of travel. The charge per mile beyond the first three miles is $0.95, with each route fare rounded to the nearest $0.05. Metrorail operating hours are from 6:00 a.m. to 12:00 a.m., Monday through Friday. Saturday hours are 8:00 a.m. to 12:00 a.m. and Sunday, 10:00 a.m. to 6:00 p.m. Holidays are assigned Saturday or Sunday schedules, except Independence Day which has special scheduling. All off-peak hour fares are $0.50.

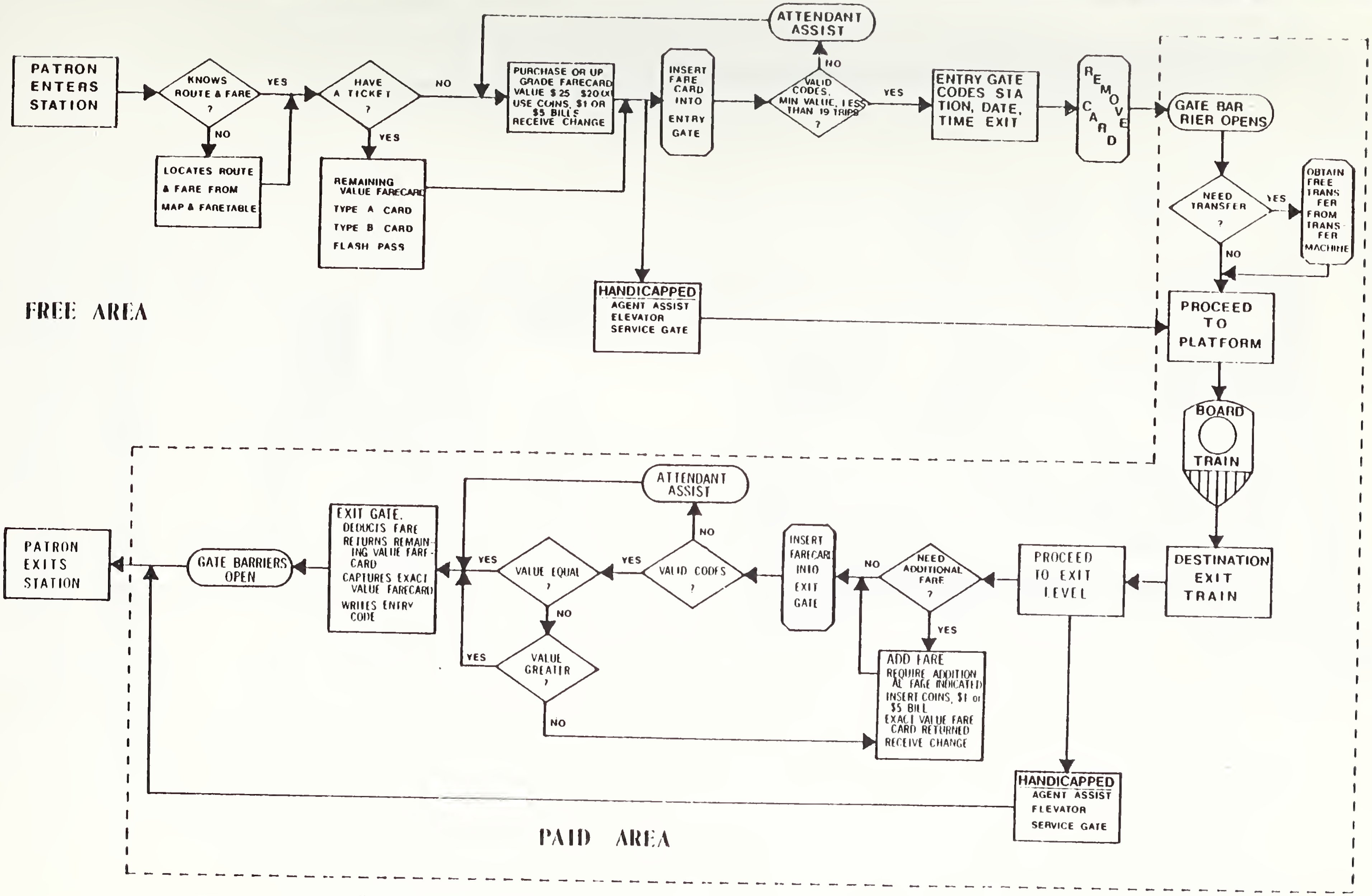
The WMATA Fare Collection System, as currently structured, consists of farecard vending machines, addfare machines, entry/exit passenger gates and control consoles in 53 mezzanines located at 37 stations. An additional 45 stations are planned to complete the 101-mile system. Each mezzanine, illustrated in Figure II-1, is divided into "free" and "paid" areas by an array formed from passenger gates, service gates, railings and attendant kiosk. Patron flow through this system is shown in Figure II-2. Patrons entering a station who do not already have a farecard can purchase one from a farecard vendor located in the "free" area. Each patron, over five years of age, must have a farecard to enter the "paid" area. Figures II-3 and II-4 respectively, show a farecard vendor and a farecard.

Passenger gates, as shown in Figure II-5, form entry and exit aisles marked by lighted green arrows on the end of the gate console facing patron. Patron entering system locates an aisle marked by a lighted arrow and inserts farecard



KEY NO.	NAME	KEY NO.	NAME
1	Farecard Vendor	6	End A Gate
2	Addfare Machine	7	End B Gate
3	Station Attendant Kiosk w/DADS	8	Entry Gate
		9	Service Gate
4	Exit Gate	10	WMATA Farecard
5	Reversible Gate	11	Railing

FIGURE II-1 WMATA TYPICAL MEZZANINE EQUIPMENT



WMATA Automatic Fare Collection System
PATRON FLOW DIAGRAM
MARCH 1980

FIGURE II-2

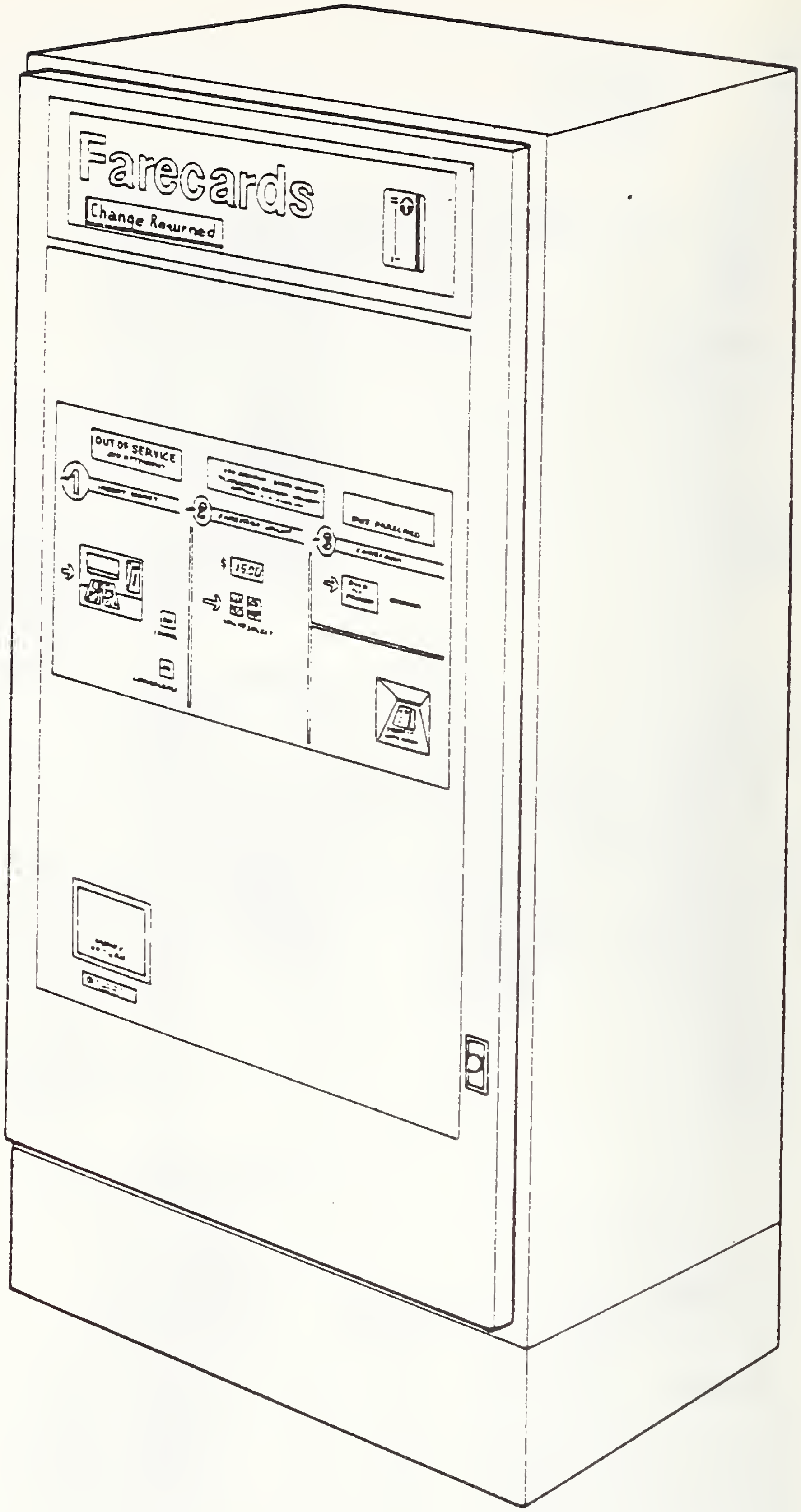


FIGURE II-3   FARECARD VENDOR

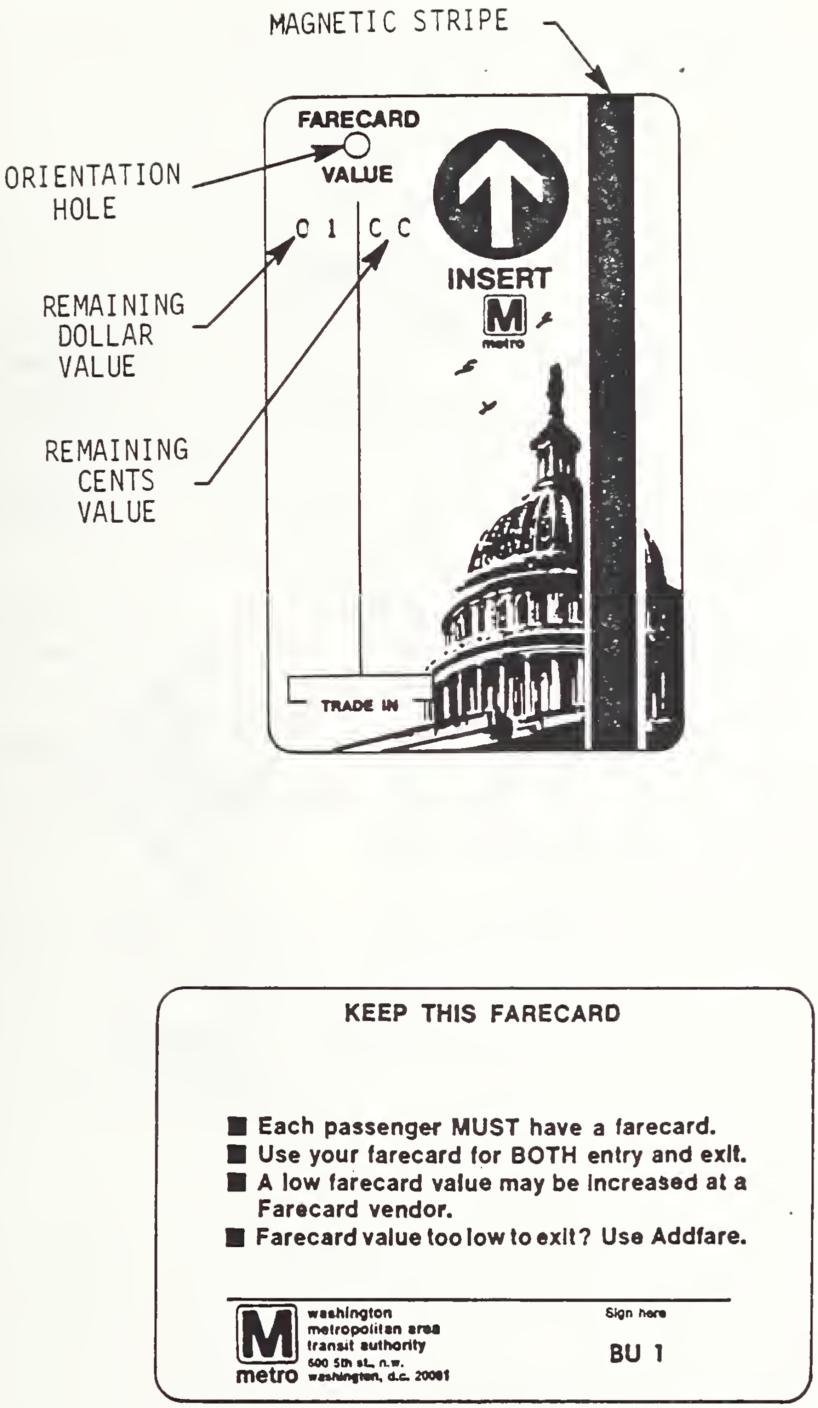


FIGURE II-4 WMATA METRO FARECARD

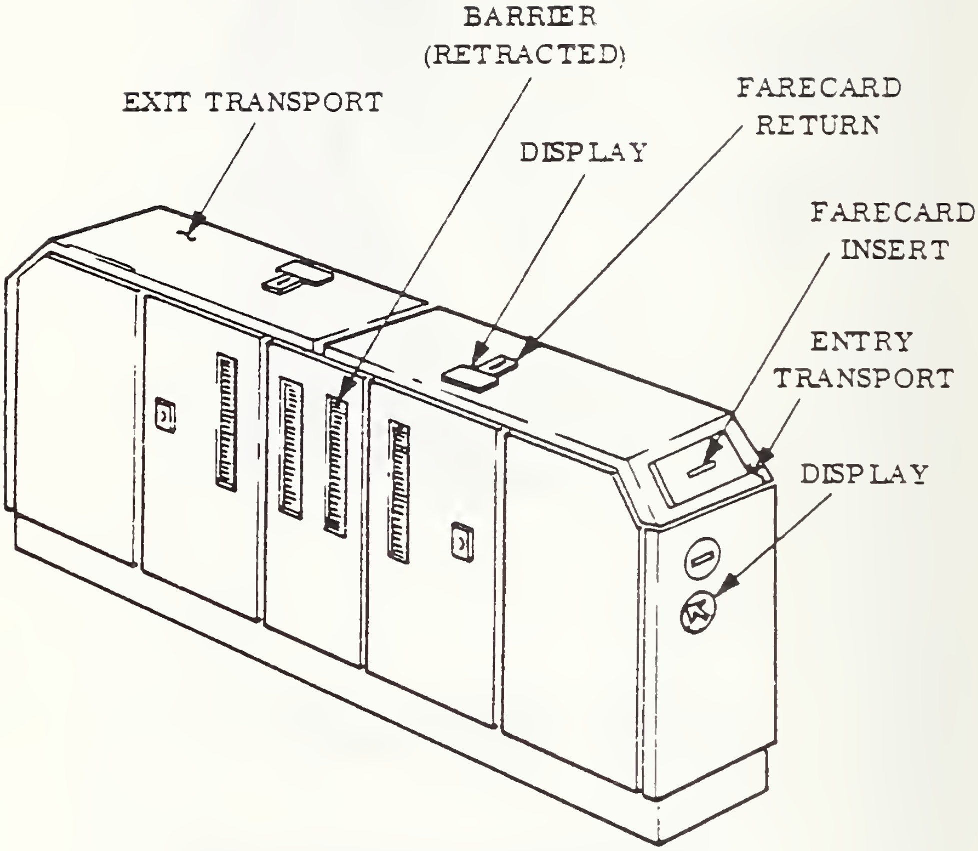


FIGURE II-5 TYPICAL REVERSIBLE PASSENGER GATE into slot located on sloping end of panel of the gate console. When farecard is returned by gate and removed by patron, aisle barriers open and allow entry to "paid" area. Patron proceeds to proper platform.

If trip is to be continued by Metrobus, patron takes a transfer slip, issued by Transfer Machine located near platform escalators. Transfer must be taken at station of entry to be valid for continuing journey on Metrobus. On arrival at destination, patron locates an exit aisle marked by lighted arrow and inserts farecard in gate. If farecard has exact fare stored, gate will capture card and open barriers for patron. If stored value is greater than fare, fare value will be subtracted and farecard with remaining value returned to patron for exit. When a farecard with less than required value for exit is inserted, gate display tells patron to go to addfare machine. When patron inserts farecard in addfare, shown in Figure II-6, the machine displays amount required to increase farecard value to that required for exit. When sufficient money is deposited, machine revalues farecard to exact value required for exit and returns card to patron. Patron inserts card in gate which captures card and opens barriers for patron.

Each mezzanine attendant, who has the basic level of responsibility for the proper operation of the Automatic Fare Collection System, has access to the Data Acquisition and Display System, shown in Figure II-7, located in the kiosk. This equipment allows the attendant remote control of some equipment operational settings, so that settings can be varied to accommodate changes in patron flow.

As of March 1980, the WMATA Automatic Fare Collection System consists of 862 pieces of equipment installed in mezzanines. There are 283 farecard vendors, 107 addfare machines, 419 passenger gate consoles and 53 data acquisition and display consoles. The total number of machines in use and their distribution will change with completion of each additional segment of the WMATA system. All equipment was procured from Cubic-Western Data.

Farecard. The WMATA Farecard as shown in Figure II-3 is a paper card 2-1/8 by 3-3/8 inches with an orientation check hole in the leading edge, space for printing remaining stored value for 19 transactions, and an attached magnetic strip to accept the following magnetic encoding:

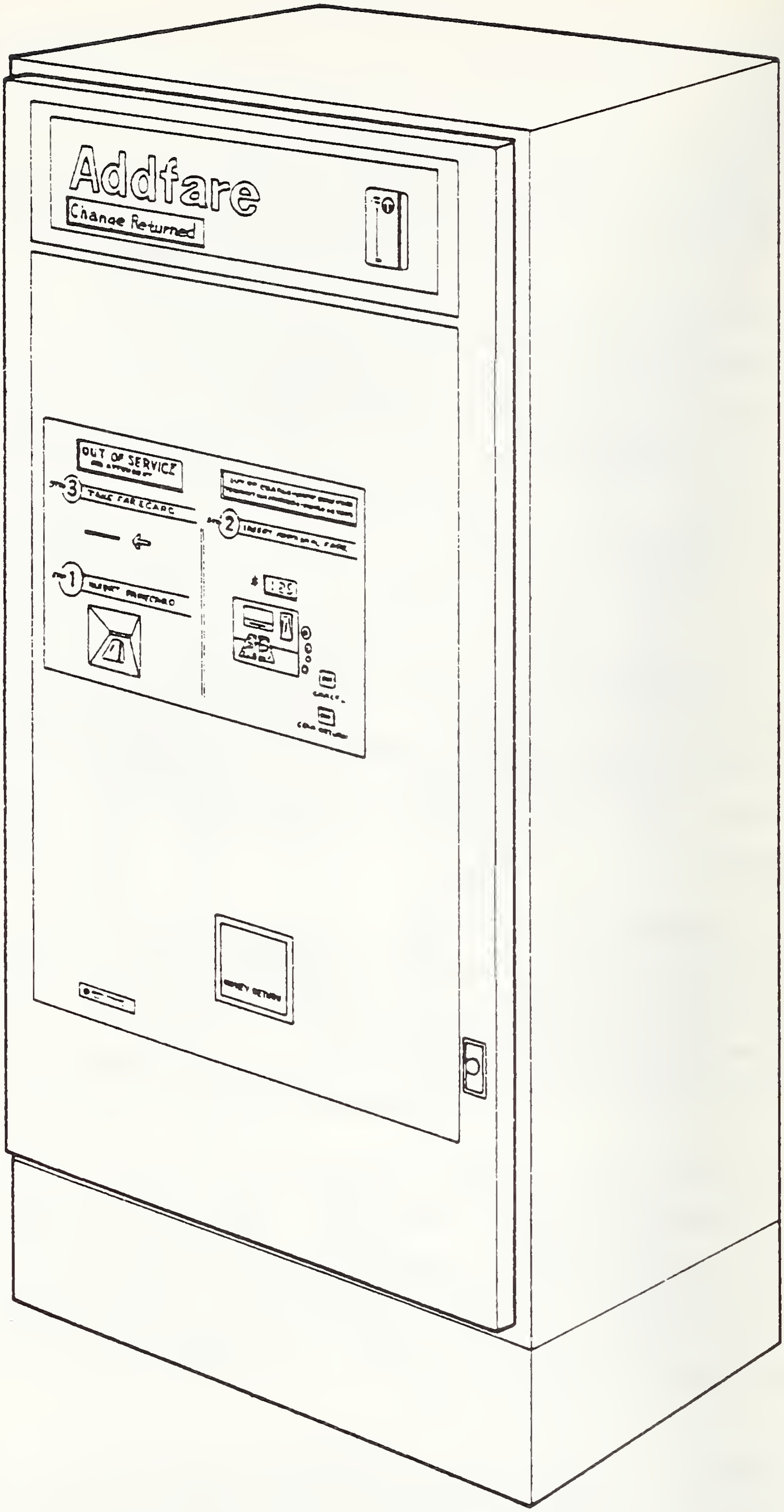


FIGURE II-6 ADDFARE MACHINE

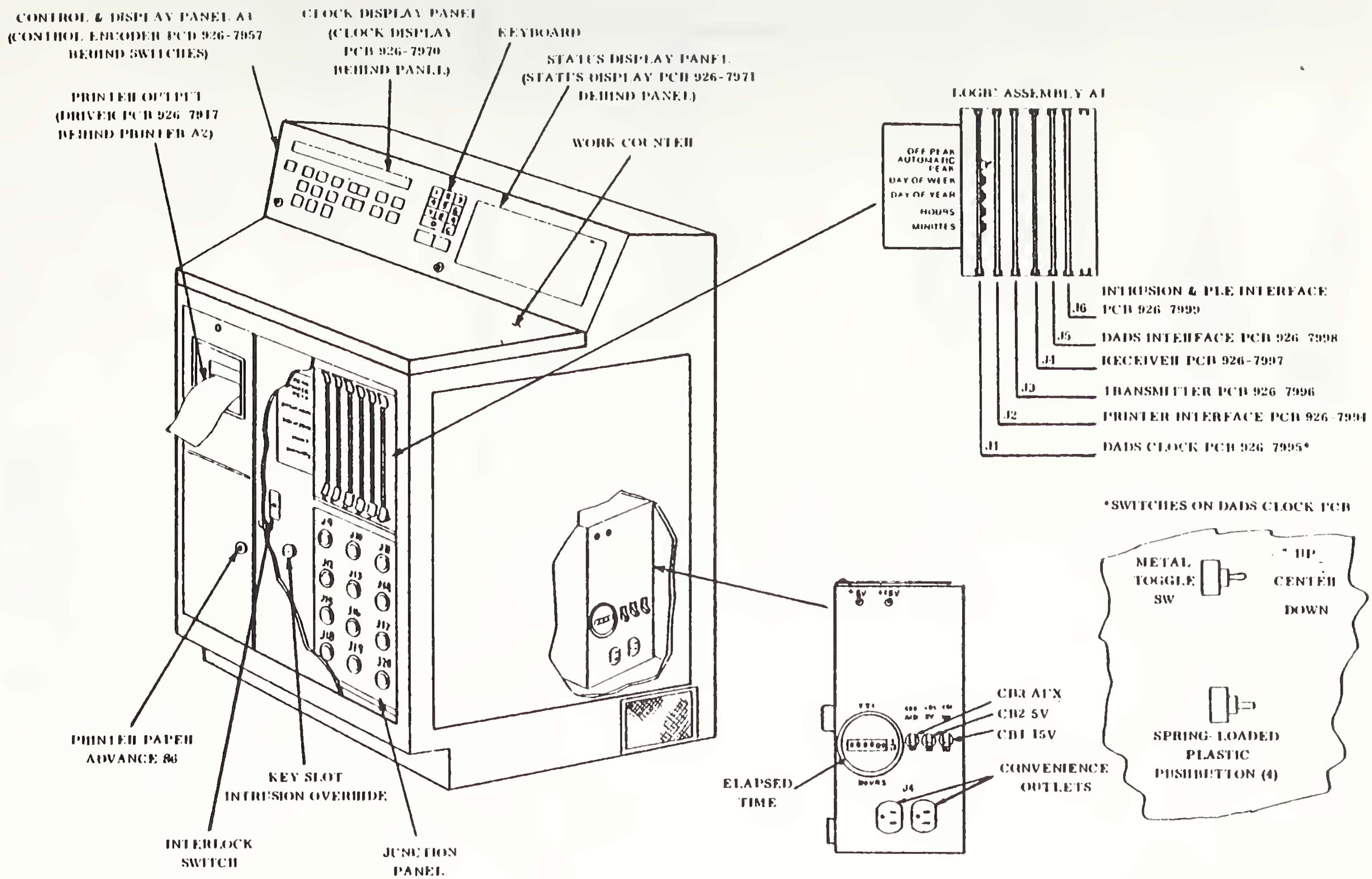


FIGURE II- 7 COMPONENTS IN DADS CONSOLE

(1) Day and Time Code - Identifies the time period of the patron's entry into the WMATA system.

(2) Station of Origin Code - Identifies the entry station to provide data for fare collection at the exit station.

(3) Entry/Exit Code - Ensures the farecard has been used in a valid sequence.

(4) Number of Uses - Directs the Exit Gate printer to print on the proper line, and ensures that only 19 lines are printed on a farecard.

(5) Remaining Value - Updated and printed on the farecard by the Exit gate.

(6) Control and Security Codes - Provide validation, completeness of recorded data, and security.

Farecard Vendor. Farecard vendors are located in the "free" area near the gate arrays. They will accept one dollar and five dollar bills and fifty cent, twenty-five cent, ten cent and five cent coins in United States money. Canadian coins will be rejected by the coin acceptor. The vendor will also accept farecards with remaining value below $1.95. A new card will be issued for remaining value, regardless of amount remaining, for farecards with 19 lines printed. The patron may insert in any order, bills, coins and a remaining value farecard to obtain a farecard of any value from $0.45 to $20.00. Figure II-8 shows the patron controls and displays.

Bills inserted in the bill slot, and having the proper orientation (portrait up,top of portrait facing right), will be scanned magnetically in the bill validator to check validity and denomination of bills. Invalid bills, bills improperly oriented and some damaged bills will be returned to patron. Bills accepted will be held in an escrow box pending completion of transaction. The value of each accepted bill will be placed in logic storage and shown on Farecard Value display panel.

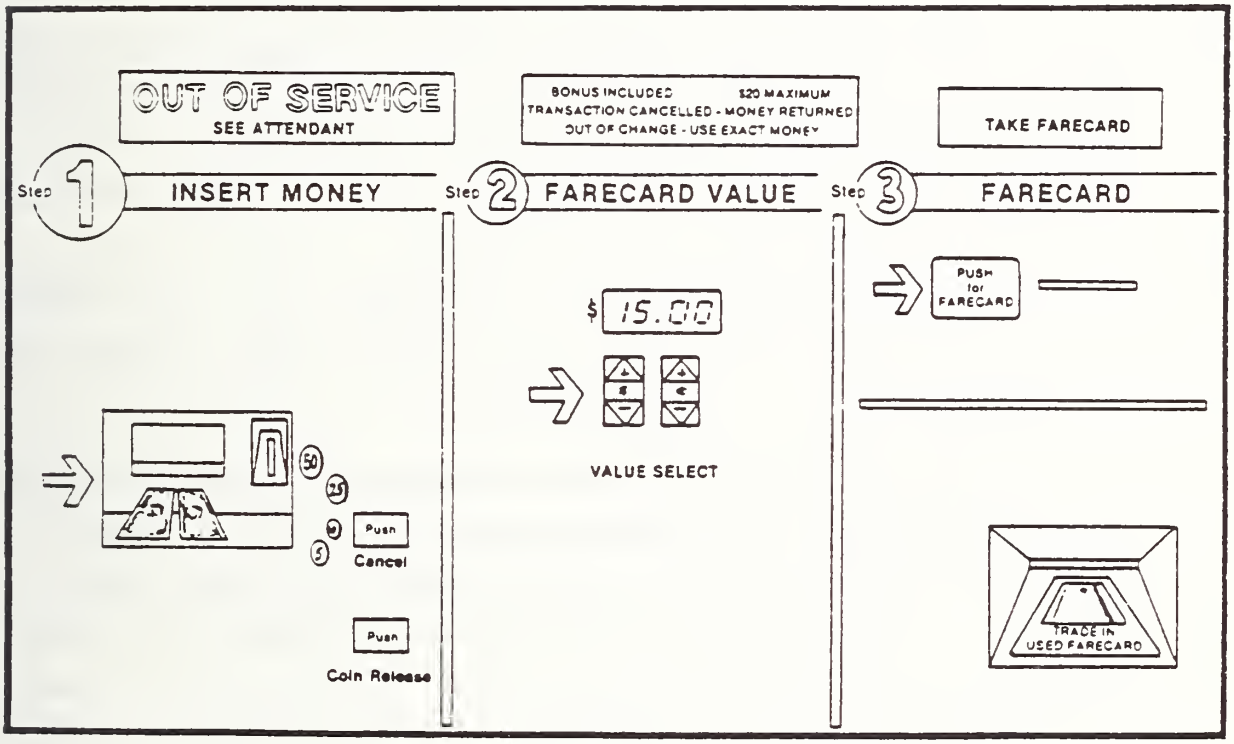


FIGURE II-8 FARECARD VENDOR PATRON CONTROLS AND DISPLAYS

Coins inserted in marked slots will be examined, in the coin acceptor, to determine that their diameter, weight, perforations and metallic content are within specifications. Invalid coins will be returned to the Money Return cup. Generally, bent coins will also be returned to Money Return cup, but may require the patron to firmly press the Coin Release.

A farecard with remaining value may be inserted in Trade In Used Farecard slot. At the first magnetic read head, the card validity will be checked and a determination made that the entry/exit code is entry. If either condition is not met, the See Agent display is lit and the card and any monies deposited are returned to patron. If card is valid, it is held in escrow pending completion of transaction. The card's remaining value will be entered in logic and added to amount shown on Farecard Value display panel.

With all currency and remaining value card deposited, patron may elect to change Farecard Value. This is done by pressing the "$-" control to produce one dollar decrements and the "¢-" control to produce nickel decrements. If Farecard Value is reduced beyond that desired by patron, value can be restored by pressing "$+" control for one dollar increments or "¢+" control for nickel increments.

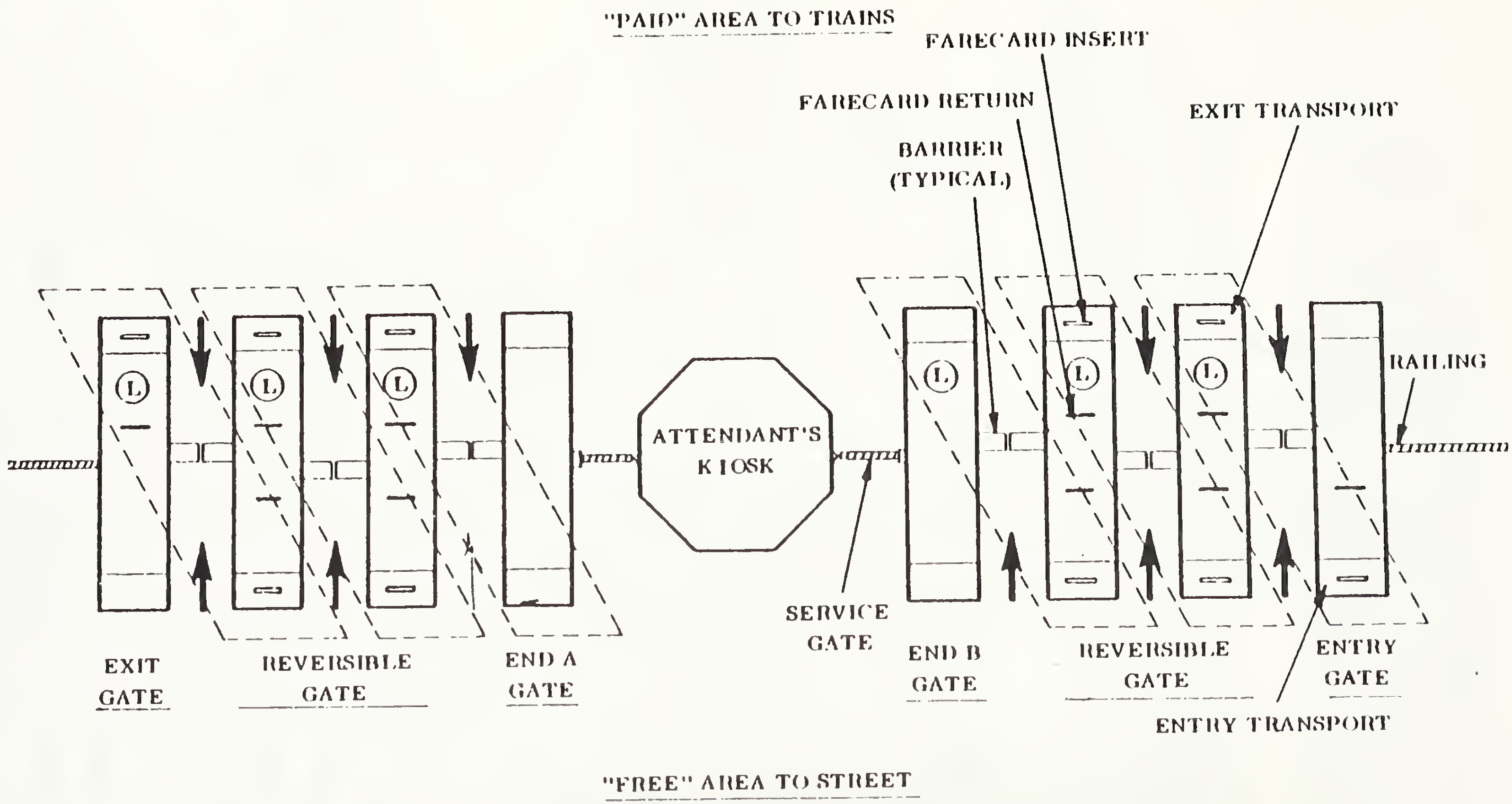
When patron has selected desired farecard value and activated the Push for Farecard control, the machine will select a blank farecard from the farecard hopper. The card's magnetic strip will be written with selected farecard value, entry code, and security and vend codes. The written data will be verified. If verification is not achieved after two machine write/verify cycles, the vendor will be automatically placed Out of Service and all currency and old farecard returned to patron.

A verified card will have its value printed in the print column and will be transported to the farecard exit slot where patron can remove it. If change is required, an appropriate number of quarters and nickels will be channeled to the Money Return cup and the cup light lit to remind patron to retrieve his change. All bill, coin, change and farecard value information in the logic unit will be transferred to the machine registers. Bills in escrow are transferred and stacked in the Bill Vault. Coins in escrow are transferred to the Coin Vault.

Patron may at anytime, prior to activating the Push for Farecard control, cancel the transaction by pushing the Cancel control. If this is done, all currency in escrow boxes are emptied into the Money Return cup and old farecard, if inserted, is sent to exit slot. Transaction Cancelled display will be lit.

Passenger Gates. Figure II-9 shows a typical gate array in the barrier between "free" and "paid" areas. As shown by the dotted lines, two gate consoles make up one passenger aisle. The combinations of exit gate/reversible gate, reversible gate/reversible gate, entry gate/ reversible gate form bidirectional aisles. An End A/reversible combination can form only an exit aisle while an End B/reversible combination forms only an entry aisle. Bidirectional aisles will be set by kiosk attendants for entry or exit depending on the patron flow pattern.

A patron going from the "free" to "paid" area locates aisle marked by illuminated arrow. Patron must insert farecard with arrow side up and pointing forward. Gate will determine proper card insertion. When proper card orientation is determined, card barrier will be opened and card transferred to magnetic read station. At the read station, gate will read magnetic strip to determine that minimum fare is encoded, that there is space remaining in print column, that card is coded for entry, and that valid security codes are present. Non-valid cards will be returned to card exit slot and Stop and See Attendant displays lit. A valid card will be transferred to the magnetic station where station of entry, time and exit codes are written on magnetic strip. The written data is checked for correctness at verification station. A verified card is sent to farecard return slot and Take Farecard display lit. If gate is unable to verify written data, the card is sent to farecard return slot and Stop and See Attendant displays are lit. Gate displays are illustrated in Figure II-10.



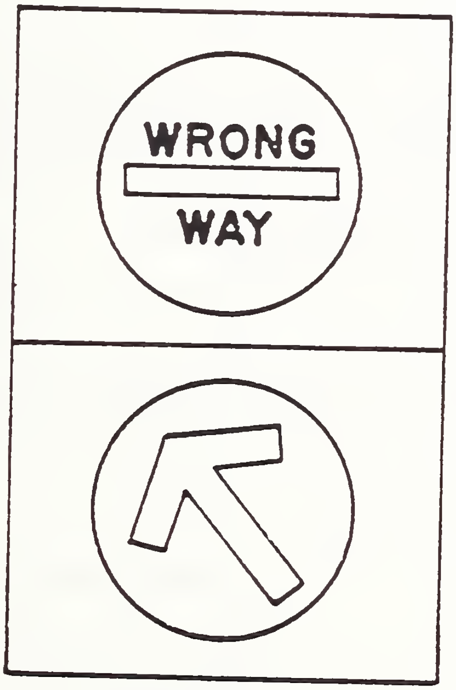
NOTES:

1. DASHED LINES ENCLOSE THE FUNCTIONALLY RELATED LOGIC UNITS, TRANSPORTS, AND AISLE BARRIERS.
2. (L) REPRESENTS CONTROLLING LOGIC ASSEMBLY

FIGURE II-9 TYPICAL PASSENGER GATE ARRAY

ENTRY DISPLAY

EXIT DISPLAY



AISLE DISPLAY

FIGURE II-10 PASSENGER GATE PATRON DISPLAYS

When patron removes verified farecard from farecard return, electric motors swing barriers into aisle consoles to allow patron to enter "paid" area. Sensors associated with barriers detect patron passage, provide a "patron in" signal to gate registers, and initiate barrier closure if there is no following patron. In order to allow smooth passenger flow under peak conditions, the barriers will remain open when a passenger processes a farecard through the gate prior to previous passenger clearing the barrier area.

A patron going from "paid" to "free" area follows same procedures as above to locate exit aisle and insert farecard. The gate will read time of entry, entry/exit, control and security codes written on magnetic strip. If data indicates same day entry with time lapse not greater than three hours, exit code and valid security codes, card will be accepted for processing. If any invalid codes are read, farecard will be sent to farecard return slot and Stop and See Attendant displays will be lit. If farecard value is exact fare required for exit, the gate will write zero value on magnetic strip, capture farecard, open barriers and light Exact Fare - Farecard Not Returned display. If farecard value is greater than fare required to exit, trip fare will be subtracted from farecard value and the remaining value, entry code, and number of uses code will be written on magnetic strip and verified. The remaining value will be printed in print column and card returned to patron. When patron removes card, barriers will open and allow entry to "free" area. When farecard value is less than fare required for exit, card is returned directly to patron and See Addfare display is lit.

Addfare. When patron knows that remaining value on farecard is insufficient to exit station or has been sent to addfare by gate display or mezzanine attendant, he goes to addfare machine located in the "paid" area. Addfare controls and displays are shown in Figure II-11. Patron puts farecard in Insert Farecard slot in proper orientation to initiate farecard transport. When valid card is accepted, the station of entry is read and fare to station of exit calculated. If card value is less than required fare, machine logic will calculate the additional fare required and

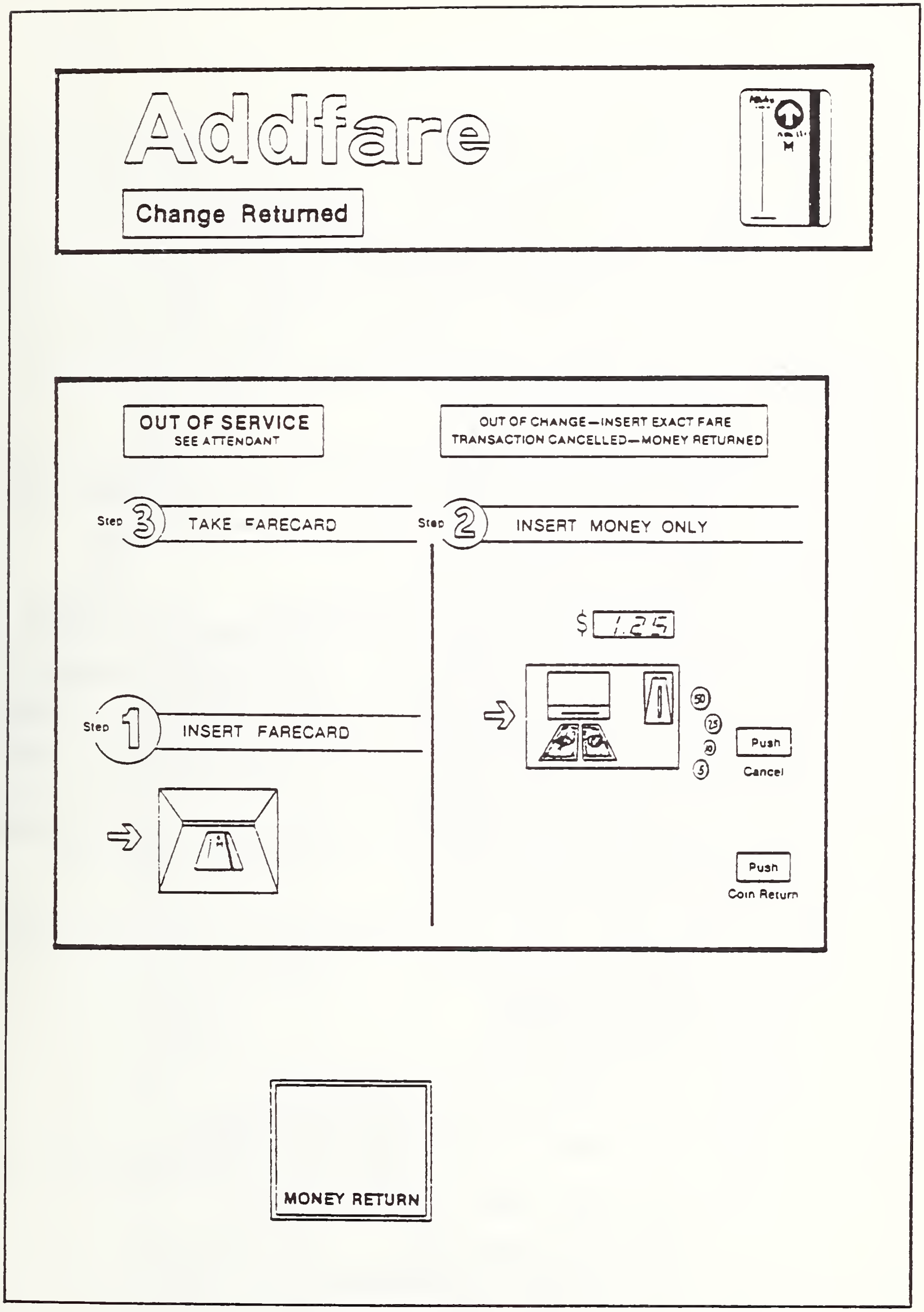


FIGURE II-11

ADDFARE PATRON CONTROLS AND DISPLAYS

show this amount in the Step 2 display window. Patron may then insert currency equal to, or greater than amount required to reduce display to zero value (unless Out of Change - Insert Exact Fare display is lit). If farecard value is equal to, or greater than the calculated fare, card is returned to patron and See Attendant display is lit. When over-payment is made, appropriate change in quarters and nickels will be returned. Farecard will be encoded with exact value required for exit (value will not be printed) and returned to patron at Step 3.

All WMATA Addfare machines have been modified to accept one and five dollar bills, without associated farecard and to return change in quarters to facilitate use of parking meters located in some mezzanines.

Data Acquisition and Display System and Console. One Data Acquisition and Display System (DADS) console is located immediately to the right when entering the attendant's kiosk. This console is electrically connected to each fare collection machine in the mezzanine to accept signals from equipment registers and malfunction/intrusion status sensors. Machine sensors are interrogated at one second intervals. Activation of any sensor is displayed as a light emitting diode indicator on the Status of Machines display. The DADS control panel is illustrated in Figure II-12.

Malfunction, intrusion and status indicators, as listed on the matrix are:

1) Out of Service
2) Test Mode
3) Door Open
4) Farecard Jam
5) Failure to Verify Farecard Encoding
6) Special Farecard (Type "A" - Student, Type "B" - Senior Citizen)
7) Entry (Gates only)
8) Exit (Gates only)
9) Farecards Low (Vendors only)
10) Bill Jam (Vendors, Addfares)

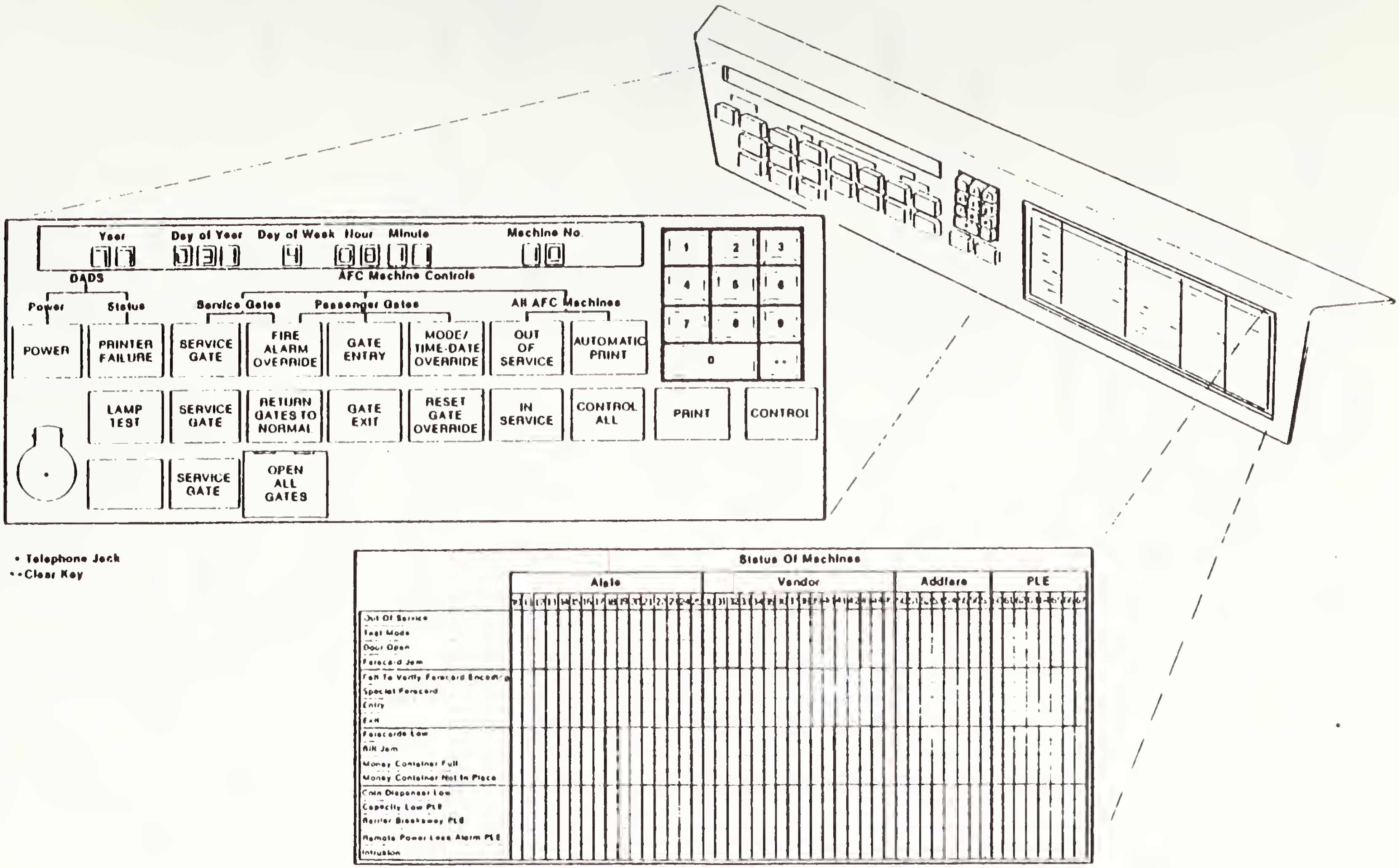


FIGURE II-12 DADS CONSOLE CONTROL AND DISPLAY PANEL

11) Money Container Full (Vendors, Addfares)
12) Money Container Not in Place (Vendors, Addfares)
13) Coin Dispenser Low (Vendors, Addfares)
14) Capacity Low (Parking lot equipment only)
15) Barrier Breakaway (Parking lot equipment only)
16) Remote Power Loss Alarm (Parking lot equipment only)
17) Intrusion (All fare and parking lot equipment with money handling capabilities)

Registers in each machine, which record cumulative transactions and fiscal information can be read out at any time, individually or automatically in numerical sequence. An example of a register readout for each equipment type is shown in Figure II-13.

The Data Acquisition and Display System also generates and transmits time signals to all gates to provide a time base for change in fare calculations during off-peak hours of operation. This signal provides a date/time base for all register printouts from any fare collection machine.

Additionally, all fare collection machines can be designated Out of Service or In Service from the Data Acquisition and Display System console by remote control. Passenger aisles can be changed from entry or exit modes, barriers can be set open, and time/date mode overridden from the console.

Automatic Fare Collection System Maintenance

From installation to the present, Automatic Fare Collection System maintenance has been performed by the equipment developer, Cubic-Western Data, on a year-by-year contract basis with WMATA. Maintenance operations are performed by Cubic-Western Data subcontractors, under the direction of Cubic-Western Data. Spare parts procurement has been carried out under the equipment procurement contract. Maintenance personnel are dedicated to a particular zone, but are stationed at L'Enfant Plaza Station. Spare parts stocks, test equipment, test and repair facilities are also located at L'Enfant Plaza.

	0000005051
	0763661430
ADDFARE (50)	
$CHANGE	0000216435
$COINS ACCEPTED	0000154150
$AMOUNT ISSUED	0000408850
$5 BILLS ACCEPTED	0000001455
$1 BILLS ACCEPTED	0000002032
SUCCESSFUL XACTIONS	0000002830
	0000005050
	0763661430
	0000005049
	0763661430
	0000005013
	0763661429
REV. GATE (12)	
PATRONS IN	0000000319
FARE EXTRACTED	0000400490
'B'	0000000195
'A'	0000000243
ZERO VALUE CAP.	0000000086
PATRONS OUT	0000008447
	0000005012
	0763661429
EXIT GATE(11)	
PATRONS IN	0000001520
FARE EXTRACTED	0001285250
'B'	0000000167
'A'	0000000177
ZERO VALUE CAP.	0000000195
PATRONS OUT	0000003242
	0000005011
	0763661429
	0000005010
	0763661429

	0000005031
	0763661429
VENDOR (30)	
$CHANGE	0000077415
$OLD FARECARDS	0001172475
$BONUS PAID	0000192225
$AMOUNT ISSUED	0001662770
FARECARDS NOT VERIFIED	0000697085
FARECARDS ACCEPTED	0000000293
NO. SUCCESSFUL XACTIONS	0000031702
$5 BILLS ACCEPTED	0000025253
$1 BILLS ACCEPTED	0000008646
	0000089931
	0000005030
	0763661429
	0000005021
	0763661429
ENTRY GATE (20)	
	0000000000
	0000000000
	0000000000
	0000000000
	0000000000
PATRONS IN	0000002528
	0000005020
	0763661429

FIGURE II-13. EXAMPLE OF REGISTER READOUT

When mezzanine attendant has determined that he cannot correct an equipment failure, he will call central maintenance dispatching and report failure details, to ensure that proper replacement units can be transported to the attendant by zone personnel. A maintenance report is initiated for each action. When all associated adjustments, replacements and shop repair actions have been completed, data from the maintenance report is entered in the Cubic-Western Data Computer Data Storage and Retrieval System.

It is planned that all Automatic Fare Collection equipment will be maintained by WMATA starting in July 1980. It is expected that the four zone system (as shown below) will be retained and that satellite offices will be established for zone personnel with appropriate parts stockage.

Zone I - National A/P, Crystal City, Pentagon City, Pentagon, Arlington Cemetery, Rosslyn, Foggy Bottom, Courthouse, Clarendon, Virginia Square, Balston.

Zone II - Farragut West, McPherson Square, Metro Center, Federal Triangle, Smithsonian, Farragut North.

Zone III - Dupont Circle, Gallery Place, Judiciary Square, Union Station, Rhode Island Avenue, Brookland, Fort Totten, Takoma, Silver Spring.

Zone IV - L'Enfant Plaza, Federal Center, Capital South, Eastern Market, Potomac Avenue, Stadium/Armory, Minnesota Avenue, Deanwood, Cheverly, Landover, New Carrollton.

FIGURE II-14 WMATA MAINTENANCE ZONES

Mezzanine Attendant Responsibilities

Prior to the start of passenger operations, attendants energize the Data Acquisition and Display System, test display lamps, and update clock signals. A safety check is made of the Open All Gates operation. An audit of all machine registers is made for use by financial and security offices. Attendant puts all fare collection equipment into service and sets all reversible aisles into the entry/exit pattern that has been determined to be optimum for the initial operating period. This configuration can be changed whenever dictated by passenger flow patterns.

After 1½ hours of operation, attendant makes a report to Maintenance Central of all Out of Service equipment.

Attendant responds to patron or equipment supplied reports of malfunctions. Specific attendant maintenance responsibilities by type of equipment are:

A. Farecard Vendor
   1. Money Jams
      a. Change hopper jam
      b. Change dispenser jam
      c. Coin acceptor jam
      d. Bill validator jam
      e. Bill escrow jam

All these jams require opening the Farecard Vendor door, disabling the intrusion alarm and reading the internal maintenance indicators to learn area of malfunction. Attendant will remove or make accessible components, such as bill escrow box or coin acceptor, to locate and remove jammed bills or coins. When jam is cleared, machine is checked by running test bills or coins through the affected mechanism to ensure that jam is not repetitive. If jam is repetitive or cannot be cleared, attendant will call maintenance dispatcher to request maintenance personnel and will enter incident into mezzanine log.

2. Farecard jams
    a. Basic farecard transport
    b. Printer
    c. Farecard return path
    d. Farecard hopper
    e. Farecard encoding station

All attendant correction procedures involve gaining access to the entire farecard transport path until the jam area is located and the farecard removed. Farecard is examined to determine its status, i.e., torn, folded, improperly loaded into hopper, etc. Test farecards are processed to determine if jam is cleared or will repeat. If jam repeats, maintenance personnel are called.

B. Addfare. Attendant responsibilities for the addfare machine are identical to those for the farecard vendor except that there is no requirement for printer or farecard hopper corrective maintenance.

C. Passenger Gates.
1. Farecard jams
    a. Entry transport
    b. Exit transport
    c. Basic transport
    c. Printer

In the event of any of the above farecard jams the attendant will (1) locate the gate affected from the DADS display, (2) open the gate and expose the farecard path, (3) remove the jammed farecard, and (4) examine the farecard and surrounding area at the jam site to determine any obvious problems. For any other gate failures, such as consistent failure to verify, the attendant will call for maintenance personnel.

Attendants may place any machine out of service in the event of consistent failure or emergency situation. In the event of a mezzanine fire, they will open all aisle barriers, either through DADS control or from individual gates.

Attendants may offer assistance to patrons having difficulties in using the fare collection system or inserting currency into the equipment.

When maintenance personnel arrive at the mezzanine, attendants set the priority for maintenance actions and provide access to locked portions of fare machines. Attendant is responsible for entering in the mezzanine log all incidents involving maintenance personnel action.

Automatic Fare Collection Data Systems

Two primary sources of AFC equipment performance and reliability have been utilized at WMATA. The first is a computer storage and retrieval system of maintenance information developed by the equipment supplier. The second is a series of peak hour performance surveys in which data collectors compiled first-hand information on AFC equipment failures.

Maintenance Computer Data Storage and Retrieval System. All maintenance actions resulting in a completed maintenance report (Figure II-15 a, b) are entered into computer memory at the Cubic-Western Data facilities in San Diego CA. Computer output is as shown in Figure II-16.

WMATA AFC Peak Hour Performance Survey.

The initial surveys, starting in October 1979, placed two observers at each of four selected mezzanines for 9.5 hours of failure recording during morning and evening rush hours. The mezzanines observed were Silver Spring (South), Farragut West (17th and Eye St.), Farragut West (18th and Eye St.), and Rosslyn. Using the Data Acquisition Display System status information display, one observer noted out of service conditions and recorded them as shown in Figure II-17, to show time of occurrence and time of return to service. The other observer obtained detailed information on nature of failure, who cleared failure, etc. Data Acquisition and Display System audits at beginning and end of each survey period were taken to record exit and entrance patronage, number of successful transactions and revenue data for each machine. As shown on Figure II-18, aggregate uptime and downtime for entry aisles, exit aisles, farecard vendors, and addfare machines for AM and PM peak hours for each day of a two-day survey period were calculated. This allowed calculation of aggretate equipment

CUBIC WESTERN DATA

AFCS MAINTENANCE REPORT   PROJECT: ☐   No. 0998

FAILURE NUMBER: PAGE ___ OF ___   OUT OF SERVICE DATE: TIME:

MEZZANINE NUMBER: MACHINE S/N: MAINT. STARTED DATE: TIME:

TYPE OF TASK: ☐
1. INSTALLATION
3. CORR. MAINT.
4. PREV. MAINT.
7. MODIFICATION
8. OTHER: ______

MEZZANINE ENVIRONMENT: ☐
1. DRY & HOT
2. DRY & COLD
3. HUMID & HOT
4. HUMID & COLD
6. OTHER: ______

EFFECT ON SERVICE: ☐
1. STOPPED
2. DEGRADED
3. NONE

TROUBLE DURING ☐
1. INSTALLATION
3. CORR. MAINT.
4. PREV. MAINT.
5. REVENUE SERVICE
6. OTHER: ______

SYMPTOMS: ______

INITIALS: ______

REGISTER DATA

HOURS: $5
PATRONS IN: $1
PATRONS OUT: SUCCESSFUL TRANS:
FARECARD INPUT:

ASSEMBLY DATA: NAME: PART NUMBER:

MAJOR ASSY: ______

SUB ASSY: ______

MODULE: ______

SERIAL NUMBER OR DATE CODE REMOVED: REPLACED:

CAUSE OF TROUBLE, DAMAGE TO MODULE, REMARKS: ______

LEAVE THIS SECTION BLANK

FAILURE ASSESSMENT: ☐ 1. RELEVANT 2. NON-RELEV

W ______ B ______

C ______ ☐ MONEY HANDLING?

REPAIR ACTION:
☐ 1. NO TROUBLE FOUND
☐ 2. REPAIR INCOMPLETE
☐ 3. MODULE REMOVED
☐ 4. MODULE REPLACED
☐ 5. JAM CLEARED
☐ 6. ADJUSTED
☐ 7. CLEANED
☐ 8. OTHER (EXPLAIN ABOVE)

ACTUAL REPAIR TIME: TYPE OF FAILURE: ☐ 1. INDEPENDE 2. DEPENDEN

COMPLETE DATE: TIME:

EMPLOYEE NUMBER: INITIALS: ______

FIGURE II-15A MAINTENANCE REPORT (FRONT)

CUBIC WESTERN DATA

AFCS MAINTENANCE REPORT

PROJECT: ☐ No.

FAILURE NUMBER: ____ STARTED DATE: ____ TIME ____ PAGE ___ OF ___

ACTUAL REPAIR TIME: ____ COMPLETE DATE: ____ TIME ____

	NAME	PART NUMBER	DATE CODE OR S/N	ACTION
MODULE:				
SUB ASSY:				
SUB ASSY:				

	NAME AND CIRCUIT DESIGNATOR	PART NUMBER	DATE CODE OR S/N	ACTION
COMPONENT:				
COMPONENT:				
COMPONENT:				
COMPONENT:				
COMPONENT:				

ACTION CODES:
1. NO TROUBLE FOUND
2. NOT REPAIRABLE
3. REMOVED
4. REPLACED
5. ADJUSTED
6. CLEANED
7. INCOMPLETE
8. OTHER (EXPLAIN BELOW)

CAUSE OF PROBLEM (REMARKS): ____

EMPLOYEE NUMBER: ____

INITIALS: ____

LEAVE THIS SECTION BLANK

FAILURE CATEGORY ☐
1. EMD
2. EMW
3. PMD
4. PMW
5. NON CLASSIFIED
6. OTHER

☐ CLOSED

CIF 2 279A

FIGURE II-15B MAINTENANCE REPORT (BACK)

REPORT NUMBER	FAIL-CLAS FAS	CAT	S	DATE	MEI NO.	MACH S/N	MAJ-ASSY P/N	MODULE P/N	MOD FLT	EDT	PRI ART	COMPONENT P/N	COMP DESG	SYMPTOMS	PRI-REP ACTION	MACH HOURS	$
021419	NON		N	01/11/78	019	GR7007	926-1703-1	**021023		11:13	01:03				ADJ CLN	62403	*
009749	NON		N	11/01/77	019	GR7007		916-2637-7		04:40	00:40				ADJ	45473	*
009801	NON		N	11/02/77	019	GR7007		926-1703-1		00:40	00:30				ADJ	45591	*
009806	NON		N	11/02/77	019	GR7007		M1A1060		17:16	00:44				INC ADJ	4574	*
009811	NON		N	11/02/77	019	GR7007		916-2637-7		00:17	00:15				ADJ	3202	*
010408	NON		N	01/02/78	019	GR7007		926-2271-1		01:45	01:00				ADJ OTH	63442	*
011018	NON		N	11/04/77	000	GR7007		916-2637-7		01:08	01:00				ADJ	46365	*
011020	NON		N	11/04/77	019	GR7007		916-2388-1		00:53	00:15				ADJ	4599	*
011035	NON		N	11/11/77	019	GR7007		916-2637-7		00:18	00:18				ADJ	5072	*
011073	NON		N	11/22/77	019	GR7007		926-1703-1		24:04	00:00				INC	0	*
011080	NON		N	11/28/77	019	GR7007				05:25	00:30				NTF	0	*
011086	REL		N	11/25/77	019	GR7007		926-1755-1		60:47	00:01				REM RPL	14524	*
011091	REL		N	11/21/77	019	GR7007		926-1549-1		26:09	01:35				RPL	3031	*
011205	NON		N	12/07/77	019	GR7007		926-1703-1		36:15	00:45	723.72			ADJ CLN	54263	*
011208	NON		N	12/12/77	019	GR7007		926-1555-1		00:03	00:03				CLN	1034	*
011217	NON		N	12/08/77	019	GR7007		916-2538-2		103:57	01:20				REM RPL	55189	*
011224	REL		N	12/16/77	019	GR7007		926-7975-1		146:02	01:30				RPL	5752	*
011234	REL		N	12/15/77	019	GR7007		926-7975-1		05:00	01:40				REM RPL	3598	*
011267	NON		N	12/28/77	019	GR7007		916-2398-1		34:00	04:00				REM RPL	57263	*
011270	NON		N	12/23/77	019	GR7007		M1A1060		00:07	00:06				ADJ	4510	*
011290	NON		N	11/30/77	019	GR7007		926-1704-1		49:02	00:03				ADJ	5219	*
011297	NON		N	12/23/77	019	GR7007		926-7959-1		123:31	00:15				CLN	4310	*
011300	REL		N	12/13/77	019	GR7007		916-1784-1		23:53	00:30				REM RPL	4102	*
011:72	NON		N	11/15/77	006	GR7007		926-1791-4		02:11	00:30				ADJ CLN	47587	*
014502	NON		N	12/05/77	025	GR7007		926-1703-1		24:50	00:15				JAM	4851	*
021427	NON		N	01/17/78	019	GR7007		926-1704-1		00:51	00:10				JAM	0	*
021442	NON		N	01/25/78	019	GR7007		926-7992-1		19:24	01:00				REM RPL	0,736	*
011556	REL		N	11/11/77	043	GR7009		SSL-55C		101:14.	01:00				REM RPL	39352	*
011586	NON		N	11/14/77	043	GR7009		1136649		32:30	00:05				RPL	33021	*
011594	REL		N	11/17/77	043	GR7009		926-7963-1		10:38	00:50	242.27			REM RPL	38843	*
015316	NON		N	01/23/78	043	GR7009		926-0016-1		05:19	00:15				REM RPL	54890	*
017072	NON		N	12/23/77	052	GR7009		916-7022-1		03:05	00:10				CLN	2.74	*
019625	NON		N	01/16/78	043	GR7009		926-7958-1		122:00	00:10				CLN OTH	54371	*
012813	REL		N	01/05/78	001	GR7013	926-1555-1	SSL-55C		06:11	02:15				RPL ADJ	6202	*
012821	NON		N	01/13/78	001	GR7013	926-1703-1	916-2637-7		00:30	00:30				ADJ	4373	*
012843	NON		N	12/28/77	001	GR7013	926-1703-1	916-2637-7		06:14	00:40				ADJ	58112	*
020311	NON		N	01/24/78	001	GR7013	926-1703-1	926-2514-1		22:01	00:10				NTF CLN	3397	*
010613	REL		N	11/03/77	046	GR7013		916-2229-7		02:55	00:10				RPL CLN	53741	*
010708	NON		N	11/18/77	001	GR7013		**040177		01:33	00:10				RPL	4844	*
011233	NON		N	12/16/77	001	GR7013		916-2637-7		05:18	00:45				ADJ	55222	*
011236	NON		N	12/16/77	001	GR7013		180065-2322		03:25	00:00	362.28			REM RPL	55222	*
011237	NON		N	12/16/77	001	GR7013		916-2538-2		125:59	00:35				ADJ CLN	56443	*
011245	NON		N	12/21/77	001	GR7013		180065-2322		00:48	00:10				REM RPL	4051	*
012808	NON		N	12/29/77	001	GR7013		916-2538-2		128:25	00:30				ADJ CLN	0	*
012809	NON		N	01/04/78	001	GR7013		926-7977-1		05:25	00:45				CLN	0	*
012823	NON		N	01/11/78	001	GR7013		916-2338-2		31:09	01:08				REM RPL	61775	*
016609	REL		N	12/14/77	001	GR7013		916-2538-2		00:43	00:43				REM RPL	54798	*
016627	NON		N	11/29/77	001	GR7013		926-1703-1		20:30	00:24				ADJ	3222	*

FIGURE II-16 CORRECTIVE MAINTENANCE REPORT

MEZZANINE ________ TIME ________ DATE ________ NAME ________

KEY: O = OUT OF SERVICE; J = FARECARD JAM; C = COIN JAM; B = BILL JAM; N = MONEY CONTAINER NOT IN PLACE; F = MONEY CONTAINER FULL; V = FAIL TO VERIFY; R = RETURNED TO SERVICE; E - ENTRY; X - EXIT

DADS TIME	AISLE 11	12	13	18	19	20	VENDORS 31	32	33	34	35	36	ADDFARES 50	54	REMARKS
0655	E	E	X	X	X	X									
0710			J												
0711				J/R											
0712			R					B							
0714								R							
0720										J					
0723										R					
0730											O				
0740													J		
0742													R		
0750											R				
0810	E	X	X	X	X	X									
0830					J										
0835					R										
0856									C						
0858									R						

RK SECT

FIGURE II-17 DATA SHEET

MEZZANINE ______

DATE ______

NAME ______

AFC PEAK HOUR PERFORMANCE SURVEY

	DAY 1 DATA			DAY 2 DATA			TOTAL AM + PM	
	Potential Equipment Availability	EQUIPMENT DOWNTIME (MIN)		Potential Equipment Availability	EQUIPMENT DOWNTIME (MIN)		Failures	Downtime
EQUIPMENT	(MIN)	AM PEAK (0700 - 0900 HRS)	PM PEAK (1600 - 1830 HRS)	(MIN)	AM PEAK (0700 - 0900 HRS)	PM PEAK (1600 - 1830 HRS)	DAY 1+2	DAY 1+2
ENTRY AISLES (EA)								
EXIT AISLES (XA)								
FARECARD VENDORS (FV)								
ADDFARES MACHINES (AM)								
SUB-TOTALS								

		NUMBER OF FAILURES/DOWNTIME (MIN)																	NUMBER OF FAILURES/DOWNTIME (MIN)															
		E A		X A		F V		A M		E A		X A		F V		A M			E A		X A		F V		A M		E A		X A		F V		A M	
FAILURE BY EQUIPMENT TYPE		#	MIN	#	MIN	#	MIN	#	MIN	#	MIN	#	MIN	#	MIN	#	MIN		#	MIN	#	MIN	#	MIN	#	MIN	#	MIN	#	MIN	#	MIN	#	MIN
OUT OF SERVICE-OTHER																																		
FARECARD JAMS																																		
COIN JAMS																																		
BILL JAMS																																		
MONEY HANDLING JAMS																																		
MONEY CONTAINER NOT IN																																		
MONEY CONTAINER FULL																																		
FAILURE TO VERIFY ENCODING																																		
SUB-TOTALS																																		

TOTAL AM FAILURES								
TOTAL PM FAILURES								
TOTAL AM DOWNTIME (MIN)								
TOTAL PM DOWNTIME (MIN)								

availability for the four machine types.

$$\frac{\text{Uptime}}{\text{Uptime + Downtime}}$$

Calculation of total failures of each type, e.g., farecard jam, and total downtime for each equipment category allowed presentation of percentage of failures by failure type and the downtime contribution of each failure type. Use of the DADS audit data allowed calculation of failures per transaction figures for all machines.

BAY AREA RAPID TRANSIT DISTRICT

The Bay Area Rapid Transit District (BART) Automatic Fare Collection System (AFCS) is described in terms of Fare Structure, Patron Flow, Composite System Description, Individual Equipment Descriptions, System Maintenance, Mezzanine Agent Interactions and System Associated Data Storage and Retrieval Systems.

General AFCS Description

BART has a mileage-based fare structure with a base fare of $.30 representin the first 6 miles of travel. The charge beyond the first 6 miles is based on total length of trip and is rounded to the nearest $0.05. BART operating hours are 6:00 a.m. to midnight, Monday through Saturday. Sunday hours are 9:00 a.m. to midnight.

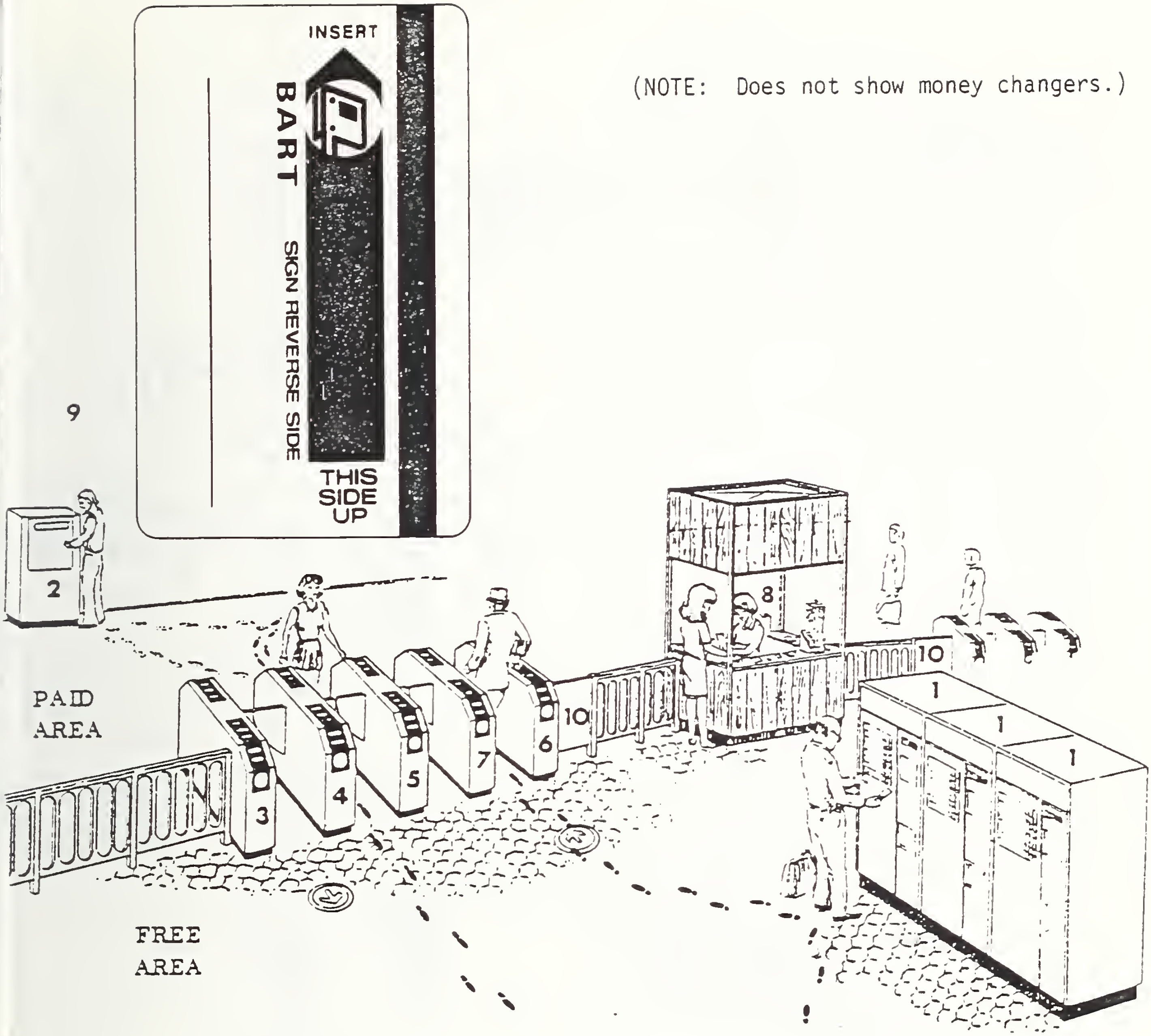
The BART Fare Collection System, as currently structured, consists of ticket vendors, addfare machines, money changers, entry/exit passenger gates and ticket readers in 44 mezzanines located at 34 stations. Equipment for the system was procured from both IBM and Cubic-Western Data. Figure II-19 illustrates a typical station mezzanine.

Each mezzanine is divided into "free" and "paid" areas by an array formed from passenger gates, service gates, railings and station agent booth. Patron flow through this system is shown in Figure II-20. Patrons entering a station, who do not already have a ticket can purchase one from a ticket vendor located in the "free" area. IBM and Cubic vendors are shown in Figures II-21 and II-22 a, b, respectively.

Each patron over four years of age must have a ticket, shown in Figure II-23, to enter the "paid" area. Children 5 to 12 years of age, senior citizens (over 65), and handicapped persons may purchase discounted tickets at specified local banks.

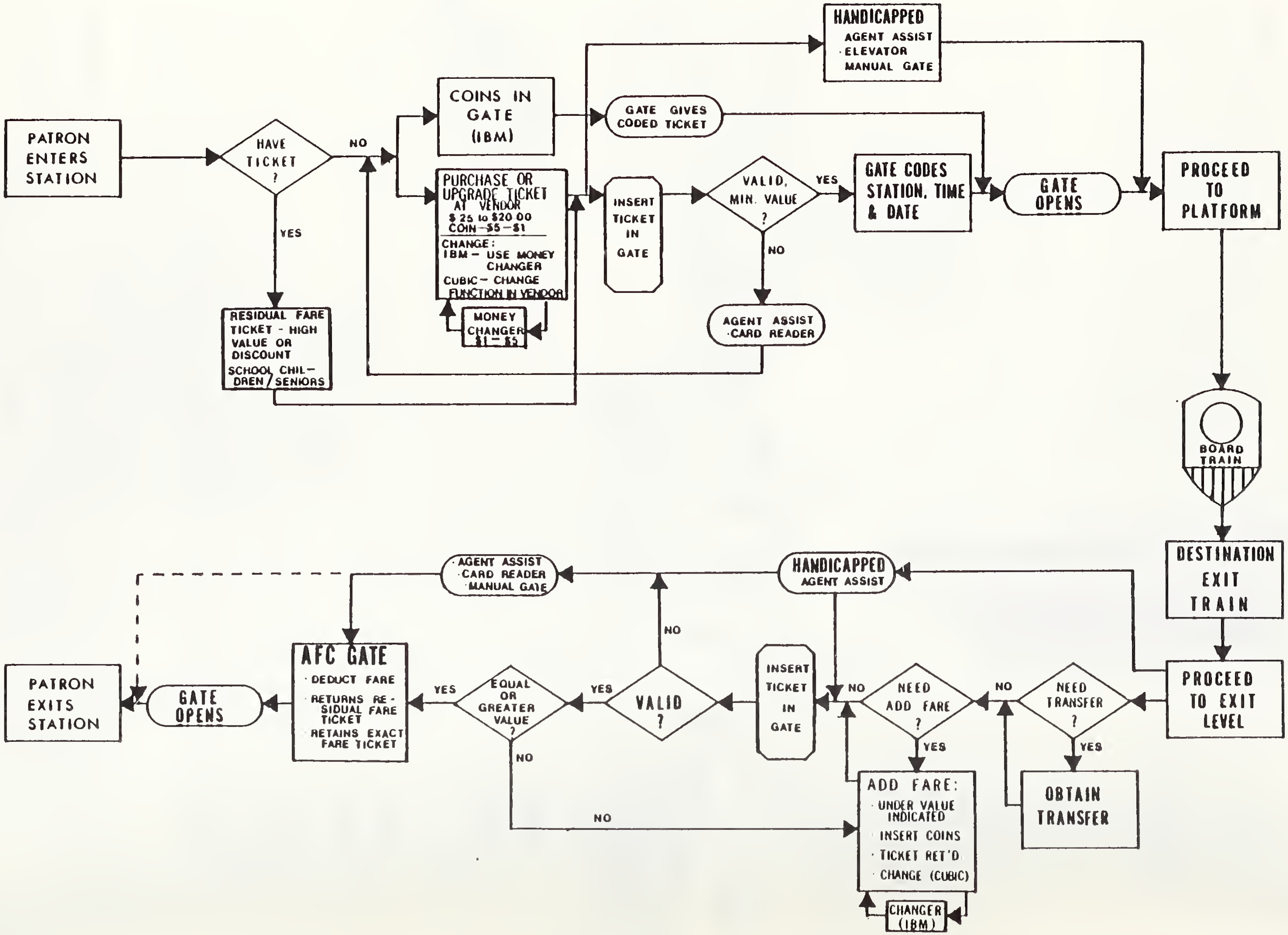
Passenger gates form entry and exit aisles marked by a fixed arrow and a latent enter or exit display on the end of the gate console facing patron. A typical aisle is shown in Figure II-24.

(NOTE: Does not show money changers.)



KEY NO.	NAME
1.	Ticket Vendor
2.	Addfare Machine
3.	Exit Gate, Type M
4.	Reversible Gate, Type N
5.	Reversible Gate, Type O
6.	Entry Gate, Type P
7.	Entry Assist Gate, Type Q
8.	Agent's Ticket Reader
9.	BART Ticket
10.	Service Gate

FIGURE II-19 TYPICAL BART STATION EQUIPMENT



BART Automatic Fare Collection
PATRON FLOW DIAGRAM

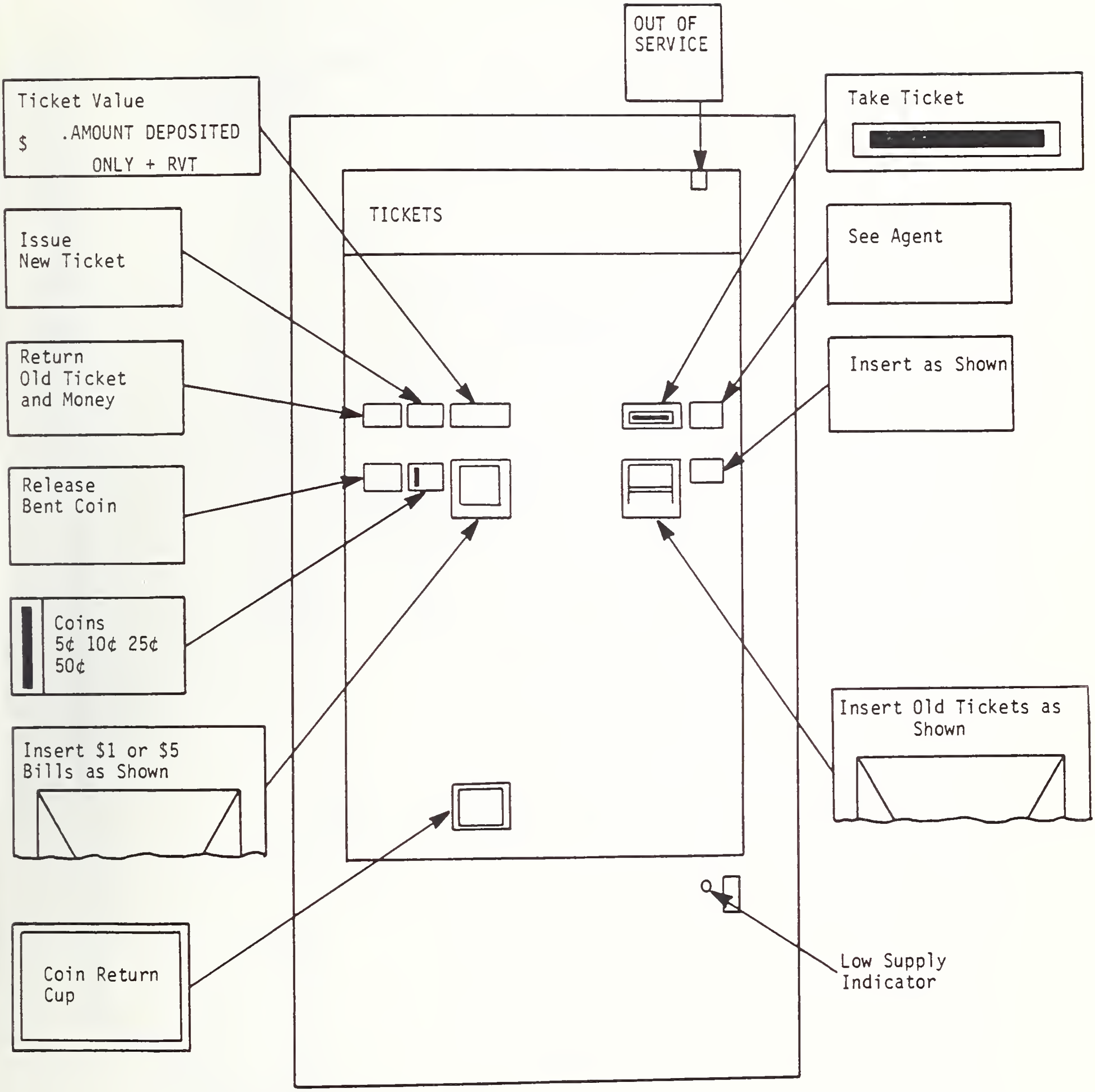


FIGURE II-21 IBM TICKET VENDOR

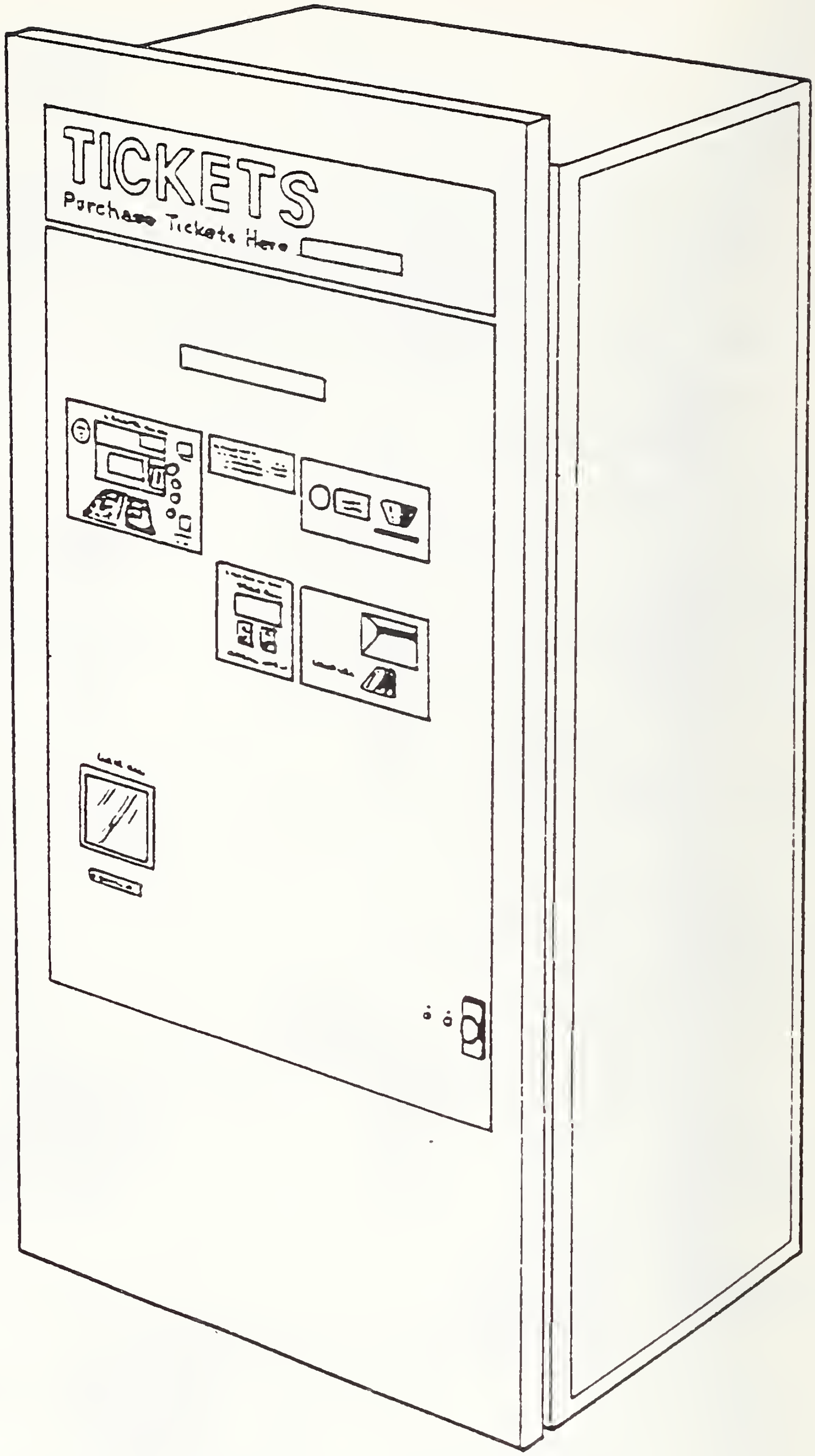


FIGURE II-22A TICKET VENDOR MACHINE
CUBIC-WESTERN DATA

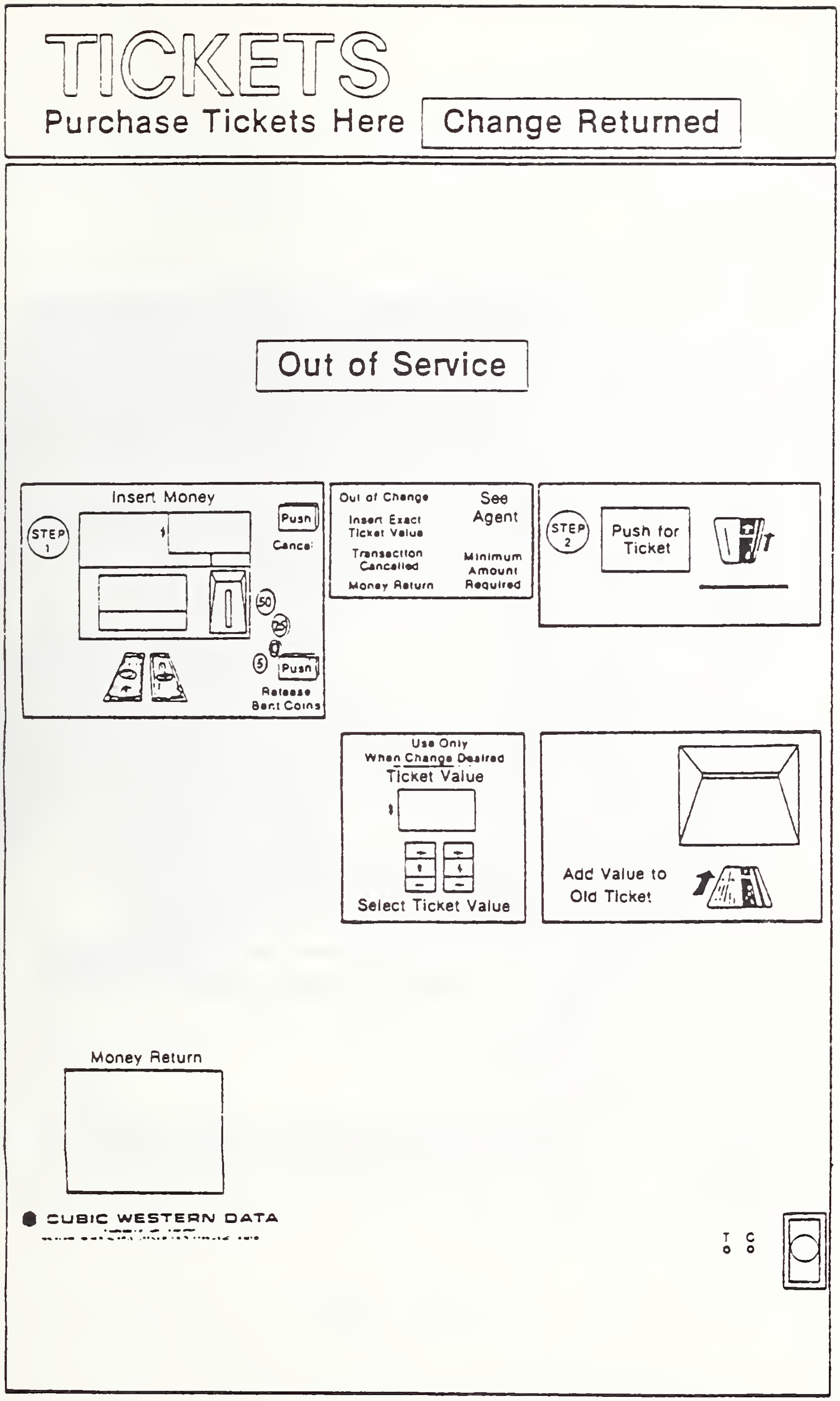
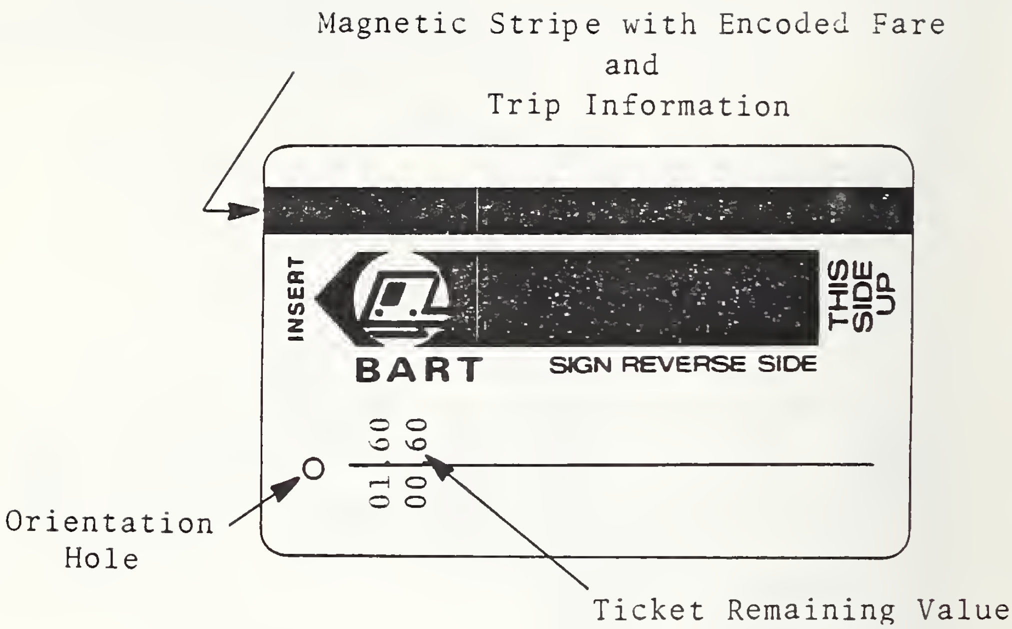
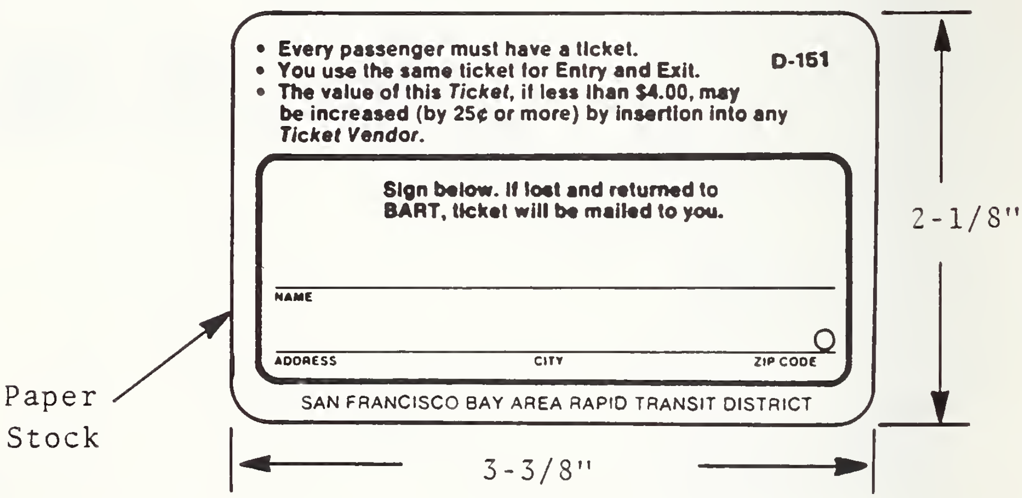


FIGURE II-22B FRONT PANEL CONTROLS AND INDICATORS



FRONT



BACK

FIGURE II-23 BART TICKET

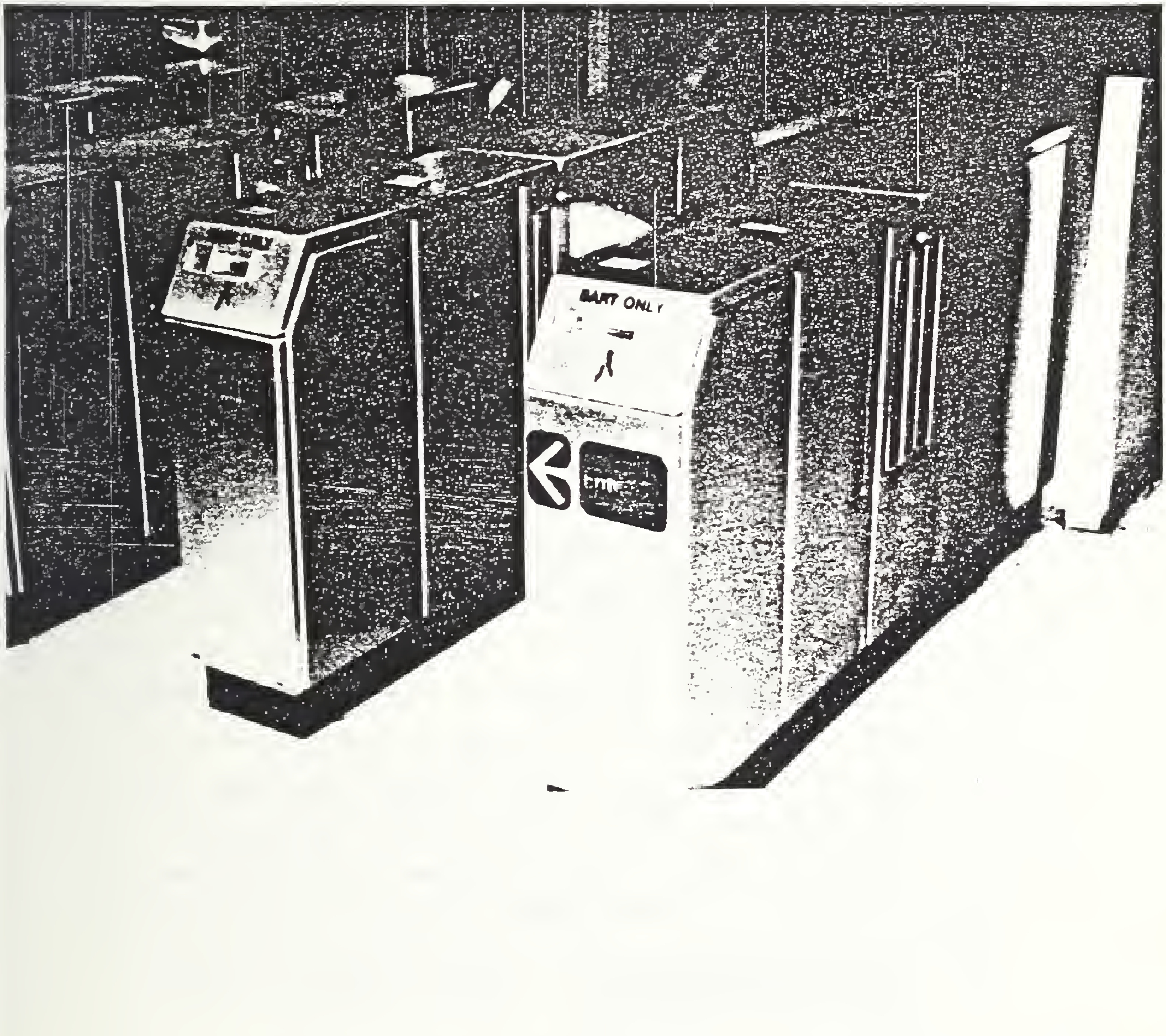


FIGURE II-24 TYPICAL BART AISLE

This system, as described with associated support functions is being examined under a recently implemented Fare Collection Reliability Improvement Project.

Ticket. The BART ticket which was shown in Figure II-23, is a paper card, 2-1/8 by 3-3/8 inches, with an orientation check hole on the leading edge, space for printing remaining stored value for 21 transactions, and an attached magnetic strip to accept the following magnetic encoding:

(1) Day and Time Code - Identifies the time period of the patron's entry into the BART system.

(2) Station Code - Identifies station where patron entered into "paid" area. Provides data for fare calculation at exit gate.

(3) Entry or Exit Code - Coded data which ensures that the ticket has been used in a valid sequence. (If the ticket has been used to enter BART system, it must be used in an exit gate with resultant fare reduction before it can be used to enter the system again).

(4) Number of Uses - The number of times the ticket has been used is coded so that machine logic can direct the printer to print on the correct line. When this code indicates that all 21 lines have been used, it will initiate exit gate action to issue a new ticket having a value equal to the remaining value of the old ticket.

(5) Ticket Remaining Value - The dollar and cents value remaining on the ticket.

(6) Contract and Security Codes - Coded data used for checking the validity of the ticket and the completeness of data recorded on the ticket.

(7) Vend Words - These words include initial money value, random code, cyclic code, and a header code.

Ticket Vendor. Ticket vendors are located in the "free" area near the gate arrays. They will accept one and five dollar bills and fifty cent, twenty-five cent, ten cent and five cent coins in United States currency. All other bills and coins will be rejected by the bill validator or coin acceptor. The vendors will also accept tickets with remaining value of less than $3.95. The patron may insert in any order, bills, coins and a remaining value ticket of any value from $0.30 to $20.00.

Bills inserted in the bill slot and having the proper orientation (portrait up - top of portrait facing right), will be scanned magnetically in the bill validator to check validity and denomination of bills. IBM ticket vendor validators will, in addition, scan the bills optically to determine proper thickness and engraved patterns. Invalid bills, bills improperly oriented and some damaged bills will be returned to the patron. Bills accepted will be held in an escrow box, pending completion of transaction. The value of each accepted bill will be placed in logic storage and shown on Ticket Value display panel.

Coins inserted in marked slot will be examined in the coin acceptor, to determine that their diameter, weight, perforations and metallic content are within specifications. Invalid coins will be returned to the patron. Generally, bent coins will also be returned, but may require the patron to activate the Release Bent Coin control.

A ticket with remaining value may be inserted in slot marked Insert Old Ticket as Shown (IBM) or Add Value to Old Ticket (Cubic-Western Data). At the first magnetic read head, the card validity will be checked and a determination made that the entry/exit code is "entry".

Patron entering system locates an entry aisle and inserts ticket into slot located on sloping end panel of the gate console. When ticket is returned by gate and removed by patron, aisle barriers open and allow entry to "paid" area. Patron may elect to deposit exact minimum fare (30 cents) in Coins Minimum Fare slot on sloping panel of IBM entry gates, as shown in Figure II-25, remove gate issued ticket, and enter "paid" area. Patron then proceeds to proper platform for train boarding.

On arrival at destination, patron locates an exit aisle and inserts ticket in gate. If ticket has exact fare stored, gate will capture card and open barriers for patron. If stored value is greater than fare, fare value will be subtracted and ticket with remaining value returned to patron for exit. When ticket with less than required value for exit is inserted, gate display will tell patron Underpaid Go To Addfare. Figure II-26 illustrates the various displays on the gate console.

When patron inserts card in Addfare, shown in Figure II-27, the machine displays amount required to increase ticket value to that required for exit. When currency is deposited, machine revalues (re-encodes) ticket to exact value required for exit and returns ticket to patron. Patron inserts card in exit gate which captures card and opens barriers for patron.

Station agents, who have the basic level of responsibility for the proper operation of the Automatic Fare Collection System, are provided with a ticket reader, shown in Figure II-28, which can be used when patron's ticket is not accepted by any fare machine, to determine ticket value, station, day and time of issue, validity of security codes, and whether coded for exit or entry. By use of the ticket reader, most disputes involving tickets and machines can be resolved.

Currently, the BART Automatic Fare Collection System consists of 761 machines installed in mezzanines. There are 167 ticket vendors, 96 addfare machines, 316 passenger gate consoles, 139 money changers, and 44 ticket readers. This equipment was procured under BART contracts with IBM and Cubic-Western Data.

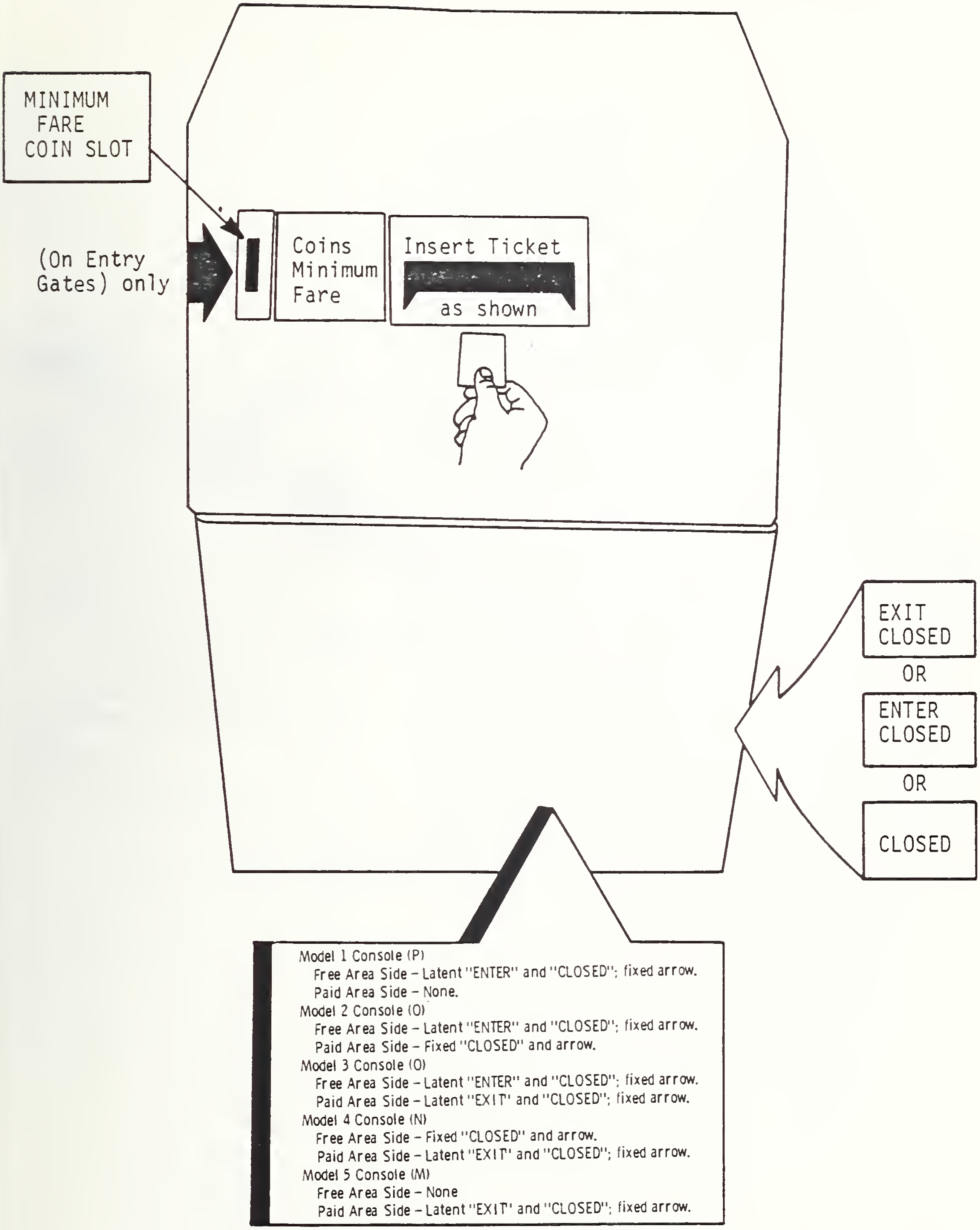


FIGURE II-25 DIRECTION AND MODE DISPLAYS FOR IBM GATES

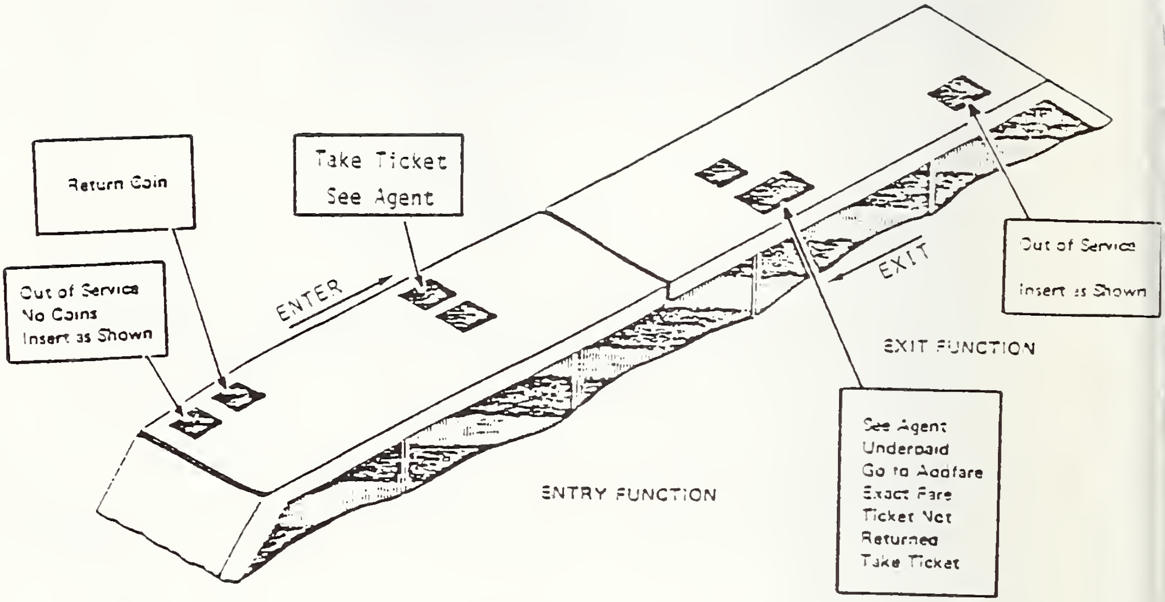


FIGURE II-26 PATRON DISPLAYS FOR IBM GATE

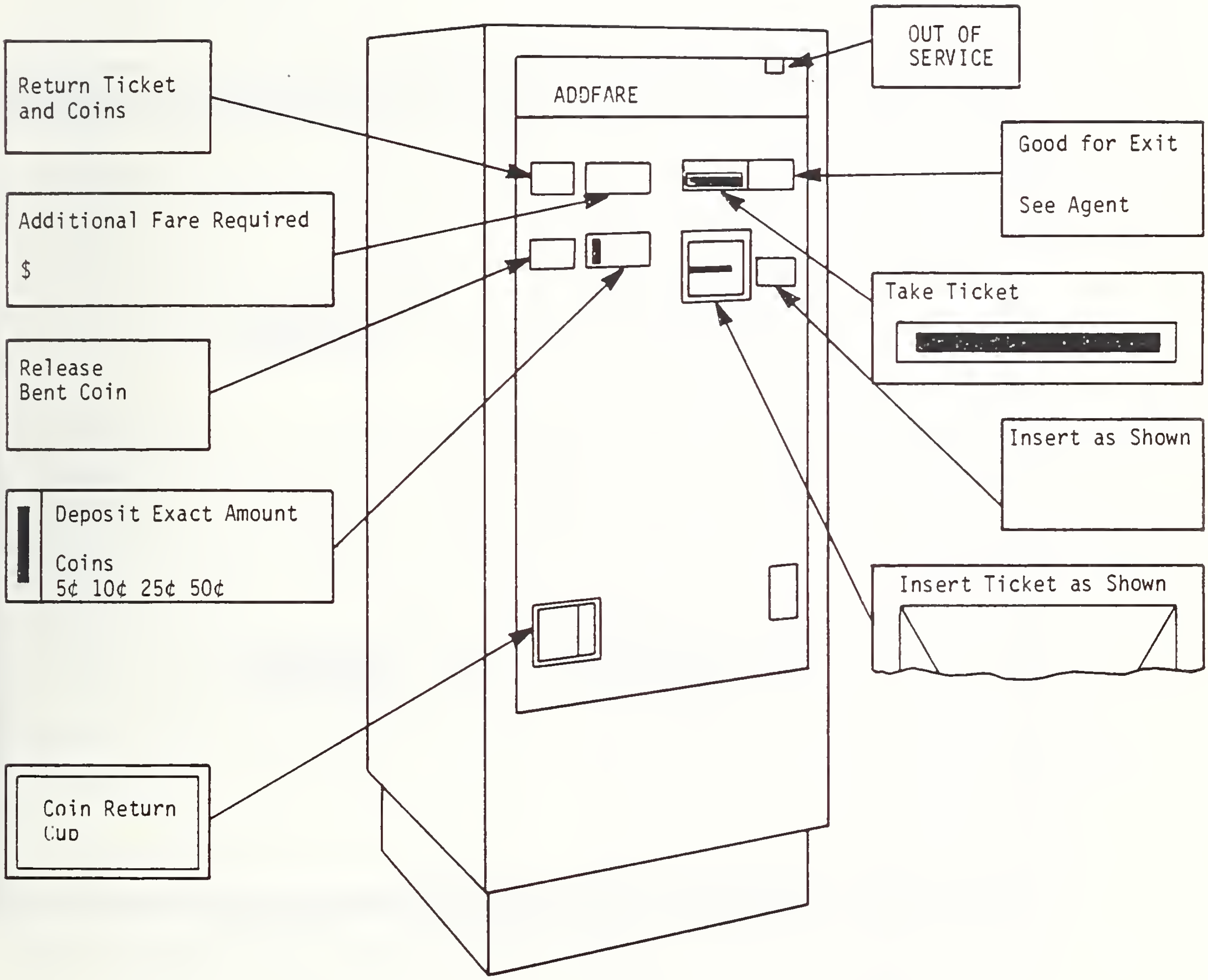


FIGURE II-27 BART ADDFARE MACHINE

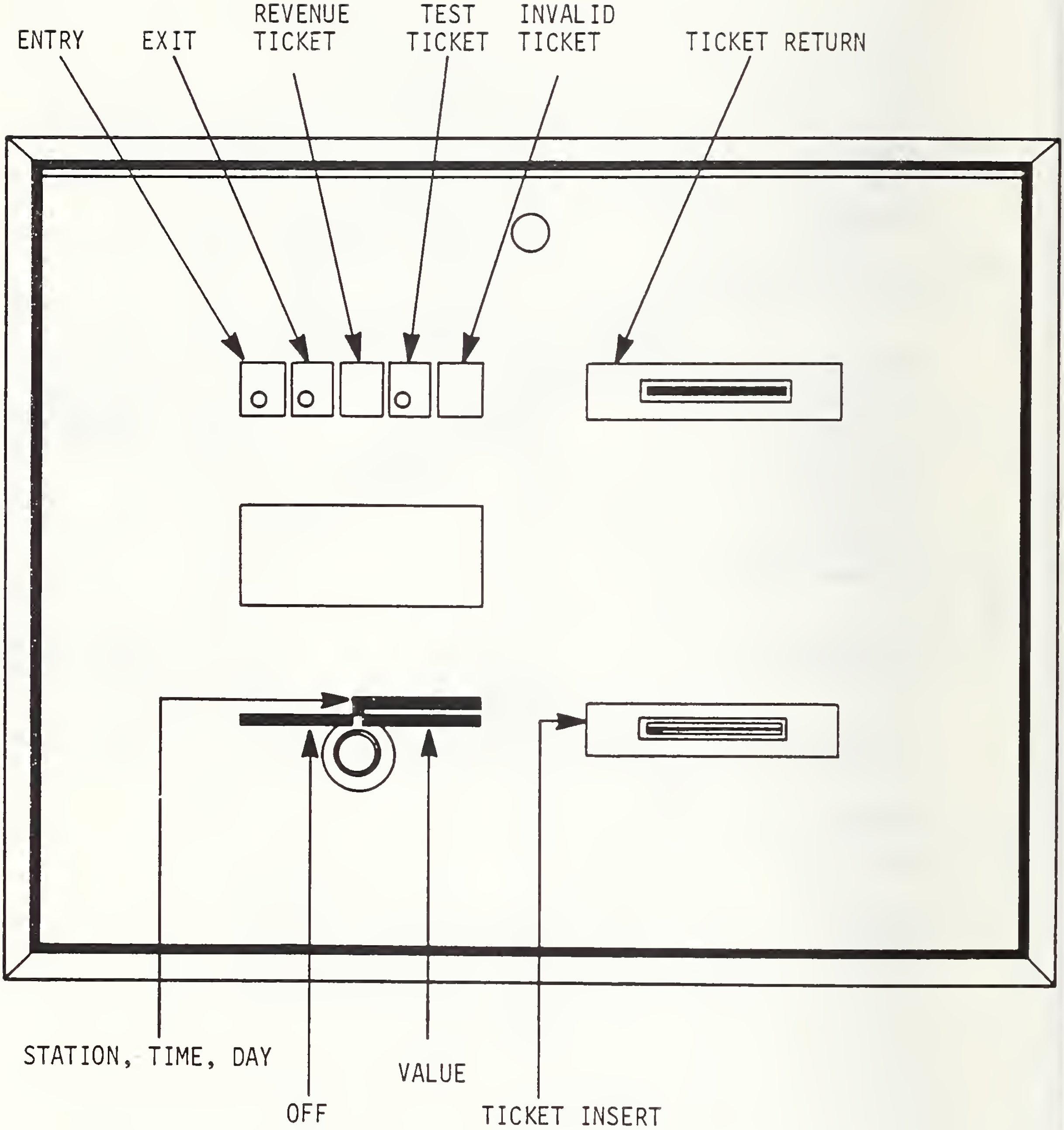


FIGURE II-28 BART TICKET READER

If ticket is not valid, the See Agent display is lit and the ticket and any monies deposited are returned to patron. If ticket is valid, it is held in escrow pending completion of transaction. The ticket's remaining value will be entered in logic and added to amount shown on Ticket Value display.

With all currency and remaining value card deposited, patron using Cubic-Western Data ticket vendor may elect to change Ticket Value. This is done using the Select Ticket Value "$-" control to produce one dollar decrements and the "¢-" control to produce nickel decrements. If ticket value is reduced beyond that desired by patron, value can be restored by pressing "$+" control for one dollar increments or "¢+" control for nickel increments.

When patron has selected desired ticket value and activated the Issue New Ticket (IBM) or Push for Ticket (Cubic-Western Data), the machine will select a blank ticket from the ticket hopper. The ticket's magnetic strip will be written with selected ticket value, security codes, station number, entry code and print line code for line one. The written data will be verified. If verification is not achieved after three machine write/verify cycles, the vendor will be placed Out of Service and all currency and old ticket returned to patron.

A verified ticket will have its value printed in the print column and will be transported to the ticket exit slot where patron can remove it. When using the Cubic-Western Data ticket vendor, if change is required, an appropriate number of quarters and nickels will be sent to the Money Return cup. All register values of coins accepted, bills accepted, bonus given, remaining value credit, and ticket value stored in the logic unit will be transferred to machine registers and to the Data Acquisition System.

Bills and coins in escrow are deposited in the security enclosure (IBM). In Cubic-Western Data ticket vendors, the bills in escrow are deposited into the bill stacker and coins in escrow are released to money bag in the coin bank. The old ticket is coded with zero value and transported to storage bin.

Patron may at any time, prior to obtaining ticket, cancel the transaction by activating the Cancel control. If this is done, all currency and old ticket are returned to patron and Transaction Cancelled display lit.

Passenger Gates. Figure II-29 shows a typical gate array in the barrier between "free" and "paid" areas. Gate arrays are formed from five types of gates as follows:

GM - Exit gate
GN - Reversible Exit Assist
GO - Reversible Center Console
GQ - Entrance Assist
GP - Entrance

The entrance (P) and Exit (M) gates can only be used to form entrance or exit aisles, in conjunction with their respective assist consoles (Q and N). The Reversible Center Console (O) gate consoles are used to fill center positions of larger arrays. The N console is reversible and works in conjunction with the Q or O console to form an aisle in either direction. The minimum number of consoles is four, forming three aisles, only one of which is reversible. To create more aisles, extra type O consoles are added. Bidirectional aisles can be set by agents to entry or exit, using gate mode switch located in consoles, to accommodate varying patterns of patron flow.

A patron going from the "free" to "paid" area locates aisle marked by latent entry display. Patron must insert ticket with arrow up and pointing

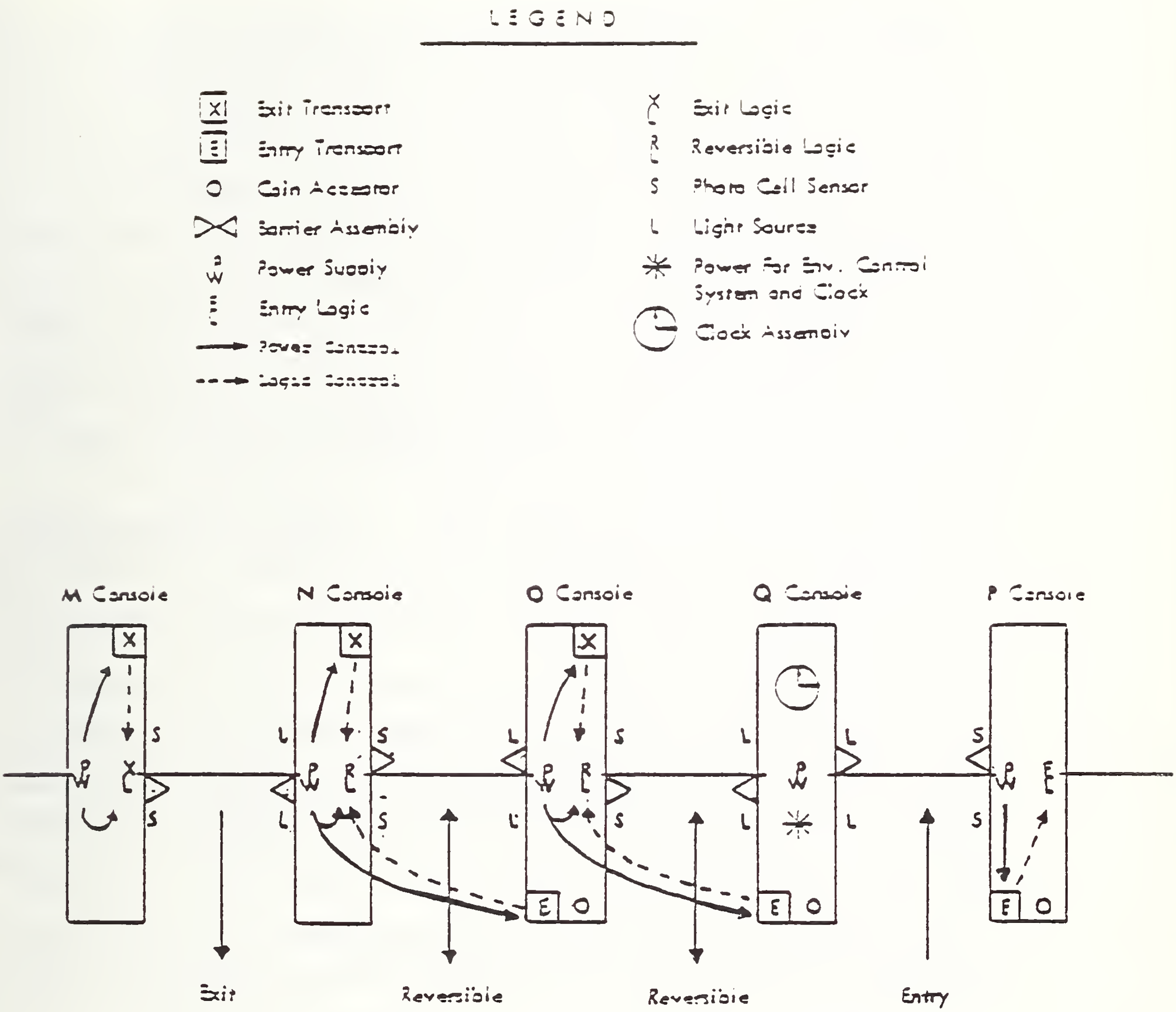


FIGURE II-29 TYPICAL GATE ARRAY

forward. Gate will determine proper ticket insertion. When proper ticket orientation is determined, ticket barrier will be opened and card transferred to magnetic read station. At read station, gate will read magnetic strip to determine that minimum fare is encoded, that there is space remaining in the print column, that the card is coded for entry and that valid security codes are present. Non-valid cards will be returned to patron and See Agent display lit. Valid tickets with 21 lines filled will be read to determine remaining value and a new ticket with the remaining value printed on line one will be issued by the gate console. A valid ticket will be transferred to the magnetic write station where station of entry, time and exit codes are written. The written data is checked for correctness at the verification station. A verified ticket is returned and Take Ticket display lit. If gate is unable to verify written data, the ticket is returned and See Agent display is lit.

When patron removes verified ticket, pneumatic motors swing barrier leaves into consoles to allow patron to enter "paid" area. Sensors associated with barriers detect patron passage, provide a "patron in" signal to gate registers and the Data Acquisition System. Barrier closure will be initiated if there is no following patron who has processed a valid ticket. In order to allow smooth patron flow under peak conditions, the barriers will remain open when a following patron processes a valid ticket prior to previous patron clearing the barrier exit sensor.

A patron going from "paid" to "free" area follows same procedures as above to locate exit aisle and insert ticket. The gate will read time and date of entry, entry/exit, security codes and value written on magnetic strip. If data indicates same day entry with time lapse not greater than three hours, exit code and proper security codes, ticket will be accepted for processing. If invalid codes are read, ticket will be returned and See Agent display lit. Agent will use Ticket Reader to determine reason for ticket rejection. For a valid ticket, if value read by gate is exact fare required for exit, the gate will write zero value on magnetic strip, capture ticket, and open barriers. If ticket value is greater than fare required to exit, trip fare will be subtracted from ticket value and the remaining value, and exit code and number of uses code will be written on magnetic strip and verified. The remaining value will be printed in print column and ticket returned to patron. If ticket cannot be verified, ticket will be returned as noted above. When patron removes valid ticket, barriers are opened to allow entry to "free" area. When ticket value is less than fare required to exit, ticket is returned to patron and Underpaid Go to Addfare display is lit.

Addfare. Where patron realizes that he does not have sufficient remaining value on ticket to exit or has inserted ticket in gate and activated Underpaid Go To Addfare display, he goes to addfare machine.

Patron must insert ticket in proper orientation. If ticket is improperly oriented, IBM Addfare will light Insert As Shown display. In Cubic Addfare, ticket handler will not start and patron must correct ticket orientation.

Ticket is then read and verified. If ticket is invalid, it will be returned and See Agent display will be lit. Agent will utilize Ticket Reader to determine reason for rejection. A valid ticket will be read to determine remaining value and station of entry. Using stored fare table, machine calculates the additional fare required and displays value on Additional Fare Required display. Patron using IBM addfare must add exact additional fare in coins (50¢, 25¢, 10¢, 5¢) to reduce display to zero. The ticket will be magnetically written for exact fare and returned to patron. If more coins are deposited, ticket and any currency deposited are returned and transaction cancelled. Patrons using Cubic Addfare may use one dollar bills, five dollar bills or coins

(50¢, 25¢, 10¢, 5¢) to reduce Additional Fare Required display to zero and may insert more money than is required. When money is inserted, ticket is magnetically encoded with exact fare, any change required is returned to money cup, monies in escrow are placed in bill stacker or coin vault and ticket returned to patron. All machine registers are updated and signals sent to the Data Acquisition System computer storage.

If a ticket with exact or greater fare value is inserted in IBM Addfare, the Good for Exit display is lit and ticket is returned. In the Cubic Addfare, the See Agent display is lit and ticket returned. Agent uses Ticket Reader to determine ticket value and directs patron to exit gate.

Money Changers (IBM). Money changers (Figure II-30) are included in "free" area near ticket vendors, and in "paid" area near addfares, so patrons can secure correct change to operate IBM fare collection equipment. Money changers located in "free" area (MF) and in "paid" area (MP) are identical in operation. The (MF) unit is physically larger to allow accommodations of air supply for gate pneumatic motors.

The changers make change in the following manner:

Input	Change
Dime	2 nickels
Quarter	2 dimes - 1 nickel
Fifty Cents	1 quarter - 2 dimes - 1 nickel
One Dollar (Bill)	3 quarters - 2 dimes - 1 nickel

When changer cannot make change for one dollar bill, it is automatically placed out of service. When change cannot be made for a particular value of coin, the coin accept path will be blocked and the coin returned to patron.

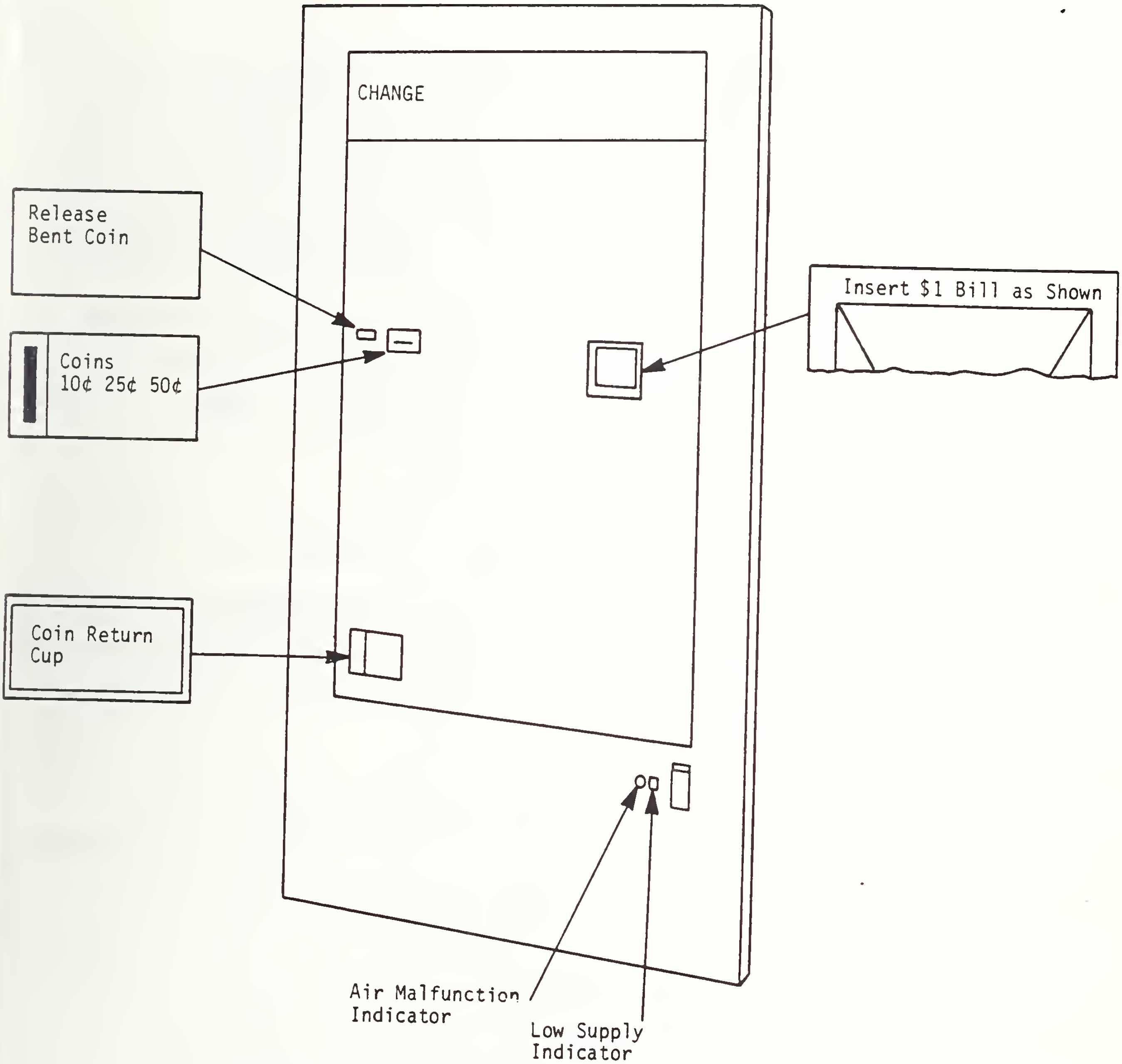


FIGURE II-30 IBM MONEY CHANGER

Dollar bills inserted in proper orientation are magnetically and optically scanned as previously described for ticket vendors. Coins are checked for diameter, weight, perforations and metal content. As each bill or coin is accepted, a signal representing its value is sent to the coin dispenser. The dispenser is a series of coin magazines, which feed a spring-operated coin shuttle with coins as shown in the table. When the shuttle returns to its normal position it dispenses coins to patron. Bills and coins accepted by the changer are stored in a self-locking money bag. When transaction is complete, registers are updated showing total value of bills and coins accepted by changer.

Ticket Reader. Each station agent/booth in the BART system has a Ticket Reader. This Reader allows the station agent to determine for any ticket submitted to him, whether the ticket is valid and its remaining value. It will also show the last station code, day/time code, and entry/exit code.

To check a ticket, the station agent puts the Selection switch in operational position (Figure II-28), and inserts ticket in Ticket Insert slot in proper orientation. If ticket is improperly oriented, a not valid display will be lit. All magnetic data on ticket is read and stored and ticket returned. Indicator lights show ticket validity. Green light (Revenue Ticket) shows a valid patron ticket. A white indication shows a valid Test Ticket. A red light indicates an Invalid Ticket or one improperly oriented. The Selector Switch is normally kept in the "Off" position. To read a ticket, it is turned to either Value or Station/Time/Day. After ticket has been read, the Value position will show remaining ticket value in dollars and cents on a four-digit numerical display. The Station/Time/Day position will display the station code and the time and day codes on a four-digit display.

Automatic Fare Collection System Maintenance

All fare collection equipment maintenance is performed by BART technicians who are assigned and report to one of the four BART lines.

Requests for corrective maintenance are initiated by station agents when equipment problems are beyond their capabilities. Line technicians respond to analyze problems, perform any required adjustment, cleaning, etc. If component or part replacement is required, parts are requested from a central parts stockage. This procedure is under revision to provide satellite parts storage.

Maintenance actions are written up on Trouble Tickets and noted in mezzanine log. Regularly scheduled preventive maintenance programs have been established and are currently in revision with respect to scheduling.

All completed Trouble Tickets are transcribed to machine readable format and entered into core storage of the ODDS data base.

Station Agent Responsibilities

Prior to start of passenger operations, station agents put all fare collection equipment into service and set all reversible aisles into the entry/exit pattern that has been determined to be optimum for the initial operating period. These configurations can be changed to meet changes in patron flow by means of entry/exit handle key-operated switches, located on reversible gate consoles.

Attendant responds to patron complaints or signals in the booth indicating machine malfunction(s). He must locate the malfunctioning machine and determine nature of malfunction by examination and use of maintenance indicators. He will generally clear money jams and ticket jams as they occur and make checks that jam is not repetitive. In the event of repeated machine failure, agent may place machine out of service and request maintenance action.

Whenever a patron ticket is rejected by fare collection machine, agent will read ticket using Ticket Reader located in booth and explain difficulty to patron and arrange corrective action.

Automatic Fare Collection Data Systems

Data Acquisition System (DAS). All register update signals, initiated in completion of fare machine cycles, are sent to a mini-computer located in the station area for short term shortages. These mini-computers are interrogated by the BART central computer approximately every two minutes and the register data is transferred to central computer core storage. This record, showing cumulative transaction and fiscal data from each machine is available as a daily, weekly and monthly read-out and is available to fiscal agents, security and engineering personnel.

ODDS System. All data transcribed from Trouble Tickets is transferred to computer core storage separate from the central computer system. This data can be accessed and combined with DAS data to provide machine individual and aggregate failure rates. Outputs of several programs are shown in Figures II-31 and II-32.

BRN DEL
10 FILES ODDS

*BRN

AFC RELIABILITY IMPROVEMENT PROGRAM
FAILURE ANALYSIS PROJECT
COMPUTER PROGRAM---FAILDATA--(FESHEL)
USES ODDS DATA BASE AND DAS DATA

NO.OF MONTHS?2

08/27/79

FAILURE ANALYSIS
ALL AFC EQUIPMENT

?MAY/JUNE-1979

ANALYSIS OF FAILURES BY STATION
================================

	TROUBLE TICKETS	% OF TOTAL	PER 1000 EXITS	PER 1000 VEND TICKETS
A20 #20--FRUITVALE				
IBM GATES	44	1.1 %	.23 (IBM EXITS ONLY)	
CUBIC GATES	0	0 %		
IBM CHANGER	38	.95 %	.2	
IBM VENDOR	53	1.33 %	.28	.58
CUBIC VENDOR	20	.5 %	.1	1.45
IBM ADDFARE	6	.15 %	.03	.35
CUBIC ADDFARE	14	.35 %	.07	
TOTAL	175	4.41 %	.93 (ALL)	.65 (VEND+AF)

EXITS 187744
GATE VEND 4258
VENDOR TKTS 103960 IBM 90261 CUBIC 13699

AF TKTS-IBM 16734

FIGURE II-31 COMPUTER OUTPUT OF FAILURES BY STATION

SRN

AFC RELIABILITY IMPROVEMENT PROGRAM
FAILURE ANALYSIS PROJECT
COMPUTER PROGRAM---FAILSUM--(PESHEL)
USES ODDS DATA BASE AND DAS DATA

NO. OF MONTHS?2

08/27/79

FAILURE ANALYSIS SUMMARY
ALL AFC EQUIPMENT

?MAY/JUNE--1979

ANALYSIS OF FAILURES BY STATION
===============================

		TROUBLE TICKETS	% OF TOTAL	PER 1000 EXITS	PER 1000 VEND TICKETS
A10 LMA	TOTAL	82	2.06 %	.56 (ALL)	.48 (VEND+AF)
A20 FRT	TOTAL	175	4.41 %	.93 (ALL)	.65 (VEND+AF)
A30 COL	TOTAL	208	5.24 %	1.45 (ALL)	.6 (VEND+AF)
A40 SNL	TOTAL	75	1.89 %	.48 (ALL)	.48 (VEND+AF)
A50 BFK	TOTAL	95	2.39 %	.51 (ALL)	.5 (VEND+AF)
A60 HAY	TOTAL	163	4.11 %	.72 (ALL)	.83 (VEND+AF)
A70 SHY	TOTAL	70	1.76 %	.58 (ALL)	.43 (VEND+AF)
A80 UCY	TOTAL	105	2.64 %	.65 (ALL)	.61 (VEND+AF)
A90 FRE	TOTAL	116	2.92 %	.46 (ALL)	.34 (VEND+AF)
C10 RKR	TOTAL	80	2.01 %	.78 (ALL)	.46 (VEND+AF)
C20 ORN	TOTAL	68	1.71 %	.68 (ALL)	.39 (VEND+AF)
C30 LAF	TOTAL	64	1.61 %	.56 (ALL)	.61 (VEND+AF)
C40 WAL	TOTAL	97	2.44 %	.44 (ALL)	.42 (VEND+AF)
C50 PHL	TOTAL	63	1.58 %	.33 (ALL)	.25 (VEND+AF)
C60 CON	TOTAL	150	3.78 %	.54 (ALL)	.37 (VEND+AF)
K10 12TH	TOTAL	134	3.37 %	.44 (ALL)	.4 (VEND+AF)
K20 19TH	TOTAL	88	2.21 %	.27 (ALL)	.52 (VEND+AF)
K30 MCA	TOTAL	74	1.86 %	.52 (ALL)	.5 (VEND+AF)
M10 OKW	TOTAL	72	1.81 %	.73 (ALL)	.79 (VEND+AF)
M16 EMB	TOTAL	328	8.27 %	.5 (ALL)	
M20 MON	TOTAL	294	7.41 %	.38 (ALL)	.36 (VEND+AF)
M30 POW	TOTAL	247	6.22 %	.45 (ALL)	.26 (VEND+AF)
M40 CIC	TOTAL	206	5.19 %	.51 (ALL)	.47 (VEND+AF)
M50 16M	TOTAL	72	1.81 %	.53 (ALL)	.39 (VEND+AF)
M60 24M	TOTAL	85	2.14 %	.43 (ALL)	.49 (VEND+AF)
M70 GLN	TOTAL	64	1.61 %	.31 (ALL)	.95 (VEND+AF)
M80 BAL	TOTAL	129	3.25 %	.55 (ALL)	.56 (VEND+AF)
M90 DAC	TOTAL	121	3.05 %	.23 (ALL)	.3 (VEND+AF)

FIGURE II-32 COMPUTER OUTPUT OF FAILURES BY STATION SUMMARY

SECTION III

METHODOLOGY AND REQUIREMENTS FOR DATA COLLECTION

The recommended methodology for collecting AFC equipment performance data was developed for application to the most sophisticated automatic fare collection environment. Therefore, the discussion of the specific elements in the methodology which follows in this section will address those issues and problems which occur in such an environment. The elements of the methodology include the types of data to be collected, procedures for collecting the data, training of data collectors, timing and frequency of data collection, use of existing data systems and the personnel and cost implications of collecting such data.

Because most of the problems encountered by patrons attempting to use the fare collection machines do not require a maintenance technician, records are rarely made of such problems. Therefore, the methodology requires on-site observation of AFC equipment performance and recording of all types of problems that occur. The methodology describes the procedures and requirements for a complete survey period; each survey period will consist of several individual data collection periods. Equipment failures are classified according to specific categories, and the time and duration of failures are also recorded.

Types of Data To Be Collected

Two basic types of data are collected, failure data and transaction data. Failure data obviously consist of some measurements of those instances in which equipment being monitored do not perform their intended function. Transaction data provide the amount of usage of AFC equipment and are necessary to provide a consistent means for interpreting failure data from all equipment.

Failures observed are further subdivided into "hard" failures and "soft" failures. Hard failures are those which require the attention of a maintenance technician, while soft failures generally can be serviced by a station agent or attendant. The hard failures designation applies when a machine is worked on by a maintenance person, or when a call for maintenance occurs. Often, it is the result of an attendant's decision to put a machine out-of-service because of a repetitive pattern of soft failures.

While they do not require technical expertise to resolve, soft failures often have greater patron impact than hard failures since they occur more frequently and are the type of problem which patrons are most likely to experience. Failures to be considered "soft failures" will include:

> Farecard (Ticket) Jam. This may occur in any AFC equipment in which a farecard (ticket) is processed through a transport mechanism, encoded, read, and verified.
>
> Coin Jam. This occurs in any of the money-handling equipment and can involve either the coin acceptor or change dispensing mechanisms.
>
> Bill Jam. In machines which accept bills, jams may occur either in the transport or bill validator mechanisms.

These types of soft failures will be observed most frequently; however, there will be some additional types of failures observed which should be considered soft failures. These will include:

> Money Container Full. When the bill vault or coin vault in AFC money-handling equipment is full, the machine will go out-of-service until the vault is emptied. While this is not specifically a machine-related failure, it does represent a failure of the fare collection system.

Failure To Verify. This category includes those instances in which farecard (ticket) handling machines are unable to verify information encoded on the farecard (ticket).

Other Soft Failure. This classification covers all other soft failures which are normally serviced by the station agent or attendant. It also includes those soft failures which occur for no identifiable reason. Some failures will be patron induced and others machine specific.

The types of transaction data that will be collected will vary according to the type of machine (gate, ticket vendor, etc.) and the level of detail available at the property under consideration. For entry/exit gates, the number of patrons either entering or exiting through each gate will be collected. For money-handling machines, some measurement of transactions completed should be obtained, e.g., number of successful transactions, total tickets, tickets processed, etc. However, since each money-handling transaction may involve a combination of coins and bills, each of which the machine must properly handle, it would also be desirable to have measurements of the total number of coins and bills by denomination, i.e., nickles, dimes, quarters, $1 bills, $5 bills. Such measurements would allow data on coin jams and bill jams to be directly related to the total number of coins and bills handled by each machine.

Data Collection Procedures

At the beginning of each data collection period, the initial task to be performed will be collecting and recording beginning transaction-status data for all machines under consideration. This is an extremely important procedure, given the necessity of transaction data for interpreting failure data; however, collecting such data can be very time-consuming, particularly if each machine must be opened to read and record the status of the transaction registers. Nevertheless, the basic methodology for collecting this data will consist of opening each machine, noting the time, and recording the status of each of the appropriate internal registers. Some sample forms for recording such information are included in Figures III-1, III-2, III-3. If appropriate, properties may utilize one or more of these forms to record transaction data or may design their own forms to reflect transaction register data required for their application.

Because the machine reading process is a lengthy one, it must begin well in advance of the data collection period. As a general guideline, a set of 20 machines (gates, vendors, addfares and changers) can be opened and read in approximately 30 minutes. If, on the other hand, an external method is available for obtaining transaction data, it may well be preferable to opening each of the machines. The DADS system at WMATA offers the perfect method for obtaining transaction data since transaction register readings for all machines may be obtained in only 2 to 3 minutes, and are virtually simultaneous with the beginning and end of the data collection period. However, even if an external method is available, the basic methodology may also be utilized as a backup measure.

Once beginning transaction data have been recorded, the on-site observation of machine failures should be conducted by a two-person team. One survey team member will maintain a master log of all failures observed and should be positioned so that equipment failures are readily seen. The second team member will also be alert to equipment failures, but will be primarily responsible for determining the exact cause and specific disposition of each failure. This will generally be accomplished by accompanying the station agent or attendant to each machine experiencing a failure, observing the agent's actions, and then querying the agent about the specific nature and disposition of the failure.

The second team member should then report this information to the first person so that the failure may be properly classified. Since AFC equipment, in general, does not provide external indications of failure types, it is clear that the two survey team members must interact closely if failure data are to be accurately recorded.

DATE: ____________________

STATION: ____________________

MACHINE STATUS FORM

IBM VENDORS, ADDFARES, AND CHANGERS

MACHINE NUMBER	TIME	VENDORS					ADD FARES		CHANGERS			
		COIN VALUE	DOLLAR VALUE	BONUS VALUE	TOTAL TICKETS	R V T	TOTAL VALUE OF COINS	TICKETS PROCESSED	TOTAL $1 BILLS	TOTAL HALF $	TOTAL QUARTERS	TOTAL DIMES

FIGURE III-1 SAMPLE IBM MACHINE STATUS FORM

MACHINE STATUS FORM

DATE: ____________

STATION: ____________

CUBIC VENDORS AND ADD FARES

MACHINE NUMBER	TIME	VENDORS						ADDFARES				
		RVT VALUE	NICKEL VALUE GVN	QUARTER VALUE GVN	COIN VALUE	BILL VALUE	TOTAL TICKETS	NICKEL VALUE GVN	QUARTER VALUE GVN	COIN VALUE	BILL VALUE	TOTAL TICKETS

DATE: ____________

STATION: ____________

MACHINE STATUS FORM					
ENTRY AND EXIT GATES					
MACHINE NUMBER	TIME	ENTRY GATES		EXIT GATES	
		PATRONS - MIN. FARE TICKETS	PATRONS	EXTRACTED FARE	EXIT PATRONS

FIGURE III-3 SAMPLE MACHINE STATUS FORM FOR ENTRY 1 EXIT GATES

Sample data collection forms are included in Figures III-4 and III-5. Figure III-4 represents the master control log for recording and classifying all failures. A coding scheme for classifying failures is provided in the upper left corner of the form. As shown in the illustrative data included on the form, operational status of each machine at the beginning of the data collection period should be the initial notation on the form. For gates, (designated aisles in Figure III-4) an indication should be made whether the gate is an entry or exit gate. As failures occur, they should be properly recorded, and the time of observation and the time that the machine returns to service should also be noted. At the end of the data collection period, the final operational status of each machine should be recorded. Figure III-5 is a sample of the form which the second survey team member might use to record the specifics of each failure or any unusual situations which might affect the data being collected.

Final transaction status readings for each machine must be taken at the conclusion of the data collection period. The procedure to be followed will be the same as that used to obtain the initial readings. Unless there is available some method for obtaining beginning and ending readings which essentially coincide with the start and end times for the data collection period, the total number of transactions obtained from the beginning and ending readings must be adjusted so that it more appropriately reflects the actual number of transactions which occurred during the period.

Training of Data Collectors

Well trained data collectors are essential for successfully conducting a reliability and maintainability assessment of AFC equipment. Before any training is begun, however, careful consideration should be given to training requirements and those details about the survey methodology and AFC equipment which will maximize data collector performance. If the training is carefully planned, necessary information can be conveyed to the data collectors in one half-day session.

KEY: B BILL JAM · C COIN JAM · F FARECARD JAM · M MONEY CONTAINER FULL · O OUT OF SERVICE · H HARD FAILURE · E ENTRY · X EXIT · R RETURN TO SERVICE

AFC SURVEY FORM
MONTGOMERY STATION — West End

NAME J. JONES · START TIME 0700 · STOP TIME 0900 · DATE 3/14/80

TIME	AISLE 5	7	9	10	12	13	14	15	16	17	18	VENDORS, CHANGERS, ADD FARES VN 02	MF 02	MF 05	VN 08	VN 09	VN 10	VN 11	VN 12	VN 13	VN 14	MF 06	MF 07	V/E 01	AF 04	AF/M 01	REMARKS
0700	X	X	X	E	X	E	X	X	X	E	X								O								VN-12 — AWPS
0703					O/F																						JAMMED IN PRINTER
0704															O/C												BENT COIN IN COIN ACCEPTOR
0706					R																						
0710															R												
0713						X																					
0714																						O/B					BILL JAM
0716																						R					
0718																						O/B					BILL JAM
0720																						H					AGENT CALLED MAINT.
0743												O/C															S.B. ANTHONY IN COIN ACCEPTOR
0748								O/																			NO PROBLEM FOUND
0815												R															
0817								R																			
0839																									O/		PATRON INSERTED COIN IN TICKET SLOT
0841															O/												PATRON CLEARED BY HITTING CANCEL BUTTON
0842															R												
0850																									R		
0900	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	O	R	R	O	R	R	R	R	

FIGURE III-4 SAMPLE MASTER CONTROL LOG-FAILURES

ACTIVITY LOG

Mezzanine: MONTGOMERY - WEST

Date: 3/14/80

Time: 0700

EVENT	MACHINE NUMBER	TIME	REMARKS
AGENT OPEN-GATE	AISLE 12	0705	CARD JAMMED IN PRINTER
AGENT OPEN. GATE	VN-08	0709	BENT NICKLE FOUND IN COIN ACCEPTOR
ENTRY TO EXIT	AISLE 13	0713	HEAVY EXIT PATRON FLOW, CHANGED AISLE TO EXIT
CHECK O/S LIGHT	MF-07	0715	BILL JAMMED - OLD BILL
" " "	MF-07	0719	BILL JAM
	MF-07	0720	AGENT DECIDED TO PUT MACHINE O/S
			AND CALL MAINT. - PROBLEM RECURRING FOR SEVERAL DAYS
CHECK PROBLEM	VN-02	0814	PATRON INSERTED S.B. ANTHONY IN SLOT
" "	AISLE 15	0816	FOUND NO PROBLEM, RESET GATE
O/S INDICATION	VN-08	0841	AS PATRON ATTEMPTED TRANS., MACHINE
			WENT O/S. PATRON CLEARED BY HITTING CANCEL BUTTON
AGENT CHECK.	AF-04	0849	PATRON INSERTED COIN IN TICKET SLOT

FIGURE III-5 INDIVIDUAL FAILURE CONTROL LOG

The plan developed for the training should be formalized into a training package which can be given to each of the data collectors. This package should contain, if possible, all the details necessary for conducting the survey. The package should begin with an overview of the survey purpose and objectives, the types of data which are to be collected, and a brief outline of the procedures for collecting the data. The overview should be followed by a detailed discussion of the duties and responsibilities of each data collector. In this discussion, the sequence of activities should be specified from initial register readings to failure observation, through final register readings. The data collection forms to be utilized should be reviewed and copies should be included in the training package. To facilitate the data collectors' understanding of how data are to be recorded, the copies of the forms included in the package should contain some representative examples of data which might be entered on the form. These examples should be discussed in detail; discussion of these examples will also provide an appropriate foundation for the overview of AFC equipment operation which should follow.

The overview of equipment operation should provide the data collectors with a basic understanding of how the equipment functions and the primary components which make up each machine. Ideally, this process should be conducted through first-hand observation of these machines and their components in operation. Observation and discussion of machine components might include bill transport, bill validator, coin acceptor, change mechanism, bill and coin storage facilities, and farecard (ticket) transport. The equipment operation overview should also familiarize data collectors with the internal transaction registers which will be the basic source for transaction data. Each register should be identified with the appropriate data element on the transaction data collection form.

The final element of the training plan should involve practice in recording failure data on the data collection forms. Sample machine failure scenarios should be developed which will provide examples for all machine types and failure types. The responsibilities of each team member in obtaining the relevant data for each example and the appropriate coding in each case should be discussed, and opportunity provided for questions.

To provide for adequate control over the data collection effort, a supervisor should be designated who will be responsible for the day-to-day survey activities. The supervisor should participate in the training, and the role of this supervisor should be made clear to the data collectors. Primarily, the supervisor would be responsible for ensuring that all survey activities are completed properly, as scheduled, and that completed data sheets are routed for further processing. The supervisor should also review the initial activities of each data collection team to ensure that training material has been absorbed and put into use. Where deficiencies are apparent, the supervisor should make suggestions for improvement. Once the data collection effort appears to have stabilized, the supervisor should make periodic, random checks to ensure that the performance of the data collectors has not deteriorated. In addition, the supervisor would serve as the single point of contact for information regarding the status of data collection efforts.

As a final note on training data collectors, there are some additional issues and problems, some of which were noted while observing AFC equipment at WMATA and BART, which should be discussed during the training session. First, the role of the data collectors as observers should be stressed. Data collectors are to observe "normal" AFC operations and should minimize any interference with these operations. Therefore, data collectors should not call the attention of station personnel to observed equipment failures since this would disrupt the usual station procedures.

Second, data collectors should strive to develop a good working relationship with the station agent or attendant. These persons can be valuable sources of information and must be relied upon in most instances to identify the specific nature and disposition of equipment failures. In addition, there may be other data collection efficiencies which can be realized through the establishment of good rapport with station personnel.

Third, it should be impressed upon data collectors that because data are being gathered on money-handling fare collection equipment, they should be sensitive to the concerns of property personnel in regard to the security of the money deposited in the AFC equipment. This caution is particularly applicable if money-handling machines must be opened in order to gather necessary transaction data. At certain properties special procedures might be necessary to accommodate all security concerns.

Included as Appendix A to this report is a sample training plan which was developed for the survey of AFC equipment at BART. This plan is, in general, representative of the kind of package which has been recommended.

Timing and Frequency of Data Collection Periods

The discussion of the methodology presented thus far relates to how to collect AFC equipment performance data. Timing and frequency of data collection periods relates to not only when data should be collected but also to how much data should be collected. Clearly, a primary concern will be to collect a sufficient volume of data to ensure a representative picture of equipment performance. However, there may also be some specific hypotheses related to time of equipment usage which may be of interest, e.g., peak-hour performance vs. off-peak hour performance.

The number of transactions observed could be maximized by restricting all data collection periods to peak-hours, i.e., 7:00 to 9:00 a.m. and 4:00 to 6:00 p.m. approximately. It may be that patrons during these hours are generally "veteran" transit users who are knowledgable about the transit system and usage of AFC equipment, whereas it may be conjectured that there is a substantially higher proportion of first-time and infrequent users among those patrons using the system during the weekday off-peak hours. The proportion may be still higher among weekend users. Therefore, it may be of interest to compare failure rates between peak and off-peak hour usage to determine what effect, if any, these different patron groupings have on the rate of failures in AFC equipment.

Because the rates of usage for peak and off-peak hours are different, however, the data collection requirements will differ for these time periods. Based on experience at WMATA and BART, the rate of usage may be two to three times higher during peak hours than off-peak hours. Thus, to observe equal numbers of peak and off-peak transactions would require two to three times more off-peak hours of observation than peak hours. While a valid statistical comparison would not require that the numbers of transactions observed for each period be exactly equal, a sufficient number of transactions must be considered for each period so that a statistically representative picture is presented for each period.

How many transactions constitute a sufficient number will depend on several factors. If baseline data for failure rates have not been established, then a "ballpark" estimate should be made upon which to base plans for survey observations. If it is felt that a certain type of equipment averages about 500 successful transactions for each failure, then it is obvious that observing 500 or fewer transactions for each machine of that type would likely tell very little about the operational reliability of these machines. In general, it would be advisable to plan the number of transactions observed so that approximately 5 or more failures may be expected during the survey period. Therefore, in the example above, observation of 2500 or more transactions per machine would provide a reasonable basis for establishing baseline data. (The choice of 5 failures as an expected number will be explained in the Analytic Techniques and Procedures section of this report.) If baseline data have been established and interest is in assessing reliability improvement, e.g., in a retrofit situation, then minimum sample sizes necessary for detecting reliability improvement for various ranges of failure rates can be calculated and put in tabular format for ease of use. The discussion of assumptions and procedures necessary for making these calculations are included under Analytic Techniques and Procedures.

Similar guidelines apply if analyses are to be made between weekday or weekend usage or for week-to-week or month-to-month changes in equipment reliability. For efficiency of analysis, survey planning could allow for sufficient hours of observation so that at least 5 failures would be expected to be analyzed during each period. For example, if weekday vs. weekend reliabilities are to be compared, then the number of observation periods to be conducted should be such that at least 5 weekday failures and 5 weekend failures might be expected. When it is not possible to plan this level of observation, minimum sample sizes necessary for detecting reliability improvement, as explained in Section IV, should be utilized as a guideline. In a month-to-month reliability analysis, for example, if the earliest month is used as a baseline, then minimum numbers of transactions to be observed in succeeding months in order to detect significant improvement over the base month can be obtained using this approach.

For those properties whose AFC equipment is operating at a satisfactory reliability level, then the focus of an AFC survey could be shifted to detecting any significant deterioration in equipment reliability. Such surveys could be conducted on a monthly basis. The necessary number of transactions observed for these surveys could be substantially less than the number necessary in order to detect reliability improvement.

As discussed in Section IV, as few as 100 transactions for an individual machine may be sufficient for detecting significant deterioration in reliability. In general, continued acceptable performance for all equipment in a single station could be evaluated through observation of the morning and evening rush hour periods for a single day. It should be re-emphasized, however, that this level of observation would be appropriate only for detecting deterioration in equipment reliability and not improvement.

Use of Existing Data Systems

In both the WMATA and BART systems, each of which was examined in preparing this report, some systems existed for collecting both failure and transaction data, but they could not be relied upon to satisfy fully all data needs. Both systems collect hard failure data, but neither system maintains retrievable soft failure data. The WMATA Data Acquisition and Display System panel in each station kiosk shows soft failures on an LED display but does not produce a record of each failure.

Existing data systems can be most beneficial if they can be utilized to collect transaction data which will correspond specifically to each failure observation period. As already noted, the DADS system at WMATA can provide beginning and ending transaction status data by machine for each data collection period. At BART, transaction data are collected automatically by the DAS, but special procedures would be necessary in order to collect data which would be specifically applicable to each period. In addition, not all machines are interfaced with the DAS.

Level of Effort Required for Data Collection

The survey methodology described calls for the use of a two-person team to collect data for each data collection period. The roles of each team member were also described. Each data collection period should last approximately 2 to 2½ hours, which will usually coincide with the length of the morning or evening rush hour. Because off-peak hour transit usage rates are considerably less than peak hour rates, off-peak hour periods might be extended to 3 hours in order to collect more transactions. If the internal machine registers must be read in order to collect transaction data, then an additional hour should be allotted for each data collection period. In summary, each data collection period will then require 5 to 7 person hours.

The total number of data collection periods which are to be conducted will be determined by the total number of observed transactions desired and by the anticipated machine transaction rate for each period. Once determined, the total number of data collection periods multiplied by the number of person hours per period will yield the personnel requirements for collecting the data.

In addition to requirements for collecting the data, personnel will also be required to reduce, summarize, and analyze the data collected. Data reduction will consist of reviewing the data sheets, making decisions on failure classification, and counting the number of failures of each type which occurred during each survey period. Data reduction will also include determining and recording the duration in minutes of each failure, as well as making necessary calculations to determine the number of transactions which occurred during the survey period. Summarizations of the data will involve using the results of the data reduction process to aggregate the data to appropriate levels and calculate statistical performance measures. Analyzing, interpreting and reporting results will be the final step. The level of effort necessary to perform all of these functions will vary somewhat depending on rate of machine usage and failure rate. This is particularly true for the data reduction phase. However, based on experience thus far with the methodology proposed, approximately 3 person hours should be allotted for reduction, summarization, and analysis of data collected for each data collection period conducted. For example, if an AFC Survey to be conducted is to include 10 observation periods, then about 30 person hours, in addition to those hours necessary to collect the data, should be allotted for data reduction, summarization, and analysis.

SECTION IV

ANALYTIC TECHNIQUES AND PROCEDURES

The utility of accurate and reliable data collected using the recommended survey methodology can be realized only through appropriate analysis and interpretation of the data. The main objective of this section is to provide some standardized techniques and procedures which can be used to analyze data collected. Statistics that can be generated from the data are enumerated, and the levels of aggregation at which these statistics can be calculated are then discussed. The final topics of this section concern the usefulness of each of the statistics and the analysis and interpretation of these statistics.

Statistics To Be Generated From The Data

In the usual engineering environment, a primary measure of equipment performance is reliability. This reliability measure is calculated by assuming that failures will follow an exponential probability distribution and that the mean time between failures (MTBF) is an appropriate parameter to utilize in the calculation. The resulting reliability coefficient represents the probabilty that the equipment will operate without failure for a specified period, e.g., a 24-hour period. Implicit in the calculation of this measure, however, is the assumption that the equipment under consideration is operating continuously, an assumption which does not hold for automatic fare collection equipment.

As an alternative to the standard reliability measure, the probability that an individual transaction using AFC equipment is completed successfully will be utilized as an indication of machine reliability. To estimate this probability from sample survey data, the following formula should be used:

$$R = \frac{(\text{Total Trans.}) - (\text{Total Failures})}{\text{Total Transactions}} = \frac{\text{Total Successful Trans.}}{\text{Total Transactions}}$$

This estimate then is simply the proportion of total observed transactions which were completed successfully.

Another statistic to be calculated from survey data is a simple function of the preceeding reliability measure. This statistic is transactions per failure and can be computed as follows:

$$TPF = \frac{\text{Total Transactions}}{\text{Total Failures}}$$

This estimate provides the average number of transactions which occurred between each observed failure. It may also be expressed in terms of the reliability statistic described above.

$$TPF = \frac{1}{1-R}$$

Equipment availability, i.e., the proportion of total survey time during which equipment was in service and available for use, may also be a desired statistic from survey data. The following formula may be used:

$$\frac{(\text{Total Survey Time}) - (\text{Total Down Time})}{\text{Total Survey Time}} = \frac{\text{Total In-Service Time}}{\text{Total Survey Time}}$$

Meantime between failures was mentioned earlier as input to the standard reliability calculation. It may also be considered as a separate statistic and would be calculated as follows:

$$MTBF = \frac{\text{Total In-Service Time}}{\text{Total Failures}}$$

This statistic yields an estimate of the average length of time between failures.

The complement of the mean time between failures statistic is mean time to repair, i.e., the average elapsed time between failure and return to service. The formula for the computation of this statistic is:

$$MTTR = \frac{\text{Total Down Time}}{\text{Total Failures}}$$

Levels of Aggregation

There are several levels at which statistics may be calculated and analyzed. The level at which statistics can always be calculated from survey data will be the individual machine level. Depending on the availability of appropriate data items, it may also be possible to calculate statistics for machine components such as the bill transport and validator and coin acceptor mechanisms. To make such calculations, however, transaction data must be available in the form of number of bills handled and number of coins handled. For example, transactions per failure statistics at the component level would appear as number of bills handled per bill jam or number of coins handled per coin jam.

Higher levels of data aggregation would include the mezzanine or station level. For example, data for all machines of a certain type (vendor, addfare, gate, etc.) could be combined and statistics calculated to provide a measure of mezzanine or station performance. These statistics might reflect overall equipment performance or might be calculated for overall component performance, again if necessary transaction data items are available. If equipment within a mezzanine or station has been supplied by more than one manufacturer, statistics could be generated separately for all equipment supplied by each manufacturer.

The highest level of data aggregation will be at the system level to provide system measures of equipment performance. As with more elementary levels of aggregation, statistics may be generated which reflect component performance or equipment performance for different suppliers.

Usefulness of Statistics Generated

Evaluating the performance of automatic fare collection equipment in terms of standard reliability and maintainability measurements presents certain difficulties in the interpretation of the significance of such measures. Generally, standard performance measures involve continuously operating equipment so that the operating requirements for each piece of equipment are equalized. This is clearly not the case for AFC equipment. None of the equipment operates continuously; in addition, rates of usage for equipment of the same type vary widely for individual machines. To interpret survey data collected on machine performance, the data must be standardized or reduced to a consistent base. Experience gained thus far at the WMATA and BART properties suggests that the data be adjusted for rate of usage to provide such a consistent base.

Statistics which utilize total transactions observed in their calculation will afford this consistent base. For example, the reliability estimate suggested earlier (proportion of total transactions completed successfully) and the transactions per failure statistic each lend themselves to consistent and meaningful interpretation. Each remaining statistic enumerated earlier presents problems of interpretation since their calculation does not involve total transactions observed. For example, if survey data indicate 95% availability for a particular piece of equipment, then this machine was available for use during 95% of the survey observation period. The fact that the machine was available for use, however, does not indicate that the machine was used at all during this time, or if used that it failed at a rate which was considered desirable.

For mean time between failures, a similar interpretation problem exists. A large MTBF figure may imply that the equipment is operating well or that the machine is not used often and therefore does not fail frequently. The mean time to repair statistic, however, can provide some indication of how long it takes for station agents or attendants to perform their designated failure correction functions.

Analysis and Interpretation of Statistics

Analysis and interpretation should focus on the reliability (R) and transactions per failure (TPF) statistics. The basic approach is to treat the reliability statistic as a measure of probability, i.e., the probability of a successful transaction. Since transactions per failure is a simple function of reliability, analysis of transactions per failure ratios will follow from results with reliability.

Two levels of analysis are suggested, confidence intervals and significance tests. Confidence interval techniques should be utilized for determining regions which can reasonably be expected to contain "true" reliability or transactions per failure values. Determination of these regions or intervals will rely on Normal probability distribution theory, if appropriate assumptions can be made. The assumptions necessary relate to the fact that the reliability statistic calculated is an estimate of the probability of completing a successful transaction. As such, it is treated as the probability (p) of success in a binominial probability distribution. Utilizing this distribution, the probability of x successful transactions in n total transactions is expressed as:

$$\frac{n!}{(n-x)!x!} (p)^x (1-p)^{n-x}$$

Because computations using this formula are usually quite tedious, these probabilities are often estimated using the Normal probability distribution. The estimation works well as long as n, the number of transactions, is large, and p, the probability of a successful transaction, is not too close to 1. In general, with n large, if n x p is at least 5, then the approximation using the Normal distribution will be reasonably accurate.

In application, a confidence interval for reliability would be calculated using the following expression:

$$p \pm k\sqrt{\frac{p(1 - P)}{n}}$$

where k is an appropriate value determined from the Normal distribution and a desired confidence level. For example, to compute a 95% confidence interval, k would equal 1.96; for a 90% confidence level, k would equal 1.645. To determine a confidence interval in terms of transactions per failure, the end points of the confidence interval computed for reliability should be converted to transactions per failure through the expression previously stated:

$$TPF = \frac{1}{1-R}$$

Significance testing for reliability statistics will also utilize the Normal probability distribution approach for approximating binomial probabilities. Significance testing situations will arise if it is desired to test the significance of survey results against some hypothesized reliability values or if differences between current survey results and previous survey results are to be examined to determine changes over time or the effect of an intervening retrofit modification. To perform the significance tests using the Normal distribution procedure, the same assumptions must be met which were required for computing confidence intervals. In practice this will require that reliability and transactions per failure statistics be computed based on observation of at least 5 failures. If results from two surveys are to be compared, then statistics from each survey should meet this requirement.

To apply a significance test of a survey reliability value (p) against a hypothesized value (h), the following should be calculated:

$$\text{test value} = \frac{p - h}{\sqrt{\frac{p(1 - p)}{n}}}$$

Assuming that it is desired to detect significant improvement in reliability, then "test value" will be positive and should be compared against an appropriate value from the Normal distribution. For example, at the 95% confidence level, if "test value" is greater than 1.645, then it would be concluded that the survey reliability value is significantly higher than the hypothesized value.

If it is desired to detect significant deterioration in reliability, then "test value" will be negative and should be compared with 1.645. If "test value" is less than 1.645 (i.e., greater in absolute value), then it would be concluded that the survey reliability value is significantly lower than the hypothesized value.

If results from two surveys are to be compared, the following "test value" should be calculated:

$$\text{test value} = \frac{p_1 - p_2}{\sqrt{\dfrac{p_1\,(1-p_1)}{n_1} + \dfrac{p_2\,(1-p_2)}{n_2}}}$$

where p_1, p_2 and n_1, n_2 are the respective reliability values and numbers of transactions observed for the two surveys. If p_1 is assumed to be the reliability computed for the current survey and it is again desired to detect improvement in reliability, then "test value" will be positive and its significance is assessed as in the previous test.

In the event that the necessary requirements for the Normal probability testing procedure cannot be satisfied, then the probabilities associated with the binomial distribution must be relied upon. The procedure will involve calculating the probability that the results obtained by the survey could have occurred if the reliability is actually the assumed hypothesized value. For example, assume that it is estimated, possibly from previous survey data, that equipment reliability is 0.9950 or 200 transactions per failure. Data from a current survey based on 1500 observed transactions show 4 failures during the survey period or a transaction per failure rate of 375, and it is desired to determine with 95% confidence whether or not current survey data indicate a significant improvement in reliability.

Because the observed number of failures is less than 5, the Normal test of significance should not be used. Instead, the procedure will be to compute the probability of obtaining 4 or fewer failures in 1500 transactions if the reliability is 0.9950 or 200 transactions per failure. If this probability is 0.05 or less, then it can be concluded with at least

95% confidence that reliability has improved. However, from the binomial formula, the probability of 4 or fewer failures is 0.13 and thus reliability has not improved significantly based on survey results.

The computation of these probabilities can be quite tedious, but can be simplified through use of the table shown in Table IV-1. The table shows, for a variety of sample sizes (numbers of transactions observed) and reliability/transactions per failure combinations, the maximum number of failures which could be observed in order to conclude with 95% confidence that reliability is better than the corresponding value given in the table. To illustrate, assume in the previous example that 3 failures, instead of 4, were observed in 1500 transactions. This result would indicate significant improvement in reliability since, according to the table, the probability of observing 3 or fewer failures in 1500 transactions, assuming a reliability of 0.9950 or 200 transactions per failure, is approximately 0.05.

Table IV-1 also provides some guidelines for determining how many survey observations should be made in order to be able to detect reliability improvement. Again using the reliability of 0.9950 to illustrate, the table shows that observation of 500 transactions would be insufficient to detect improvement (95% confidence level) even if 0 failures were observed. This determination is based on the fact that for reliability of 0.9950, the probability of observing 0 failures in 500 transactions is about 0.08. In planning surveys to assess reliability improvement, the table can be a convenient aid in planning the level of survey effort necessary to meet objectives.

A similar table can be constructed which will aid the planning and analysis of surveys that are designed to detect significant decreases in reliability of equipment performance. Analysis of such surveys

TABLE IV-1

MAXIMUM NUMBER OF OBSERVED FAILURES
INDICATING RELIABILITY IMPROVEMENT
(95% CONFIDENCE LEVEL)

NUMBER OF TRANS. OBSERVED	RELIABILITY/TRANS. PER FAILURE				
	0.9900/100	0.9950/200	0.9967/300	0.9975/400	0.9980/500
400	0	Insuf.[1]	Insuf.	Insuf.	Insuf.
500	1	Insuf.	Insuf.	Insuf.	Insuf.
750	3	0	Insuf.	Insuf.	Insuf.
900	4	0	Insuf.	Insuf.	Insuf.
1,000	N[2]	1	0	Insuf.	Insuf.
1,250	N	2	1	0	Insuf.
1,500	N	3	1	0	0
1,750	N	4	2	1	0
2,000	N	N	2	1	0
2,250	N	N	3	1	1
2,500	N	N	3	2	1
2,750	N	N	4	2	1
3,000	N	N	N	3	2
3,500	N	N	N	4	2
4,000	N	N	N	N	3
4,500	N	N	N	N	4

[1]Insuf. indicates that given number of transactions is insufficient to detect improvement in reliability, even if no failures are observed.

[2]N indicates that significance testing procedures based on Normal probability distribution can be utilized when 5 or more failures are observed.

requires tabulation of the minimum number of observed failures which would indicate a significant decrease in reliability from a specified level. Table IV-2 shows, for each sample size (total transactions observed) and reliability/transactions per failure combination, the minimum number of failures necessary to conclude, with 95% confidence, that reliability is less than the corresponding value given in the table. For example, if reliability is assumed to be 0.9975 or 400 transactions per failure, then the probability of observing 2 or more failures in 300 transactions is approximately 0.05. Thus, if a survey found 2 or more failures in 300 transactions, it could be concluded with 95% confidence that reliability was significantly less than 0.9975 or 400 transactions per failure.

It should also be noted that because sample size requirements for such an analysis are considerably less than those for assessing reliability improvement, Table IV-2 includes a maximum sample size of only 1000. Surveys which include more than 1000 transactions will require at least 5 observed failures, at any of the specified reliabilities, in order to show significant results. Because of this fact, statistical significance can be assessed using testing procedures based on the Normal probability distribution as described earlier.

TABLE IV-2

MINIMUM NUMBER OF OBSERVED FAILURES
INDICATING DECREASE IN RELIABILITY

NUMBER OF TRANS. OB-SERVED	RELIABILITY/TRANS. PER FAILURE				
	0.990/100	0.9950/200	0.9967/300	0.9975/400	0.9980/500
100	3	2	1	1	1
200	4	3	2	2	1
300	6	4	3	2	2
400	7	4	3	3	2
500	9	5	4	3	3
750	12	7	5	4	3
900	14	8	6	5	4
1,000[1]	15	9	6	5	4

[1]For sample sizes greater than 1,000, the minimum number of failures required will be 5 or more, and thus testing procedures based on the Normal probability distribution can be utilized for assessing significance of decrease.

SECTION V
REPORTING AND PRESENTATION OF RESULTS

Effective reporting and presentation of results are the logical final steps necessary for realizing completely the utility and the analyses of the collected data. This section provides a suggested format for reporting results and includes some comments on procedural and methodological detail to be included, a discussion of results, and visual displays such as tables and charts which may enhance the presentation.

Suggested Format

A survey of automatic fare collection equipment should not require any special format to ensure effective reporting. General formats for technical reports should work well for reporting results from the type of survey recommended here. However, some discussion of a possible format which may be applied to an AFC survey may be helpful.

The body of such a report might reasonably be divided as follows:

- I. Introduction
- II. Highlights (or Executive Summary)
- III. Methodology
- IV. Survey Results
- V. Recommendations for Future Surveys

The Introduction will discuss the reasons for the survey, its goals, and the data collection method. The Highlights or Executive Summary will summarize the methodology and the significant survey results.

The details of the data collection methodology and the procedures used for analyzing the data collected should be continued in the methodology section. While this section should already contain details on methodological procedures, the level of detail should be carefully considered. This section should present only those details which are essential for a clear understanding of the survey results. If a full documentation of all methods and procedures is also desired, then nonessential and highly technical details should be included as an appendix so as not to detract from the readability of the report.

The presentation of data in the Survey Results section will have different forms and emphases depending upon the objectives of the survey. For example, if the survey is conducted in order to establish baseline data for equipment reliability, the presentation and analysis of results will be primarily descriptive. On the other hand, if the purpose of the survey was to monitor changes in reliability over time, then the Survey Results section would also include inferences about the significance of changes in reliability as measured by previous surveys. A similar format should be employed if the objective of the survey is to evaluate improvements due to retrofits, additional maintenance personnel, in-service maintenance training programs, increased frequency of preventive maintenance, or some other program or procedure intended to improve equipment reliability.

Tables, charts, and other visual displays should be interspersed with the discussion of results, whenever their inclusion would appear to reinforce the importance of the results presented. Such displays might include station layouts showing machine locations so that the reader could have a clear picture of patron flow through the station. Alternatively, station layouts might be presented in the methodology section, if desired.

Some flexibility might be exercised in the level of detail included in these tables or displays, depending on survey objectives. The simpler the presentation, the more likely it is to be effective. If highly detailed tables are desired, they might be presented in an appendix so they do not interfere with the continuity and readability of the text.

The final section of the report should contain recommendations for future surveys. These recommendations should take into account the results of the survey and any shortcomings in the data. Recommendations may take the form of suggested changes in procedures for both data collection and analysis, additions to or deletions from the list of data items collected, alterations in the frequency of equipment observation, or scheduling of subsequent surveys.

SECTION VI

APPLICATIONS TO OTHER PROPERTIES

The development of the methodology described in this report included examination of two properties, BART and WMATA, which utilize fare collection equipment whose sophistication equals or exceeds that of all other transit properties in the United States. The methodology developed, therefore, had to include a level of detail appropriate to this sophistication. It is hoped, however, that the description of the methodology and procedures presented in this report is sufficiently general so that other properties may see application of the methodology for assessing the performance of their fare collection equipment. The methodology can be tailored to suit the needs of each individual property.

Before undertaking a survey of equipment performance, the property must first consider the objectives of the survey.
Properties which have not adequately assessed equipment reliability levels may wish to utilize the methodology to conduct a system-wide evaluation of AFC equipment performance. Other objectives for an AFC survey utilizing the recommended methodology would include assessing the effects of reliability improvement programs. Assessments might be conducted on a system-wide, station, equipment type, or machine component level. Still other objectives might involve examining differences in reliability between stations, or tracking reliability on a month-to-month or week-to-week basis.

If the objectives decided upon appear reasonable and worthwhile, then thought should be focused on the resources necessary for conducting the survey. Properties, therefore, will need to concentrate on determining how much survey observation is required to achieve the objectives. The basis for this determination will consist of specifying the elementary unit for which analysis is to be conducted and the required number of patron transactions which should be observed in order to conduct the analyses. For example, if the performance of individual machines is to be analyzed, then the number of transactions observed for each machine must be sufficient to conduct the analysis within prescribed levels of confidence. Guidelines for determining the number of transactions required were presented in Sections III and IV. It should be emphasized that requirements may vary considerably depending on whether the survey objectives are to establish baseline reliability data, assess reliability improvement, or monitor and detect any significant deviation from desired reliability levels.

Based on the individual property's patron transaction rate and the total number of transactions determined necessary, the number of survey periods and the number of survey personnel can be assessed. Because the survey methodology recommended is extremely labor-intensive, personnel availability could necessitate altering survey objectives so that useful results can be obtained utilizing available personnel. Some flexibility is possible, however, in scheduling data collection periods and personnel. For example, the original survey design may call for all data to be collected within one week, but because sufficient numbers of personnel are not available, the required amount of data would have to be collected over a period of one month. If, based on all estimates and calculations, it appears that sufficient personnel can be made availabe, then the specific data items to be collected can be addressed.

Each property will have to define the specific types of "soft" and "hard" failures which may occur and can be easily categorized. However, to provide some standardization, it is recommended that the general definitions of "soft" and "hard" failures be adhered to, i.e., machine failures which can be handled by a station agent or attendant should be classified as "soft", while those requiring a maintenance technician should be classified as "hard". In some cases, the property may desire to collect information which is more detailed than that described in this report. For example, the property may be interested not only in the reliability of specific machine components but also in the sub-components which make up the major component. This situation could arise if the property is interested in isolating major component failures to the specific sub-component involved, or possibly to assess the effects of a sub-component retrofit. With appropriate training of data collectors, this goal can be achieved within the constraints of the general methodology described.

Except for personnel availability, the two-person data collection teams approach should present little, if any, difficulty for the properties. In general, one member of the team should be positioned in a central location which affords maximum opportunity to view the operations of the fare collection equipment. This person will maintain the master log of all failures and their resolution. The second team member will accompany the station agent or attendant to ascertain the specific nature of each failure and will report these findings to the first team member. Properties may need to develop specific recommendations for appropriate positioning of each member of the survey team to accommodate the specifics of their station arrangements.

Analysis, reporting, and presentation of results should be adjusted so that they suit the particulars of the data collection methodology as determined by the property, and so that they will address the analytic questions which are of interest to the property. Such adjustments might include developing decision rules for interpreting and classifying failures, e.g., classifying soft failures into those which are machine-related and those which are patron-induced. Some failure categories which occur infrequently may need to be combined in order to form a reasonable basis for analysis. If patron transaction data do not correspond exactly to the data collection period, a methodology for adjusting these data may be required.

Analysis of statistics which are calculated from survey data should focus on the reliability (as defined in this report) and transactions per failure statistics. Because these statistics are calculated utilizing the total number of transactions which are observed, they provide a consistent basis for analysis and comparison at each level of aggregation. The guidelines presented in Section IV should be used in assessing the significance of statistics calculated. Particular care should be exercised in the interpretation of statistics based on a small number of patron transactions or on fewer than 5 failures.

TRAINING FOR BART

AUTOMATIC FARE COLLECTION (AFC)

SURVEY

APPENDIX A

(This pacakge was utilized to train survey personnel for the BART AFC Survey. The package is included to illustrate the type of training package which is described in the body of the report.)

TRAINING PACKAGE FOR BART AFC SURVEY

The packet includes the following items:

- Overview of the survey purpose,
- Discussion of survey procedures,
- Survey Schedule,
- Data Collection Procedures,
- AFC Survey Forms,
- Machine Status Forms,
- Activity Log, and
- Station Layouts (Montgomery, Embarcadero, Lafayette)

1. OVERVIEW OF BART SURVEY PURPOSE

The Transportation Systems Center of the United States Department of Transportation desires to develop a methodology for collection and analysis of reliability and maintainability data on Automatic Fare Collection (AFC) equipment. As a part of the overall development effort, Automated Services, Inc., under contract to the Transportation Systems Center, is conducting a survey of AFC equipment at three BART stations over a period of eight weeks.

The objectives of the survey are to:

1. Further the development of a methodology for the collection and analysis of AFC data.
2. Provide BART with useful information on their AFC equipment.
3. Gather data that can be used to make comparisons between BART and WMATA equipment.

In order to meet these objectives, it is essential that complete and accurate data is obtained. The data collected will be used to make comparisons between machines, retrofits, manufacturers, locations, and between peak and non-peak hours. Your cooperation in ensuring that valid data are collected will make these comparisons meaningful and useful.

There are four types of AFC equipment to be studied in this survey; entry/exit gates, farecard vendors, add-fare machines, and money changers. Some of the equipment was manufactured by IBM and some by Cubic-Western Data.

The effectiveness of each type of machine will be assessed by determining the number of transactions, number and types of failures, and amount of time each machine was out-of-service during each survey period. Data collection is described in greater detail in the following section.

2. DISCUSSION OF SURVEY PROCEDURES

GENERAL INSTRUCTIONS. The success of the survey depends on establishing a good rapport with the station attendants. Although you will need their cooperation for opening machines to read the registers, you should minimize any interference with their regular duties. This includes not pointing out any machine failures to the attendants. More specifically, you should not bias the study by doing more than observing and recording the data called for. Additionally, we do not wish to impede patron flow through the station.

The general guideline for the survey is simply to be accurate and complete in gathering data, while minimizing interruptions to patrons or station attendants.

SPECIFIC INSTRUCTIONS.

A. PRE-SURVEY. In order to determine the number of transactions (machine usage) for each survey period, it is necessary to open each machine and record register information before and after each data collection period. This means that if a survey is scheduled for 7:00 a.m. to 9:00 a.m., you should arrive at least 30 minutes before 7:00 a.m. at Embarcadero or Lafayette Stations and 45 minutes before at Montgomery Station to read and record registers data. You should also plan on 30 to 45 minutes after the survey period to read and record the registers again.

Since most survey periods involve rush hours it is important to start reading registers on time in order to be finished before patron flow becomes heavy.

Information from machine registers is to be recorded for all equipment (entry/exit gates, farecard vendors, add-fare machines, and money changers) on the Machine Status Forms.[1] There are 3 Machine Status Forms, one for

---

1. Note that at Montgomery Station some equipment is not included in the survey. This equipment need not have the registers read, nor should any failures be recorded for them.

entry/exit gates only, and separate forms for IBM and Cubic fare card vendor, add-fare, and money changer machines. The IBM form includes fare card vendors, add-fare machines, and money changers. The Cubic form covers only fare card vendors and add-fare machines since the Cubic machines make change in addition to the vend and add-fare functions.

You will need a flashlight to read these registers. Please be extremely accurate in reading and recording these data, otherwise it will not be possible to determine the number of transactions per survey period.

Please be sure to fill out the station name and date on the Machine Status Forms, as well as the machine number and time of the reading.

B. SURVEY. Once the machines have been read and the data recorded, the survey can begin. Two forms are needed, the AFC Survey Form and the Activity Log (you will need several copies of each).

Complete the heading information first. For the Activity Log this includes the name of the mezzanine or station, the date and time of the survey. For the AFC Survey Form it includes the surveyor's name, date, and start time for the survey. Note particularly that there are 3 versions of the AFC Survey Form, one for each survey station.

You should start and stop the survey period as closely as you possibly can to the scheduled time.

One survey team member will complete the proper AFC Survey Form. To do this you should position yourself in the station so that you can readily see any equipment failure. As failures occur you should note them in the appropriate column on the form and record the time (hour and minute). When failures are corrected, i.e., the machine is back in service, that should be noted and the time recorded.

A classification code for failure is noted at the top of each AFC Survey Form. These are more fully explained on the following table.

TABLE 1
CLASSIFICATION OF FAILURES

Soft failures are those normally serviced by the attendants in the station. Failures to be considered "soft failures" will include:

J = Farecard Jam.
This may occur in all types of equipment except the money changer when the farecard is processed through the transport and encoded, read and verified.

C = Coin Jam.
This occurs in the farecard vendor, add-fare, and money changer machines, usually due to a bent or foreign coin.

B = Bill Jam.
This occurs in the farecard vendor and add-fare machines, or money changer and is usually due to torn or crumpled bills.

F = Money Container Full.
When the bill vault or coin vault in a vendor, add-fare, or money changer is full, the machine will go out-of-service until the vault is emptied.

O = Out-of-Service.
This classification covers many types of soft failures, including those that occur for no identifiable reason. This is used for all other soft failures.

Hard Failures

H = Hard Failures
This group includes machines that are out-of-service because they are awaiting parts. It applies when a machine is worked on by a maintenance person, or when a call for maintenance person occurs. It also applies to situations where a constant coin, ticket or bill jam occurs and the machine is put out-of-service by an attendant.

The second team member will complete the Activity Log. The primary purpose of the Activity Log is to gather information about the cause of failures and the disposition of repetitive or noncorrectible failures. Consequently, the team member completing the Activity Log will observe the activities of station attendants when they clear jams or other failures and note the reason for the failure, either by first asking the attendant or by noting the failure, either by first asking the attendant or by noting the cause directly. In such cases, the observer should note the type of event (e.g., bill jam), the machine number (see station layout), the time, and the cause or disposition under "remarks."

The Activity Log recorder will also note each time the attendant uses the farecard reader located in the attendants kiosk. The reader is used to read information coded on a farecard. When the farecard reader is used note whether or not the reader operates successfully and when possible, the reason why it was necessary to use the reader, i.e., what was the problem with the card.

While the Activity Log recorder is not necessarily to duplicate the AFC Survey Form recorder, such duplication as occurs is fine. It will be particularly helpful when the cause of a problem can be identified for the AFC Survey Form that would otherwise have been in question.

C. POST SURVEY. At the conclusion of the survey period note the "stop time" on the AFC Survey Form and indicate the status of each piece of equipment at the conclusion of the survey as O for Out-of-Service or R for In-Service.

Next, the equipment registers need to be re-read and recorded to determine the number of transactions that occurred during the survey period. Follow the same procedures as those used for reading registers prior to the survey, including reading the machines in the same order, if possible. Make sure to note the time each machine is read.

> NOTE: It would be helpful if three lines (rows) were reserved for each machine, one for the pre-survey reading, the second for the post-survey reading, and the third left blank for later use in subtraction to determine transactions.

At the conclusion of each survey period, the entire set of forms should be checked for completeness and then given to the survey supervisor.

The set of survey forms for each period will be photocopied with the originals forwarded to Automated Services and the copy retained as back up.

DATA COLLECTION PROCEDURES

Pre Survey Procedures:

1. Arrive at station mezzanine thirty minutes prior to scheduled survey time (forty-five minutes in the case of Montgomery-West) with required forms, clip board, and flashlight.

2. Record transaction data for all survey machines on the MACHINE STATUS FORM(S).

3. Complete the information requested at the top of the AFC SURVEY FORM including the date, your name, and the time you start the survey.

4. For each faregate at the AFC SURVEY FORM mark E (Entry) or X (Exit). (Entry means a patron is entering the paid area.)

Survey Procedures:

1. Be sure the exact start time appears on the AFC SURVEY FORM.

2. Collect and record survey data.

   - One team member will complete AFC SURVEY FORMS noting the time of each survey event, the type of event, and when the equipment was returned to service.

   - The second team member will complete the ACTIVITY LOG and will accompany the station attendant for any maintenance activity to determine, as best as possible, the nature and cause of the problem.

   NOTE: NEITHER TEAM MEMBER SHOULD CALL ATTENTION TO ANY EQUIPMENT PROBLEMS NOR IN ANY WAY INTERFERE WITH THE STATION ATTENDANTS DUTIES.

End of Survey Procedures:

1. Record the exact time that the data collection ended.

2. Record the status of each machine at the end of the survey on the AFC SURVEY FORM.

3. Record transaction data for all survey machines on the MACHINE STATUS FORM(S).

4. Assemble pre-and post-MACHINE STATUS FORMS: AFC SURVEY FORMS; and ACTIVITY LOGS. Check to see that all information is recorded including the surveyor's name, dates, and times.

5. Deliver the completed survey forms to the survey supervisor.

DATA COLLECTION SCHEDULE FOR BART AFC SURVEY (3/10/80 - 5/2/80)

STATION/TIME	WEEK 1					WEEK 2					WEEK 3					WEEK 4					WEEK 5					WEEK 6					WEEK 7					WEEK 8				
	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F
MONTGOMERY-WEST END																																								
7:00am - 9:00am	X						X						X						X						X	X						X						X		
2:00pm - 4:00pm		X		X		X		X				X			X			X		X		X		X				X		X	X			X		X	X			
4:00pm - 6:00pm	X						X						X						X						X	X						X						X		
EMBARCADERO-WEST END																																								
7:00am - 9:00am		X						X						X						X	X						X						X						X	
4:00pm - 6:00pm		X						X						X						X	X						X						X						X	
LAYFAYETTE																																								
7:00am - 9:00am			X						X						X	X						X					X							X						X
4:00pm - 6:00pm			X						X						X	X						X					X							X						X

MACHINE STATUS FORM

ENTRY AND EXIT GATES

DATE: ____________

STATION: ____________

MACHINE NUMBER	TIME	ENTRY GATES		EXIT GATES	
		PATRONS - MIN. FARE TICKETS	PATRONS	EXTRACTED FARE	EXIT PATRONS

AFC SURVEY FORM

MONTGOMERY STATION — West End

KEY: B = BILL JAM; C = COIN JAM; J = FARECARD JAM; F = MONEY CONTAINER FULL; O = OUT-OF-SERVICE; H = HARD FAILURE; E = ENTRY; X = EXIT; R = RETURN TO SERVICE

NAME: J. JONES | START TIME: 0700 | STOP TIME: 0900 | DATE: 3/14/80

TIME	AISLE											VENDORS, CHANGERS, ADD FARES															REMARKS
	5	7	9	10	12	13	14	15	16	17	18	VN 02	MF 02	MF 05	VN 08	VN 09	VN 10	VN 11	VN 12	VN 13	VN 14	MF 06	MF 07	V/M 01	AF 04	AF/M 01	
0700	X	X	X	E	X	E	X	X	X	E	X								O								VN-12 - AWPS
0703					O/J																						JAMMED IN PRINTER
0704															O/C												BENT COIN IN COIN ACCEPTOR
0706					R																						
0710															R												
0713						X																					
0714																						O/B					BILL JAM
0716																						R					
0718																						O/B					BILL JAM
0720																						H					AGENT CALLED MAINT.
0743												O/C															S.B. ANTHONY IN COIN ACCEPTOR
0748								O/																			NO PROBLEM FOUND
0815												R															
0817								R																			
0839																									O/		PATRON INSERTED COIN IN TICKET SLOT
0841															O/												PATRON CLEARED BY HITTING CANCEL BUTTON
0842															R												
0850																									R		
0900	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	O	R	R	O	R	R	R	R	

KEY:
B = BILL JAM
C = COIN JAM
J = FARECARD JAM
F = MONEY CONTAINER FULL
O = OUT-OF-SERVICE
H = HARD FAILURE
E = ENTRY
X = EXIT
R = RETURN TO SERVICE

AFC SURVEY FORM

EMBARCADERO STATION West End

NAME:

START TIME	STOP TIME	DATE

Time	Aisle										Vendor, Changer, Add Fare										Remarks
	1	2	3	19	20	21	5	6	7	8	VM 01	VM 02	AF/M 01	VM 03	VM 04	MF 01	VM 05	VM 06	AF/M 02	MP 01	

KEY:
B = BILL JAM
C = COIN JAM
J = FARECARD JAM
F = MONEY CONTAINER FULL
O = OUT-OF-SERVICE
H = HARD FAILURE
E = ENTRY
X = EXIT
R = RETURN TO SERVICE

AFC Survey Form

LAFAYETTE STATION

NAME		
START TIME	STOP TIME	DATE

Time	Aisle						Vendor, Changer, Add Fare								Remarks
	1	2	3	5	6	7	VN 01	MF 01	V/M 01	AF/M 01	MP 01	AF 01	VN 02	MF 02	

MACHINE STATUS FORM

DATE: ____________________

STATION: ____________________

CUBIC VENDORS AND ADD FARES

MACHINE NUMBER	TIME	VENDORS						ADDFARES				
		RVT VALUE	NICKEL VALUE GVN	QUARTER VALUE GVN	COIN VALUE	BILL VALUE	TOTAL TICKETS	NICKEL VALUE GVN	QUARTER VALUE GVN	COIN VALUE	BILL VALUE	TOTAL TICKETS

DATE: ____________________

STATION: ____________________

MACHINE STATUS FORM

IBM VENDORS, ADDFARES, AND CHANGERS

MACHINE NUMBER	TIME	VENDORS					ADD FARES		CHANGERS			
		COIN VALUE	DOLLAR VALUE	BONUS VALUE	TOTAL TICKETS	R V T	TOTAL VALUE OF COINS	TICKETS PROCESSED	TOTAL $1 BILLS	TOTAL HALF $	TOTAL QUARTERS	TOTAL DIMES

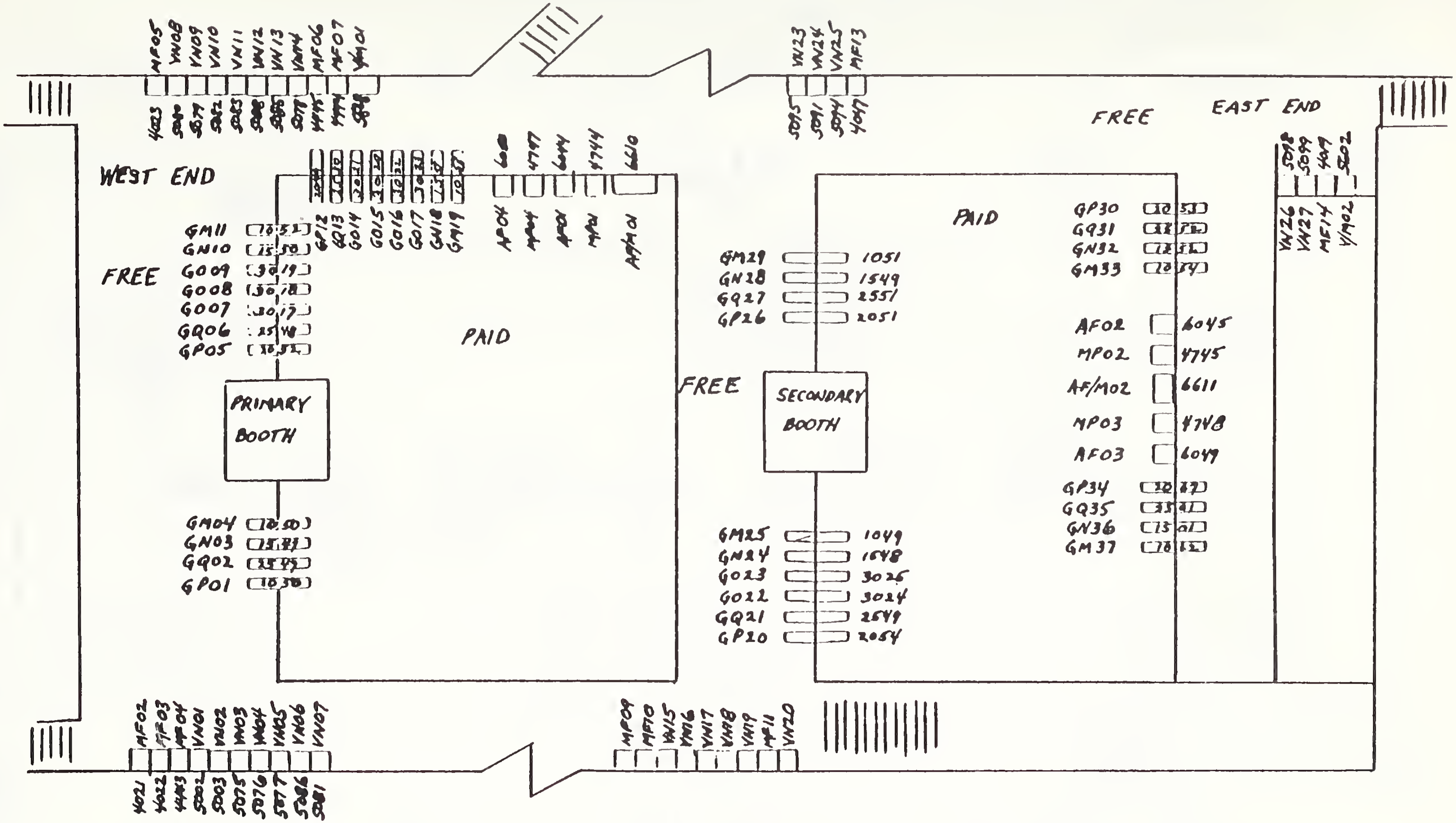
ACTIVITY LOG

Mezzanine: MONTGOMERY - WEST

Date: 3/14/80

Time: 0700

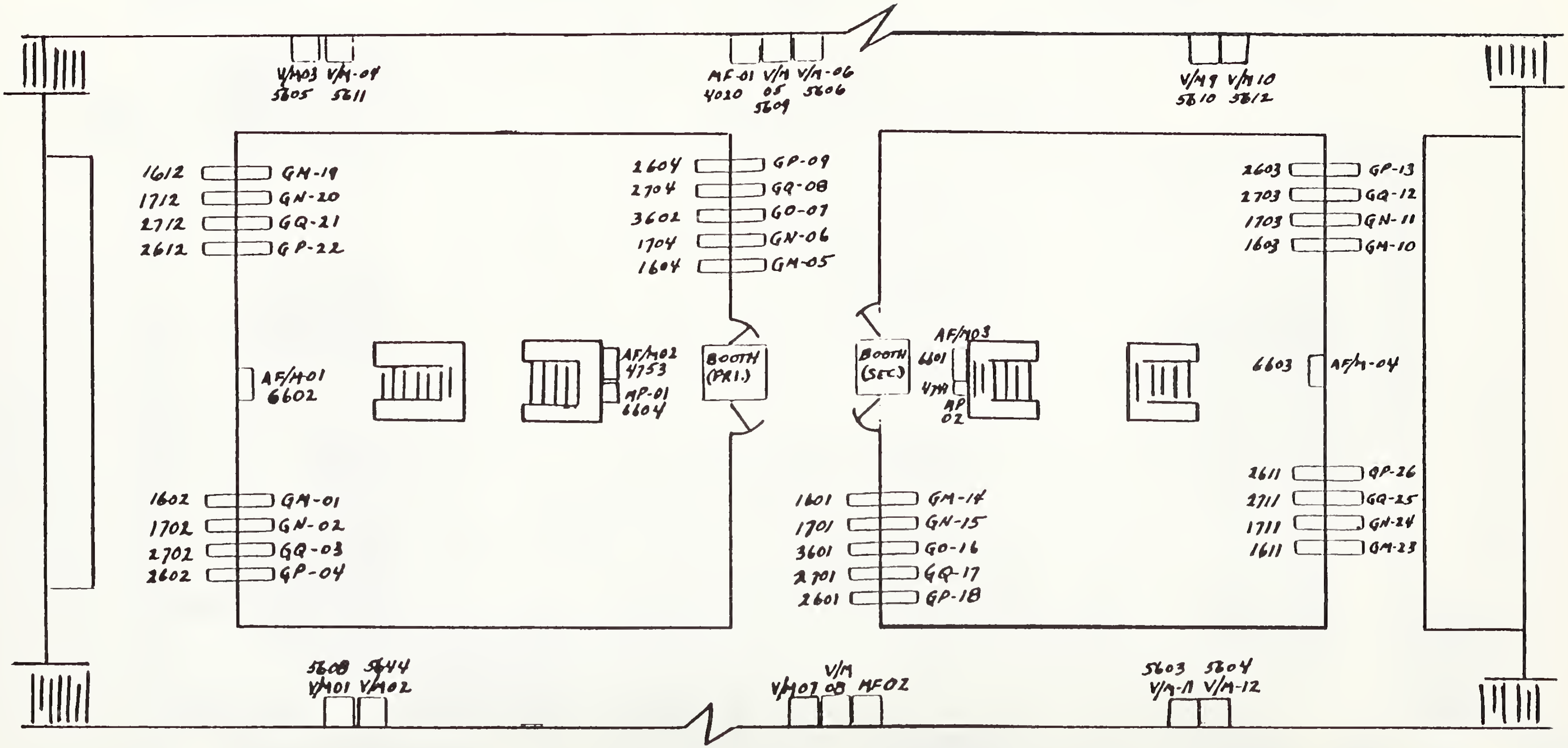
EVENT	MACHINE NUMBER	TIME	REMARKS
AGENT OPEN. GATE	AISLE 12	0705	CARD JAMMED IN PRINTER
AGENT OPEN. VENDOR	VN-08	0709	BENT NICKLE FOUND IN COIN ACCEPTOR
ENTRY TO EXIT	AISLE 13	0713	HEAVY EXIT PATRON FLOW, CHANGED AISLE TO EXIT
CHECK O/S LIGHT	MF-07	0715	BILL JAMMED - OLD BILL
" " "	MF-07	0719	BILL JAM
	MF-07	0720	AGENT DECIDED TO PUT MACHINE O/S
			AND CALL MAINT. - PROBLEM RECURRING FOR SEVERAL DAYS
CHECK PROBLEM	VN-02	0814	PATRON INSERTED S.B. ANTHONY IN SLOT
" "	AISLE 15	0816	FOUND NO PROBLEM - RESET GATE
O/S INDICATION	VN-08	0841	AS PATRON ATTEMPTED TRANS., MACHINE
			WENT O/S. PATRON CLEARED BY HITTING CANCEL BUTTON
AGENT CHECK.	AF-04	0849	PATRON INSERTED COIN INTO TICKET SLOT



4 DIGIT NUMBERS ARE SERIAL NOS.

GATES (IBM)	37	ADDFARE (IBM)	4
VEND (IBM)	25	ADDFARE (CUBIC)	2
VEND (CUBIC)	2	CHANGERS	15
		TOTAL	85

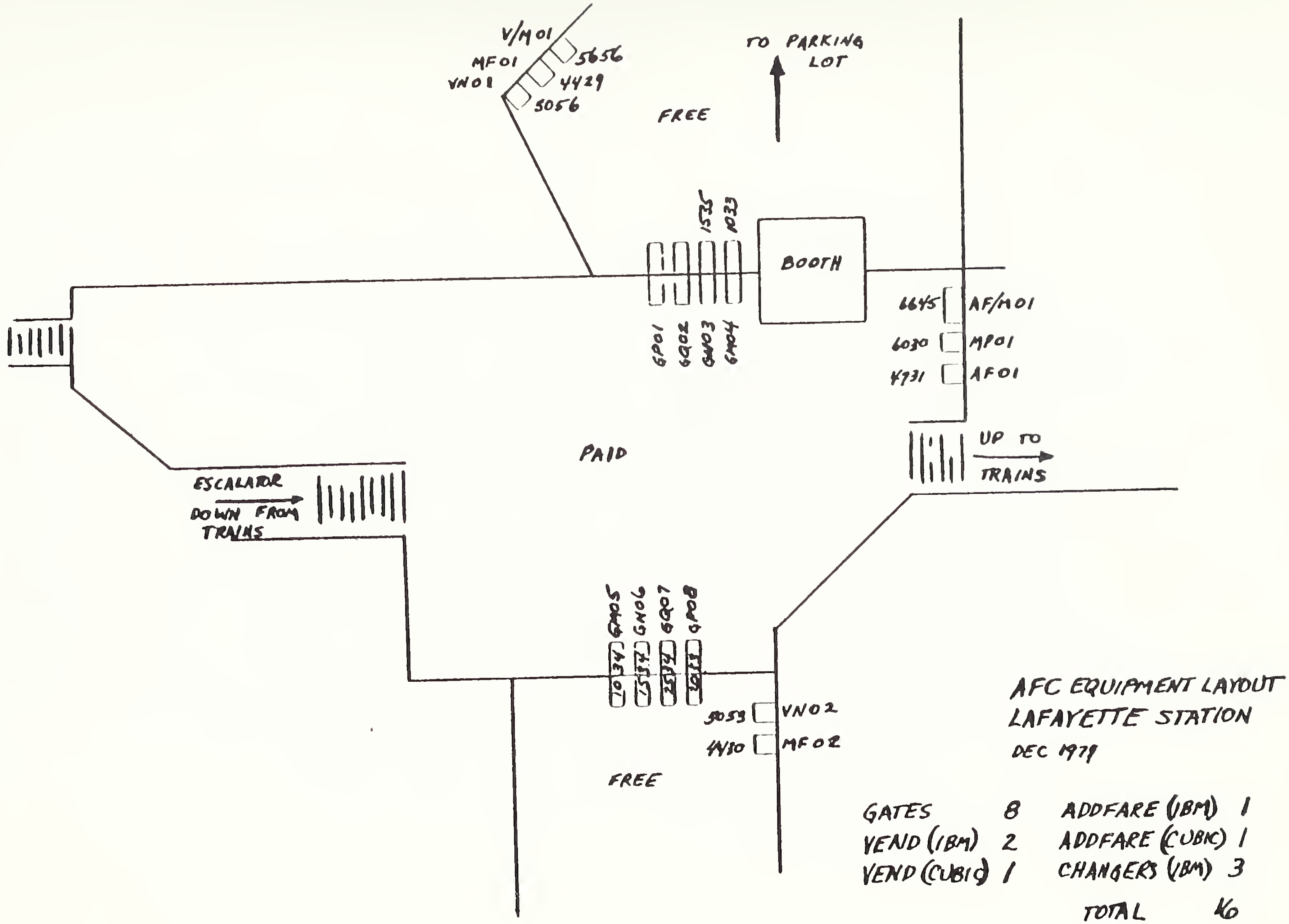
AFC EQUIPMENT LAYOUT
MONTGOMERY ST STATION
DEC 1979



4 DIGIT NUMBERS
ARE SERIAL NOS.

GATES (CUBIC)	26	ADDFARE (CUBIC)	4
VEND. (CUBIC)	12	CHANGERS (IBM)	4
		TOTAL	50

AFC EQUIPMENT LAYOUT
EMBARCADERO STATION
DEC 1979



V/M01
MF01
VN01
5656
4429
5056
FREE
TO PARKING LOT
1535
1033
BOOTH
GP01
GQ02
GM03
GM04
6645
AF/M01
6030
MP01
4931
AF01
PAID
UP TO TRAINS
ESCALATOR
DOWN FROM TRAINS
GM05
GN06
GQ07
GP08
5053
VN02
4430
MF02
FREE
AFC EQUIPMENT LAYOUT
LAFAYETTE STATION
DEC 1979
GATES 8
VEND (IBM) 2
VEND (CUBIC) 1
ADDFARE (IBM) 1
ADDFARE (CUBIC) 1
CHANGERS (IBM) 3
TOTAL 16

BART
AUTOMATIC FARE COLLECTION
SURVEY

APPENDIX B

BART
AUTOMATIC FARE COLLECTION
SURVEY

APPENDIX B

INTRODUCTION

The ultimate goal of the reliability and maintainability assessment plan developed by Automated Services is a set of procedures that will allow any property to systematically and efficiently gather reliability data on automatic fare collection equipment. To provide some empirical validation for the methodology developed, a survey of AFC equipment at the Bay Area Rapid Transit (BART) District was conducted utilizing the methodology. It was not the intent of the survey to produce a complete set of performance data on the AFC equipment at BART. Rather, the intent was to collect useful performance data on a selected set of equipment at BART and to generate a sufficient amount of data to demonstrate the utility of the methodology.

To fulfill these objectives it was decided to restrict data collection to three station mezzanines. The three mezzanines to be surveyed were selected in consultation with BART personnel. The Montgomery Street-West and Embarcardero-West mezzanines are both located in heavily used, downtown stations. The Lafayette station is primarily a suburban, commuter station, with heavy traffic only during the morning and evening rush hours. These three mezzanines were selected because it was felt that the level of usage at each station would ensure that a sufficient amount of data would be produced and that these mezzanines would provide some useful comparisons between types of usage, equipment configurations, and equipment manufacturers. For example, the Lafayette station offered an opportunity to compare equipment performance in a suburban commuter station, where patron flow is essentially restricted to peak, rush-hour periods, with downtown station usage, where there is substantial off-peak hour patron flow. The Embarcadero-West mezzanine provided contrast in equipment configuration since, with the exception of the money-changers, it is equipped solely with Cubic machines.

The survey was conducted during an eight-week period beginning March 10, 1980 and ending May 2, 1980. One morning rush-hour (7:00 a.m. - 9:00 a.m.) and one evening rush-hour (4:00 p.m. - 6:00 p.m.) data collection session were conducted at each mezzanine during each week of the eight-week period. In addition, non-peak usage data were collected at the Montgomery-West mezzanine from 2:00 p.m. to 4:00 p.m. on two days each week. The specific schedule for the data collection is included in Appendix A, the training plan for the survey.

Because of the time required to collect transaction data for each machine surveyed, it was determined that not all machines in the Montgomery-West mezzanine should be surveyed. Thus, in consultation with BART personnel, a subset of the AFC equipment in this mezzanine was selected for study.

Problems Encountered During Data Collection

As anticipated prior to beginning the survey at BART, collecting necessary patron transaction data presented the major obstacle to successfully conducting the survey. It was expected that recording this data from the internal machine registers would be time consuming, but security concerns about opening money-handling machines were quickly raised by BART Treasury personnel. To alleviate these concerns, a Treasury person was required to be present each time the machines were opened for survey personnel to read the registers. Difficulties were also encountered with non-working machine registers, particularly in the gates at Embarcadero-West. At the beginning of the survey, registers in only 2 of the 10 gates at this station were accumulating transaction data. All gate registers were working, however, during the last 5 data collection periods, and these data were utilized to estimate missing transaction data for the prior survey period. In addition, one farecard vendor, VN-02, at the Montgomery-West mezzanine did not register transaction data during the entire survey period, and thus does not appear in the data tabulations.

Because collecting the transaction data generally required about 30 minutes before and after each survey observation period, the total number of transactions recorded between the initial and final readings did not correspond exactly to the two-hour survey period. If failure analysis statistics were based upon these transaction totals, an overly optimistic picture of equipment performance would result. Therefore, in tabulating and analyzing the data collected, the transaction totals were adjusted so that they would more accurately represent the number of transactions which occurred during the survey period. To make the adjustment, an average transactions-per-minute rate was determined for each machine by dividing the total number of transactions between the initial and final readings by the total number of minutes between the two readings. The adjustment for peak, rush-hour periods is based on the assumption that the rate of transactions during the peak hours is higher than the rate both before and after the peak hours. Therefore, one-half of the per minute average was used to adjust the transaction totals for peak hours, i.e., one-half the rate per minute was multiplied by the total number of minutes before and after the survey period, and the result subtracted from total transactions between the initial and final readings. For off-peak survey periods, the average transactions per minute rate was calculated as above, but the full rate per minute, instead of one-half the rate, was utilized to adjust the transaction totals. The transaction totals which appear in the tabulations of the survey data are adjusted transaction figures.

One final problem was encountered during the data collection. A moneychanger, MF-02, at the Montgomery station was removed early in the survey. Therefore, no data are reported for this machine.

Survey Results

Data on 58 AFC machines in three mezzanines were tabulated from the survey. These machines included 17 vendors (9 IBM, 8 Cubic), 6 addfares, (2 IBM, 4 Cubic), 8 money changers (all IBM), and 27 gates (13 IBM, 14 Cubic). Table 1 provides cumulative statistics by machine type and manufacturer for all data collected. Statistics displayed include total transactions observed (adjusted), availability, reliability, mean time between failures, and transactions-per-failure ratios for all failures combined and for individual failure types. For the three mezzanines surveyed, the data indicate that the IBM vendors and addfare equipment seem to operate slightly better than the corresponding Cubic equipment, although the differences in reliability levels are not statistically significant. A highly significant difference in reliability (99% confidence level), however, is apparent for IBM gates vs. Cubic gates.

Tables 2, 3, and 4 are similar in format to Table 1 and provide statistics for Montgomery-West, Embarcadero-West, and Lafayette station mezzanines, respectively. These tables include results for individual machines as well as totals for each type of equipment by manufacturer. When equipment performance is compared across stations, IBM gates show consistently better performance than Cubic gates. For the Embarcadero mezzanine, which is essentially all Cubic equipment, the Cubic vendor and addfare equipment performed as well or better than IBM equipment at the other stations. Vendor and addfare equipment, both IBM and Cubic, at the Lafayette station performed poorly in comparison with the other two stations. Because the Montgomery and Embarcadero stations experience greater patron flow than the Lafayette station, rate of equipment usage may have a relationship with reliability of equipment performance.

TABLE 1

FAILURE ANALYSIS FOR BART AFC SURVEY

ALL MEZZANINES

EQUIPMENT TYPE AND MANUFACTURER	ADJ. TOTAL TRANS-ACTION	TRANSACTIONS PER FAILURE								AVAIL-ABILITY	RELI-ABILITY	MEANTIME BETWEEN FAILURES
		ALL FAILURES	TICKET JAM	COIN JAM	BILL JAM	FAILURE TO VERIFY	OTHER	ALL HARD FAILURES	ALL SOFT FAILURES			
ALL VENDORS	28,027	140.8	849.3	1,038.0	337.7	14,013.5	519.0	1,401.4	160.2	93.04	.9929	225.1
ALL IBM VENDORS	14,457	149.0	1,032.6	1,112.1	321.3	*	578.3	2,065.2	168.1	95.77	.9933	306.9
ALL CUBIC VENDORS	13,570	133.0	714.2	969.3	357.1	6,785.0	467.9	1,043.9	152.5	87.77	.9925	147.3
ALL ADDFARES	6,964	224.6	994.9	1,160.7	1,392.8	*	535.7	6,964.0	232.1	99.34	.9956	481.1
ALL IBM ADDFARES	1,856	232.0	927.9	618.6	1,856.0	*	927.9	*	232.0	99.86	.9957	696.9
ALL CUBIC ADDFARES	5,108	222.1	1,021.7	1,702.8	1,277.1	*	464.4	5,108.0	232.2	99.04	.9955	406.0
ALL MONEY CHANGERS (ALL IBM EQUIPMENT)	3,780	118.1	*	1,260.1	199.0	*	378.0	1,890.1	126.0	99.52	.9915	640.5
ALLGATES	151,035	1,135.6	1,841.9	30,207.0	*	16,781.7	4,315.3	75,517.5	1,179.8	88.59	.9991	480.5
ALL IBM GATES	76,772	1,968.5	4,798.2	15,354.3	*	25,590.5	5,905.5	*	1,968.5	94.28	.9995	898.4
ALL CUBIC GATES	74,263	790.0	1,125.2	*	*	12,377.1	3,375.6	37,131.4	825.1	85.19	.9987	307.1

*INDICATES NO FAILURES OF TYPE OBSERVED.

TABLE 2

FAILURE ANALYSIS STATISTICS FOR BART AFC SURVEY

MONTGOMERY - WEST MEZZANINE

EQUIPMENT NUMBER	ADJ. TOTAL TRANS-ACTIONS	TRANSACTIONS PER FAILURE								AVAIL-ABILITY	RELIA-BILITY	MEANTIME BETWEEN FAILURES
		ALL FAILURES	TICKET JAM	COIN JAM	BILL JAM	FAILURE TO VERIFY	OTHER	ALL HARD FAILURES	ALL SOFT FAILURES			
V/M-01	3,832	174.2	⁚	1,277.3	479.0	⁚	348.4	⁚	174.2	97.98	.9943	163.1
VM-08	1,929	214.3	⁚	⁚	321.5	⁚	964.4	⁚	241.1	99.61	.9953	405.4
VM-09	1,219	121.9	⁚	406.0	203.1	⁚	1,219.0	⁚	121.9	99.69	.9918	365.2
VM-10	1,516	505.2	1,516.0	⁚	1,516.0	⁚	1,516.0	⁚	757.8	99.91	.9980	1,220.0
VM-11	1,035	43.1	207.0	345.1	86.3	⁚	258.8	517.6	47.1	93.01	.9768	142.0
VM-12	1,868	233.6	⁚	1,868.0	467.1	⁚	622.8	⁚	266.9	96.45	.9957	441.6
VM-13	1,743	249.0	⁚	435.7	871.4	⁚	871.4	1,742.8	290.5	92.16	.9960	482.3
VM-14	3,027	378.4	1,009.1	1,513.7	1,513.7	⁚	3,027.0	3,027.0	432.5	93.74	.9974	429.3
TOTAL ALL VENDORS	16,169	178.0	1,796.6	1,077.9	394.4	⁚	621.9	1,243.8	185.9	96.57	.9944	311.0
TOTAL IBM VENDORS	12,337	178.8	1,370.8	1,028.1	373.9	⁚	822.5	949.0	189.8	96.37	.9944	358.1
TOTAL CUBIC VENDORS	3,832	174.2	⁚	1,277.3	479.0	⁚	348.4	⁚	174.2	97.98	.9943	163.1
AF-04	1,432	358.0	716.0	1,432.0	⁚	⁚	1,432.0	⁚	358.0	99.89	.9972	914.8
AF/M-01	1,436	239.3	1,436.0	⁚	1,436.0	⁚	359.0	⁚	239.3	99.84	.9958	609.5
TOTAL ALL ADDFARES	2,868	286.8	956.0	2,868.0	2,868.0	⁚	573.6	⁚	286.8	99.87	.9965	731.6
TOTAL IBM ADDFARES	1,432	358.0	716.0	1,432.0	⁚	⁚	1,432.0	⁚	358.0	99.89	.9972	914.8
TOTAL CUBIC ADDFARES	1,436	239.3	1,436.0	⁚	1,436.0	⁚	359.0	⁚	239.3	99.84	.9958	609.5
MF-05	443	63.3	⁚	443.0	110.8	⁚	221.6	443.0	73.9	99.65	.9842	521.4
MF-06	1,095	219.1	⁚	⁚	365.1	⁚	547.7	⁚	219.1	99.86	.9954	731.6
MF-07	433	61.8	⁚	433.0	144.2	⁚	144.2	⁚	61.8	99.81	.9838	522.3
TOTAL ALL MONEY CHANGERS (ALL IBM EQUIPMENT)	1,971	103.7	⁚	985.5	197.1	⁚	281.6	1,971.0	109.5	99.77	.9904	577.1
G-5	4,609	419.0	1,536.3	⁚	⁚	1,536.3	921.8	⁚	460.9	96.86	.9976	322.5
G-7	3,906	1,301.8	1,952.8	⁚	⁚	⁚	3,906.0	⁚	1,301.8	71.63	.9992	874.7
G-9	2,157	359.5	719.1	⁚	⁚	2,157.0	1,078.6	⁚	431.4	73.68	.9972	449.8
G-10	1,444	1,444.0	1,444.0	⁚	⁚	⁚	⁚	⁚	1,444.0	72.45	.9993	265.4
G-12	8,540	2,135.0	4,270.0	4,270.0	⁚	⁚	⁚	⁚	2,135.0	99.89	.9995	914.8
G-13	6,823	974.7	2,274.3	3,411.5	⁚	6,823.0	6,823.0	⁚	974.7	99.75	.9990	522.0
G-14	5,582	1,116.3	5,582.0	⁚	⁚	2,791.0	2,791.0	⁚	1,116.3	51.35	.9991	376.2
G-15	16,829	2,804.8	8,414.5	⁚	⁚	⁚	8,414.5	⁚	2,804.8	99.51	.9995	607.5
G-16	7,983	3,991.7	⁚	7,983.0	⁚	⁚	7,983.0	⁚	3,991.7	96.64	.9997	1,770.0
G-17	8,948	2,237.0	2,982.5	⁚	⁚	⁚	8,948.0	⁚	2,237.0	96.54	.9996	884.0
G-18	13,287	4,429.1	⁚	⁚	⁚	⁚	4,429.1	⁚	4,429.1	98.69	.9993	1,205.0
TOTAL ALL GATES	80,108	1,540.5	4,005.4	16,021.6	⁚	11,444.0	4,450.4	⁚	1,540.5	86.99	.9994	655.5
TOTAL IBM GATES	67,992	2,193.3	6,181.1	13,598.4	⁚	22,663.9	6,799.2	⁚	2,193.3	91.77	.9995	759.0
TOTAL CUBIC GATES	12,116	577.0	1,346.2	⁚	⁚	3,029.0	1,514.5	⁚	577.0	72.06	.9983	502.8

⁚INDICATES NO FAILURES OF TYPE OBSERVED

TABLE 3

FAILURE ANALYSIS STATISTICS FOR BART SURVEY

EMBARCEDERO - WEST MEZZANINE

EQUIPMENT NUMBER	ADJ. TOTAL TRANS-ACTIONS	TRANSACTIONS PER FAILURE								AVAIL-ABILITY	RELIA-BILITY	MEANTIME BETWEEN FAILURES
		ALL FAILURES	TICKET JAM	COIN JAM	BILL JAM	FAILURE TO VERIFY	OTHER	ALL HARD FAILURES	ALL SOFT FAILURES			
VM-01	1,505	125.4	*	301.0	501.7	*	376.3	752.6	150.5	76.18	.9920	122.1
VM-02	247	30.9	*	123.6	*	123.6	61.8	247.0	35.3	35.67	.9676	85.8
VM-03	2,107	175.6	2,107.0	*	301.0	*	526.7	2,107.0	191.5	97.03	.9943	155.5
VM-04	1,649	137.4	549.6	549.6	412.2	*	824.5	*	137.4	98.34	.9927	157.6
VM-05	1,670	208.8	556.7	*	417.6	*	1,670.0	1,670.0	238.6	99.06	.9952	238.1
VM-06	1,334	95.3	166.8	1,334.0	335.5	*	1,334.0	222.3	166.8	90.07	.9895	123.7
TOTAL ALL VENDORS (ALL CUBIC EQUIP.)	8,512	152.0	567.5	773.8	386.9	4,256.0	532.0	773.8	154.8	82.7	.9934	144.6
AF/M-01	2,256	752.0	*	*	*	*	752.0	*	752.0	96.31	.9987	617.3
AF/M-02	1,057	211.4	1,057.0	1,057.0	528.5	*	1,057.0	*	211.4	99.74	.9953	383.6
TOTAL ALL ADDFARES (ALL CUBIC EQUIP.)	3,313	414.1	3,313.0	3,313.0	1,656.5	*	1,104.3	*	414.1	98.02	.9976	471.3
MF-01	658	164.5	*	658.0	219.3	*	*	*	164.5	99.53	.9939	478.5
MP-01	292	146.1	*	*	292.0	*	292.0	*	146.1	99.90	.9932	960.5
TOTAL ALL MONEY CHANGERS (ALL IBM EQUIPMENT)	950	158.3	*	950.0	237.5	*	950.0	*	158.3	99.71	.9937	639.2
G-1	5,825	253.2	291.2	*	*	*	1,941.2	5,825.0	264.8	83.67	.9961	70.0
G-2	8,091	449.5	1,011.4	*	*	4,045.5	1,011.4	8,091.0	475.9	92.40	.9978	98.7
G-3	9,924	3,307.9	3,307.9	*	*	*	*	*	3,307.9	98.64	.9997	632.3
G-19	7,782	3,891.1	3,891.1	*	*	*	*	*	3,891.1	87.41	.9997	840.5
G-20	8,372	523.2	598.0	*	*	*	4,185.9	*	523.2	92.19	.9981	110.8
G-21	6,473	1,618.2	1,618.2	*	*	*	*	*	1,618.2	99.68	.9994	479.3
G-5	2,625	875.1	1,312.6	*	*	*	2,625.0	*	875.1	88.87	.9989	569.7
G-6	3,232	1,616.0	1,616.0	*	*	*	*	*	1,616.0	71.55	.9994	688.0
G-7	6,401	6,401.0	6,401.0	*	*	*	*	*	6,401.0	99.94	.9998	1,922.0
G-8	3,422	3,422.0	3,422.0	*	*	*	*	*	3,422.0	87.41	.9997	1,681.0
TOTAL ALL GATES (ALL CUBIC EQUIP.)	62,147	850.3	1,089.0	*	*	31,037.5	4,433.9	31,037.5	874.3	90.18	.9988	237.6

*INDICATES NO FAILURES OF TYPE OBSERVED.

TABLE 4

FAILURE ANALYSIS STATISTICS FOR BART AFC SURVEY

LAFAYETTE STATION

EQUIPMENT NUMBER	ADJ. TOTAL TRANS-ACTIONS	TRANSACTIONS PER FAILURE								AVAIL-ABILITY	RELIA-BILITY	MEANTIME BETWEEN FAILURES
		ALL FAILURES	TICKET JAM	COIN JAM	BILL JAM	FAILURE TO VERIFY	OTHER	ALL HARD FAILURES	ALL SOFT FAILURES			
VN-01	1,330	102.3	443.2	1,330.0	332.4	::	265.9	1,330.0	120.9	93.75	.9902	138.5
VN-02	791	52.7	395.3	::	98.8	::	158.1	395.3	60.8	89.79	.9810	114.9
VM-01	1,226	87.6	306.5	::	153.3	::	613.0	613.0	102.2	98.65	.9986	135.3
TOTAL ALL VENDORS	3,347	79.7	371.9	1,330.0	167.4	::	278.9	669.4	93.0	93.87	.9875	128.7
TOTAL IBM VENDORS	2,121	75.8	424.2	2,121.0	176.8	::	212.1	707.0	88.4	91.48	.9868	125.5
TOTAL CUBIC VENDORS	1,226	87.6	306.5	::	153.3	::	613.0	613.0	102.2	98.65	.9886	135.3
AF-01	424	106.0	::	212.0	424.0	::	424.0	::	106.0	99.79	.9906	479.0
AF/M-01	360	39.9	119.8	179.8	360.0	::	119.8	360.0	44.9	95.53	.9749	212.3
TOTAL ALL ADDFARES	784	60.3	261.3	196.0	392.0	::	196.0	784.0	65.3	99.66	.9834	294.4
TOTAL IBM ADDFARES	424	106.0	::	212.0	424.0	::	424.0	::	106.0	99.79	.9906	479.0
TOTAL CUBIC ADDFARES	360	39.9	119.8	179.8	360.0	::	119.8	360.0	44.9	95.53	.9749	212.3
MF-01	428	107.0	::	::	213.9	::	213.9	428.0	142.6	96.98	.9907	465.5
MF-02	137	68.3	::	::	68.3	::	::	::	68.3	99.84	.9854	958.5
MP-01	295	295.0	::	::	295.0	::	::	::	295.0	99.95	.9966	1,919.0
TOTAL ALL MONEY CHANGERS (ALL IBM EQUIPMENT)	860	122.9	::	::	172.0	::	430.0	860.0	143.3	98.92	.9919	814.0
G-1	4,763	4,763.0	4,763.0	::	::	::	::	::	4,763.0	99.95	.9998	1,919.0
G-2	4,909	818.1	1,227.2	::	::	::	2,454.3	::	818.1	99.38	.9988	318.0
G-3	3,935	::	::	::	::	::	::	::	::	100.00	::	::
G-5	1,484	::	::	::	::	::	::	::	::	100.00	::	::
G-6	1,723	1,723.0	::	::	::	::	1,723.0	::	1,723.0	99.95	.9994	1,919.0
G-7	1,637	::	::	::	::	::	::	::	::	100.00	::	::
TOTAL ALL GATES (ALL IBM EQUIPMENT)	18,451	2,306.4	3,690.2	::	::	::	6,150.3	::	2,306.4	99.88	.9996	1,438.3

::INDICATES NO FAILURES OF TYPE OBSERVED.

Figure 1 summarizes equipment performance for mezzanines and machine types. This figure displays graphically, for each mezzanine and for all mezzanines combined, the transactions-per-failure ratios for each machine type and for each manufacturer. Because survey periods at Montgomery-West mezzanine included both peak, rush-hour observation and off-peak (2:00 - 4:00 p.m.) observation, failure rates for equipment in the mezzanine were computed separately for peak and off-peak operation. Table 5 shows the comparison between peak and off-peak transactions-per-failure ratios. With the exception of the money changers, the AFC equipment at Montgomery-West appears to be more reliable during peak-hour usage than off-peak usage, although there are exceptions on an individual machine basis. If, in fact, there is a significant difference between peak and off-peak reliabilities, two possibilities are suggested: 1) that high rate of usage tends to enhance equipment performance or 2) that the higher proportion of infrequent transit users during off-peak hours increases the rate of patron-induced failures, thus lowering reliability. The data collected in this survey, however, are not sufficient to support either possibility, or to conclude with a reasonable degree of confidence that there is a real difference between peak and off-peak reliabilities.

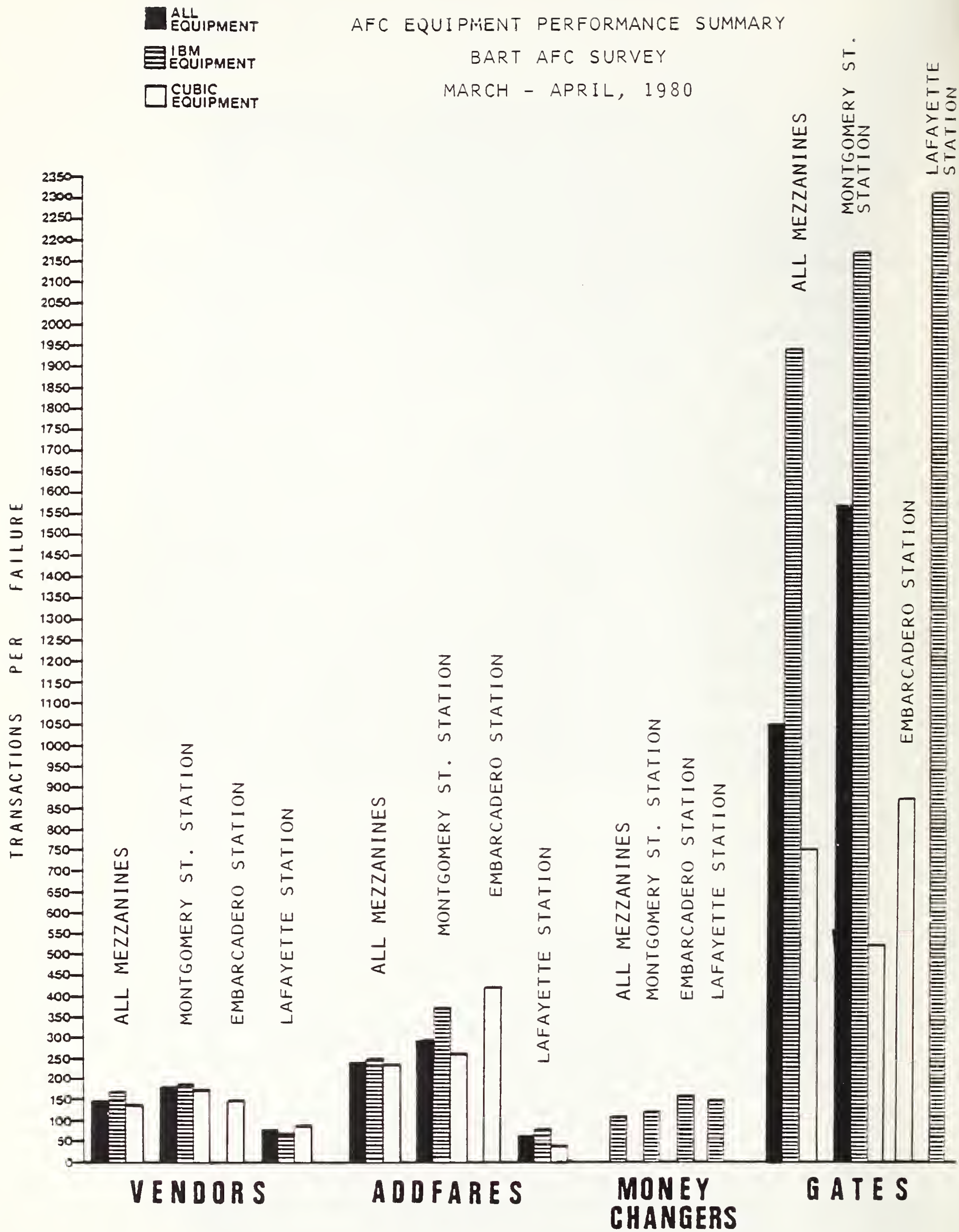

ALL EQUIPMENT
IBM EQUIPMENT
CUBIC EQUIPMENT
AFC EQUIPMENT PERFORMANCE SUMMARY
BART AFC SURVEY
MARCH - APRIL, 1980
TRANSACTIONS PER FAILURE
ALL MEZZANINES
MONTGOMERY ST. STATION
EMBARCADERO STATION
LAFAYETTE STATION
VENDORS
ADDFARES
MONEY CHANGERS
GATES

FIGURE 1

Table 5 - Peak vs Off-Peak Transactions-Per-Failure Ratios
Montgomery-West Mezzanine

	Total Transactions		Transactions Per Failure	
Equipment/Manufacturer	Peak	Off-Peak	Peak	Off-Peak
VN-08 (IBM)	1,225	703	204.3	234.4
VN-09 (IBM)	902	317	128.8	105.6
VN-10 (IBM)	1,159	357	386.3	*
VN-11 (IBM)	763	272	58.7	24.8
VN-12 (IBM)	1,242	626	248.4	208.7
VN-13 (IBM)	991	752	247.7	250.6
VN-14 (IBM)	1,781	1,247	890.4	207.8
VM-01 (CUBIC)	2,047	1,785	292.4	119.0
TOTAL (ALL VENDORS)	10,110	6,059	215.1	137.7
TOTAL (IBM)	8,063	4,274	201.6	147.4
TOTAL (CUBIC)	2,047	1,785	292.4	119.0
AF-04 (IBM)	1,078	354	539.0	176.9
AF/M-01 (CUBIC)	1,011	425	202.2	424.9
TOTAL (ALL ADDFARES)	2,089	779	298.5	259.7
TOTAL (IBM)	1,078	354	539.0	176.9
TOTAL (CUBIC)	1,011	425	202.2	424.9

*Indicates No Failures Observed.

MF - 05 (IBM)	208	235	52.1	78.3
MF - 06 (IBM)	611	484	152.8	484.3
MF - 07 (IBM)	93	340	30.8	85.1
TOTAL (ALL CHANGERS) (ALL IBM EQUIPMENT)	912	1,059	82.9	132.4
G - 5 (CUBIC)	2,015	2,594	671.8	324.2
G - 7 (CUBIC)	3,422	483	1,140.6	*
G - 9 (CUBIC)	1,606	551	401.6	275.5
G - 10 (CUBIC)	1,124	321	1,123.5	*
G - 12 (IBM)	5,248	3,292	5,248.0	1,097.4
G - 13 (IBM)	4,693	2,131	1,564.0	532.6
G - 14 (IBM)	4,232	1,350	1,410.6	674.8
G - 15 (IBM)	11,323	5,506	1,887.2	*
G - 16 (IBM)	6,707	1,282	6,707.1	1,282.2
G - 17 (IBM)	7,010	1,937	2,336.8	1,937.1
G - 18 (IBM)	9,250	4,037	4,625.0	4,037.2
TOTAL (ALL GATES)	56,630	23,484	1,887.7	1,067.4
TOTAL (IBM)	48,463	19,535	2,550.7	1,627.9
TOTAL (CUBIC)	8,167	3,949	742.5	394.9

*Indicates No Failures Observed.

APPENDIX C
REPORT OF INVENTIONS

This study examined Automatic Fare Collection systems and improvement programs in urban rail transit properties and developed standardized procedures for collecting automatic fare collection equipment performance data. For the first time uniform procedures can be utilized at rail properties with stored-value systems for basic assessment of equipment performance, tracking performance over time, or for evaluating the effects of reliability improvement programs.

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