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OPTICAL AUTOMATIC CAR IDENTIFICATION (OACI) FIELD TEST PROGRAM

TRANSPORTATION SYSTEMS CENTER

PREPARED FOR
FEDERAL RAILROAD ADMINISTRATION

MAY 1976

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OPTICAL AUTOMATIC CAR IDENTIFICATION (OACI)

Field Test Program

U.S. DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER
Kendall Square
Cambridge MA 02142

MAY 1976

FINAL REPORT

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Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
Office of Research and Development
Washington DC 20590

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16. Abstract

The results of the Optical Automatic Car Identification (OACI) tests at Chicago conducted from August 18 to September 4, 1975 are presented. The main purpose of this test was to determine the suitability of optics as a principle of operation for an automatic car identification. Readabilities by standard and "modified" scanners were measured. Based on the optical information available in the label-scanner communication channel and the determination of the non-read causes, the label-scanner readability and limit of readability were obtained. Also the same readabilities were obtained using multiplexed data from two scanners, one at each side of the track. The benefits of redundancy in the multiplexed data are based on the analysis of the test results. Conclusions and recommendations are presented. No attempt has been made to evaluate the hardware implementation of the OACI systems used during the Chicago test.

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ERRATA

p. iii second paragraph, bottom line, after "Mr. C. R. Hussey, Assistant Vice President of Operations—Administration" add "of Chicago and North Western Transportation Company,"

p. 1 second paragraph, first sentence, after "the FRA became aware of further new developments and" delete "requested" add "the request for "

p. 103 first sentence, delete "This means the initiation of" add "There should be initiated"

PREFACE

An Optical Automatic Car Identification (OACI)* Field Test Program was conducted at Chicago from August 18 to September 4, 1975 by the Federal Railroad Administration (FRA) with the technical direction and support received from the Transportation Systems Center (TSC). This OACI field test program was part of a joint effort between the Association of American Railroads (AAR), the Railway Progress Institute (RPI), the FRA and TSC.

This crash program could not have been carried out without the expertise and contributions of several individuals and organizations. The author wishes to acknowledge Mr. A. Bang, Acting Chief, Freight Services Division of the FRA who was the initiator of the OACI field test program within the Federal Government and provided the necessary leadership and management skills to bring about the field test and Mr. W. Cracker of the same FRA division who contributed and assisted from the planning stage of the OACI field test, and the OACI AAR/RPI/FRA Steering Committee for providing the necessary guidance and coordination for the successful execution of this task. The author also wishes to acknowledge the contribution of Mr. L. Brophy, Executive Vice President of Chicago Railroad Terminal Information Systems, Inc. (CRTIS) for making available the test site and providing the necessary arrangements for the installation of the scanners at the site and the interfacing with the Chicago and North Western Transportation Co., owners of the property, Mr. M. L. Clawson, communications engineer of the CRTIS who provided technical and administrative support during the test, Mr. C. R. Hussey, Assistant Vice President of Operations-Administration for his coordination with

*To avoid confusion in the designation of automatic car identification systems that may use different technologies, we use the generic acronym xACI from which other acronyms reflecting specific technologies may originate. By substituting the x with the first letter of the given technology designation, OACI is generated from Optics, MACI from Microwaves, IRACI from Infrared, FACI from fluorescence, etc.

CRTIS which led to the availability of the test site and the Mead Electric Co. which handled expeditiously the installation of the scanners for the suppliers of the scanners as well as all the other ancilliary site work. At TSC, several individuals provided their timely expertise which made possible the field test: Mr. M. Yaffee, assistant engineer who was responsible for the successful field test implementation, data gathering, processing, and all other phases of the test program; Mr. R. Stone, field test representative who carried out on a day-to-day basis all the responsibilities of the field test and interface with OACI suppliers and visitors to the test site; Mr. R. Yatsko who gave TSC logistic support to the field test; Mr. A. Votolato and Mr. R. Valente, Procurement Branch, for processing procurements in an unusually short period of time; Mr. C. Pandil, Chief Operations Branch who implemented, with a very short notice, the data coding from the test; Mr. P. Doyle and Mr. S. Cultrera of the same branch, who spent long hours including weekends in carrying out the actual data coding. An acknowledgment also to Ms. C. Zimmerman, of Kentron, Hawaii, Ltd. who had to learn in a very short time the details of the test and the required output format, on the basis of which she wrote the computer program.

The author also wishes to acknowledge the management and personnel at Aerospace Systems, Inc., Burlington, Massachusetts who provided general services and worked long hours and weekends to support the timely preparation and production of the Preliminary Results distributed to the interested organizations and individuals concerned with OACI.

The author wishes to acknowledge also the unconditional support and dedication to the test of suppliers of OACI equipment, by facilitating equipment, personnel and technical consultation when required.

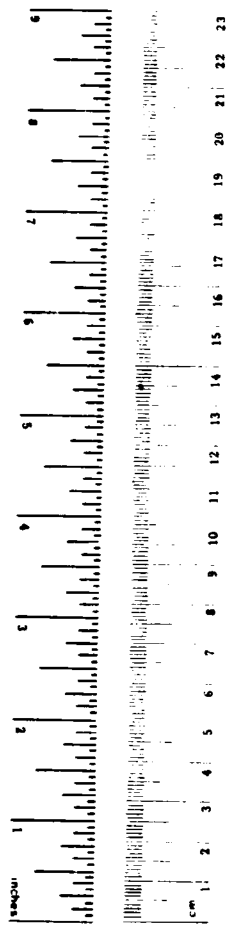
It should be mentioned that the OACI field test was an example of cooperation between suppliers of railroad equipment (RPI), the railroads and the body that represents the industry (AAR) and the Federal Government (FRA and TSC). As Mr. N. Lennartson, president of RPI put it, "The harmony and constructive results that came from this joint RPI/AAR/FRA activity represents a standard for other such cooperative efforts in the future."

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

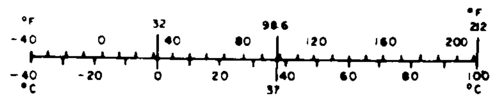
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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

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



Approximate Conversions from Metric Measures

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



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SYMBOL DEFINITIONS

A	total number of freight cars correctly read by the OACI system
D	total number of rolling stock scanned
F	functionability
$\bar{F}$	mean functionability
M	total number of rolling stock correctly read by the OACI system
O	total number of labels correctly read from the scanner analog signal using TSC test equipment and visual analysis
P	total number of labels affected by the operating environment and management causes correctly read from scanner analog signal using TSC test equipment and visual analysis
R	readability
$\bar{R}$	mean readability
R'	label-scanner readability
$\bar{R}'$	mean label-scanner readability
R_{limit}	scanner system performance limit of readability
$\bar{R}_{limit}$	mean limit of readability
R_n^m	readability of train m on track side n (1 or 2)
$\bar{R}_n^m$	mean readability of train m on track side n (1 or 2)
R_{1+2}^m	readability resulting from multiplexing the readabilities

SYMBOL DEFINITIONS (Continued)

R_x^s	readability of car type x by scanner s
$R_x^{'s}$	label-scanner readability of car type x by scanner s
R_B^s	box car readability by scanner s
$R_B^{'s}$	box car label-scanner readability by scanner s
R_H^s	hopper readability by scanner s
$R_H^{'s}$	hopper label-scanner readability by scanner s
R_F^s	flat car readability by scanner s
$R_F^{'s}$	flat car label-scanner readability by scanner s
R_C^s	car carrier readability by scanner s
$R_C^{'s}$	car carrier label-scanner readability by scanner s
R_G^s	gondola readability by scanner s
$R_G^{'s}$	gondola label-scanner readability by scanner s
R_T^s	tank car readability by scanner s
$R_T^{'s}$	tank car label-scanner readability by scanner s
R_O^s	readability of other cars by scanner s

SYMBOL DEFINITIONS (Continued)

T	total number of freight cars scanned
a	total number of non-labeled cars scanned
b	total number of misapplied labels
c	total number of mixed new and old labels
d	total number of labels with rusted background
e	total number of labels with black anodize failure on backing plate
α	fractional contribution of box cars in the car mix observed
β	fractional contribution of hoppers (open or covered) in the car mix observed
γ	fractional contribution of flat cars in the car mix observed
δ	fractional contribution of car carriers in the car mix observed
ϵ	fractional contribution of gondolas in the car mix observed
η	fractional contribution of tank cars in the car mix observed
θ	fractional contribution of other cars in the car mix observed

1. INTRODUCTION

At the request of the Association of American Railroads (AAR), a Federal Railroad Administration (FRA) representative from the Office of Research and Development attended the organizational meeting of the AAR Optical Automatic Car Identification (OACI) Task Force on November 10, 1974. From discussions at that meeting, it was determined that FRA could contribute to the purpose of the Task Force, particularly in the area of providing unique test facilities available at the Transportation Systems Center (TSC). As a consequence, initial laboratory research began on automatic car identification at TSC on December 28, 1974. Shortly thereafter, TSC was in receipt of approximately 100 specimen problem labels sent in by Task Force members for evaluation. Early laboratory findings were reported to the Task Force indicating that many important new aspects of label readability required attention.

Shortly after the May 1975 meeting of the AAR Operating-Transportation (O-T) General Committee, the FRA became aware of further new developments and requested a special report on the present Optical Automatic Car Identification system from the AAR Research and Test Department. Based upon laboratory research up to this point in time, on May 29, 1975, FRA proposed to the Research and Test Department and the OACI Ad Hoc Subcommittee of the Rolling Stock Committee of the Railway Progress Institute (RPI) a special expeditious field test of OACI in order to rapidly expand on the initial laboratory indications. At the request of these two bodies, an ACI Working Group consisting of representatives of AAR, TSC, FRA and the two OACI suppliers convened at TSC on June 5, 1975, to outline an agreeable test plan. From the results of this meeting a definitive test plan was prepared and presented to the new RPI/AAR/FRA Joint OACI Research Project Committee on

June 10, 1975, at which time the Electro-Optical Automatic Car Identification Field Test Program (Reference 1) received unanimous endorsement. Implementation of this cooperative effort was initiated on the following day under the technical direction of the TSC.

The test was conducted in Chicago at the site indicated as No. 15 in the Chicago Railroad Terminal Information System, Inc. (CRTIS) network, which is located on the property of the Chicago and North Western Transportation Company.

This test was carried out on the basis of a partnership between the suppliers of OACI equipment (Servo Corporation of America and Computer Identics Corporation); the AAR, which represents the railroads; the RPI, which represents the suppliers of railroad equipment; the Federal Government via FRA and TSC; the host railroad, Chicago and North Western Transportation Company; and CRTIS, which represents the 21 other railroads operating in the Chicago Railroad Terminal.

An executive summary of the results described herein were presented to the RPI/AAR/FRA Joint ACI Research Project Committee and FRA officials on September 30, 1975, in Washington DC. Also, a document entitled "Preliminary Results Optical Automatic Car Identification Field Test Program" was provided to the industry on October 15, 1975.

2. OBJECTIVE

The objective (Reference 1) of the OACI Chicago Test was to determine the OACI Scanner Operational System Performance, the OACI Label-Scanner Readability and the Scanner System Performance Limit. Furthermore, part of the objective was to determine the causes of non-read and error-read. By meeting these objectives in a controlled-railroad operational environment, it was expected to obtain solid elements of judgment to evaluate electro-optics as a conceptual principle to be used in an automatic railroad car identification system and to evaluate the scanner system engineering configuration used in commercially available hardware as an implementation of this principle. Evaluation of commercial products for specification compliance and/or maintenance were not included in the test objective.

2.1 SCANNER OPERATIONAL SYSTEM PERFORMANCE

The objective in measuring the OACI scanners operational system performance was to quantitatively ascertain in a controlled railroad environment the ability of the scanners to read documented labels. These labels were documented by video tape and photographic recording as well as visual inspection.

Another important objective of this task was to intercompare the difference in readability, if any, between modified scanners and between standard and modified scanners. The modifications could include hardware, scanner-track relationship and/or alignment procedures or adjustments.

2.2 LABEL-SCANNER READABILITY

The objective of this task was to determine how much information could be decoded from labels that were not within AAR specifications and/or maintenance, when the signal obtained by the OACI scanners was processed by auxiliary test equipment. The readability obtained by this method is called label-scanner readability, R'. It should be indicated that the readability expressed by R' is not a theoretical limit based on optical communication theory, but is based on observed label population, scanner-track configuration, scanner characteristics and the limitations of the test equipment.

2.3 SCANNER SYSTEM PERFORMANCE LIMIT

The objective of this task was to determine the capabilities of the principle of operation of the OACI. In order to achieve this objective, the operating environment non-read and error-read related causes and the management non-read and error-read related causes have to be decoupled and evaluated separately. This will allow the Scanner System Performance Limit for automatic car identification to be obtained. The assessment of this limit will determine what is in fact the limit of the OACI as a principle of operation.

3. FIELD TEST DESCRIPTION

The OACI Chicago Test was carried out at the test site by TSC, Servo Corporation of America and Computer Identics Corporation (see Appendix A). The objectives, test data, results and recommendations are documented through this report.

3.1 SITE

The OACI test was conducted at the Proviso Yard, Melrose Park, in the Greater Chicago area. This site is the property of the Chicago and North Western Transportation Company and is identified as #15 in the Chicago Railroad Terminal Information System, Inc. (CRTIS), where two OACI scanners are installed as part of the CRTIS network. One of these two scanners was included in the test and was identified as Scanner #1. Partial layout of the OACI Scanner sites in the CRTIS network is indicated in Figure 1.

The site was selected by the AAR/RPI/FRA ACI Committee on the basis of "Test Site Selection Criteria" (Appendix B). The traffic at this site is approximately 700 cars per day.

3.2 INSTRUMENTATION

The basic instrumentation consisted of five OACI scanners, two supplied by Servo, two by Computer Identics Corporation and one on-site scanner, property of CRTIS. The rest of the test instrumentation was supplied by TSC. The instrumentation was set up at the site in accordance with the layout shown in Figure 2. Figure 3 gives a general view of the OACI Chicago Test installation. Figure 4 gives a view of a car passing two of the five scanners.

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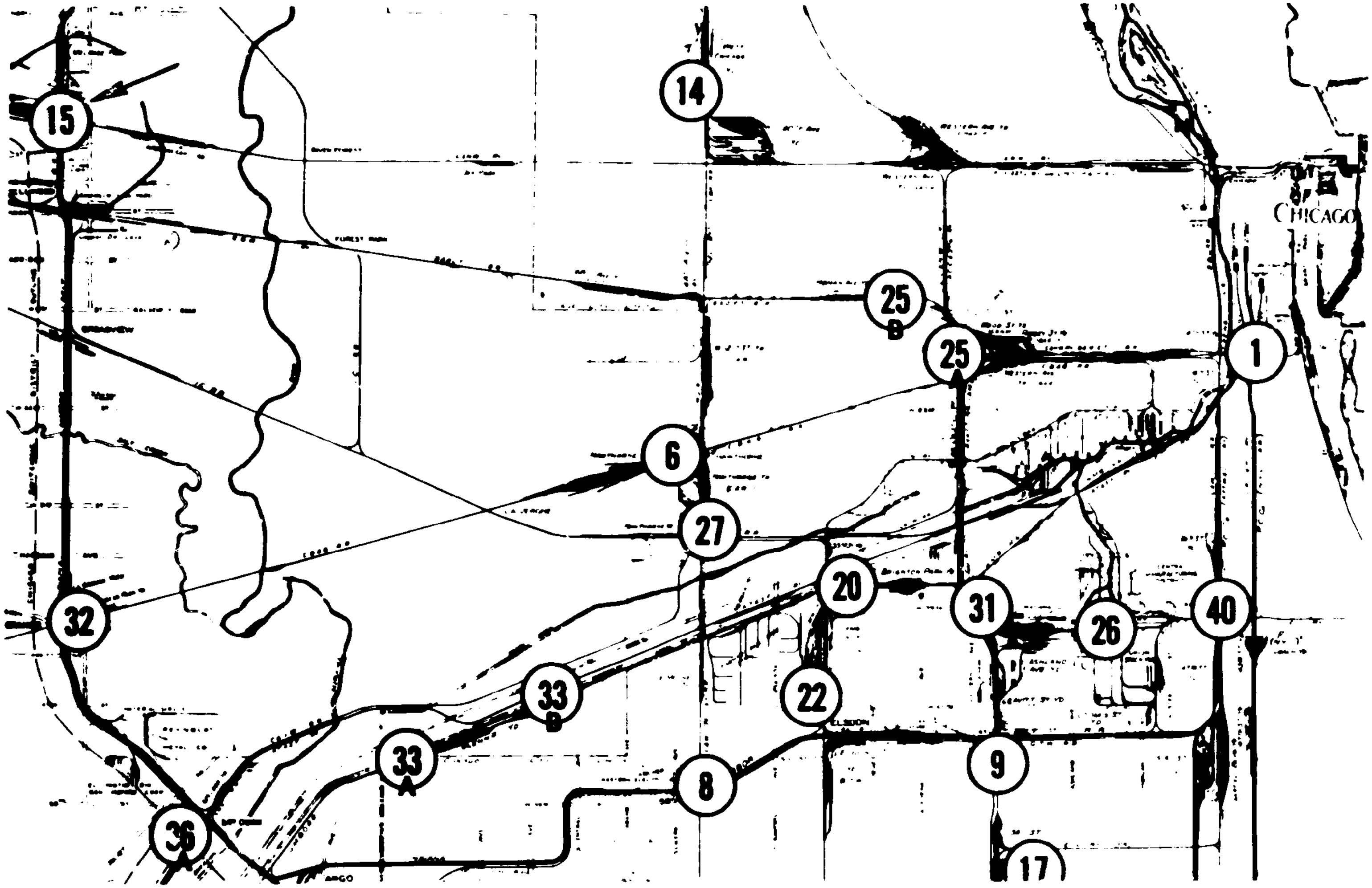

Figure 1. Partial Layout of the OACI Scanner Sites in the Chicago Railroad Terminal Information System, Inc. (CRTIS). The TSC OACI Test was Conducted at Site #15, Proviso Yard, Property of the Chicago and North Western Transportation Company.

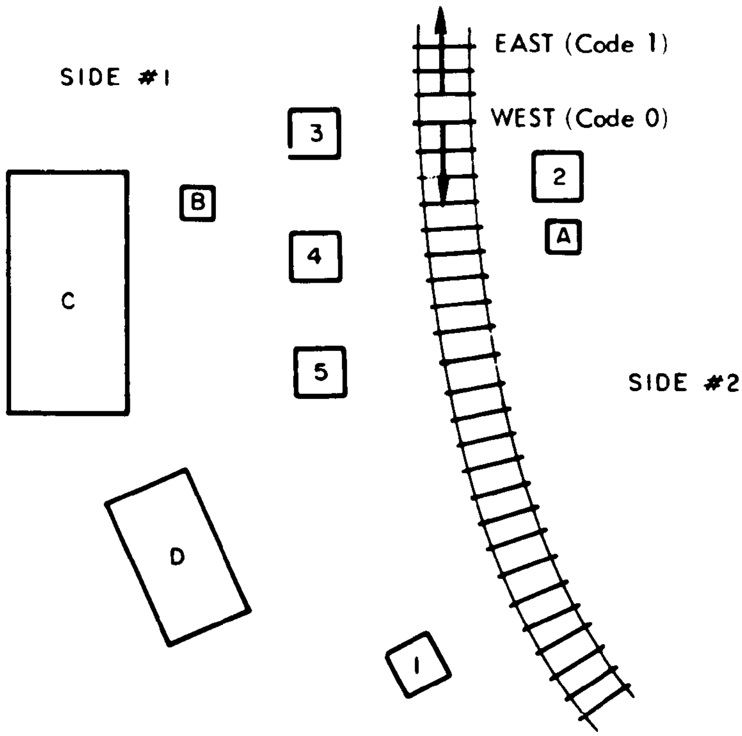

Figure 2. Layout of OACI Scanners, Television, and Photographic Cameras in the Chicago Test Site (Site #15 CRTIS).

Legend:

(1) Scanner #1, (Standard) Computer Identics Corp. (Part of CRTIS Network).
(2) Scanner #2, (Modified) Computer Identics Corp.
(3) Scanner #3, (Modified) Computer Identics Corp.
(4) Scanner #4, (Modified) Servo Corporation of America
(5) Scanner #5, (Modified) Servo Corporation of America

(A) Television Camera
(B) Photographic Camera
(C) Instrument Trailer
(D) TSC Van

Figure 3. General View of the OACI Chicago Test Site. In the Foreground is Scanner #2. On the Other Side of the Track from Left to Right, Scanners #1, 5, 4 and 3. The TSC Van (Left) and the OACI Instrumented Trailer (Right) are Also in View.

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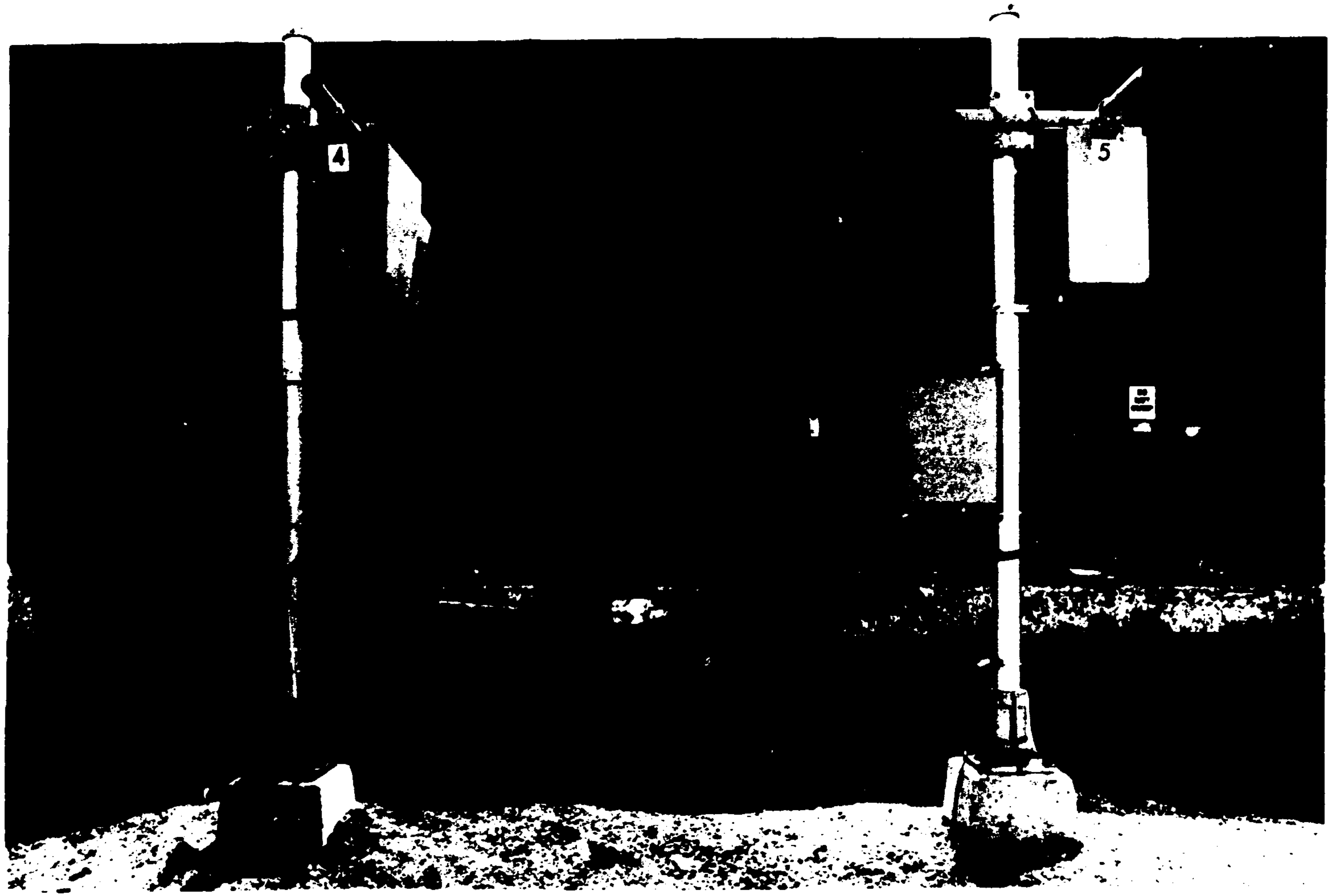

Figure 4. View of OACI Label on Railroad Car Passing Scanners #4 and #5 at the DOT TSC OACI Field Test Installation at Chicago Railroad Terminal Information System (CRTIS) Site #15 (Proviso Yard, Melrose Park, Illinois).

3.2.1 Computer Identics Corporation Scanner Systems*

Computer Identics Corporation provided two scanners (#2 and 3) for the OACI Chicago Test. These two scanners were modified. A third scanner (#1), also manufactured by Computer Identics Corporation, was the property of CRTIS and part of the CRTIS network. This third scanner was standard and was maintained by standard procedures also.

It should be understood that the scanners are commercial products and therefore there is a great deal of proprietary information in the modification. It is understandable that they are not discussed in detail in this document.

The location of the Computer Identics Corporation scanners can be identified in the general view of the OACI Chicago Test presented earlier in Figure 3.

3.2.1.1 Standard Scanner #1 - The standard Scanner #1 is a Computer Identics Corporation rail scanner. The rail scanner system is well documented (Reference 2). The Scanner #1 has been in use at CRTIS for about two years. This scanner did not receive any modification or alteration from the original design and the past history of this scanner can be considered typical of the Computer Identics Corporation until November 1974. Since then CRTIS awarded a Maintenance Contract to the Meade Electric Company of Chicago to maintain it. During the test the Scanner #1 was also maintained by the Mead Electric Company from whom the Test Director received the teletype printouts corresponding to the trains scanned during the test.

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* Computer Identics Corporation, Westwood, Massachusetts, is the parent company of ACI Systems Corporation which markets and services the company railroad commercial products line.

The geometry of the Scanner #1 is described in Figure 5. The gain in Scanner #1 was adjusted at 8 volts for the blue and 6 volts for the red using standard modules.

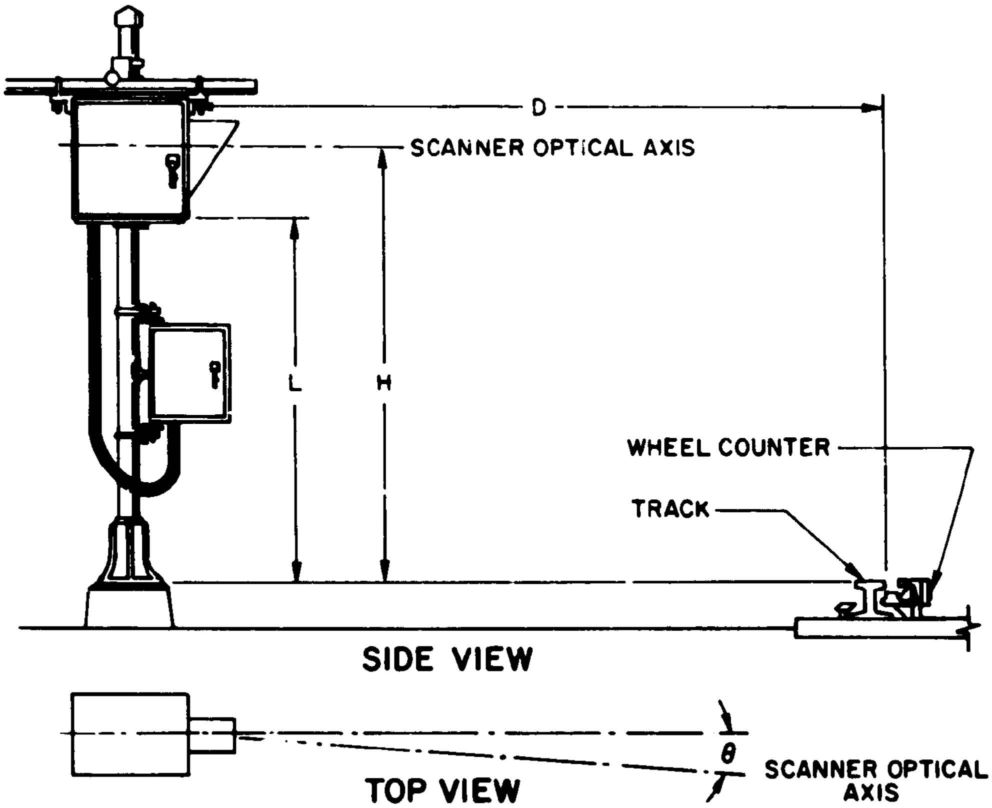
3.2.1.2 Modified Scanners #2 and 3 - The Scanners #2 and 3 are also Computer Identics rail scanners. Hardware modifications were made in both scanners: these were in the standardizer, selection of photomultiplier tubes, and photomultiplier high voltage power supply.

The modified standardizer allows the processing of scanner signals from OACI labels which are degraded and out of specifications. This modification relaxes the specification on the amplitude ratio between signals from adjacent half-modules or adjacent modules.

The photomultiplier tubes used in Scanners #2 and 3 had different spectral responses than those used in the standard scanners. They also are characterized by less internal noise. This reduces the overall internal scanner noise.

The high voltage power supply for the photomultiplier tube was a new design to minimize any possible spikes that could interfere with the decoder.

These changes are proprietary in nature and they will not be discussed herein. It should be pointed out that Scanners #2 and 3 use only one computer which allows the analog electrical signals from both scanners to be recorded, and therefore allows oscillograms of the labels on both sides of the cars to be obtained.



SCANNER #	H (in.)	L (in.)	D (in.)	θ (deg.)
AAR Standards	85	--	143	11
1	73	60	146	7-1/2
2	65	55	146	7-1/2
3	73	60	146	7-1/2
4	85	76	143	12±2
5	85	76	143	12±2

Figure 5. Geometry of OACI Scanners Used in the Chicago Test

3.2.2 Servo Corporation of America Scanner Systems

Servo provided two scanners for the OACI Chicago Test. One scanner (#5) had alignment calibration and adjustments modifications plus some selected optical components (Modification #1). A second scanner (#4) provided by Servo had the Modification #1 plus hardware modifications (Modification #2). It should be understood that the scanners are commercial products and, therefore, there is a great deal of proprietary information in the modifications. Therefore, it is understandable that they are not discussed in detail.

Figure 4 (previously shown) includes a view of the two Servo scanners.

3.2.2.1 Modified Scanner #4 - The Scanner #4 is a Servo Kartrak Scanner, 800 series. The geometry of the scanner at the test site was in accordance with the AAR Standards shown earlier in Figure 5.

The modifications introduced in this scanner were similar to the ones introduced in Scanner #5 described below, plus hardware modifications in the standardizer. The new standardizer has a dynamic signal detection range in excess of 60 dB versus 40 dB for the standard Kartrak Scanner, 800 series.

3.2.2.2 Modified Scanner #5 - The Scanner #5 is also a Servo Kartrak Scanner, 800 series. The geometry of the scanner at the test site was in accordance with the AAR standard (Figure 5). The Servo Scanner system is well documented (Reference 3).

The modifications introduced to the 800 series Scanner #5 system at the Chicago Test site were in the areas of alignment, calibration and adjustment. A selection of some optical components was part of the modification. From the hardware design point of view, no modification was introduced, but from the performance point of view modification has been introduced, since the optical components change the performance of the scanner system. These changes are proprietary in nature and they will not be discussed in this document.

The adjustments to the Servo scanners were carried out using an improved calibration and adjustment procedure. This procedure used a Servo test label (Part 89-74962-1). The gains of the red and blue channels were adjusted to output 8.2 volts for either module (red or blue) on the test label.

3.2.3 TSC Data Recording and Logging System

The TSC data recording and logging system used in the OACI Chicago Test was designed to record and document all the information required to carry out the Test Plan (Reference 1). This data logging and recording system provided enough redundancy to assure the completeness of the data even in cases where a subsystem failed. The data pertaining to the cars were recorded on video tape, color film, verbal description recorded on the audio channel of the video tape, and additional and redundant data on a log book. Information pertaining to the labels were recorded by means of a digital transient recorder in connection with an oscilloscope and closed TV system and video tape. Also, the visual description of the labels by experienced observers were recorded on magnetic tape. This description pertains to both sides of the cars. A block diagram of the TSC instrumentation is shown in Figure 6.

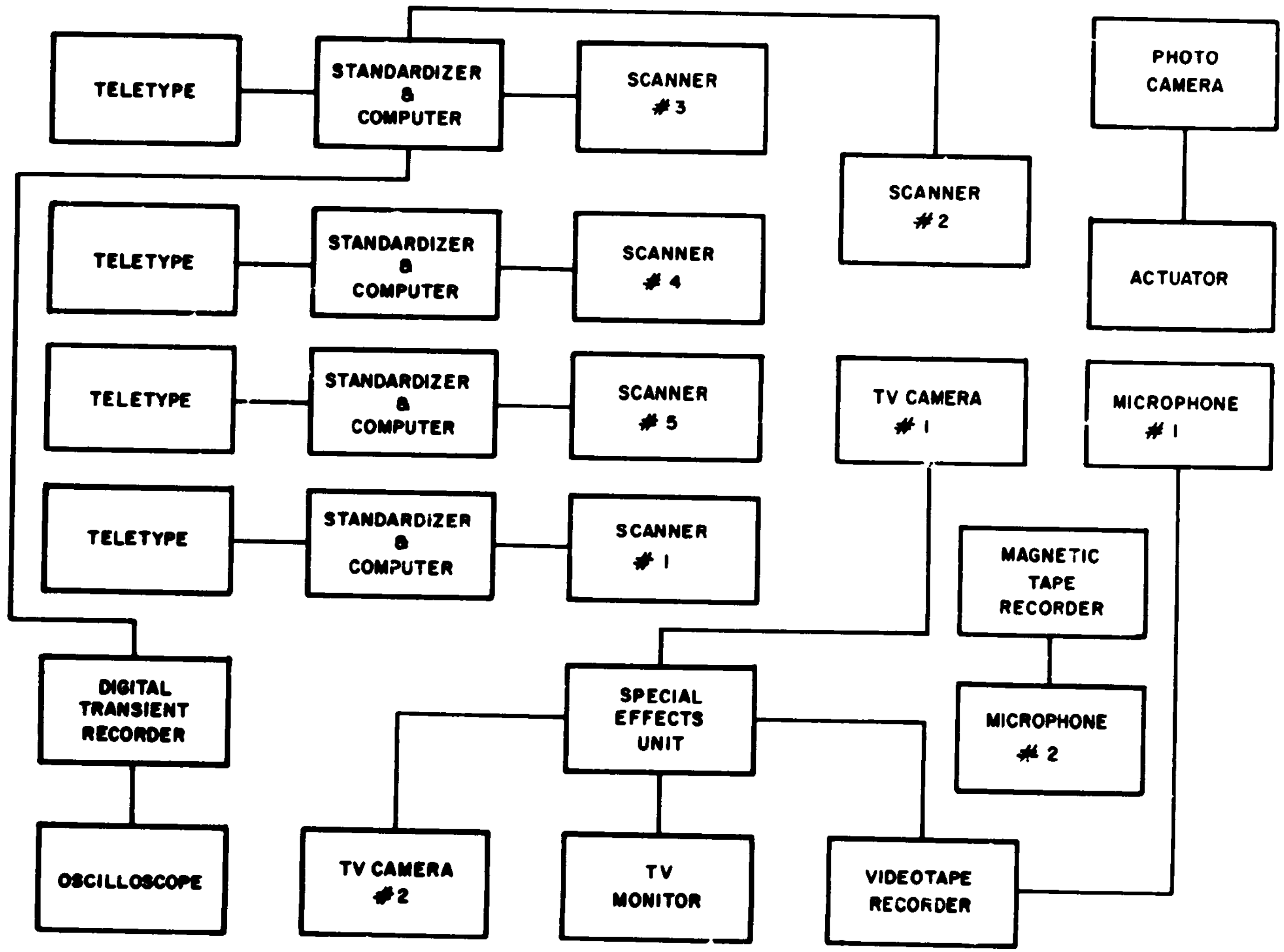


Figure 6. Block Diagram of the TSC Instrumentation Used at the OACI Chicago Test Site.

3.2.3.1 Video Tape System - A video tape system was used at the field test to record and document the visual appearance of the scanned cars (which includes the stencil car number), and the red and blue channel oscillograms corresponding to the outputs of Scanners #2 and 3. The audio channel of the system was used to record the account given by the observer on a car-by-car basis which included the stencil car number and the OACI label condition.

The video tape system consisted of two TV cameras, a special effects unit, a video tape recorder and a monitor. The cameras were GBC Closed Circuit TV Corp. Model CTC 500. One of the cameras was equipped with a Polaris Zoom Lens f/1.8, 18 to 90 mm focal length and the other with a 25 mm focal length CCTVC lens. The camera with the Polaris Lens was set to 30 mm focal length and the f-number was manually adjusted by the observer in accordance with the ambient level of illumination. The camera with the CCTVC lens was used to monitor the output of the digital transient recorder displayed on the oscilloscope.

A GBC special effect unit Model MEA-5100 was used to allow simultaneous sharing of the monitor screen by the two TV cameras (#1 and 2). The unit was adjusted to allow an approximately 50 percent sharing by each TV camera. One half of the screen displayed the railroad cars passing the observing site and the other half displayed the red and blue channels output of the Scanners #1 and 2 corresponding to the OACI labels (both sides) on the car being viewed simultaneously on the screen.

The output of the TV cameras #1 and 2 being monitored was black and white recorded on a Panasonic Model NV-3020SD Video Tape Recorder. This recorder uses 1/2 inch tape at a speed of 7.5 inches per second. The tape was in a 7-inch reel with a capacity of 2400 feet length giving 64 minutes of continuous recording time. The monitor was a 17-inch GBC Closed Circuit Corp. video monitor Model MV-17.

3.2.3.2 Photographic Camera - A photographic camera with color film was used at the field test to record and document the visual appearance of the scanned cars and the chromatic information of the OACI labels. The photographic camera used was a Nikon Photomic FTN with an f/1.4 Nikon S,50 mm focal length lens. The camera was provided with an electric motor drive F250 and remote control unit. This drive has a 250 frame capacity.

The film used throughout the test was Kodak Ektrachrome 5256 (daylight). The shutter speed was set at 1/125 seconds and the f-number was adjusted from 1.4 to 16 in accordance with the actual exposure meter readings. The photographic camera was located at the field test as indicated in Figure 2. The distance from the camera to the track was approximately 30 feet. The camera remote control unit was located in the instrument trailer from which an observer triggered the camera on a car-per-frame basis.

The film was developed by Eastman Kodak, in their Chicago or Rochester NY plants. Due to the field test tight schedule, some film logistics and camera maintenance problems developed which reduced the photographic documentation to 2595 cars of the 5349 cars scanned during the test, or 48.5 percent of the total.

3.2.3.3 Digital Transient Recorder - The digital transient recorder was a Biomation Model 8100. This recorder is a compact solid state electronic instrument which stores the digital equivalent of electrical waveforms in a memory. The output of the transient recorder was displayed in a Tektronix Oscilloscope Model 454.

The transient recorder was adjusted to provide a sample of the analog signal every .2 μ sec per scanner channel (red or blue), during 2 nsec and with an amplitude resolution of 8 bits (256 discrete levels). The maximum number of sample channels was 1025 per scanner channel.

The transient recorder was triggered by signals from Scanners #1 or 2. By proper siting of the OACI scanners, the signals from the two scanners were observed sequentially. The triggering signal was the signal from the start or stop module followed by the signal of four consecutive modules. The observation of these five signals triggered the digital transient recorder to record the red and blue signals corresponding to the full OACI label.

The geometry of the scanners used during the Chicago test is indicated in Figure 5. For Scanners #2 and 3, the scanning linear speed is 12.3 μsec in^{-1}. Since a module is 1 in. wide, the signal is 12.3 μ sec if scanned with an infinitely small width aperture at the focal plane of the scanner, and therefore it will be sampled 60 times by the digital transient recorder used for the test.

3.2.3.4 Log Book - General information such as weather conditions, changes in the field test set up, maintenance and gain checks of scanners were recorded daily in the log book. On a train-by-train basis, the time, direction and speed of train passage, total number of cars, cabooses and engines were recorded. A separate visitors log book was also maintained.

4. DATA ANALYSIS

The type of analysis used to process the OACI Chicago test data was developed to satisfy the objectives stated in Section 2. In addition, certain requirements were imposed on the computer program to properly assess, based on statistical estimation theory, the modification introduced to some of the scanners used in the Chicago Test.

4.1 SAMPLE SIZE

The difference in performance between standard and modified scanners is based on the difference between the proportion of labels correctly read by each scanner. Based on statistical estimation theory, accuracy and confidence levels were selected to determine the sample size. The typical minimum acceptable confidence level for a test such as the one conducted in Chicago is 95 percent.

Based on computations by Charles Taylor* and Aviva Shulman**, the sample size for the OACI Chicago Test was determined to be 5,000 cars for a 95 percent confidence level. As an example a readability of 82.3 percent from a modified scanner compared to an 80.1 percent readability from a standard scanner, results in an improved readability of 2.2 percent. Considering a 95 percent confidence level, this 2.2 percent is within 1.5 percent of the improvement.

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**Operations Research Analyst, Association of American Railroads, Washington DC.

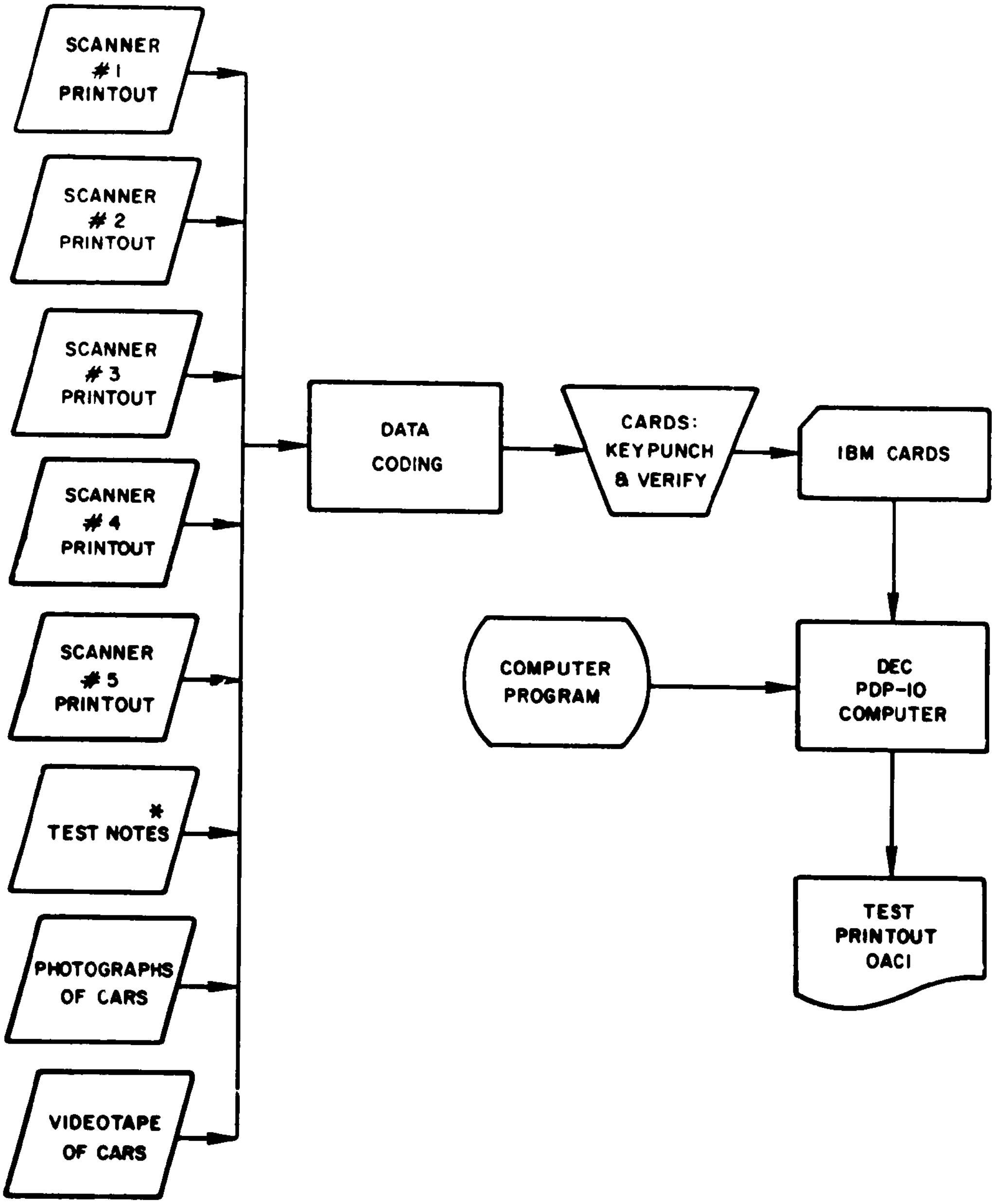
4.2 DATA HANDLING

Data from the test site in the form of scanners printout (Appendix C), test notes (log book and recorded verbal account by observers), video tapes of the cars scanned and the corresponding scanner (#2 and 3) analog signals and car photographs were physically transported to TSC. This data was properly coded in accordance with a format developed at TSC (Appendix D). The coded data were then sent to the keypunch operation; this consisted of punching the same information two times (on different cards) to allow for verification of the data. The cards were then sent for processing using a computer program developed at TSC for the OACI Chicago Test. All processing was performed by a DEC PDP-10 at the TSC Data Processing Center. Figure 7 shows the data handling flow chart to determine the OACI Operational System Performance. The data handling flow chart to determine the label-scanner readability limit and statistics of non-read and error-read causes is shown in Figure 8.

4.3 DATA CODING

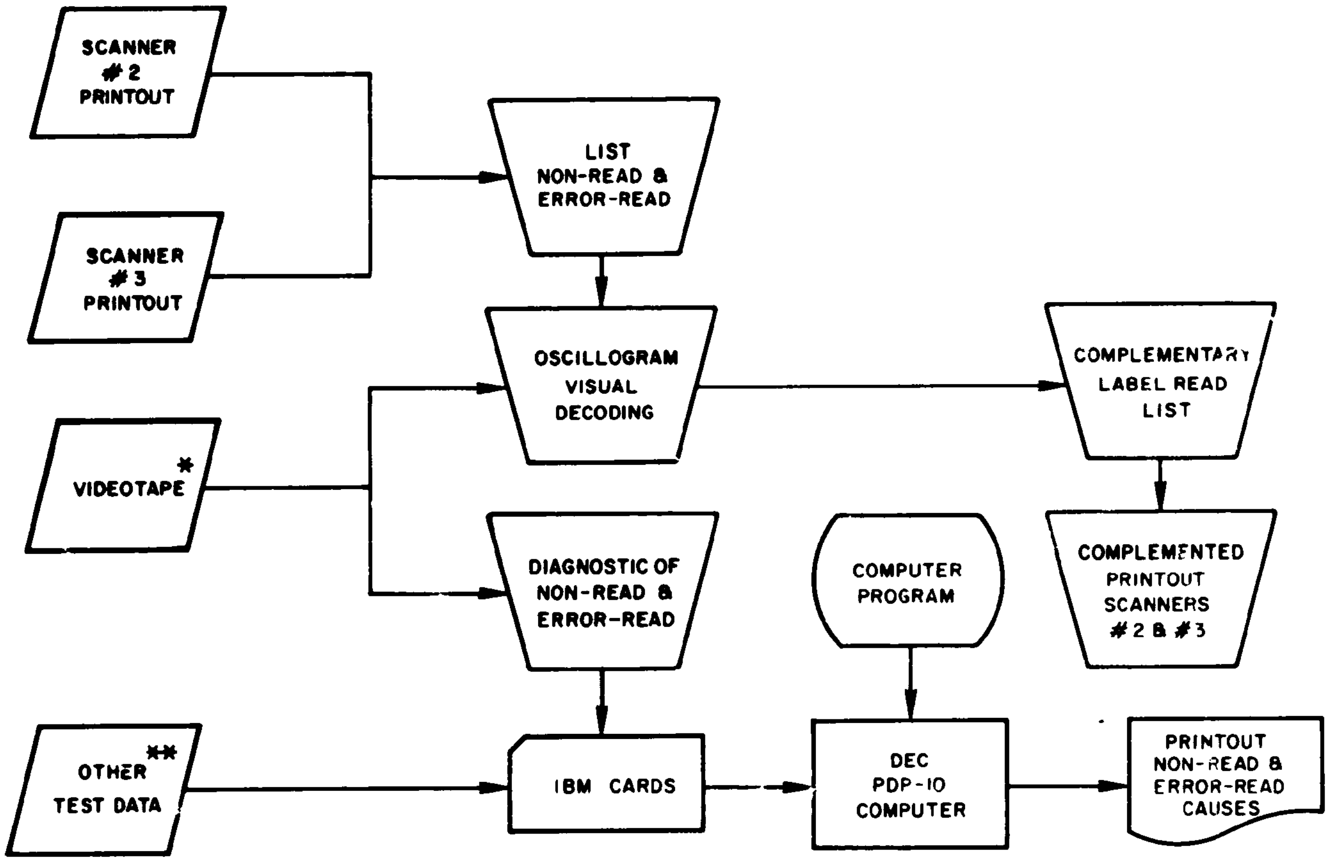
The data gathered at the Chicago Test was properly coded at TSC, keypunched onto IBM cards and verified. Extreme care was exercised to minimize errors in the coding and punching. Errors were kept to less than 1 percent for two scanners and less than 2 percent for the other three. Errors due to improper coding or keypunching appear in the computer printouts as error-reads under the cause heading "no code." Since these errors were coded, we could identify them and therefore correct the final results.

To facilitate the data coding, enlarged photographic copies of the printouts from all scanners were made and assembled side by side in sequential order. Therefore, the five scanner outputs corresponding to the same railroad car are on the same line of the composite printout (see Table C-1, Appendix C). Also, the Header and Trailers of



* LABEL CONDITIONS, i.e., WEATHER, TRAIN SPEED, ETC.

Figure 7. Data Handling Flow Chart to Determine OACI Operational System Performance from the Chicago Test.



* OSCILLOGRAM, CAR VIEW AND VERBAL DESCRIPTION OF CAR AND LABEL

** LABEL CONDITIONS, CAR TYPE, CAR SPEED, ETC.

Figure 8. Data Handling Flow Chart to Determine Label-Scanner Readability and Statistics of Non-Read and Error-Read Causes Based on the Chicago Test Data.

the printouts were composed on the same page. Train sequential number, car range per printout, and data were added later.

The cards were grouped by trains with one heading card for the whole train and two cards per car. The heading card contains the following information:

- Train number in sequence
- Julian date
- Time of day (when the first car passes the scanners)
- Train direction
- Train speed
- Weather conditions
- Number of cars in train
- Number of labeled cars in train (Track Side #1)
- Number of labeled cars in train (Track Side #2)
- Range of car sequence numbers in train.

The first card for each car contains the following information:

- OACI label readout Scanner #1
- OACI label readout Scanner #2
- OACI label readout Scanner #3
- OACI label readout Scanner #4
- OACI label readout Scanner #5
- Train number
- Car number.

The second card for each car contains the following information:

- Train number
- Car number

- Actual car number (stenciled number)
- Decoded OACI label number from TSC instrumentation
- Oscillogram scanner source
- Diagnosis: non-read or error-read causes (Side #1)
- Car type
- Code for instrumentation-related problems.

The sources for the data gathered are:

- OACI computer printouts
- Field test log book
- Video tape with visual information of the car
- Video tape with the analog signal from Scanners #2 and 3
- Audio portion of the video tape containing the description of the train, stenciled car number, and condition of the labels
- Magnetic tape recording by observers, one on each side of the track, reporting label conditions.

4.4 DATA PROCESSING

A computer program (see Appendix E) was developed at TSC to process the data from the OACI Chicago Test. The program requirements have been previously established (Reference 1). The readability per car is reported at the car level, per scanner, and the mean readability and functionability values on a per train basis. Figures 9, 10 and 11 show sample printouts for different non-read causes. Figure 12 shows the mean readability and functionability per train and other information required to interpret the test results. The data given in Tables 3 through 8 in the next section were obtained from

ACTUAL CAR# : 0695459828- 8
TRAIN #: 21
CAR #: 1924
CAR TYPE: BOX

SCANNER #	READ LABEL #	ACTUAL LABEL # -READ LABEL #	PARITY CHECK	NON-READ	CAUSES
1	0695459828	0000000000	8		
2	0665406828	0010711002	8		BLACK ANODIZED
3	0695459828	0000000000	8		
4	0695459628	0000000000	8		FAILURE
5	0695459828	0000000000	8		
2&3	0695459028	0000000000	8		

ACTUAL CAR # : 0595190166- 0
TRAIN #: 21
CAR #: 1925
CAR TYPE: BOX

SCANNER #	READ LABEL #	ACTUAL LABEL # -READ LABEL #	PARITY CHECK	NON-READ	CAUSES
1	0595190166	0000000000	0		
2	0595190166	0000000000	0		
3	0595190166	0000000000	0		
4	0595190166	0000000000	0		
5	0595190166	0000000000	0		
2&3	0595190166	0000000000	0		

Figure 9. Sample Printout for Train No. 21, Cars No. 1924 and 1925 Obtained from TSC Computer Program to Determine Non-Read, Error-Read Parity Check Errors and Causes of Non- or Error-Read. The Results are Given per Car and per Scanner.

ACTUAL CAR # : 0131048501-10
TRAIN #: 34
CAR #: 3028
CAR TYPE: FLATCAR

SCANNER #	READ LABEL #	ACTUAL LABEL # -READ LABEL #	PARITY CHECK	NON-READ	CAUSES
1	10434348501	0101100000	10		LOW AND DIRTY
2	10131048501	0000000000	10		
3	10131048501	0000000000	10		
4	10736448501	0101100000	10		LOW AND DIRTY
5	10000000000	0111011101	? 0	X	LOW AND DIRTY
263	10131048501	0000000000	10		

ACTUAL CAR # : 0721191345-10
TRAIN #: 34
CAR #: 3029
CAR TYPE: BOX

SCANNER #	READ LABEL #	ACTUAL LABEL # -READ LABEL #	PARITY CHECK	NON-READ	CAUSES
1	10721191345	0000000000	10		
2	10721191345	0000000000	10		
3	10721191345	0000000000	10		
4	10721191345	0000000000	10		
5	10721191345	0000000000	10		
263	10721191345	0000000000	10		

Figure 10. Sample Printout for Train No. 34, Cars No. 3028 and 3029 Obtained from TSC Computer Program to Determine Non-Read, Error-Read Parity Check Errors and Causes of Non- or Error-Read. The Results are Given per Car and per Scanner.

ACTUAL CAR # : 0695453097- 1
TRAIN #: 34
CAR #: 3034
CAR TYPE: BOX

SCANNER #	READ LABEL #	ACTUAL LABEL # -READ LABEL #	PARITY CHECK	NON-READ	CAUSES
1	0695453097	0000000000	1		
2	0695453097	0000000000	1		
3	0695453097	0000000000	1		
4	0695453097	0000000000	1		
5	0695453097	0000000000	1		
2&3	0695453097	0000000000	1		

ACTUAL CAR # : 1202011703- 8
TRAIN #: 34
CAR #: 3035
CAR TYPE: BOX

SCANNER #	READ LABEL #	ACTUAL LABEL # -READ LABEL #	PARITY CHECK	NON-READ	CAUSES
1	0000000000	1101011101	7 0	X	RUSTED BACKGROUND
2	1202011703	0000000000	8		
3	1202011703	0000000000	8		
4	1202011703	0000000000	8		
5	1202011703	0000000000	8		
2&3	1202011703	0000000000	8		

Figure 11. Sample Printout for Train No. 34, Cars No. 3034 and 3035 Obtained from TSC Computer Program to Determine Non-Read, Error-Read Parity Check Errors and Causes of Non- or Error-Read. The Results are Given per Car and per Scanner.

OPERATIONAL SYSTEM PERFORMANCE

PER TRAIN

TRAIN #: 21

DATE: 234

TIME: 17:13

SPEED: 12MPH

TRAIN DIRECTION: EAST

WEATHER: CLOUDY AND BRIGHT

TOTAL CARS: 108

TOTAL LABELED CARS (NORTH): 107

TOTAL LABELED CARS (SOUTH): 107

TOTAL LABELS READ CORRECTLY BY SCANNER #1,3,4,5 (NORTH): 100

TOTAL LABELS READ CORRECTLY BY SCANNER #2 (SOUTH): 96

SCAN	TOTAL READ	NON-READ	READ ERROR	PARITY ERROR	PROPORTION OF LABELS READ	PROPORTION CARS READ
1	82	12	13	12	.77	.76
2	96	6	5	6	.90	.89
3	96	5	6	7	.90	.89
4	98	7	2	7	.92	.91
5	92	y	6	9	.86	.85
2&3	100	4	3	9	.93	.93

Figure 12. Sample Printout Obtained from the TSC Computer Program to Calculate Readabilities from the OACI Chicago Test Data. The Results are Given per Train and per Scanner.

computer printouts. Also, the computer program gives the label-scanner readability on a per train basis.

4.5 SCANNER OPERATIONAL SYSTEM PERFORMANCE CALCULATION

Different ratios, coefficients, or percentages have been used and are used to measure the OACI performance. On July 28, 1970, the AAR OACI Ad Hoc Committee approved a set of "Definitions of OACI Performance Measurements" (Reference 1). These definitions are divided into three basic groups: Scanner Measurements, Label Measurements, and OACI System Measurements. By this group classification, it is clear that the ratios defined in these groups are designed to measure different characteristics of OACI Systems. In the analysis of the Chicago Test data we were concerned about supplying quantifiable information. This information was designed to assist in the performance evaluation of the OACI system as the input/output data for FREIGHT CAR MANAGEMENT SYSTEMS. Therefore, the test concentrated on freight cars and excluded locomotives, cabooses, passenger cars, and/or work trains. Based on these considerations the Operational System Performance was measured by the readability, R, which is defined as:

$$R = \frac{A}{T - a} \tag{1}$$

where:

A = total number of freight cars correctly read by the OACI system

T = total number of freight cars scanned

a = total number of non-labeled cars scanned

In this test at Chicago, the readability, R, is defined for each train side since the cars should have labels on both sides. Therefore, based on the Chicago Test design the readabilities are expressed as R_n^m where m is the train number assigned during the test and n the train (or track) side identified with the number 1 or 2.

It should be clearly stated that in the definition of the readability, the word "scanned" means that the OACI system for which the readability is being computed was operating within the specified performance. When the OACI system was inoperative and trains passed the scanner, the cars which integrated that train are not counted as non-read; they are , simply, not part of the computation. This criteria for the readability computation decouples the readability governed by the OACI principles of operation from other system and management considerations. Such considerations are electrical power failure, communication link failure, wheel sensor failure, maintenance management, etc. These major systems constraints, at the present level of understanding, are considered common to any automatic car identification input/output system regardless of the principle of operation.

When used to intercompare scanners the mean readability expressed by:

$$\bar{R} = \frac{\sum_{i=1}^{N} R_i}{N} \qquad (2)$$

is based on the same car population (see Appendix F). This means the readability is based on cars scanned by all scanners and on labels scanned by all scanners with the exception of Scanner #2 which scanned the other side of the car. In cases where a scanner was inoperative, the corresponding data from all the other scanners was not considered for intercomparison purposes.

The AAR, Communication and Signal Section, has been issuing bulletins giving the OACI functionability by reporting railroads. The functionability, F, given in percentage, is defined by AAR as:

$$F = \frac{M}{D} \tag{3}$$

where: M = total number of rolling stock correctly read by the OACI system

D = total number of rolling stock scanned

In the present report, functionability is defined as

$$F = \frac{A}{T} \tag{4}$$

where A and T are as in Equation (1).

4.6 LABEL-SCANNER READABILITY CALCULATION

The basic concept of OACI lies in the remote sensing of color-coded labels by means of an optical scanner. By the action of scanning, optical information is obtained from the label, which properly processed will decode the original code on the label. This means that in order to process information, it must exist in the label-scanner channel. If this does not exist, processing will not be able to retrieve the code. This basic concept was used at the OACI Chicago Test to determine how much information could be decoded from labels that are not within AAR specifications and/or maintenance. Within this context the label-scanner readability, R', is expressed as:

$$R' = \frac{A + O}{T - a} \tag{5}$$

where:

A, T and a are as in Equation (1)

O = labels correctly read from the scanner analog signal using TSC test equipment and visual analysis.

It should be indicated that the readability expressed by R' is not a theoretical limit based on optical communication theory, but based on observed label population, scanner-track configuration, scanner characteristics and the limitations of the test equipment. It will be safe to assume that the theoretical limit will be higher than the one measured and that even more sophisticated test equipment will be able to reach higher label-scanner readabilities.

4.7 SCANNER SYSTEM PERFORMANCE LIMIT CALCULATION

Since the main purpose of the OACI Chicago Test is to determine the capabilities of the OACI as a principle of operation, all the other factors that could mask the evaluation of this capability should be isolated and decoupled from the raw data. Therefore, non-read and error-read causes were identified and grouped into management and environment related causes. It is assumed that the management related causes are not an intrinsic limitation of the OACI principle of operation and in fact they are considered common to any automatic car identification system regardless of the principle of operation.

Based on the above considerations the scanner system performance limit is expressed by:

$$R_{limit} = \frac{A+P+(a+b+c+d+e)+f}{T} \qquad (6)$$

where:

A, T, and a are as in Equation (1)

P = total number of labels affected by the operating environment causes correctly read from scanner analog signal using TSC test equipment and visual analysis

b = total number of misapplied labels

c = total number of mixed new and old labels

d = total number of labels with rusted background

e = total number of labels with black anodize failure on backing plate.

f = total number of labels classified as non-read due to management-related data reduction causes.

4.8 DESCRIPTION OF "NON-READ AND ERROR-READ" CAUSES

To properly identify the OACI non-read and error-read causes and to statistically determine the contribution of those causes by the operating environment and by management practices, a set of 17 parameters and causes have been defined. They are as follows:

Car Label Information Parameters

1. Total Cars Scanned - Number of freight cars (excluding locomotives, cabooses, work train and/or passenger equipment) scanned during the test.

2. Total Labeled Cars Scanned - Number of freight cars scanned actually having a label on the side scanned during the test.

3.* Total Non-Labeled Cars - Number of freight cars scanned not having a label physically present on the side scanned during the test.

Non-Read and Error-Read Related Causes

4.+ Dirt - Heavy dirt accumulation reducing the visibility of modules in different degrees.

5.+ Damage - Torn or missing modules, broken brackets, bent or iron backing plates, loose or missing fasteners or vandalized labels.

6.* Misapplication - Applied modules not corresponding to actual car number or parity check module having wrong digit.

7.+ Others - This category covers situations not easily describable, which could be the result of changes caused mainly by extreme heat or cold or other unknown cause.

8.+ Undetermined - No readily apparent reason can be established to characterize the problem.

9.+ Phosphate Accumulation and/or Deterioration Due to Chemicals - Phosphate or chemical carrying cars which have overflowed and obscured or deteriorated the label.

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*Management related non-read and error-read causes.

+Operating environment non-read and error-read causes.

10.[+] Label Modules Fading - Actual colors fading or bleached out due to severe washing or scrubbing (obvious from area immediately surrounding label).

11.[+] Label Modules Damaged - One or two modules missing, scratched, vandalized or in some way unidentifiable.

12.[*] New Modules in Old Labels - Old label partially replaced with one or more new modules.

13.[*] Rusted Backing Plate and/or Side of Car - Running rust partially covering label.

14.[+] Low Label and Bent Backing Plate - On flat cars a low label plate bent back severely such as to preclude visibility of sufficient area of module surface.

15.[+] Dirty Low Label - Besides dirt accumulation, label is positioned very low as appearing mostly on flat cars and some car carriers. Also, some labels appeared to have the upper one or two modules obscured from scanner line-of-sight due to car structure overhang.

16.[*] Black Anodize Failure on Backing Plate - A black anodized backing plate that has changed color from black to silver.

17. No Code - Test and/or initial data reduction related mostly to coding and keypunch errors.

Photographs of Chicago Test OACI labels affected by causes 4, 5, 7, 9, 10, 11, 12, 13, 14, 15 and 16 are given in Appendix G.

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*Management related non-read and error-read causes.

+Operating environment non-read and error-read causes.

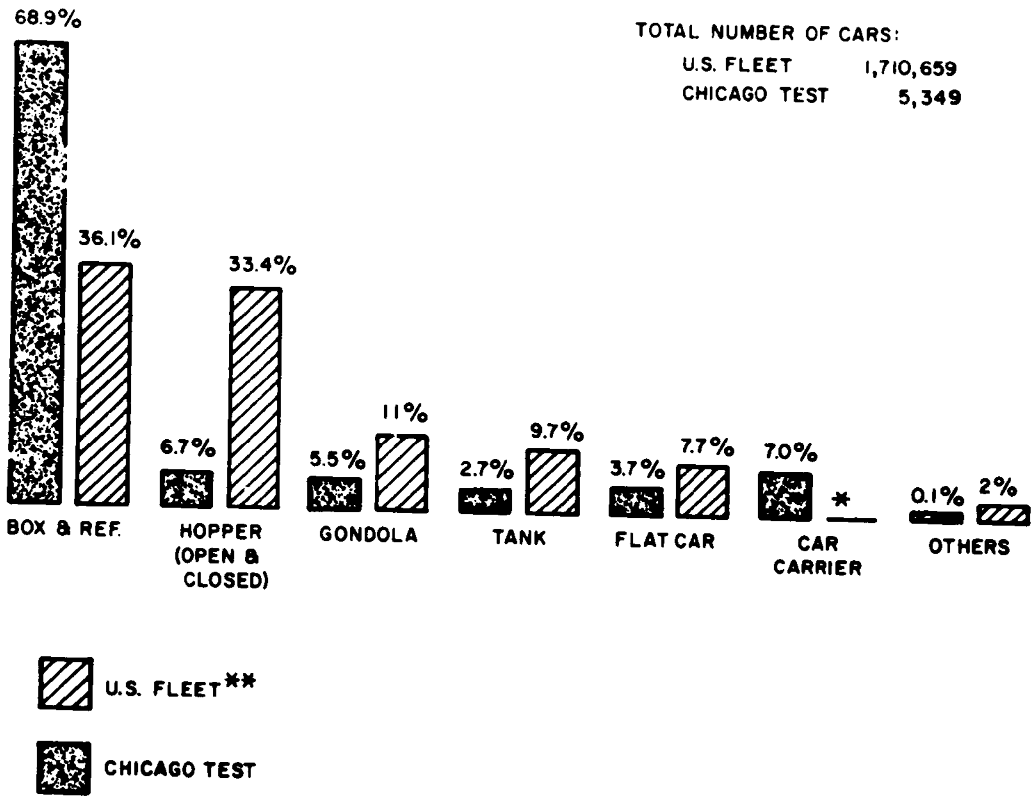
5. OBSERVATIONAL DATA AND TEST RESULTS

During the Chicago Test the observational data was gathered by OACI scanners, television cameras, photographic cameras, visual inspection by different observers of the cars and labels with these observations recorded on magnetic tape, notes in a log book, and oscillograms of the analog signal from Scanners #2 and 3. Thus, there is sufficient redundancy in the data collection to assure completeness of data and proper reduction and interpretation of the test results.

5.1 RAILROAD CAR POPULATION

To permit railroad management to properly evaluate the results obtained from the OACI Chicago Test and to adjust these results to different traffic mixes, the total number of different car types was counted. The total number of cars scanned at the Chicago Test was 5,349, of which 3,740 were box and refrigeration types, 376 hoppers (open and closed), 297 gondolas, 151 tank cars, 190 flat cars, 383 car carriers,* and 7 others. The relative car mix of both the U.S. fleet and the sample observed during the test are shown in Figure 13. Since each existing or potential OACI scanner location can be expected to experience a traffic mix unique to the geographic location rather than a population mix typical of the national fleet, normalizing of the sample to reflect the national fleet is considered unnecessary. Instead, more relevant information can be obtained from the Chicago Test design and the data gathered for use in formulating a clearer definition of the readability problem associated with the overall railroad environment. This is discussed further in Section 5.7 of this report.

*Car carriers observed in the test had both high (on rack) and low (on flat car body) mounted labels with an estimated distribution of 50 percent in each category.



*No information available in U.S. fleet.

**Data from Railroad Facts, 1974 Edition, AAR.

Figure 13. Comparison of Types of Railroad Cars in the U.S. Fleet and in the OACI Chicago Test.

5.2 SCANNER OPERATIONAL SYSTEM PERFORMANCE

To evaluate the performance of each scanner operational system the readability, R, was calculated using Equation (1) on a train-by-train basis. The total number of trains that passed the Chicago Test site during the active hours of the test was 59 with a total of 5,349 cars. The readability per train and scanner is shown in Table 1. To calculate the mean value of readability $\bar{R}$ per scanner, only the cars that were observed by all scanners were taken into account. Because some scanners were not operational during the passage of Trains 11, 15, 16 and 51, the readability values corresponding to those trains were eliminated from the computation of the mean values, that is, a total of 55 trains were taken into account with a total of 5,065 cars. It should be pointed out that of the total 5,349 cars, Side #1 (see Figure 2) had 5,206 labels and Side #2 had 5,217 labels. The readabilities obtained with the modified scanners is substantially higher than the 85.6 percent obtained with the unmodified Scanner #1. The data of Scanner #1 was output at the test site and also directly transmitted via the usual telephone line to the CRTIS Information Center. This allowed an independent measurement of the same car population scanned at the test site. The readability measured by CRTIS, properly corrected for non-label cars, is within a few tenths of one percent of the one obtained at the test site, which is an excellent agreement. Also the AAR (Reference 4), using CRTIS data during the period June 9 - 13, 1975, measured a functionability F of 80.2 percent over a population of 290,000 cars. By removing the locomotives, cabooses, commuter and passenger equipment the previous value was adjusted by the AAR to 82.7 percent. Based on the Chicago Test measurements, the mean value of unlabeled cars was 2.6 percent which added to the previous AAR adjusted value gives R = 85.3 percent. This value is in excellent agreement with the 85.6 percent obtained during the Chicago Test with Scanner #1, which is one of the scanners in the CRTIS OACI system. The mean value of readability for Scanner #2

Table 1. OACI Chicago Test Scanner Operational System Performance.*

Train #	Cars per Train**	Cars Labeled Side #1	Cars Labeled Side #2	Readability, R, %					
				Scan. #1	Scan. #2	Scan. #3	Scan. #4	Scan. #5	Scans. #2&3
1	98	93	94	87	84	89	87	88	96
2	93	89	89	92	89	93	93	85	98
3	61	57	57	81	88	91	88	86	98
4	93	90	90	79	89	92	86	86	89
5	126	125	125	88	91	94	93	86	95
6	104	104	104	88	91	97	95	93	98
7	128	125	125	84	93	90	90	89	95
8	84	81	82	91	91	95	93	94	98
9	102	100	101	87	92	91	92	90	96
10	83	82	81	83	90	91	95	91	98
11	95	90	95	83	92	23	92	88	94
12	117	116	116	87	90	91	93	93	96
13	93	90	90	78	87	84	83	86	90
14	79	77	77	88	92	94	94	92	99
15	81	80	81	86	0	0	92	91	0
16	54	52	52	69	81	0	79	79	81
17	91	88	89	95	93	97	97	97	98
18	107	105	105	87	88	90	91	90	95
19	87	84	83	85	90	89	92	90	94
20	113	108	108	85	86	90	92	91	93
21	107	106	106	77	90	90	92	86	93
22	118	117	117	91	95	94	95	95	97
23	88	86	83	83	94	94	94	90	97
24	65	63	62	79	97	89	89	92	97
25	87	80	81	79	88	81	88	89	94
26	120	117	116	88	95	92	94	92	96
27	92	92	92	85	95	97	96	92	99
28	71	66	67	92	96	89	91	92	96
29	46	43	42	84	79	86	86	86	91
30	91	89	90	82	94	92	93	91	97
31	65	62	63	89	87	94	94	92	100
32	70	70	70	87	94	94	94	91	96

Table 1. OACI Chicago Test Scanner Operational System Performance.* (Continued)

Train #	Cars per Train**	Cars Labeled Side #1	Cars Labeled Side #2		Readability, R, %				
				Scan. #1	Scan. #2	Scan. #3	Scan. #4	Scan. #5	Scans. #2&3
33	89	86	87	87	84	92	93	93	93
34	79	73	74	84	89	90	90	89	81
35	97	97	97	85	98	96	96	92	100
36	89	85	86	92	94	93	95	95	97
37	102	99	100	79	83	87	88	85	93
38	41	40	41	95	90	98	98	98	100
39	62	60	58	82	86	87	90	90	93
40	136	134	134	90	88	93	93	93	94
41	89	87	87	70	94	93	97	93	97
42	78	75	75	84	88	89	89	91	93
43	76	73	73	86	90	88	95	90	93
44	87	82	83	89	87	90	90	91	93
45	96	96	93	82	95	86	88	89	95
46	85	85	85	89	94	92	95	92	96
47	102	98	100	91	92	94	94	92	95
48	87	87	87	85	94	98	98	94	99
49	54	51	52	90	88	88	92	94	92
50	129	124	125	86	81	94	89	89	94
51	54	54	54	87	85	0	91	87	85
52	116	116	115	77	94	87	85	82	95
53	120	118	117	83	94	92	95	92	97
54	51	47	48	79	90	83	79	81	92
55	122	119	122	83	95	96	98	92	98
56	57	54	53	85	96	96	96	94	100
57	124	123	122	86	89	86	88	88	92
58	98	96	96	92	95	97	95	94	100
59	120	120	120	97	96	99	99	98	100
Totals	5349	5206	5217	$\bar{R}$ = 85.6	90.7	91.4	92.0	90.7	95.5

* Data corresponding to trains #11, 15, 16 and 51 have not been considered in the readability averages due to the fact that Scanners #2 and/or 3 were not operational when the trains passed. The total number of cars in the 59 trains was 5,349; deleting trains #11, 15, 16 and 51, the total number of cars is 5,065.

** Locomotives and cabooses were not included in the number of cars per train. In the 59 trains represented in this sample, no passenger cars and/or work trains were observed.

was $\bar{R}$ = 90.7 percent and for Scanner #3, $\bar{R}$ = 91.4 percent. The multiplexing of Scanners #2 and 3 readabilities from the two sides of the train gives a very high value of 95.5 percent. This multiplexed value is very important information to be used for future OACI system analysis. Also, the aspect of redundancy should be pointed out. During the passage of Trains #16 and 51, Scanner #3 was not operational; nevertheless, the multiplexed values gave 81 and 85 percent readabilities, respectively. During the passage of the Train #11, Scanner #3 became inoperable, therefore only part of the total number of cars were scanned by Scanner #3, but the multiplexed data with Scanner #2 gave a 94 percent readability value. The readabilities of Scanners #4 and 5 were 92.0 and 90.7 percent, respectively, values which are only less than one percent of the ones obtained by Scanners #2 and 3.

5.3 LABEL-SCANNER READABILITY

To evaluate the label-scanner readability the coefficient R' was calculated using Equation (5). The purpose of this coefficient is to determine how much optical information still in the label-scanner optical communication channel could be processed. This information could not be processed by present OACI systems because it is carried in a noisy signal and completely out of specifications due to causes originated, in some instances, on the back plates where the labels are mounted, the car side-wall where some of the labels are mounted, or by dirty and damaged labels. The analog electrical signals analyzed during the OACI Chicago Test were from Scanners #2 and 3, but since these signals were tapped at the output of the photomultiplier tube amplifier, it is safe to assume that if the same measurement is conducted at the same point in the scanners provided by the other supplier, similar results will be obtained. The values of R and R' are given in Table 2. The difference $\bar{R}' - \bar{R}$ for Scanner #2 is 2.1 percent and for Scanner #3 is 1.8 percent, which is a substantial increase since we are already in the

90 percent readability value range. The same considerations about the number of trains used to compute the mean value readabilities $\bar{R}$ were also applied to compute $\bar{R}'$. Then, how does this increase in readability materialize? Before considering the hardware implementation of these results this matter has to be carefully analyzed and has to be answered first from a system cost-effectiveness point of view to maximize total system effectiveness. Also this excess readability should be considered as an element of tradeoff between more relaxed label maintenance and more stringent scanner performance, if required.

5.4 NON-READ AND ERROR-READ CAUSES

To properly identify the OACI non-read and error-read causes and determine the weight of each cause, a careful data recording and data logging was carried out at the Chicago Test. Each car when passing the test site was recorded in photographic color film, in video tape as well as the analog electrical signal from Scanners #2 and 3. The photographic recording is of such a quality that an enlargement reveals the modules of the labels with great chromatic fidelity and resolution. Figure 14a shows the photograph of Car #2665 in Train #29 passing the test site at 15 mph. Figure 14b shows an enlargement of the corresponding label on that car. Figure 15 shows the car recorded in video tape as well as the corresponding analog signal recorded from Scanner #3. The photographic, video and electrical documentation indicates that this label was properly maintained. Figure 16a shows the photograph of Car #2644 in Train #29. Figure 16b shows an enlargement of the corresponding label on that car. Figure 17 shows the car recorded in video tape as well as the corresponding analog signal recorded from Scanner #3. The information contained in Figures 16b and 17 is representative of the majority of the labels observed at the Chicago Test. Figure 18a shows a photograph of Car #2647 in Train #29. Figure 18b shows an enlargement of the corresponding label

Table 2. OACI Chicago Test Label-Scanner Readability.*

Train #**	Scanner #2 R, %+	Scanner #2 R', %++	Scanner #3 R, %+	Scanner #3 R', %++
1	84	90	89	91
2	89	90	93	94
3	88	93	91	93
4	89	91	92	93
5	91	94	94	95
6	91	92	97	97
7	93	94	90	93
8	91	91	95	95
9	92	92	91	94
10	90	98	91	91
11	92	99	not	oper.
12	90	92	91	93
13	87	87	84	84
14	92	94	94	94
15	0	0	0	0
16	81	83	0	0
17	93	93	97	97
18	88	88	90	91
19	90	93	89	95
20	86	88	90	90
21	90	94	90	93
22	95	95	94	94
23	94	98	94	100
24	97	97	89	89
25	88	92	81	82
26	95	96	92	92
27	95	98	97	98
28	96	97	89	91
29	79	81	86	86
30	94	97	92	94
31	87	87	94	94
32	94	97	94	97
33	84	84	92	92
34	89	92	90	93
35	98	100	96	98
36	94	95	93	94
37	88	89	87	87
38	90	93	98	98
39	86	88	87	87
40	88	89	93	93
41	94	95	93	98
42	88	91	89	95

Table 2. OACI Chicago Test Label-Scanner Readability.* (Continued)

Train #**	Scanner #2		Scanner #3	
	R, %+	R', %++	R, %+	R', %++
43	90	93	88	92
44	87	91	90	93
45	95	96	86	88
46	94	94	92	92
47	92	95	94	96
48	94	96	98	100
49	88	90	88	92
50	81	86	94	97
51	85	85	00	00
52	94	96	87	90
53	94	95	92	93
54	90	91	83	87
55	95	98	96	99
56	96	96	96	96
57	89	90	86	88
58	95	96	97	98
59	96	96	99	99
	$\overline{R}$ = 90.7	$\overline{R'}$ = 92.8	$\overline{R}$ = 91.4	$\overline{R'}$ = 93.2

* Data corresponding to trains #11, 15, 16 and 51 have not been considered in the readability averages due to the fact that scanners #2 and/or 3 were not operational when the trains passed. The total number of cars in the 59 trains was 5,349; deleting trains #11, 15, 16 and 51, the total number of cars is 5,065.

** Locomotives and cabooses were not included in the number of cars per train. In the 59 trains represented in this sample, no passenger cars and/or work trains were observed.

\+ Readability.

++ Label-Scanner Readability.

on that car. Figure 19 shows the car recorded in video tape as well as the corresponding analog signal recorded from Scanner #3. The label on this car is representative of labels degraded by dirt observed at the Chicago Test. This label was read by all scanners on Side #1.

Figure 20 shows Car #598 in Train #6 as well as the corresponding analog signal recorded from Scanner #3. The output from Scanner #3 was in error. By visual inspection, the cause of the error-read was identified as dirt. Analysis of the oscillogram provided the correct label information, 0995454745-5. Figure 21 shows Car #617 in Train #7 as well as the corresponding analog signal recorded from Scanner #3. The output from Scanner #3 was 06954(10)9059?0. By visual inspection, the cause of the error-read was identified as dirt. Analysis of the oscillogram provided the correct label information, 0695459059-0. Figure 22 shows Car #2655 in Train #29 and the corresponding analog signal from Scanner #3. The label on this car was a non-read with the cause identified as dirt. Analysis of the oscillogram provided the correct label information 0131095683-10. Figure 23 shows the video record corresponding to Car #517 in Train #6. The corresponding label was properly read by Scanners #3, 4 and 5 but misread by Scanner #1. The error-read was 8995457957 and the correct read from the oscillogram is 0995457957-6. Figure 24 shows the video record corresponding to Car #2213 in Train #24. The label on the car was a non-read and the cause was identified as modules damage. With the gain setting of the test equipment, there is not enough optical information for a reliable decoding, but this does not mean that at higher amplification the decoding could be carried out. Figure 25 shows the video record of Car #2156 in Train #23 and the oscillograms corresponding to both sides of the car. One label reads 0131069923-1 and the other 013106929-3. The second car label value is the result of label misapplication. Figure 26 gives the video record of Car #747 in Train #8. The output from

Scanner #1 gave an error-read 8725570415?2. The causes of error, the 8 instead of a 0 and the first 5 instead of a 0 were identified as damaged modules. The reading of the oscillogram gave the correct value of 0720570415-2. Figure 27 gives the video record of Car #685 in Train #7. The identified cause of error-read by Scanner #1 and non-read by Scanner #4 was due to a mixture of old and new modules in the same label (observe the three large new modules signals compared with the rather low old modules signals). The decoding from the oscillogram gave the correct value of 0802490285-1. Figure 28 gives the video record of Car #1097 in Train #12. The cause of non-read was identified as rusted background which affected the front surface of the label. At the gain setting of the test equipment, not enough optical information was recorded to allow decoding.

5.4.1 Per Cause, Car Type, and Scanner

The summaries of the non-read and error-read causes per cause, car type and for Scanners #1 through 5 are presented in Tables 3 to 7. The multiplexed data of Scanners #2 and 3 are presented in Table 8. The non-read or error-read causes associated with the dirt are shown in columns 4 and 15. The addition for these two columns gives 258 for Scanner #1, and 139, 135 and 169 for Scanners #3 through 5, respectively. The total of the two columns for the multiplexed values from Scanners #2 and 3 is 86. It is interesting to note that the values from modified Scanners #3 and 4 reduced practically to half the problem cases attributed to dirt. Moreover, the multiplexed values of Scanners #2 and 3 reduced these cases to one-third by observing both sides of the car, in fact two correlated label populations. Also, it is interesting to intercompare the results given in column 12 for all the scanners. The cause of non-read or error-read included in this column is due to the mixture of new modules in old labels. For Scanner #1 this is 63, and it is 30, 26 and 34 for Scanners 3 through 5, respectively. This indicates a reduction in the modified scanner to one half the problem cases attributed to this cause.

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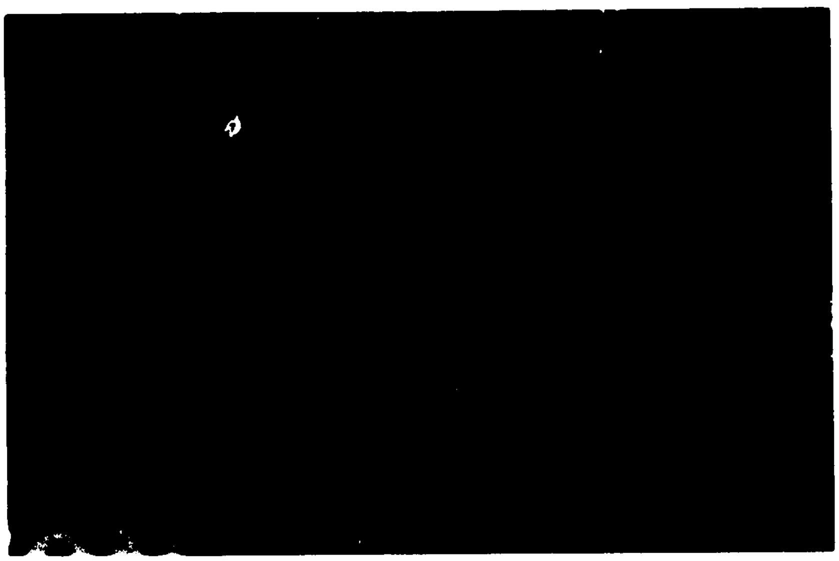
a)



b)

Figure 14. a) Photograph of Car #2665 (Train #29) Passing the OACI Test Site in Chicago at 15 MPH.
b) Enlargement Showing the OACI Label Portion of Photograph "a".
The Corresponding OACI Oscillogram is Shown in Figure 15.

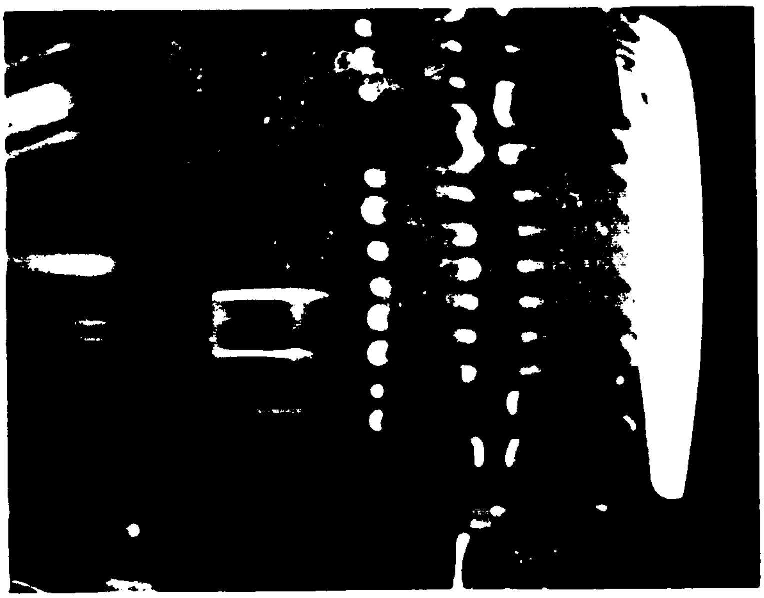
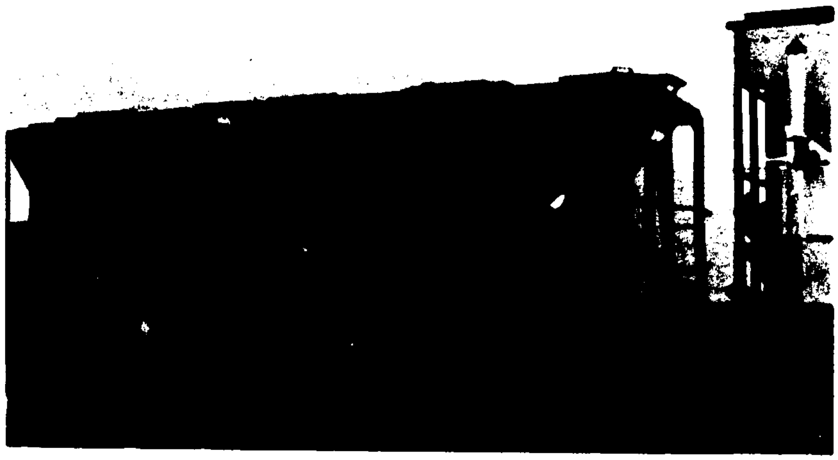
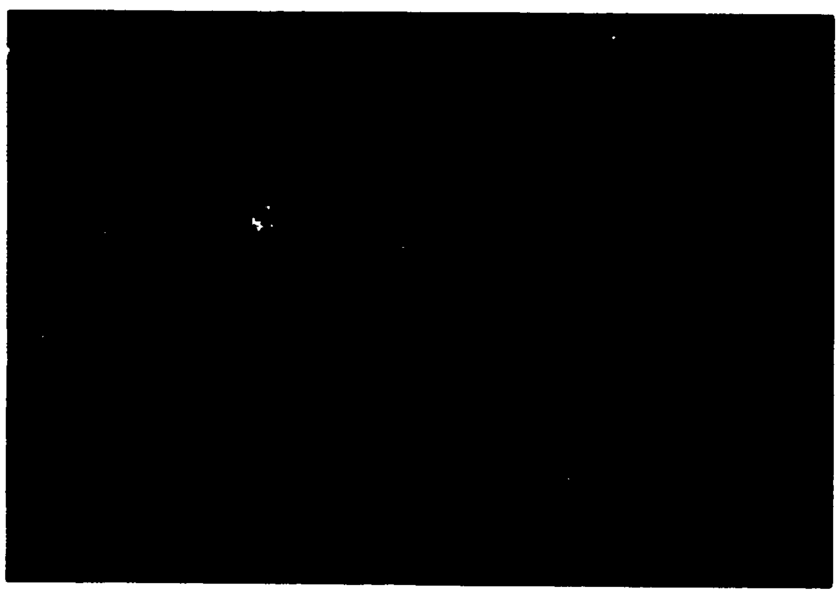


Figure 15. TV Image Corresponding to Car #2665 (Train #29, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). This Signal is Typical of a Properly Maintained Label Observed at the Chicago Test.



a)



b)

Figure 16. a) Photograph of Car #2644 (Train #29) Passing the OACI Test Site in Chicago at 15 MPH.
b) Enlargement Showing the OACI Label Portion of Photograph "a".
The Corresponding OACI Oscillogram is Shown in Figure 17.

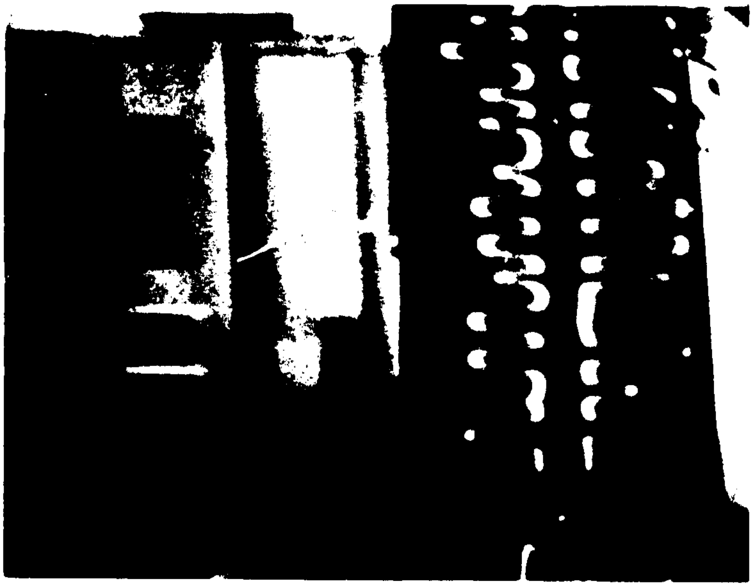


Figure 17. TV Image Corresponding to Car #2644 (Train #29, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). This Signal is Representative of the Majority of Labels in Service Observed at the Chicago Test.

a)

b)

Figure 18. a) Photograph of Car #2647 (Train #29) Passing the OACI Test Site in Chicago at 15 MPH.
b) Enlargement Showing the OACI Label Portion of Photograph "a".
The Corresponding OACI Oscillogram is Shown in Figure 19.

Figure 19. TV Image Corresponding to Car #2647 (Train #29, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). This Signal is Representative of Degraded Labels Not Properly Maintained Observed at the Chicago Test.

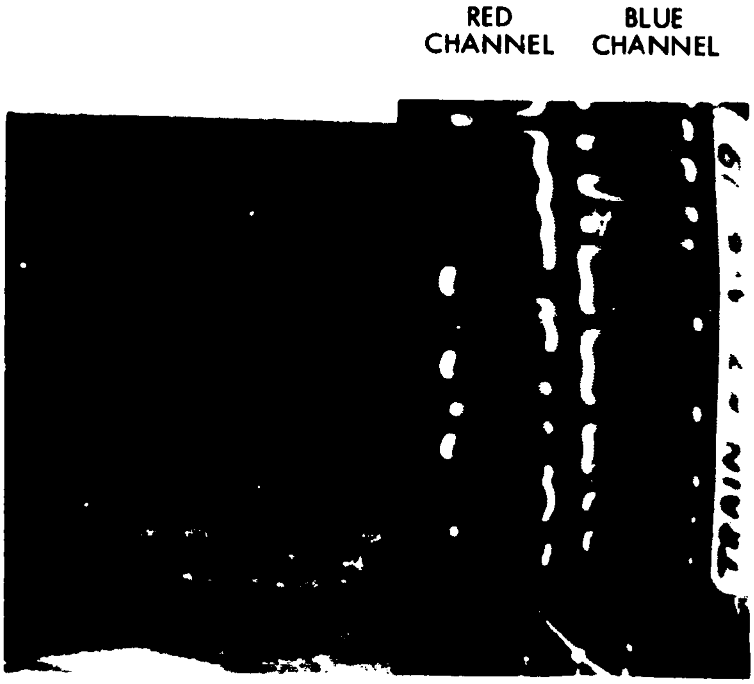


Figure 20. TV Image Corresponding to Car #598 (Train #6, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). The Cause of Error-Read was Identified as Dirt on the Label by Visual Inspection. Visual Analysis of the Oscillogram Gives the ACI Code 0995454745-5 Which is Correct.

Figure 21. TV Image Corresponding to Car #617 (Train #7, Side #2) The Analog Signal is Recorded from Scanner #3 (Track Side #1). The Cause of Error-Read was Identified as Dirt on the Label by Visual Inspection. Visual Analysis of the Oscillogram Gives the ACI Code 0695459059-0 Which is Correct.

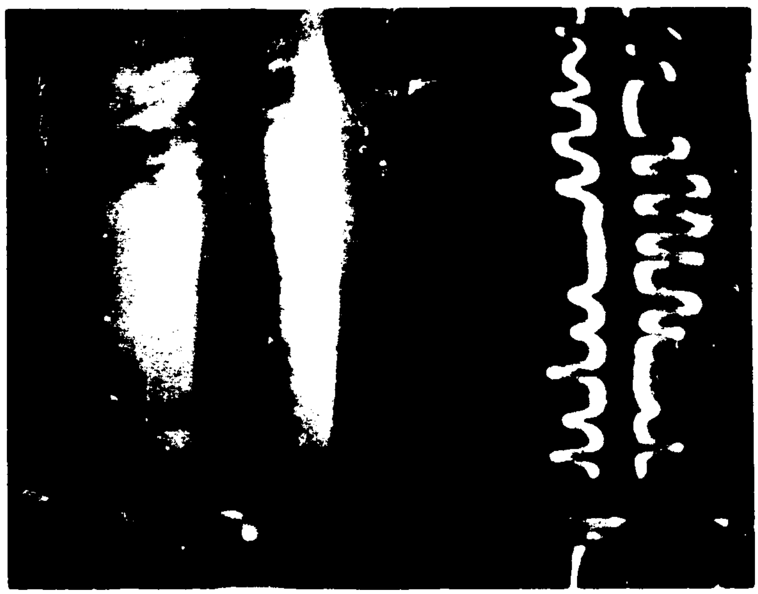


Figure 22. TV Image Corresponding to Car #2655 (Train #29, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). The Cause of Non-Read was Identified as Dirt on the Label by Visual Inspection. Visual Analysis of the Oscillogram Gives the ACI Code 0131095683-10 Which is Correct.

Figure 23. TV Image Corresponding to Car #517 (Train #6, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). The Cause of Error-Read by Scanner #1 was Identified as Due to Dirt on the Label. Visual Analysis of the Oscillogram Gives the ACI Code 0995457957-6 Which is Correct.

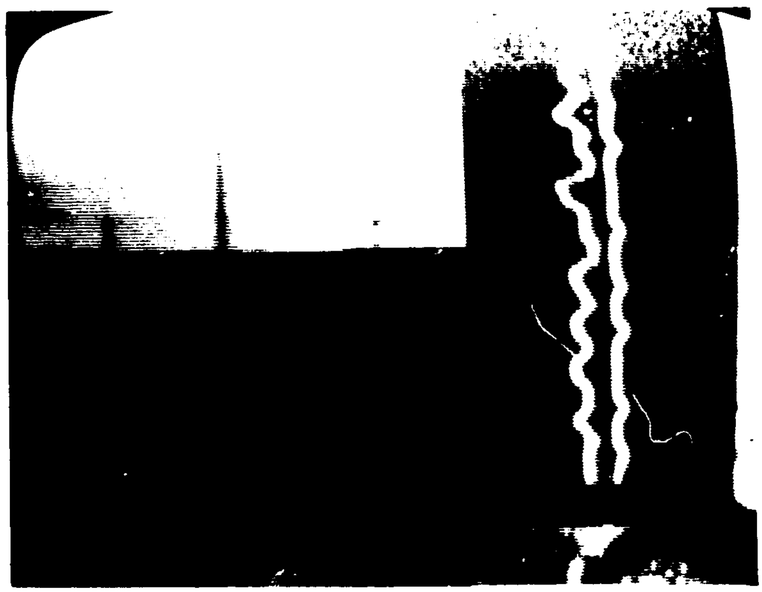


Figure 24. TV Image Corresponding to Car #2213 (Train #24, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). The Cause of Non-Read was Identified as Modules Damaged. There is not Enough Optical Information to Read the Oscillogram.

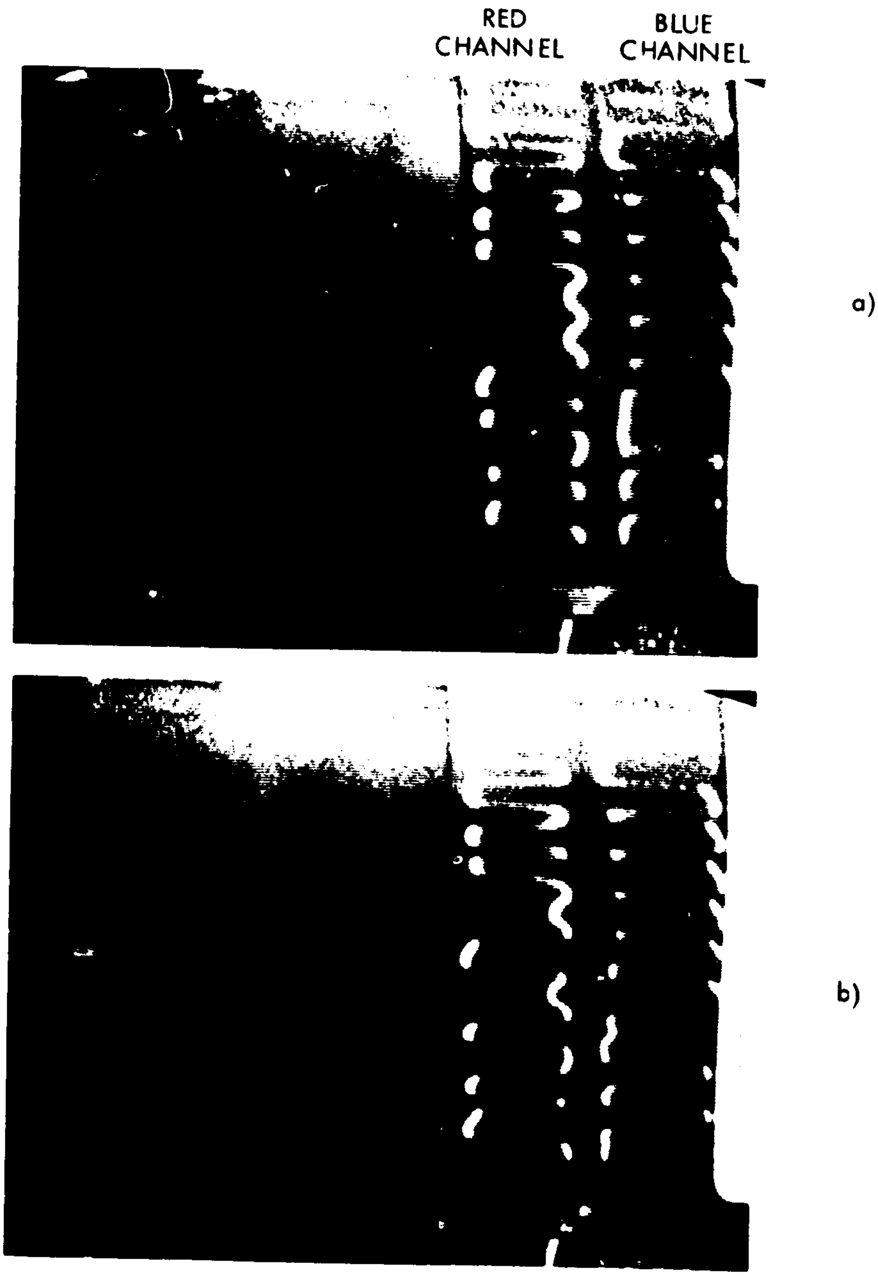


Figure 25. TV Image Corresponding to the Car #2156 (Train #23, Side #2).
a) The Analog Signal is Recorded from Scanner #3 (Track Side #1) Showing the ACI Code 0131069923-1.
b) The Analog Signal is Recorded from Scanner #2 (Track Side #2) Showing ACI Code 013106929-3 as a Result of Modules Misapplication.

RED CHANNEL BLUE CHANNEL

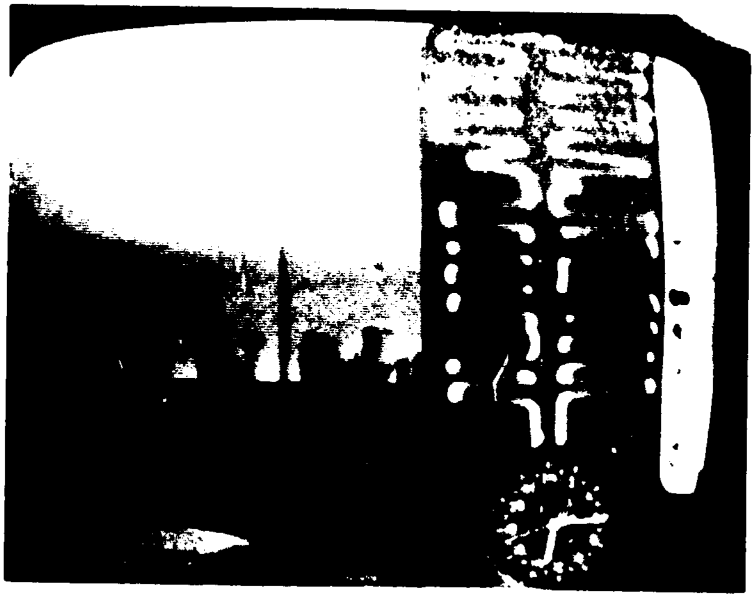


Figure 26. TV Image Corresponding to Car #747 (Train #8, Side #2). The Analog Signal is Recorded From Scanner #3 (Track Side #1). The Cause of Error-Read by Scanner #1(8725570415?2) was Identified as Damage on One Module by Visual Inspection. Visual Analysis of the Oscillogram Gives the ACI Code 0720570415-2 Which is Correct.

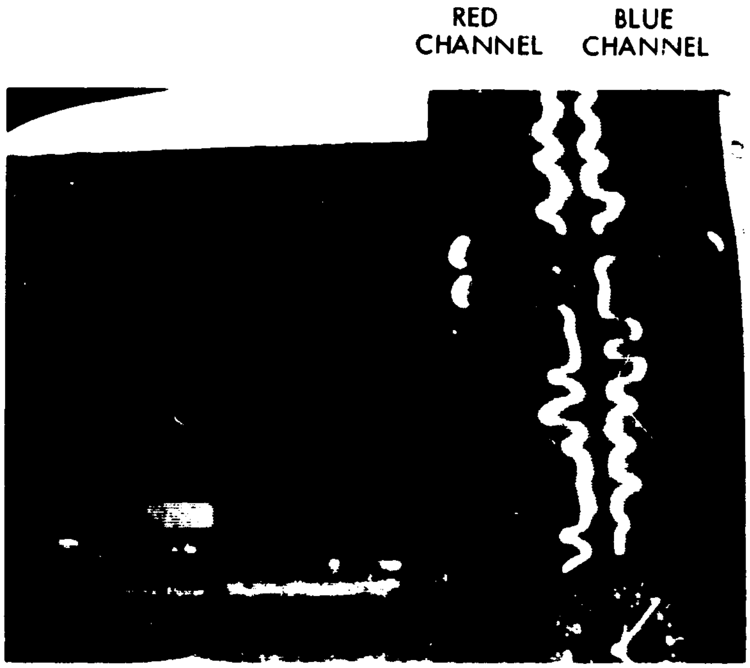


Figure 27. TV Image Corresponding to Car #685 (Train #7, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). The Cause of Error-Read by Scanner #1 and Non-Read by Scanner #4 was Identified as Due to a Mixture of Old and New Modules in the Same Label. Visual Analysis of the Oscillogram Gives the ACI Code 0802490285-1 Which is Correct.

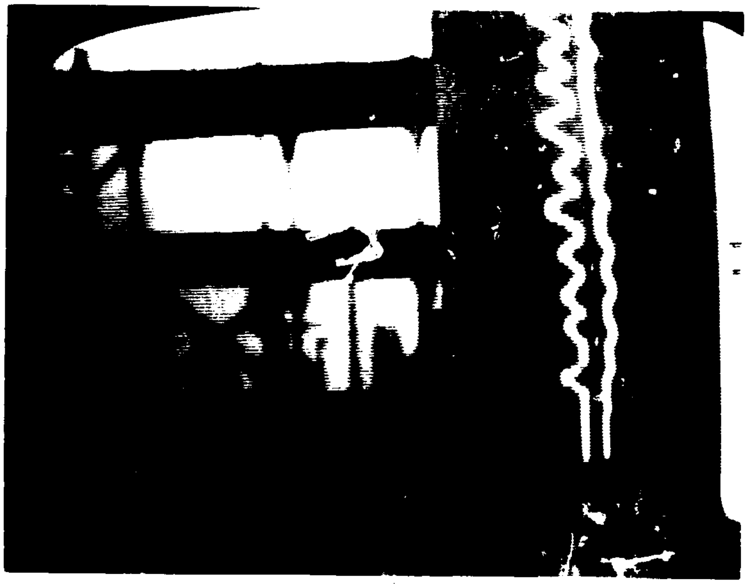


Figure 28. TV Image Corresponding to Car #1097 (Train #12, Side #2). The Analog Signal is Recorded from Scanner #3 (Track Side #1). The Cause of Non-Read was Identified as Rusted Background Which Affected the Front Surface of the Labels.

Table 3. OACI Chicago Test Non-Read and Error-Read Causes per Car Type, Scanner #1.

Car Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Box Car	3,740	3,697	43	110	7	11	4	55	0	17	11	58	16	1	6	51	109	456
Hopper	376	353	23	24	1	1	1	10	6	0	0	2	1	1	0	5	8	60
Flat Car	190	181	9	3	1	0	0	3	0	1	0	0	0	6	15	4	9	42
Car Carrier	383	356	27	8	1	1	2	1	0	1	1	1	4	1	56	1	3	81
No Information	205	205	0	5	0	0	1	2	1	0	0	0	0	0	2	1	2	14
Gondola	297	272	25	14	5	4	11	10	0	2	5	2	2	0	0	8	10	73
Tank Car	151	135	16	10	0	1	0	1	1	2	1	0	1	0	4	0	3	24
Other	7	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Totals	5,349	5,206	143	174	15	18	19	82	8	23	18	63	24	9	84	70	144	751

Car Label Information

1. Total Cars Scanned
2. Total Labeled Cars Scanned
3. Total Non-labeled Cars

Non-Read & Error-Read Related Causes*

4. Dirt
5. Damage
6. Misapplication
7. Others
8. Undetermined
9. Phosphate Accumulation and/or Deterioration due to Chemicals
10. Label Modules Fading
11. Label Modules Damage
12. New Modules in Old Label
13. Rusted Backing Plate and/or Side of Car
14. Low Label and Bent Backing Plate
15. Dirty Low Label
16. Black Anodize Failure on Backing Plate
17. No Code
18. Total of Items 4 Through 17

*See Section 4.8, Description of "Non-Read and Error-Read" Causes.

Table 4. OACI Chicago Test Non-Read and Error-Read Causes per Car Type, Scanner #2.

Car Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Box Car	3,740	3,697	43	58	3	7	1	21	0	6	6	11	3	0	4	50	64	234
Hopper	376	357	19	12	0	0	0	5	3	0	1	1	0	1	1	6	8	38
Flat Car	190	182	8	2	1	0	0	0	0	1	0	0	0	3	15	4	6	32
Car Carrier	383	358	25	17	1	2	1	4	0	1	1	1	3	1	37	7	8	84
No Information	205	205	0	3	1	0	0	1	0	0	0	0	0	0	4	1	0	10
Gondola	297	270	27	15	4	1	7	6	0	1	4	1	0	0	1	5	11	56
Tank Car	151	139	12	9	0	0	0	0	1	2	0	0	1	0	4	0	2	19
Other	7	9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Totals	5,349	5,217	134	116	10	10	9	37	4	11	12	14	7	5	67	73	99	474

Car Label Information

1. Total Cars Scanned
2. Total Labeled Cars Scanned
3. Total Non-labeled Cars

Non-Read & Error-Read Related Causes*

4. Dirt
5. Damage
6. Misapplication
7. Others
8. Undetermined
9. Phosphate Accumulation and/or Deterioration due to Chemicals
10. Label Modules Fading
11. Label Modules Damage
12. New Modules in Old Label
13. Rusted Backing Plate and/or Side of Car
14. Low Label and Bent Backing Plate
15. Dirty Low Label
16. Black Anodize Failure on Backing Plate
17. No Code
18. Total of Items 4 Through 17

*See Section 4.8, Description of "Non-Read and Error-Read" Causes.

Table 5. OACI Chicago Test Non-Read and Error-Read Causes per Car Type, Scanner #3.

Car Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Box Car	3,740	3,697	43	33	7	10	1	15	0	8	8	26	7	1	4	41	33	194
Hopper	376	353	23	8	4	0	0	5	7	0	0	1	1	1	1	8	5	41
Flat Car	190	181	9	2	0	0	0	1	0	1	0	0	0	2	12	4	4	26
Car Carrier	383	356	27	7	1	0	1	2	0	1	0	1	5	0	54	4	1	77
No Information	205	205	0	0	0	0	1	2	1	0	0	0	0	0	2	2	0	8
Gondola	297	272	25	6	4	1	10	2	0	2	4	2	2	0	1	12	3	49
Tank Car	151	135	16	6	0	1	0	0	1	2	1	0	1	0	2	0	0	14
Other	7	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Totals	5,349	5,206	143	62	16	12	13	27	9	14	13	30	16	4	77	71	46	410

Car Label Information

1. Total Cars Scanned
2. Total Labeled Cars Scanned
3. Total Non-labeled Cars

Non-Read & Error-Read Related Causes*

4. Dirt
5. Damage
6. Misapplication
7. Others
8. Undetermined
9. Phosphate Accumulation and/or Deterioration due to Chemicals
10. Label Modules Fading
11. Label Modules Damage
12. New Modules in Old Label
13. Rusted Backing Plate and/or Side of Car
14. Low Label and Bent Backing Plate
15. Dirty Low Label
16. Black Anodize Failure on Backing Plate
17. No Code
18. Total of Items 4 Through 17

*See Section 4.8, Description of "Non-Read and Error-Read" Causes

Table 6. OACI Chicago Test Non-Read and Error-Read Causes per Car Type, Scanner #4.

Car Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Box Car	3,740	3,697	43	31	6	10	2	12	0	9	8	21	6	1	4	37	43	190
Hopper	376	353	23	8	4	0	0	4	6	0	0	2	1	1	0	4	5	35
Flat Car	190	181	9	2	1	0	0	1	0	1	0	0	0	7	16	4	5	37
Car Carrier	383	356	27	6	1	1	1	1	0	2	1	1	4	1	54	5	2	80
No Information	205	205	0	0	0	0	1	2	1	0	0	0	0	0	1	0	0	5
Gondola	297	272	25	7	4	2	11	3	0	2	5	2	1	0	0	12	2	51
Tank Car	151	135	16	4	0	1	0	1	1	2	1	0	1	0	1	0	0	12
Other	7	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Totals	5,349	5,206	143	58	16	14	15	24	8	16	15	26	13	10	77	62	57	411

Car Label Information

1. Total Cars Scanned
2. Total Labeled Cars Scanned
3. Total Non-labeled Cars

Non-Read & Error-Read Related Causes*

4. Dirt
5. Damage
6. Misapplication
7. Others
8. Undetermined
9. Phosphate Accumulation and/or Deterioration due to Chemicals
10. Label Modules Fading
11. Label Modules Damage
12. New Modules in Old Label
13. Rusted Backing Plate and/or Side of Car
14. Low Label and Bent Backing Plate
15. Dirty Low Label
16. Black Anodize Failure on Backing Plate
17. No Code
18. Total of Items 4 Through 17

*See Section 4.8, Description of "Non-Read and Error-Read" Causes.

Table 7. OACI Chicago Test Non-Read and Error-Read Causes per Car Type, Scanner #5.

Car Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Box Car	3,740	3,697	43	52	6	11	0	18	0	10	7	30	12	1	4	46	60	257
Hopper	376	353	23	8	3	0	0	7	5	0	0	1	1	1	0	4	6	36
Flat Car	190	181	9	2	1	0	0	1	0	1	0	0	0	8	14	3	5	35
Car Carrier	383	356	27	8	1	0	2	3	0	1	0	1	5	1	56	3	2	83
No Information	205	205	0	3	0	0	1	2	1	0	0	0	0	0	2	0	1	10
Gondola	297	272	25	7	6	1	11	3	0	2	4	2	2	0	2	9	2	51
Tank Car	151	135	16	6	6	1	0	1	1	2	1	0	1	0	4	0	3	26
Other	7	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Totals	5,349	5,206	143	86	23	13	14	35	7	16	12	34	21	11	83	65	79	499

Car Label Information

1. Total Cars Scanned
2. Total Labeled Cars Scanned
3. Total Non-labeled Cars

Non-Read & Error-Read Related Causes*

4. Dirt
5. Damage
6. Misapplication
7. Others
8. Undetermined
9. Phosphate Accumulation and/or Deterioration due to Chemicals
10. Label Modules Fading
11. Label Modules Damage
12. New Modules in Old Label
13. Rusted Backing Plate and/or Side of Car
14. Low Label and Bent Backing Plate
15. Dirty Low Label
16. Black Anodize Failure on Backing Plate
17. No Code
18. Total of Items 4 Through 17

*See Section 4.8, Description of "Non-Read and Error-Read" Causes.

Table 8. OACI Chicago Test Non-Read and Error-Read Causes per Car Type, Scanners #2 and 3.

Car Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Box Car	3,740	3,697	43	14	1	5	1	6	0	3	2	4	1	0	3	27	37	104
Hopper	376	353	23	5	0	0	0	3	2	0	1	1	0	1	1	4	5	23
Flat Car	190	181	9	1	0	0	0	0	0	1	0	0	0	1	6	2	5	16
Car Carrier	383	356	27	10	1	0	1	0	0	0	1	0	2	1	34	3	4	57
No Information	205	205	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	3
Gondola	297	272	25	4	2	1	7	1	0	1	3	0	0	0	0	2	6	27
Tank Car	151	135	16	4	0	0	0	0	1	2	0	0	1	0	2	0	1	11
Other	7	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Totals	5,349	5,206	143	38	4	6	9	11	3	7	7	5	4	3	48	39	58	242

Car Label Information

1. Total Cars Scanned
2. Total Labeled Cars Scanned
3. Total Non-labeled Cars

Non-Read & Error-Read Related Causes*

4. Dirt
5. Damage
6. Misapplication
7. Others
8. Undetermined
9. Phosphate Accumulation and/or Deterioration due to Chemicals
10. Label Modules Fading
11. Label Modules Damage
12. New Modules in Old Label
13. Rusted Backing Plate and/or Side of Car
14. Low Label and Bent Backing Plate
15. Dirty Low Label
16. Black Anodize Failure on Backing Plate
17. No Code
18. Total of Items 4 Through 17

*See Section 4.8, Description of "Non-Read and Error-Read" Causes.

The observational data given above are very useful in quantitatively understanding the label-scanner interface. The data are of great importance for tradeoffs and/or cost-effectiveness analysis.

5.4.2 Per Cause Group and Scanner

The seventeen non-read and error-read related causes (see Section 4.8) are classified into three main groups: 1) operating environment, 2) management* and 3) test and data reduction.

- Operating Environment
  - Dirt
  - Label damage
  - Others
  - Undetermined
  - Phosphate accumulation and/or deterioration caused by chemicals
  - Label modules fading
  - Modules damaged
  - Low label and bent plate
  - Dirty low label
- Management
  - Non-labeled cars
  - Label misapplication
  - New modules in old labels
  - Rusted backing plate on side of the car
  - Black anodize failure on backing plate

*The non-read and error-read management related causes could be generally defined as those causes due to the lack of compliance with the OACI management procedures prescribed in Reference 5.

- Test and Data Reduction

  No code (error in data coding).

A summary of the operating environment non-read and error-read related causes in the OACI Chicago Test is given in Table 9. Management related causes are presented in Table 10, and the test and data reduction related causes are shown in Table 11. The data provided in these tables is for all the scanners and the multiplexed data Scanners #2 and 3.

Tables 9 through 11 contain two columns for each scanner, A and B. Column A contains data corresponding to all the car types scanned by the particular scanner and Column B only car types scanned by all the scanners (data corresponding to Trains #11, 15, 16 and 51 were deleted and totals and percentages properly adjusted). It is interesting to note from the data on Tables 9 and 10 that Scanners #3 and 4 reduced the number of non-read and error-reads due to the operating environment related causes to 54 percent of the cases reported by Scanner #1. In the case of the management related causes, the totals for the Scanners #4 and 5 were reduced to 81 percent and 89 percent of the values reported by Scanner #1. These reductions are attributed to the modifications (and alignment procedures) introduced in Scanners #3, 4 and 5. The inspection of Table 11 gives higher test and data reduction non-read and error-related causes for Scanner #1, compared to the values obtained from Scanners #2 through 5. The explanation of this higher value resides in the fact that this teletype did not print as clearly as the others and therefore errors were introduced in the coding of the data from that printout. Nevertheless, it should be pointed out that the coding and keypunching errors reflected in these percentages are extremely low for a crash program of this type. These errors are identifiable since the computer's printout is at the car level, and when an error appears without an identifiable cause, the computer prints "no code." Further examination of the data will enable correction of these minor errors.

Table 9. Operating Environment Related Non-Read and Error-Read Causes in the OACI Chicago Test.

Cause*	Scanner #1		Scanner #2		Scanner #3		Scanner #4		Scanner #5		Scanners #2&3	
	A**	B***	A**	B***	A**	B***	A**	B***	A**	B***	A**	B***
4. Dirt	174	170	116	111	62	62	58	55	86	80	38	33
5. Label Damage	15	14	10	10	10	9	16	15	13	12	4	4
7. Others	19	16	9	7	13	13	15	13	14	13	9	7
8. Undetermined	81	74	36	34	25	25	23	22	35	34	11	10
9. Phosphate Accumulation and/or Chemical Deterioration	9	8	5	4	11	11	9	8	7	6	3	2
10. Label Modules Fading	23	22	11	11	14	14	16	15	16	15	7	7
11. Modules Damaged	18	17	12	11	13	13	15	14	12	11	7	6
14. Low Label & Bent Plate	9	7	5	4	4	4	10	8	11	9	3	2
15. Dirty Low Label	84	82	67	67	77	77	77	75	83	82	48	48
TOTAL	432	410	271	259	229	228	239	225	277	262	130	119
% Per # Total Cars	8.1	8.1	5.2	5.3	4.3	4.5	4.5	4.4	5.2	5.2	2.4	2.3

*See Section 4.8, Description of "Non-Read and Error-Read" Causes.

**The percentages at the bottom of the column are based on the cars scanned by the respective scanner.

***All the cars and causes corresponding to trains #11, 15, 16 and 51 are deleted from the totals and percentages, due to one or more inoperative scanners.

Table 10. Management Related Non-Read and Error-Read Causes in the OACI Chicago Test.

Cause*	Scanner #1		Scanner #2		Scanner #3		Scanner #4		Scanner #5		Scanners #2&3	
	A**	B***	A**	B***	A**	B***	A**	B***	A**	B***	A**	B***
3. Non-Labeled Cars	143	135	132	130	143	143	143	135	143	135	119	119
6. Misapplication	18	18	10	10	12	12	14	14	13	13	6	6
12. New Modules in Old Labels	63	60	14	14	30	30	26	24	34	31	5	5
13. Rusted Backing Plate and/or Side of Car	24	24	7	7	16	16	13	13	21	21	4	4
16. Black Anodize Failure on Backing Plate	69	62	73	68	71	69	62	56	65	58	39	34
TOTAL	317	299	236	229	272	270	258	242	276	258	173	168
% Per Total # Cars	5.9	5.9	4.5	4.6	5.1	5.3	4.8	4.8	5.2	5.1	3.2	3.3

Table 11. Test and Data Reduction Related Non-Read Causes in the OACI Chicago Test.

Cause*	Scanner #1		Scanner #2		Scanner #3		Scanner #4		Scanner #5		Scanners #2&3	
	A**	B***	A**	B***	A**	B***	A**	B***	A**	B***	A**	B***
17. No Code	144	130	99	90	46	46	57	51	79	70	58	50
% Per Total # Cars	2.7	2.6	1.9	1.8	0.9	0.9	1.1	1.0	1.5	1.4	1.1	1.0

*See Section 4.8, Description of "Non-Read and Error-Read" Causes.
**The percentages at the bottom of the column are based on the cars scanned by the respective scanner.
***All the cars and causes corresponding to trains # 11, 15, 16 and 51 are deleted from the totals and percentages, due to one or more inoperative scanners.

5.5 SCANNER SYSTEM PERFORMANCE LIMIT

One of the main objectives of the OACI Chicago Test was to evaluate the OACI as a principle of operation. The test was not intended to perform hardware test and evaluation or any other aspects related to commercial product development or client–supplier relations, reliability, maintenance, etc.

The scanner systems were properly calibrated at the beginning of each test day to ensure that the transfer function of the respective scanner system was maintained. Also, the performance of each scanner was checked at the end of each test day to ensure constancy of performance during the day.

The question presents itself: What is the performance limit of the optical scanners with the label population observed at the Chicago Test? This limit of readability, R_{limit}, is given by Equation (6) and computed as follows:

$$R_{limit} = \frac{A + P + (a + b + c + d + e) + f}{T}$$

$$= \left(\frac{A}{T}\right) + \left(\frac{P}{T}\right) + \left(\frac{a + b + c + d + e}{T}\right) + \left(\frac{f}{T}\right)$$

$\left(\frac{A}{T}\right)$: Functionability

$\left(\frac{P}{T}\right)$: Operating Environment Related Causes Read from Oscillograms

$\left(\frac{a + b + c + d + e}{T}\right)$: Management Related Causes

$\left(\frac{f}{T}\right)$: Data Coding and/or Punching Causes

The term $\frac{P}{T}$ was found to be approximately 50 percent of $\frac{O}{T}$ $(= R' - R)$, and $\left(\frac{f}{T}\right)$ was found to be approximately 50 percent of the "no code" errors (item No. 7, Table 11). Based on the data supplied in Tables 2, 10, and 14, the mean limit of readability for Scanner #2, $\bar{R}_{limit,2}$ is estimated as:

1.	Functionability (5,065 cars)	88.1%
2.	Environmental related causes read from oscillogram, $0.5 \times (\bar{R}' - \bar{R})$	1.0%
3.	Management related causes	4.5%
4.	Data coding and/or [illegible], 0.5 x Cause #17	1.0%
	Estimated $\bar{R}_{limit,2}$	94.6%

Similarly, the estimate of $\bar{R}_{limit,3}$ (Scanner #3) is:

1.	Functionability	88.8%
2.	Environmental related causes read from oscillogram, $0.5 \times (\bar{R}' - \bar{R})$	0.9%
3.	Management related causes	5.3%
4.	Data coding and/or punching error, 0.5 x Cause #17	0.5%
	Estimated $\bar{R}_{limit,3}$	95.5%

Due to the similarity in performance between Scanner #2 and Scanner #5, and Scanner #3 and Scanner #4, the $(\bar{R}' - \bar{R})$ values of the respective scanners will be applicable.

Estimate of $\bar{R}_{limit,4}$ (Scanner #4):

1.	Functionability	89.4%
2.	Environmental related causes read from oscillogram, $0.5 \times (\bar{R}' - \bar{R})$	0.9%
3.	Management related causes	4.8%
4.	Data coding and/or punching error, 0.5 x Cause #17	0.5%
	Estimated $\bar{R}_{limit,4}$	95.6%

Estimate of $\bar{R}_{limit,5}$ (Scanner #5)

1.	Functionability	88.0%
2.	Environmental related causes read from oscillogram $0.5 \times (\bar{R}' - \bar{R})$	1.0%
3.	Management related causes	5.1%
4.	Data coding and/or punching error, 0.5 x Cause #17	0.7%
	Estimated $\bar{R}_{limit,5}$	94.8%

Estimate of $\bar{R}_{limit,2+3}$ (Multiplexed Scanners #2 & 3)

1.	Functionability	93.2%
2.	Environmental related causes read from oscillogram, $0.5 \times (\bar{R}' - \bar{R})$	1.0%
3.	Management related causes	3.3%
4.	Data coding and/or punching error, 0.5 x Cause #17	0.5%
	Estimated $\bar{R}_{limit,2+3}$	98.0%

Estimate of $\bar{R}_{limit,1}$ (Scanner #1)

1.	Functionability	82.9%
2.	Environmental related causes read from oscillogram, $0.5 \times (\bar{R}' - \bar{R})$	1.5%
3.	Management related causes	5.9%
4.	Data coding and/or punching error, 0.5 x Cause #17	1.3%
	Estimated $\bar{R}_{limit,1}$	91.6%

5.6 FUNCTIONABILITY AND THE CHICAGO TEST RESULTS

Based on data supplied by reporting railroads, the AAR, Communication & Signal Section, issued monthly reports on OACI functionability. Table 12 is the report issued in July 1975, and contains the functionabilities reported by eleven railroads corresponding to the months of April and May 1975. Table 13 gives similar data but by grouping the data of individual reporting railroads on a monthly basis. Figure 29 gives a plot of the data shown in Table 13. Table 14 gives the functionability obtained at the OACI Chicago Test on a train by train basis and for each one of the five scanners. Also, it includes the multiplexed functionability from Scanners #2 and 3. Since Scanner #2 is on Side #2 of the track and the rest of the scanners are on Side #1, information is given on the cars labeled per train and per track side.

The AAR functionability data and the functionability data from the OACI Chicago Test is provided to establish a "link" between the two sets of data. A detailed comparison was not established due to the stringent time limitations in preparing this Chicago Test summary of results.* Nevertheless, the 82.9 percent functionability of Scanner #1 (CRTIS Site #15 scanner) is well within the upper and lower bounds of 78.0 percent (CRTIS) and 83.5 percent (Southern Pacific) functionabilities given in Table 12 for May 1975, by the AAR. The functionability data, 90.9 percent, from the Duluth, Missabe and Iron Range Railroad was not included due to this railroad's unique operational aspects (captive fleet). It should be pointed out that in the AAR data Equation (2) is used.

* The utilization of the mean functionability as an indicator of the national trend will be further investigated and reported by TSC.

Table 12. OACI Functionability Report (by Reporting Railroads) May and April 1975.*

Reporting U.S. Railroads**	Cars Scanned	Cars Correctly Read	Cars Correctly Read, % May 1975	Cars Correctly Read, % April 1975
1	217,921	171,578	78.7	79.5
2	252,036	207,005	82.1	82.3
3	587,174	490,154	83.5	83.4
4	664,179	540,866	81.4	80.7
5	119,510	99,253	83.1	82.5
6	162,813	148,065	90.9	95.0
7	238,759	198,977	83.3	83.2
8	1,691,249	1,319,340	78.0	78.0
9	88,643	71,091	80.2	78.8
Total	4,022,284	3,246,329	80.7	80.4

Reporting Canadian Railroads**	Cars Scanned	Cars Correctly Read	Cars Correctly Read, % May 1975	Cars Correctly Read, % April 1975
10	732,349	655,347	89.5	89.6
11	145,701	120,591	82.8	82.2

* Prepared by the Association of American Railroads, Communication & Signal Section, July 2, 1975

** KEY:

1. Union Pacific
2. Atchison, Topeka and Santa Fe
3. Southern Pacific
4. Norfolk and Western
5. Elgin, Joliet and Eastern Railway
6. Duluth, Missabe and Iron Range
7. Detroit, Toledo and Ironton
8. Chicago Railroad Terminal Information System, Inc.
9. Seaboard Coast Line
10. Canadian National
11. Canadian Pacific

Table 13. OACI Functionability Report (by Year and Month) May 1975.*

Year	Month	Reporting U.S. Railroads**	Cars Scanned	Cars Correctly Read, %
1970	Dec	1	27,895	87.0
1971	Jan	1	26,405	87.0
	Feb	1	28,390	87.4
	Mar	1	30,674	87.2
	Apr	1	44,876	87.3
	May	1	45,387	87.0
	Jun	1	81,976	87.1
	Jul	1	80,287	84.4
	Aug	1	66,929	85.0
	Sep	1	88,935	84.0
	Oct	1	128,010	83.9
	Nov	1	171,668	84.4
	Dec	1	158,915	84.2
1972	Jan	1	171,420	84.3
	Feb	1	172,350	85.1
	Mar	1 and 2	405,148	83.4
	Apr	1 and 2	459,896	83.0
	May	1 and 2	447,571	82.5
	Jun	1 and 2	--	82.1
	Jul	1 and 2	474,081	82.4
	Aug	1 and 2	399,813	81.9
	Sep	1 and 2	438,473	81.3
	Oct	1 and 2	416,524	81.3
	Nov	1, 2 and 3	958,645	81.1
	Dec	1,2,3,4 and 5	1,268,887	81.5
1973	Jan	1,2,3,4 and 5	1,356,566	79.4
	Feb	1,2,3,4 and 5	1,387,939	79.3
	Mar	1,2,3,4 and 5	1,641,362	79.4
	Apr	1,2,3,4 and 5	1,535,936	79.3
	May	1,2,3,4 and 5	1,523,395	78.4
	Jun	1,2,3,4 and 5	1,689,655	79.4
	Jul	1,2,3,4 and 5	1,463,543	79.5
	Aug	1,2,3,4 and 5	1,608,625	80.6
	Sep	1,2,3,4 and 5	1,540,334	79.9
	Oct	1,2,3,4 and 5	1,488,420	79.7
	Nov	1,2,3,4 and 5	1,645,907	78.3
	Dec	1,2,3,4 and 5	1,910,346	77.6

* Prepared by the Association of American Railroads, Communication & Signal Section, July 2, 1975.

** See key on following page.

Table 13. OACI Functionability Report (by Year and Month) May 1975.* (Continued)

Year	Month	Reporting U.S. Railroads**	Cars Scanned	Cars Correctly Read, %
1974	Jan	1,3,4 and 5	1,622,471	77.5
	Feb	1,2,3,4 and 5	2,003,058	78.5
	Mar	1,2,3,4 and 5	2,212,263	77.9
	Apr	1,2,3,4 and 5	2,206,745	78.7
	May	1,2,3,4 and 5	2,230,964	79.3
	Jun	1,2,3,4 and 5	2,171,505	79.4
	Jul	1,2,3,4 and 5	2,012,606	79.8
	Aug	1,2,3,4 and 5	2,219,261	80.1
	Sep	1,2,3,4 and 5	2,102,515	79.9
	Oct	1,2,3,4 and 5	2,225,306	79.2
	Nov	1,2,3,4 and 5	2,148,544	78.8
	Dec	1,2,3,4 and 5	1,813,600	78.4
1975	Jan	1,2,3,4 and 5	1,786,107	78.6
	Feb	1,2,3,4 and 5	1,664,031	79.4
	Mar	1,2,3,4 and 5	2,014,820	81.5
	Apr	1,2,3,4 and 5	1,882,095	81.8
	May	1,2,3,4 and 5	1,840,820	82.0

* Prepared by the Association of American Railroads, Communication & Signal Section, July 2, 1975.

** KEY:

1. Union Pacific
2. Atchison, Topeka, and Santa Fe Railway
3. Southern Pacific
4. Norfolk and Western
5. Elgin, Joliet, and Eastern Railway

Table 14. OACI Chicago Test Scanner Functionability.*

Train #	Cars per Train**	Cars Labeled Side #1	Cars Labeled Side #2	Functionability, F, %					
				Scan. #1	Scan. #2	Scan. #3	Scan. #4	Scan. #5	Scans. #2&3
1	98	93	94	83	84	89	87	84	92
2	93	89	89	88	85	89	89	82	94
3	61	57	57	75	82	85	82	80	92
4	93	90	90	76	80	83	83	83	86
5	126	125	125	87	80	93	92	86	94
6	104	104	104	88	91	97	95	93	98
7	128	125	125	82	91	88	88	87	93
8	84	81	82	80	89	92	89	90	95
9	102	100	101	85	91	89	90	88	95
10	83	82	81	82	88	90	94	90	96
11	95	90	95	79	92	22	87	83	94
12	117	116	116	86	89	91	92	92	95
13	93	90	90	75	84	82	81	83	87
14	79	77	77	86	90	91	91	90	96
15	81	80	81	85	00	00	91	90	0
16	54	52	52	67	78	00	76	76	78
17	91	88	89	92	91	93	93	93	96
18	107	105	105	85	86	88	90	88	93
19	87	84	83	82	86	86	89	87	91
20	113	108	108	81	82	86	88	87	88
21	107	106	106	76	89	89	91	85	93
22	118	117	117	90	94	93	94	94	97
23	88	86	83	81	89	92	92	88	94
24	65	63	62	77	92	86	86	89	94
25	87	80	81	72	82	75	80	82	87
26	120	117	116	86	92	90	92	90	93
27	92	92	92	85	95	97	96	92	99
28	71	66	67	86	90	83	85	86	90
29	46	43	42	78	72	80	80	80	85
30	91	89	90	80	93	90	91	89	96
31	65	62	63	85	83	89	89	88	95
32	70	70	70	87	94	94	94	91	95

Table 14. OACI Chicago Test Scanner Functionability* (Continued).

Train #	Cars per Train**	Cars Labeled Side #1	Cars Labeled Side #2	Functionability, F, % Scan. #1	Scan. #2	Scan. #3	Scan. #4	Scan. #5	Scans. #2&3
33	89	86	87	84	82	89	90	90	91
34	79	73	74	77	88	84	84	82	85
35	97	97	97	85	98	96	96	92	100
36	89	85	86	88	91	89	91	91	93
37	102	99	100	76	86	84	85	82	91
38	41	40	41	93	90	95	95	95	100
39	62	60	58	79	81	84	87	87	90
40	136	134	134	86	87	91	91	92	93
41	89	87	87	69	92	91	94	91	94
42	78	75	75	81	85	86	86	87	90
43	76	73	73	83	87	84	91	87	89
44	87	82	83	84	83	85	85	86	89
45	96	96	93	82	92	86	88	89	95
46	85	85	85	89	94	92	95	92	96
47	102	98	100	87	90	90	90	88	93
48	87	87	87	85	94	98	98	94	99
49	54	51	52	85	85	83	87	89	89
50	129	124	125	83	78	90	85	85	91
51	54	54	54	87	85	00	91	87	85
52	116	116	115	77	93	87	85	82	95
53	120	118	117	82	92	91	93	91	96
54	51	47	48	73	84	76	73	75	86
55	122	119	122	81	93	94	96	90	96
56	57	54	53	81	89	91	91	89	95
57	124	123	122	85	87	85	87	87	91
58	98	96	96	90	93	95	93	92	98
59	120	120	120	97	96	99	99	96	100
Totals	5349	5206	5217	$\bar{F}$ = 82.9	88.1	88.8	89.4	88.0	93.2

* Data corresponding to trains #11, 15, 16 and 51 have not been considered in the readability averages due to the fact that Scanners #2 and/or 3 were not operational when the trains passed. The total number of cars in the 59 trains was 5,349; deleting trains #11, 15, 16 and 51, the total number of cars is 5,065.

** Locomotives and cabooses were not included in the number of cars per train. In the 59 trains represented in this sample, no passenger cars and/or work trains were observed.

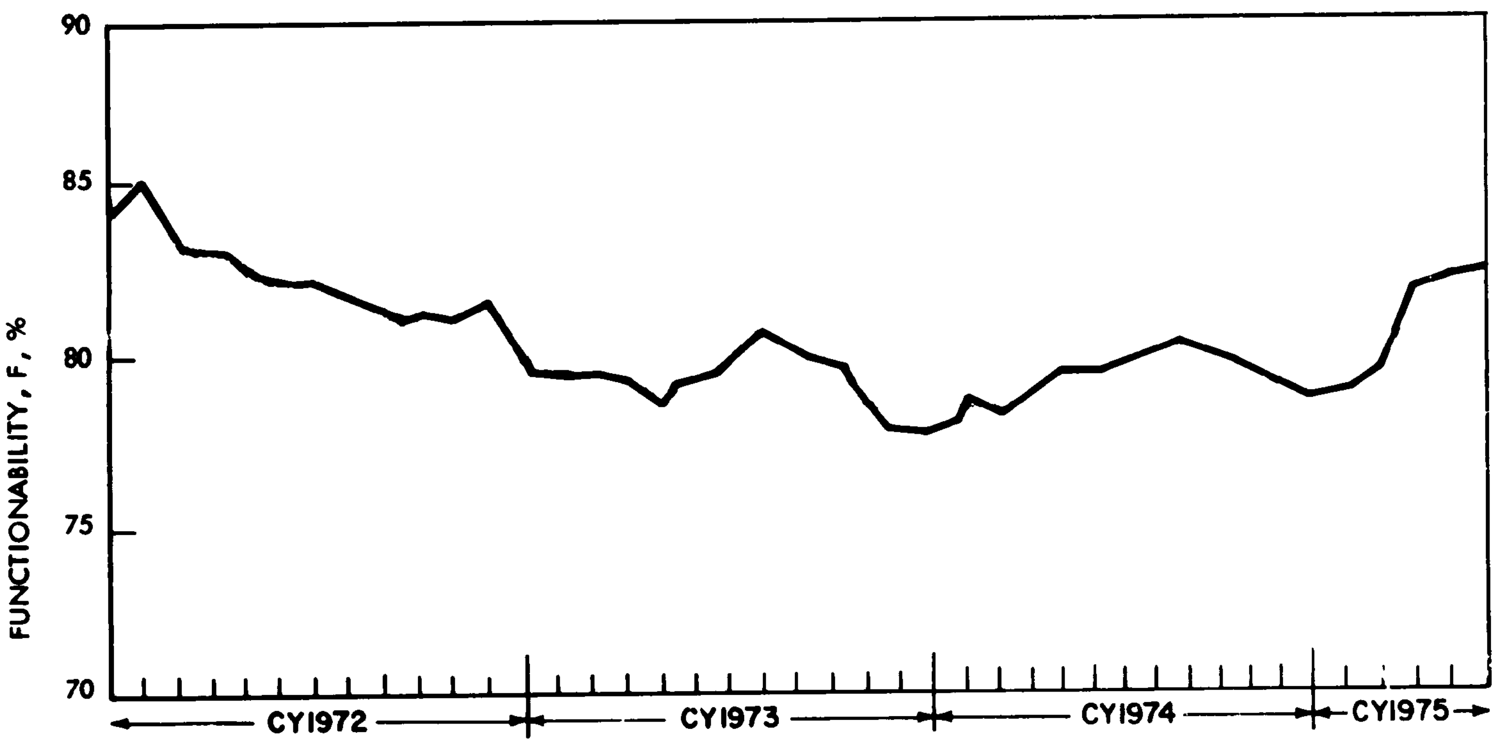


Figure 29. OACI Functionability Report (By Reporting Railroads) May and April 1975 as Given in Table 13 (Prepared by the Association of American Railroads, Communications and Signal Section, July 2, 1975).

5.7 SCANNER OPERATIONAL SYSTEM PERFORMANCE AND PERFORMANCE LIMIT PER CAR TYPE AND DIFFERENT CAR MIXES

As indicated in Section 5.1, normalizing the car mix of the sample to reflect the national fleet is considered unnecessary if one wants to formulate a clear definition of the readability problem of a given OACI installation associated with the specific overall railroad environment. Since each railroad is interested in its OACI return on investment, the only readability in which the railroad management will be interested is the projected or actual readability of its OACI installations. The readability adjusted to the national fleet car mix is only to reflect a trend. Since the AAR published an OACI mean functionability based on the functionability supplied by the participant railroads, we will correct our values to the national mix to intercompare the Chicago Test data and the AAR data.

To reach conclusions and proposed recommendations, the readability R_x^s of car type x by scanner s will be obtained from the Chicago Test data, and the label-scanner readability $R_x^{\prime s}$ of car type x by scanner s will be computed.

5.7.1 Box Cars

The total number of box cars scanned was 3,740 of which 3,697 were labeled. The corresponding box car readabilities R_B^s, and $R_B^{\prime s}$ per scanner are given in Table 15.

Table 15. Box Car Readabilities R_B^s and $R_B^{\prime s}$ Obtained at the OACI Chicago Test.

Scanner #	Readability R_B^s, %	Label-Scanner Readability $R_B^{\prime s}$, %
1	87.7	N.I.
2	93.7	95.2
3	94.8	96.1
4	94.9	N.I.
5	93.0	N.I.
2&3	97.2	98.0

N.I.: no information.

5.7.2 Hoppers (Open or Covered)

The total number of hoppers (open or covered) scanned was 376 of which 353 were labeled. The corresponding hopper readabilities R_H^S and $R_H^{\prime S}$ per scanner are given in Table 16.

Table 16. Hopper Readabilities R_H^S and $R_H^{\prime S}$ Obtained at the OACI Chicago Test.

Scanner #	Readability R_H^S, %	Label-Scanner Readability $R_H^{\prime S}$, %
1	83.0	N.I.
2	89.4	91.9
3	88.4	89.8
4	90.1	N.I.
5	89.8	N.I.
2&3	93.5	94.6

N.I.: no information.

5.7.3 Flat Cars

The total number of flat cars scanned was 190 of which 181 were labeled. The corresponding flat car readabilities R_F^S and $R_F^{\prime S}$ per scanner are given in Table 17.

Table 17. Flat Car Readabilities R_F^S and $R_F^{\prime S}$ Obtained at the OACI Chicago Test.

Scanner #	Readability R_F^S	Label-Scanner Readability $R_F^{\prime S}$
1	76.8	N.I.
2	82.4	85.2
3	85.6	88.4
4	79.6	N.I.
5	80.7	N.I.
2&3	91.2	93.4

N.I.: no information.

5.7.4 Car Carriers

The total number of car carriers scanned was 383 of which 356 were labeled. The corresponding car carrier readabilities R_c^s and $R_c'^s$ per scanner are given in Table 18.

Table 18. Car Carrier Readabilities R_C^s and $R_C'^s$ Obtained at the OACI Chicago Test.

Scanner #	Readability R_C^s	Label-Scanner Readability $R_C'^s$
1	78.0	N.I.
2	76.5	79.9
3	78.4	80.3
4	77.5	N.I.
5	76.7	N.I.
2&3	84.0	85.1

N.I.: no information.

5.7.5 Gondolas

The total number of gondolas scanned was 297 of which 272 were labeled. The corresponding gondola readabilities R_G^s and $R_G'^s$ per scanner are given in Table 19.

Table 19. Gondola Readabilities R_G^s and $R_G'^s$ Obtained at the OACI Chicago Test.

Scanner #	Readability R_G^s	Label-Scanner Readability $R_G'^s$
1	78.3	N.I.
2	79.3	81.1
3	82.0	85.3
4	81.3	N.I.
5	81.3	N.I.
2&3	90.4	91.5

N.I.: no information.

5.7.6 Tank Cars

The total number of tank cars scanned was 151 of which 135 were labeled. The corresponding tank car readabilities R_T^s and R_T^{ls} per scanner are given in Table 20.

Table 20. Tank Car Readabilities R_T^s and R_T^{ls} Obtained at the OACI Chicago Test.

Scanner #	Readability R_T^s	Label-Scanner Readability R_T^{ls}
1	82.2	N.I.
2	86.3	91.4
3	89.6	91.1
4	91.1	N.I.
5	80.7	N.I.
2&3	91.9	92.6

N.I.: no information.

5.7.7 Others

In the category of others we include the cars which did not have specific designation and the cars for which descriptions were not recorded. Since only 0.1 percent of the cars observed at the Chicago Test site are in this category, the sample size is too small to have a statistical meaning. Therefore, no readability (R_O) information is provided for this car group.

5.7.8 Car Mixes

In order to attain the R for given car mixes we should use the following linear combination:

$$R = \alpha R_B^s + \beta R_H^s + \gamma R_F^s + \delta R_C^s + \epsilon R_G^s + \eta R_T^s + \theta R_O^s \qquad (7)$$

where α, β, γ, δ, ϵ, η and θ are the fractional contribution in the car mix of the box cars, hoppers, flat cars, car carriers, gondolas, tank cars, and other cars, respectively. These car mix coefficients should satisfy the following relation

$$1 = \alpha + \beta + \gamma + \delta + \epsilon + \eta + \theta \qquad (8)$$

It should be pointed out that in order to have equal weight, the Rs coefficients should be obtained by measuring equal sample sizes per corresponding car type. In our Chicago Test we do not have equal sample size per car type but for the purpose of assessing Equation (7) we assume equal weight for all Rs.

Introducing the R values corresponding to Scanner #1 and the values reflecting the national mix into Equation (7),

$$R^{(1)} = (0.361)87.7 + (0.334)83.0 + (0.077)76.8 + (0.000)78.0$$
$$+ (0.11)78.3 + (0.097)82.2 + (0.020)80.0^{*}$$
$$R^{(1)} = 83.5$$

That means that the so called "bias" on the R due to the traffic mix in the Chicago Test in comparison with the car mix of the U.S. fleet is only a 2.1 percent difference. For the Scanner #2 $R^{(2)} = 88.6$, giving a difference of only 2.1 percent. For the multiplexed Scanners #2 and 3 $R^{(2\&3)} = 93.9$ or a difference of 1.6 percent with the value obtained with the Chicago Test traffic mix. Therefore, we can conclude that the difference for all Rs corresponding to the Chicago test and the adjusted values for a traffic mix corresponding to the U.S. fleet is approximately 2 percent.

5.8 NUMBER READ FOR ACTUAL MODULE CODE NUMBER

The purpose of the Chicago Test was to determine if optics was an acceptable principle of operation for an automatic car identification and not to evaluate the two hardware implementations of that principle represented by systems deployed by two suppliers. Nevertheless, there is available from the Chicago Test valuable experimental data that will be helpful for an understanding of the hardware performance and which we

*This value is based on the R_O^s obtained for the other car types. No observational data of statistical significance was obtained for this classification group (see Section 5.7.7).

do not want to leave unrecorded. Therefore, this data will be presented in this section but without major comments and/or conclusions.

5.8.1 OACI Label Code

Each OACI label consists of thirteen modules affixed to the side of the railroad vehicle in a vertical arrangement. Each full module consists of an upper half module and a lower half module. The lower half module can be blue, red or white. The upper half module can be blue, red, white or black. Using the allowable combinations of the four colors provides thirteen unique codes (see Figure 30).

The two-color combinations least likely to occur in nature were selected for the start and stop modules. The eleven combinations representing numerals were chosen for their compatibility to teletype code format.

At the center of the OACI scanner field of view each half module produces a nominal 10 μsec pulse at the output of the scanner, and therefore, a full module produces a nominal 20 μsec pulse. For example, a red or blue half module produces a 10 μsec pulse in the respective channel. A white half module produces a 10 μsec pulse in both channels.

In order to validate the reading of the label by the scanner each OACI label contains a validity check digit (error detecting code) that is calculated in accordance with the AAR Automatic Car Identification Manual (Reference 5) as follows:

> "The validity check digit is calculated by the use of an AAR approved validity check digit calculation sheet. The validity check digit calculation is made in the following manner. The number of each succeeding label module, starting with the equipment code number at the bottom of the label, is multiplied by an increasing power of two, starting with (2^0). Values of the increasing powers of two are:

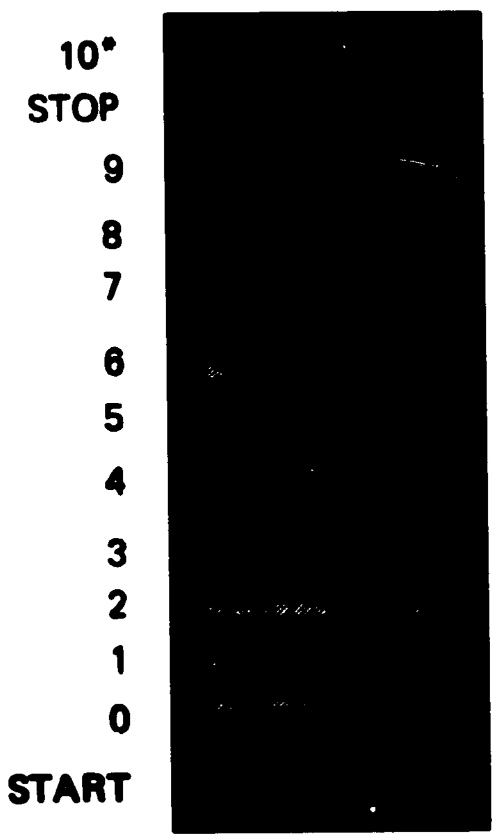


Figure 30. OACI Label Showing the 11 Modules Corresponding to the 11 Numbers Used in the Code Plus the Start and Stop Modules.

$2^0 = 1$	$2^5 = 32$
$2^1 = 2$	$2^6 = 64$
$2^2 = 4$	$2^7 = 128$
$2^3 = 8$	$2^8 = 256$
$2^4 = 16$	$2^9 = 512$

The results of these multiplications are added, the sum divided by eleven and the remainder is the validity check digit. The validity check digit may have a value from 0 through '10*', e.g., if a freight car having an equipment code number of 0, an identification code number 972 and car number 123456 was to be labeled, the label format would be:

Validity check digit	6		
	STOP		
	6	x 512 (2^9) =	3072
	5	x 256 (2^8) =	1280
	4	x 128 (2^7) =	512
	3	x 64 (2^6) =	192
	2	x 32 (2^5) =	64
	1	x 16 (2^4) =	16
	2	x 8 (2^3) =	16
	7	x 4 (2^2) =	28
	9	x 2 (2^1) =	18
	0	x 1 (2^0) =	0
	START		5198

```
      472
11 /5198
    44
     79
     77
      28
      22
       6 = remainder = Validity check digit
```

Therefore, a label module having a value of 6 is placed in the top section of the label. If the remainder is 0, a label module 0 is applied; if the remainder is 10, a label module marked '10*' is applied."

5.8.2 Per Train and Scanner

To determine the ability of each scanner to read the thirteen digits in the OACI code the TSC computer program developed for the Chicago Test outputs a matrix indicating for each one of the numbers in the code, how many times it has been read. Figures 31 through 35 show the printouts corresponding to Scanners #1 through #5 for Train #17. This train had 91 cars of which 88 cars were labeled on Side 1 and 89 on Side 2. For each of the 59 trains scanned during the Chicago Test a printout per scanner was output.

5.8.3 Per Test and Scanner

The data on a per train and scanner basis described in Subsection 5.8.2 has been compiled on a per test and scanner basis and is presented in Tables 21 through 25. The data presented in these tables will assist in the diagnosis of the error-read causes for each one of the OACI systems tested in Chicago. Since the error-reads are not only related to the cause that affects the labels but they are also related to the characteristics of the OACI scanners, interpretation of this data will be part of a subsequent report.

Based on the data obtained with any one of the scanners, the number of times that each one of the numbers was recorded during the test can be determined. This data is important since it is proportional to the module number a priori probability in the label-scanner communication channel. The percentage of the total number of modules read with a given module number during the Chicago Test by Scanner #1 is given in Figure 36. The percentage of the total given module code number error-reads by the different scanners is presented in Figure 37.

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THE NUMBER OF TIMES SCANNER 1 READ A
PARTICULAR NUMBER FOR THE ACTUAL LABEL NUMBER
PER TRAIN
TRAIN ## 17

ACTUAL NUMBERS ON LABEL	NUMBERS READ 0	1	2	3	4	5	6	7	8	9	10
0	199	0	0	1	0	0	1	0	0	0	0
1	0	131	0	0	0	0	0	0	0	0	0
2	0	0	141	0	0	0	0	0	0	0	0
3	0	0	0	75	0	0	0	1	0	0	0
4	0	0	0	0	75	0	0	0	0	0	0
5	0	0	0	0	0	52	0	0	0	0	0
6	0	0	0	0	0	0	79	0	0	0	0
7	1	0	0	0	0	0	1	62	0	0	0
8	0	0	0	0	0	0	0	0	62	0	0
9	0	0	0	0	0	0	0	0	0	64	0
10	0	0	0	0	0	0	0	0	0	0	11

Figure 31. Sample Printout for Train No. 17 and Scanner #1 Obtained from the TSC Computer Program to Determine the Number Read by Each Scanner for the Module Code Number of all the OACI Modules Scanned Per Train.

THE NUMBER OF TIMES SCANNER 2 READ A

PARTICULAR NUMBER FOR THE ACTUAL LABEL NUMBER

PER TRAIN

TRAIN # 17

ACTUAL NUMBERS ON LABEL	NUMBERS READ 0	1	2	3	4	5	6	7	8	9	10
0	197	0	0	0	0	0	1	0	0	0	0
1	0	130	0	0	0	0	0	0	0	0	0
2	0	0	142	0	0	0	0	0	0	0	0
3	0	0	0	75	0	0	0	0	0	0	0
4	0	0	0	0	71	0	0	0	0	0	0
5	0	0	0	0	0	52	0	0	0	0	0
6	0	0	0	0	0	0	77	0	0	0	0
7	0	0	0	0	0	0	1	63	0	0	0
8	0	0	0	0	0	0	0	0	63	0	0
9	0	0	0	0	0	0	0	0	0	63	0
10	0	0	0	0	0	1	0	0	0	0	10

Figure 32. Sample Printout for Train No. 17 and Scanner #2 Obtained from the TSC Computer Program to Determine the Number Read by Each Scanner for the Module Code Number of all the OACI Modules Scanned Per Train.

THE NUMBER OF TIMES SCANNER 3 READ A
PARTICULAR NUMBER FOR THE ACTUAL LABEL NUMBER
PER TRAIN
TRAIN # 17

ACTUAL NUMBERS ON LABEL	NUMBERS READ 0	1	2	3	4	5	6	7	8	9	10
0	200	0	0	1	0	0	0	0	0	0	0
1	0	131	0	0	0	0	0	0	0	0	0
2	0	0	141	0	0	0	0	0	0	0	0
3	0	0	0	76	0	0	0	1	0	0	0
4	0	0	0	0	75	0	0	0	0	0	0
5	0	0	0	0	0	52	0	0	0	0	0
6	0	0	0	0	0	0	79	0	0	0	0
7	1	0	0	0	0	0	1	62	0	0	0
8	0	0	0	0	0	0	0	0	62	0	0
9	0	0	0	0	0	0	0	0	0	64	0
10	0	0	0	0	0	0	0	0	0	0	11

Figure 33. Sample Printout for Train No. 17 and Scanner #3 Obtained from the TSC Computer Program to Determine the Number Read by Each Scanner for the Module Code Number of all the OACI Modules Scanned Per Train.

THE NUMBER OF TIMES SCANNER 4 READ A

PARTICULAR NUMBER FOR THE ACTUAL LABEL NUMBER

PER TRAIN

TRAIN # 17

ACTUAL NUMBERS ON LABEL	NUMBERS READ 0	1	2	3	4	5	6	7	8	9	10
0	200	0	0	1	0	0	0	0	0	0	0
1	0	131	0	0	0	0	0	0	0	0	0
2	0	0	141	0	0	0	0	0	0	0	0
3	0	0	0	76	0	0	0	1	0	0	0
4	0	0	0	0	75	0	0	0	0	0	0
5	0	0	0	0	0	52	0	0	0	0	0
6	0	0	0	0	0	0	79	0	0	0	0
7	1	0	0	0	0	0	1	62	0	0	0
8	0	0	0	0	0	0	0	0	62	0	0
9	0	0	0	0	0	0	0	0	0	64	0
10	0	0	0	0	0	0	0	0	0	0	11

Figure 34. Sample Printout for Train No. 17 and Scanner #4 Obtained from the TSC Computer Program to Determine the Number Read by Each Scanner for the Module Code Number of all the OACI Modules Scanned Per Train.

THE NUMBER OF TIMES SCANNER 5 READ A
PARTICULAR NUMBER FOR THE ACTUAL LABEL NUMBER
PER TRAIN
TRAIN # 17

ACTUAL NUMBERS ON LABEL	NUMBERS READ 0	1	2	3	4	5	6	7	8	9	10
0	200	0	0	1	0	0	0	0	0	0	0
1	0	131	0	0	0	0	0	0	0	0	0
2	0	0	141	0	0	0	0	0	0	0	0
3	0	0	0	76	0	0	0	1	0	0	0
4	0	0	0	0	75	0	0	0	0	0	0
5	0	0	0	0	0	52	0	0	0	0	0
6	0	0	0	0	0	0	79	0	0	0	0
7	1	0	0	0	0	0	1	62	0	0	0
8	0	0	0	0	0	0	0	0	62	0	0
9	0	0	0	0	0	0	0	0	0	64	0
10	0	0	0	0	0	0	0	0	0	0	11

Figure 35. Sample Printout for Train No. 17 and Scanner #5 Obtained from the TSC Computer Program to Determine the Number Read by Each Scanner and the Module Code Number of all the OACI Modules Scanned Per Train.

Table 21. Total Number of Times Scanner #1 Read a Particular Number for the Actual Module Number During the Chicago Test.

Actual Module Numbers	Numbers Read										
	0	1	2	3	4	5	6	7	8	9	10
0	10262	31	5	16	2	12	4	3	154	6	10
1	5	6539	8	3	10	0	2	5	14	0	0
2	2	7	5454	9	2	1	1	2	32	0	3
3	2	1	7	3924	3	6	2	2	7	2	0
4	0	3	0	1	4453	2	0	3	1	4	0
5	1	0	1	4	1	6044	2	1	8	9	1
6	17	1	0	4	1	3	4079	0	10	6	0
7	4	4	3	2	4	0	1	2977	31	0	2
8	2	3	3	4	0	6	5	2	3080	3	0
9	2	0	0	1	0	31	13	2	5	4745	0
10	3	1	0	1	0	0	0	0	0	0	473

Table 22. Total Number of Times Scanner #2 Read a Particular Number for the Actual Module Number During the Chicago Test.

Actual Module Numbers	Numbers Read										
	0	1	2	3	4	5	6	7	8	9	10
0	10483	17	6	12	1	12	5	3	10	2	4
1	24	6717	5	1	1	2	5	4	7	4	0
2	14	10	5555	3	3	1	5	3	5	1	1
3	7	2	4	3898	7	4	2	0	13	1	1
4	6	4	2	1	4519	4	1	2	1	5	0
5	6	2	4	1	0	6156	4	1	0	10	0
6	2	1	0	3	1	5	4134	0	7	3	1
7	3	7	1	2	3	1	2	3032	1	0	1
8	7	3	3	3	0	1	3	1	3314	5	0
9	7	1	1	2	1	11	5	2	2	5110	1
10	4	0	0	0	0	1	0	0	0	0	420

Table 23. Total Number of Times Scanner #3 Read a Particular Number for the Actual Module Number During the Chicago Test.

Actual Module Numbers	Numbers Read										
	0	1	2	3	4	5	6	7	8	9	10
0	10174	17	5	4	3	9	2	3	6	11	2
1	6	6301	4	1	1	2	6	3	6	1	2
2	8	7	5277	7	0	4	3	2	3	1	0
3	3	1	3	3799	1	5	1	1	9	1	0
4	2	4	1	2	4312	2	0	2	0	5	0
5	4	0	1	2	1	6003	2	1	1	4	0
6	3	1	0	0	1	1	3965	0	2	3	1
7	3	3	1	4	1	0	0	2880	1	1	0
8	3	3	2	1	0	2	4	3	3295	2	0
9	1	0	0	2	1	13	5	3	1	4673	0
10	3	1	0	0	0	0	0	0	0	1	484

Table 24. Total Number of Times Scanner #4 Read a Particular Number for the Actual Module Number During the Chicago Test.

Actual Module Numbers	Numbers Read										
	0	1	2	3	4	5	6	7	8	9	10
0	10651	36	3	5	2	3	3	1	14	5	5
1	9	6965	4	1	2	2	4	4	3	1	0
2	2	13	5482	7	6	0	1	2	1	1	0
3	1	3	1	4003	5	6	2	1	4	1	0
4	0	3	1	1	4661	1	0	1	0	5	0
5	1	1	1	2	1	6351	3	1	1	11	0
6	3	5	0	1	1	4	4234	0	4	5	1
7	2	7	1	0	3	0	1	3096	2	0	1
8	2	8	2	3	0	3	3	1	3416	2	0
9	0	0	0	2	1	5	5	2	1	4958	0
10	3	1	0	0	0	1	0	0	1	1	432

Table 25. Total Number of Times Scanner #5 Read a Particular Number for the Actual Module Number During the Chicago Test.

Actual Module Numbers	Numbers Read										
	0	1	2	3	4	5	6	7	8	9	10
0	10467	51	5	14	2	1	3	0	38	1	6
1	8	6716	3	3	5	3	4	6	5	0	0
2	4	17	5596	5	2	0	1	2	18	1	2
3	3	5	1	3376	2	7	1	0	7	3	0
4	0	4	0	2	4539	1	0	3	1	4	5
5	1	0	1	4	0	5182	3	1	3	5	0
6	3	7	0	3	1	13	3518	0	18	4	1
7	1	13	1	0	4	0	0	2426	13	3	2
8	3	5	2	12	0	3	2	1	2878	2	0
9	0	1	0	2	0	8	6	2	3	4045	0
10	3	1	0	0	0	0	0	0	0	1	350

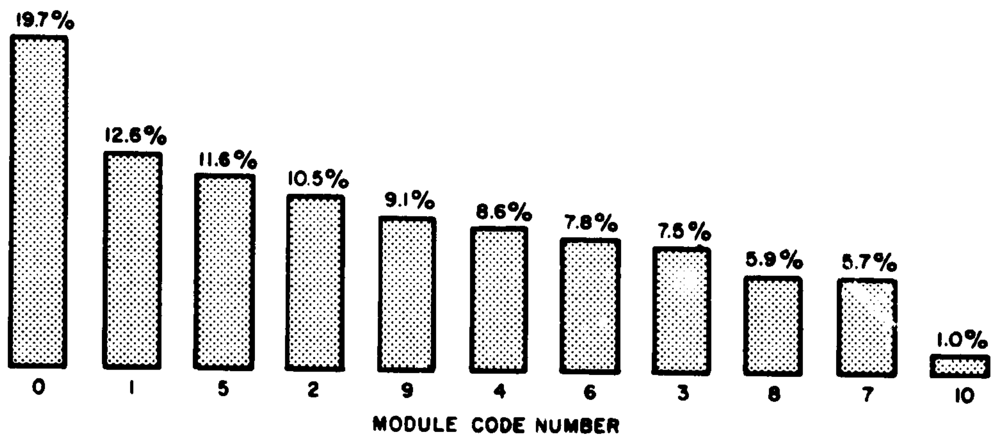

Figure 36. Percentage of the Total Number of Modules Read with a Given Module Code Number During the Chicago Test by Scanner #1.

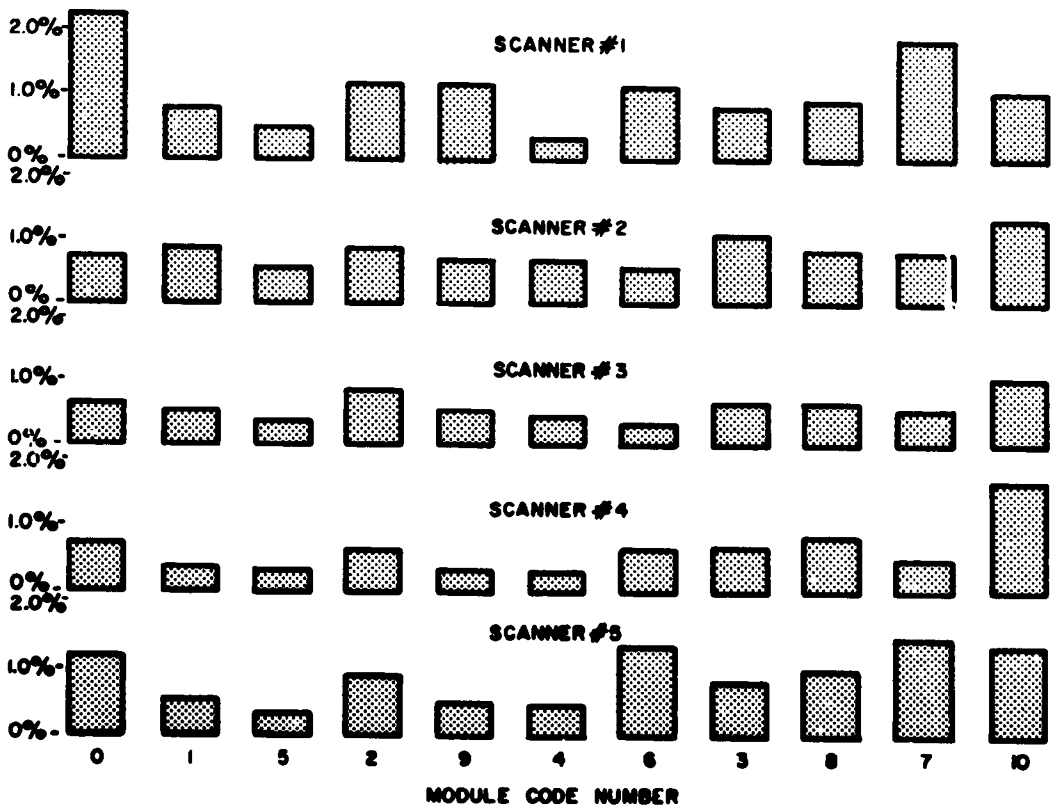

Figure 37. Percentage of the Total Given Module Code Number Error-Reads by the Different Scanners During the Chicago Test.

6. OACI CHICAGO TEST CONCLUSIONS AND RECOMMENDATIONS

The OACI Chicago Test objectives set forth in the Field Test Program (Reference 1) have been accomplished. Furthermore, during the performance of the test and data reduction at TSC, new areas of investigation not contemplated in the original program were established and results obtained.

6.1 CONCLUSIONS

The important conclusions of the OACI Chicago Test are summarized as follows:

a. OACI Scanners Operational System Performance

Mean Readability $\bar{R}$		Residual Operating Environment and Management Non-Read Cause	
Scanner #1	85.6%	Scanner #1	14.5%
Scanner #2	90.7%	Scanner #2	9.3%
Scanner #3	91.4%	Scanner #3	8.6%
Scanner #4	92.0%	Scanner #4	8.0%
Scanner #5	90.7%	Scanner #5	9.3%
Scanners #2&3	95.5%	Scanners #2&3	4.3%

b. OACI Label-Scanner Readability

Mean Label-Scanner Readability $\bar{R}'$	
Scanner #1	86.4%
Scanner #2	92.8%
Scanner #3	93.2%
Scanner #4	95.4%
Scanner #5	94.4%
Scanners #2&3	96.7%

The estimated error on the above values is ±1.5 percent.

c. OACI Scanner System Performance Limit

Mean Readability Limit, $\bar{R}_{limit}$		Residual Operating Environment Non-Read Causes	
Scanner #1	91.6%	Scanner #1	8.4%
Scanner #2	94.6%	Scanner #2	5.4%
Scanner #3	95.5%	Scanner #3	4.5%
Scanner #4	95.6%	Scanner #4	4.4%
Scanner #5	94.8%	Scanner #5	5.2%
Scanners #2&3	98.0%	Scanners #2&3	2.0%

The estimated error on the above values is ±1.5 percent.

Based on the summary results given above and the elements of judgment generated during the OACI Chicago Test and data processing at TSC, some basic conclusions can be summarized as follows:

a. In OACI assessments conducted prior to the OACI Chicago Test, the limitations attributed to the OACI system as principle of operation, were system and management related non-read and error-read causes. The operating environment non-read and error-read causes account for approximately one-half of the non-read problems of which dirt is a subset. The values of mean readability limit $\bar{R}_{limit}$ indicates that the operating environment related causes are, for the modified scanners, on the order of 4.9 percent on the average of which the non-read dirt cause is a fraction of the 4.9 percent. Therefore, an intensive cleaning program will not have a major effect on the readability in a car mix population of the type observed at the OACI Chicago Test.

b. The results indicate that a label cleaning program should be substituted by a label maintenance program. This program should be directed to:

- Label non-labeled cars,
- Re-label cars with misapplied labels,
- Change labels which are out of specifications due to mixture of new label modules in old labels,
- Take care of labels which have been affected by improperly painted back, surface, or plates and therefore rust affecting the front surface of the labels,
- Replace or repair back plates that have been anodized with a technique which is improper for the railroad operating environment. Due to the ultraviolet solar radiation, a change from black to silver color occurs,
- Label cleaning.

Based on the OACI test data (Tables 9 and 10) the above label maintenance elements account for a 6.4 percent average non-read and error-read for the modified scanners and 9.1 percent for the unmodified scanner.

c. The present OACI standard scanner systems were designed based on characteristics of a given label population. It appears that the assumptions of those characteristics and maintenance of those characteristics have changed over the years. Therefore, to accommodate a new label-scanner interface, modifications have been introduced in some of the scanners at the OACI Chicago Test. Those modifications and proper scanner maintenance indicate that this could accommodate a degraded label population. The scanner modifications show an improvement in scanner readability on the order of 5 percent. It should be clearly stated that a <u>properly designed label maintenance</u> program will reduce the importance of the scanner modifications.

This means the initiation of a cost-effectiveness study to determine the trade-offs between a label maintenance program and scanner modifications.

d. The measurement of the mean label-scanner readability, $\bar{R}'$, indicates there are at least 2 percent ($\bar{R}' - \bar{R}$) of the total labels which are not read by the scanners when illuminated but give sufficient information to allow decoding of the original label code. That means that 2 percent of the labels give signals which are completely out of specification but still could be read by means of some other decoder. As in item c., a cost effectiveness study would be necessary to determine the trade-offs between scanner processor redesign and a label maintenance program.

e. Based on the OACI Chicago Test data, it is clear that by removing the management non-read and error-read related causes, the modified scanners tested in this program approach a readability limit on the order of 95 percent. This readability limit is predicated on implementing hardware to the limits achieved during the Chicago Test. Also, this is considering the present cleaning program reflected on the sample scanned at the Chicago Test.

f. The multiplexed results of Scanners #2 and 3, one installed on each side of the track, having mean readabilities of 90.7 percent and 91.4 percent respectively, gave a multiplexed mean readability of 95.5 percent! That is 10 percent higher than Scanner #1 and approximately 5 percent higher than either Scanner #2 or #3. The built-in redundancy in the multiplexing, at least for part of the system, will increase the overall system readability over long periods of time.

g. Evaluating the OACI Chicago Test data results summarized above, it is clear that optics as the principle of operation for an automatic car identification is a sound one. The optical principle of operation allows also for other system extensions to solve a given railroad's specific needs or specific traffic mixes. These system extensions or additions still need to be explored. To evaluate the OACI for a specific railroad, or traffic mix, or management needs based on national averages is not applicable. The OACI scanners are sensors with a high readability capability demonstrated at the Chicago Test and the usage of these sensors in a car management system depends upon the ability of the system designer to use those sensors. In the case of a network with n nodes, providing, for example, 95 percent readability at each node will render a high readability system.

As a general conclusion, it should be stated that the major danger in optimizing the OACI system (which also includes the label) among several alternative system configurations or to choose among alternative modifications (which includes label maintenance) is that of reduction to sub-optimization. It may be that in the criterion selection, one relevant factor is overweighted at the expense of others equally important, or that some subsystem is optimized rather than the overall system. Clearly, the entire question of OACI optimization versus OACI sub-optimization is merely a restatement of the question of balance judgment versus overemphasized consideration of certain criteria. System analysis and system cost-effectiveness studies are of paramount importance to assist in the OACI optimization or the selection of modification alternatives.

6.2 RECOMMENDATIONS

The field test demonstrated that information is available in the retroreflective signal to significantly increase the readability of scanners. A laboratory investigation complemented with an OACI system engineering analysis and system cost-effectiveness analysis would develop a set of equipment performance parameters (i.e., dynamic range, MTBF, MTTR, etc.) with the objective of reaching warranted readability and with the upper limits shown by the field test data.

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APPENDIX A

PARTICIPANTS IN THE OACI CHICAGO TEST

ORGANIZATIONS

Federal Railroad Administration
Transportation Systems Center
Association of American Railroads
Railroad Progress Institute
Chicago & North Western Transportation Co.
Chicago Railroad Terminal Information Systems, Inc.

SUPPLIERS

Servo Corporation of America
Computer Identifics Corporation

CONTRACTORS

Kentron Hawaii, Ltd.
Aerospace Systems, Inc.

PERSONNEL AT THE TEST SITE

Transportation Systems Center

Hector C. Ingrao, Test Director
Robert L. Stone, Field Test Representative
Melvin A. Yaffee, Assistant Engineer
Robert S. Yatsko, Electronic Engineer
Charmaine Shultz, Administrative Support (Contractor)

Servo Corporation of America

Robert Maynard, Director of Systems Engineering
James W. Johnson, Project Engineer
Robert Foltz, Design Engineer

Computer Identics Corporation

Christo B. Kapsambelis, Vice-President of Systems Engineering
Clyde F. Ugalde, Director of Field Engineering
James Galloway, Field Engineer

APPENDIX B

TEST SITE SELECTION CRITERIA

The DOT TSC OACI Field Test was conducted at the Chicago Railroad Terminal Information System (CRTIS) Site #15, Proviso Yard (property of the Chicago and North Western Transportation Company), Melrose Park, Illinois. Some of the parameters used in the selection of this site are discussed below:

- Existence at site of late model scanner including a label decoder processor and printout device
- Track configuration to permit scanning on both sides of the train
- Minimum switch moves (stops, reversals, etc.) at the site
- Train speed less than 5 mph to provide good fidelity on the video recorder, and ability to physically inspect labels after passing through scanners
- Representative mix of car types; i.e.:

box car	35%	gondola	11%
hopper (closed)	13%	tank car	10%
hopper (open)	21%	other	2%
flat car	8%		

- Adequate sample size (960 cars)
- Minimum preparation requirements
- Availability for preparation and test during the selected time period (June 11 through September 5, 1975)
- Accessibility on a 24 hour/day, 7 day/week basis
- Test equipment configuration and monitoring with no interference in yard operations and/or unnecessary delays because of railroad safety rules and regulations
- Physical security for scanning and monitoring equipment
- Electrical power available: 115v 60 cycles 20 kva
- Likelihood of electromagnetic interference minimized (i.e., not near electric high voltage lines)

- Communications (maintenance shop space in general vicinity)
- Mutually convenient location for test personnel, particularly sites for each manufacturer co-located such that each views the same population of labels
- Close proximity (within 30 feet of scanners) of parking area for test support vehicle
- Availability of manpower for limited support, and local labor considerations.

APPENDIX C

PRINTOUT FROM THE OACI SCANNERS AT THE CHICAGO TEST

The output of the five OACI scanners at the Chicago Test are in the form of teletype printouts. Scanners #1, 4, and 5 have independent teletypes and Scanners #2 and 3 share a teletype. To facilitate data coding, enlarged photographic copies of all printouts were made and assembled side by side, in sequential order. Therefore, the five scanner outputs corresponding to the same railroad car are on the same line of the composite printout. Also, the Header and Trailers of the printouts were composed on the same page. Train sequential number, car range per printout, and data were added later. Table C-1 presents the composite printout for Train #002, car sequences 99 to 191.

To facilitate the interpretation of the printouts, the following codes and symbols are used:

/ ?	in position 11 of the readout indicates incorrect parity
& NO LABEL 000000000000	Scanner unable to read label. Codes also used for unlabeled cars.
* - /	in 12 position of the readout indicates a parity check 10

<u>Printout Header From Scanner #1 (CRTIS Scanner)</u>

CRT-HDR	046	015	21	265	230	1231	00	096
a	b	c	d	e	f	g	h	i

a. CRTIS Header
b. Number identifying scanner in CRTIS network
c. CRTIS site number
d. Direction of train
e. Message number
f. Julian day

g. Time of day
h. Power and buffer failure report
i. Number of cars in train as recorded by the wheel counter

Printout Header from Scanners #2 and 3

```
SEQ:105  SCAN:1  CARS:097  DIR:12  TIME:1233  DATE:230  PWR:0  BUF:0
  a  b      c        d       e        f         g       h      i
```

a. Sequence
b. Sequence number
c. Scanner number
d. Number of cars in train as recorded by wheel counter
e. Direction of train
f. Time of day
g. Julian day
h. Power failure report
i. Buffer failure report

Printout Header from Scanner #4

```
KZWR  TOWER  ACI  029  230  1234  E
  a      b    c    d    e    f    g
```

a. Not applicable to Chicago Test
b. Not applicable to Chicago Test
c. ACI
d. Message number
e. Julian day
f. Time of day
g. End

Printout Header from Scanner #5

```
CHGO  TEST  CNTR  DATA  230  1234  W  029
  a     b     c     d    e    f    g   h
```

a. Chicago
b. Test

c. Center

d. Data

e. Julian day

f. Time of day

g. Direction of train (West)

h. Message number

<u>Printout Trailer from Scanner #1</u>

CRT-TLR	046	015	21	268	230	1243	0	0	097
a	b	c	d	e	f	g	h	i	

a. CRTIS Trailer

b. Number identifying scanner in CRTIS network

c. CRTIS site number

d. Direction of train

e. Message number

f. Julian day

g. Time of day

h. Piggy back count

i. Car count by wheel counter

<u>Printout Trailer from Scanner #2 and 3</u>

END	CARS: 097	PRIME: 083	NO LABEL: 014	TIME: 1245	DATE: 230
a	b	c	d	e	f

a. End of printout

b. Number of cars in train as recorded by wheel counter

c. Message number from decoder-processor

d. Cars not read or no label

e. Time of day

f. Julian day

<u>Printout Trailer from Scanner #4 and 5</u>

No information.

Table C-1. Composite Printout from the Five OACI Scanners Tested in Chicago.

TRAIN:002 CAR: 99-191 AUGUST/18/75

CLCKT-HLL 646 015 81 265 230 12310 (SCANNER 1)
SEQ:105 SCAN:1 CARS:097 DIR:12 TIME:1233 DATE:230 PWR:0 BUF:0 (SCANNER 2)
SEQ:106 SCAN:2 CARS:097 DIR:21 TIME:1233 DATE:230 PWR:0 BUF:0 (SCANNER 3)
KZUR TOWER ACI 029 230 1234 (SCANNER 4)
CHGO TEST CNTR DATA 230 1234 W 029 (SCANNER 5)

SCANNER 1	SCANNER 2	SCANNER 3	SCANNER 4	SCANNER 5
$-----------	NO LABEL	NO LABEL	C000 00C00000	0000 00000000
$-----------	NO LABEL	NO LABEL	0000 0000000C	0000 00000000
$-----------	NO LABEL	NO LABEL	C000 C0000000	0000 00000000
0308375248 /	0308375248-*	0308375248-*	0308 375248--	0305 375249--
0622270911 1	0622270911-1	0622270911-1	0622 270911-1	0522 270911-1
0622260662 2	0622260662-2	0622260662-2	0622 260662-2	0522 250552-2
0131091382 2	0131091382-2	0131091382-2	0131 C91382-2	0000 00000000
0620129116/1	0620129886-0	062012911670	0520 1291167C	0520 12911571
$-----------	0308383009-4	NO LABEL	0C00 C000000C	0000 00000000
$-----------	NO LABEL	NO LABEL	C0C0 00000000	0000 00000000
1609941303 9	1609941303-9	1609941303-9	1609 941303-9	1509 941303-9
1515912345 4	1515912345-4	1515912345-4	1515 912345-4	1515 912345-4
$-----------	682990903276	1615909032-6	1615 909032-5	0000 00000000
1562092212 1	1562092212-1	1562092212-1	1562 C92212-1	1552 222212-1
$-----------	NO LABEL	NO LABEL	0000 00000000	0000 00000000
0076198874 3	0076198874-3	0076198874-3	C076 198874-3	0075 198974-3
0622167607 6	0622167607-6	0622167607-6	0622 157607-6	0522 167507-5
0622167771 9	0622167771-9	0622167771-9	0E22 157771-9	0522 167771-9
1448091438 9	1448091438-9	1448091438-9	1446 C91438-9	1443 091433-9
0131161185 3	0131161185-3	0131161185-3	0131 161185-3	0131 151135-3
0131091471 0	0131091471-0	0131091471-0	C131 091471-0	0131 091471-0
0620111563 5	0620111563-5	0620111563-5	C620 111563-5	0520 111553-5
0620110219 7	0620110219-7	0620110219-7	0520 110219-7	0520 110219-7
0620110214 /	0620110214-*	0620110214-*	0620 110214--	0520 110214--
0550052952 1	0550052952-1	0550052952-1	0550 052952-1	0550 052952-1
0620110297 8	0620110297-8	0620110297-8	0620 110297-8	0520 110297-8
$-----------	6356051830-6	NO LABEL	C0C0 CCC0C000	0000 00000000
1609941355 3	1609941355-3	1609941355-3	1609 941355-3	1509 941355-3
1197850503 7	1197850503-7	1197850503-7	1197 850503-7	1197 350503-7
1197850535 6	1197850535-6	1197850535-6	1197 850535-6	1197 350535-5
1197850908 /	1197850908-*	1197850908-*	1197 850908--	1197 350908--
1197850580 2	1197850580-2	1197850580-2	1197 850580-2	1197 350580-2
0995457651 4	0995457651-4	0995457651-4	C995 457651-4	0995 457551-4
0022084253 0	002208425375	0022084253-0	C022 C84253-0	0022 084253-0
0309307520 /	0309307520-*	0309307520-*	0309 307520--	0309 307520--
0694084753 3	NO LABEL	0694084753-3	0694 084753-3	0594 084753-3
0802171482 4	0802171482-4	0802171482-4	08C2 171482-4	0802 171482-4
0802170625 9	0802170625-9	0802170625-9	08C2 170625-9	0802 170625-9
0550171652 7	0550171652-7	0550171652-7	C550 171652-7	0550 171552-7
0695452834 1	0695452834-1	0695452834-1	0695 452834-1	0595 452834-1
0131170750 7	0131170750-7	0131170750-7	0131 170750-7	0131 170750-7
0622110064 7	NO LABEL	NO LABEL	0C0C 0C000000	0000 00000000
0128004400 6	0128004400-6	0128004400-6	0128 0C44CC-6	0128 004400-5
0131174119 /	0131174119-*	0131174119-*	0131 174119--	0131 174119--
0131174055 2	0131174055-2	0131174055-2	0131 174C55-2	0131 174055-2
0802491222 7	0802491222-7	0802491222-7	0802 491222-7	0802 491222-7
0721224875 5	0721224875-5	0721224875-5	0721 224875-5	0721 224375-5
0135005475 2	0135005475-2	0135005475-2	0135 CC5475-2	0135 005475-2

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Table C-1. Composite Printout from the Five OACI Scanners Tested in Chicago (Continued).

TRAIN: 002 CAR: 99-191

SCANNER 1	SCANNER 2	SCANNER 3	SCANNER 4	SCANNER 5
1185004010 4	1185004010-4	1185004010-4	1165 004010-4	1185 004010-4
0721223785 3	0721223785-3	0721223785-3	0721 223735-3	0721 223795-3
0721202250 /	0721202250-*	0721202250-*	0721 202250--	0721 202250--
0131160016 5	NO LABEL	0131160016-5	0131 160016-5	0131 150015-5
1682076009 8	1682076009-8	1682076009-8	1662 076009-8	1592 075009-8
0721202468 9	0721202468-9	0721202468-9	0721 202458-9	0721 202453-9
1202012290 2	1202012290-2	1202012290-2	1202 012290-2	1202 012290-2
1202012486 5	1202012486-5	1202012486-5	1202 012486-5	1202 012495-5
0131154542 7	0131154542-7	0131154542-7	0131 154542-7	0131 154542-7
0721231546 6	0721231546-8	0721231546-8	0721 231546-8	0721 231545-8
0995452078 9	0995452078-9	0995452078-9	0995 452078-9	0995 452073-9
0695459020 3	0695459020-3	0695459020-3	0695 459020-3	0595 459020-3
0995458667 8	0995458667-8	0995458667-8	0995 458667-8	0995 458557-8
0721192077 8	0721192077-8	0721192077-8	0721 192077-8	0721 192077-8
$-----------	NO LABEL	NO LABEL	0000 00000000	0000 00000000
0721213339 7	0721213339-7	0721213339-7	0721 213339-7	0721 213339-7
$-----------	NO LABEL	NO LABEL	0000 00000000	0000 00000000
0622149135 /	0622149135-*	0622149135-*	0622 149135--	0522 149135--
0622174432 9	0622174432-9	0622174432-9	0622 174432-9	0522 174432-9
0802517132 4	0802517132-4	0802517132-4	0602 517132-4	0802 517132-4
0721231681 6	0721231681-8	0721231681-8	0721 231681-8	0721 231531-8
0840068207 0	0840068207-0	0840068207-0	0840 068207-0	0840 053207-0
0131023153 /	0131023153-*	0131023153-*	0131 023153--	0131 023155--
0622369317 5	0622369317-5	0622369317-5	0622 369317-5	0522 359317-5
$-----------	0218605433-4	NO LABEL	0000 00000000	0000 00000000
0620118273 6	0620118273-6	0620118273-6	0620 118273-6	0520 118273-5
0695459873 4	0695459873-4	0695459873-4	0695 459673-4	0595 459873-4
0622268489 9	0622268489-9	0622268489-9	0622 268439-9	0522 253489-9
0760255661 0	0760255661-0	0760255661-0	0760 255661-0	0750 255551-0
0622267213 6	0622267213-6	0622267313-6	0622 267213-6	0522 [illegible]7213-6
0131009540 7	0131009540-7	0131009540-7	0131 009540-7	0131 009540-7
0721222013 0	NO LABEL	0721222013-0	0721 222013-0	0721 222013-0
0802450235 1	0802450235-1	0802450235-1	0802 450235-1	0802 450235-1
0802450165 3	0802450165-3	0802450165-3	0802 450165-3	0802 450155-3
0218581811 9	0218581811-9	0218581811-9	0218 581811-9	0218 581811-9
0802498517 8	NO LABEL	0802498517-8	0802 498517-8	0802 498517-8
0802490394 5	NO LABEL	0802490394-5	0802 490394-5	0802 490394-5
0802167987 3	NO LABEL	0802167987-3	0802 167987-3	0802 157937-3
0622266853 7	0622266853-7	0622266853-7	0622 266853-7	0522 255853-7
0622154377 2	0622154377-2	0622154377-2	0622 154377-2	0522 154377-2
0695453432 3	0695453432-3	0695453432-3	0695 453432-3	0595 453432-3
0802160379 6	0802160379-6	0802160379-6	0802 160379-6	0802 150379-5
0995451735 6	0995451735-8	0995451735-8	0995 451735-8	0995 451735-8
0995451525 2	0995451525-2	0995451525-2	[illegible] 451525-2	0995 451525-2
1202010175 1	1202010175-1	1202010175-1	1202 010175-1	1202 010175-1
0140029858 4	0140029852-4	0140029852-4	0140 029552-4	0140 029352-4
0131117367 5	0131117367-5	0131117367-5	0131 117367-5	0131 117357-5
0721192059 3	0721192059-3	0721192059-3	0721 192059-3	0721 192059-3
0622023354 6	8622023354-8	8622023354-8	8622 023354-8	8622 023354-8
			END	END

G.T-TLR 046 015 81 262 230 1245 0 [illegible] 097 (SCANNER 1)

END CARS:097 PRIME:083 NO LABEL:014 TIME:1845 DATE:230 (SCANNER 2)

END CARS:097 PRIME:086 NO LABEL:011 TIME:1845 DATE:230 (SCANNER 3)

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APPENDIX D

INSTRUCTIONS FOR KEYPUNCHING DATA ONTO IBM CARDS*

D.1 INTRODUCTION

This appendix contains the instructions for keypunching data obtained from the ACI field test described in the report "Electro-Optical Automatic Car Identification Field Test Program" (see Report No. FRA-OR&D-75-79). Also included are tables of information sources for the data cards (Table D-1) and an estimation of the number of IBM cards that will be required.

When the data have been obtained, all relevant information will be transferred onto IBM cards (see Report No. FRA-OR&D-75-79, pp. 9-12). The cards will be grouped by trains with one heading card for the whole train followed by two cards for each car in that train.

The IBM cards for the whole train will have the following information keypunched onto it:

IBM Card Data Per Train (See Figure D-1)

Data Description	Columns on IBM Card
1. Train Number	1-4
2. Julian Date	5-7
3. Time of Day (that first car in train passes scanners)	8-11

* Written by the author and Stephen F. Schaedel, a student and FRA summer employee.

Data Description		Columns on IBM Card
4.	Train Direction	12
		13 Blank
5.	Train Speed	14-15
6.	Weather Conditions	16
7.	Number of Cars in Train	17-19
8.	Number of Labeled Cars in Train (Side 1)	20-22
9.	Number of Labeled Cars in Train (Side 2)	23-25
		26-28 Blank
10.	Range of Car Sequence Number in Train	29-40
		41-80 Blank

The IBM card per car will have the following information keypunched onto it:

IBM Cards (2) Data Per Car

Card #1 (See Figure D-2)

Data Description		Columns on IBM Card
1.	Car Label #: Standard Scanner #1	12
2.	Car Label #: Modified Scanner #2	13-24
3.	Car Label #: Modified Scanner #3	25-36
4.	Car Label #: Modified Scanner #4	37-48
5.	Car Label #: Modified Scanner #5	49-60
6.	Train Number	61-64
7.	Car Number	65-69
	Card #2 (See Figure D-3)	
8.	Train Number	1-4
9.	Car Number	5-9
10.	Actual Label Number	10-21

Table D-1. Data Sources for Keypunching IBM Cards.

<u>IBM Card Data Per Train</u>

Item #	Field Log Book	Video Tape		Computer Printout	
		Audio	Video	Manufacturer A	Manufacturer B
1	X	X			
2	X			X	X
3		X		X	X
4	X	X	X	X	X
5			X		
6	X				
7		X	X	X	X
8		X	X	X	X
9		X	X	X	X
10	X				

<u>IBM Card Data Per Car</u>

Item #	Field Log Book	Video Tape		Computer Printout	
		Audio	Video	Manufacturer A	Manufacturer B
1				X	
2				X	
3				X	
4					X
5					X
6		X			
7		X	X		
8		X	X		
9			X		
10	X				
11	X				

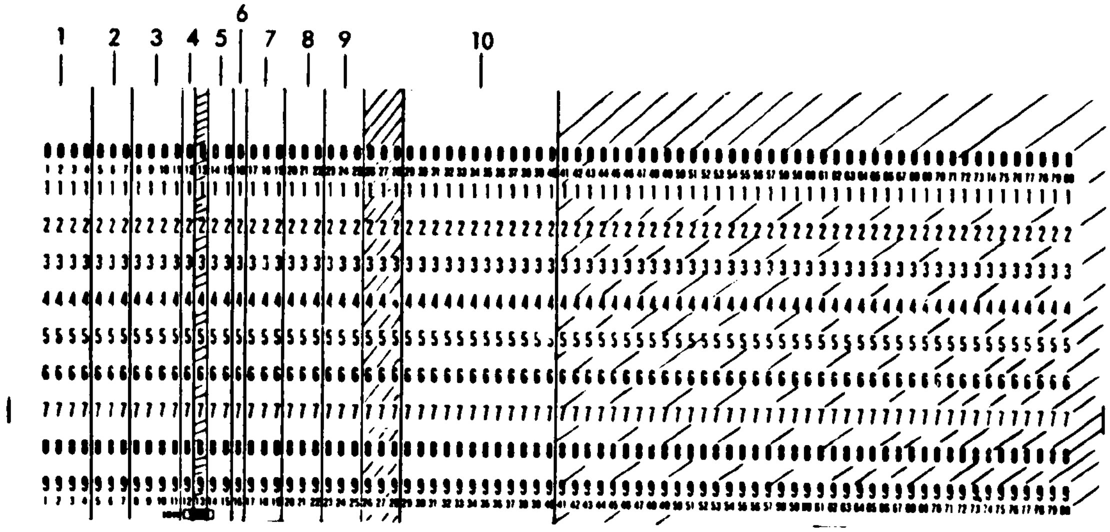

Figure D-1. IBM Card Data Format per Train Scanned at the Chicago Test.

1. Train number
2. Julian date
3. Time of day
4. Train direction
5. Train speed
6. Weather condition
7. Number of cars in train
8. Number of labeled cars in train (side 1)
9. Number of labeled cars in train (side 2)
10. Range of car sequence number in train

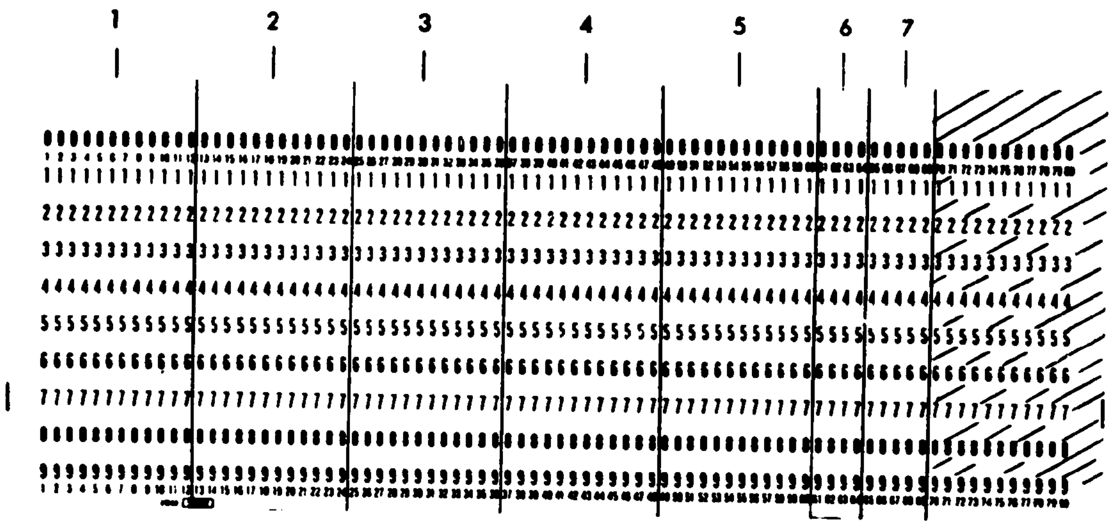

Figure D-2. IBM Card #1 Data Format per Car Scanned at the Chicago Test.

1. Car label # Scanner #1
2. Car label # Scanner #2
3. Car label # Scanner #3
4. Car label # Scanner #4
5. Car label # Scanner #5
6. Train Number
7. Car Number

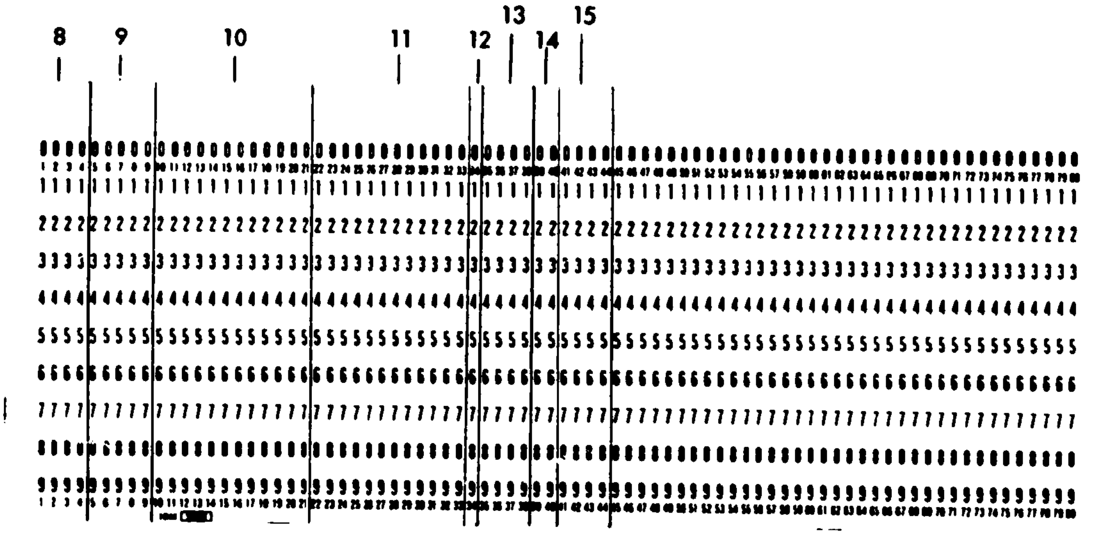

Figure D-3. IBM Card #2 Data Format per Car Scanned at the Chicago Test.

8. Train Number
9. Car Number
10. Actual Label Number
11. Oscillogram Label Number
12. Scanner Source for Oscillogram
13. Diagnosis of Non-Read and Error-Read, Causes Side 1, Causes Side 2
14. Car Type
15. Code for Instrumentation Related Problems

Data Description		Columns on IBM Card
11.	Oscillogram Label Number	22-23
12.	Scanner Source for Oscillogram	24
13.	Diagnosis of Non-Read and Read Error	
	Causes Side 1	35-36
	Causes Side 2	37-38
14.	Car Type	39-40
15.	Code for Instrumentation Related Problems	41-44

D.2 CODES FOR IBM CARD DATA PER TRAIN (See Figure D-1)

1. Train Number. There are 4 columns (1-4) for the train number. The first column will contain a slash (/) to indicate a new train number. The next three columns will contain the sequence number of the train in the experiment (not in the scanners).

2. Julian Date. There are 3 columns (5-7) for the Julian date. These columns will contain a number from 1 to 365.

3. Time of Day. There are 4 columns (8-11) for the time of day when the first car passes the scanners. The first two columns contain the hour and the following two the minute. For example, 2:30 p.m. would be keypunched:

column	8	9	10	11
time	1	4	3	0

The hours range from 00 to 23.

4. Train Direction. There is 1 column (12) for train direction. A 0 or a 1 will be keypunched in accordance with Figure D-2.

5. Train Speed. There are two columns (14-15) for train speed. For example, if the train was moving 5 mph, 05 would be keypunched onto an IBM card in these columns. The speed information will be obtained by timing the passage of the cars between two poles 145 feet apart. This information will be retrieved from the video tape.

6. Weather Conditions (Column 16).

Condition	Code Number
Clear, bright and sunny	0
Cloudy and bright	1
Overcast	2
Light drizzle	3
Rain	4
Heavy rain	5
Fog	6
Hail or Sleet	7
Thick smoke or air pollution	8

7. Number of Cars in the Train. There are 3 columns (17-19) for the number of cars in the train. This number is obtained from any of the scanners printout minus the number of locomotives and cabooses.

8. Number of Labeled Cars in Train (Side 1). There are 3 columns (20-22) for the number of labeled cars in the train (Side 1). The number of labeled cars is obtained from the total number of cars minus the non-labeled cars. The non-labeled cars are obtained from visual observation and reported in the audio channel of the video tape.

9. Number of Labeled Cars in Train (Side 2). There are 3 columns (23-25) for the number of labeled cars in the train (Side 2). This number is obtained as indicated in item 8.

10. Range of Car Sequence Numbers in Train. There are 12 columns for this category (29-40). The first 6 columns (columns 29-34) will contain the sequence number of the first car in the train. The last six columns (columns 35-40) will contain the sequence number of the last car in the train. Of course, locomotives and cabooses are not counted. For example, if the first car in train number 8 is sequence number 2535 and the last car is sequence number 2585, then this data is keypunched:

column	29	30	31	32	33	34	35	36	37	38	39	40
range	0	0	2	5	3	5	0	0	2	5	8	5

D.3 CODES FOR IBM DATA PER CAR (see Figure D-2 and D-3)

1-5. Car Label Number from Scanner Computer Printouts

The car label numbers from scanner computer printouts will be keypunched in 12 columns for each scanner. The first 10 columns (1-10) on the first car data card will contain the car ID numbers. The following two columns (11 and 12) will contain the parity check number. The first group of 12 columns from Scanner #1 will be followed by the label numbers from Scanners #2, 3, 4 and 5.

6 and 8. Train Number

Columns 61-64 on the first car data card and columns 1-4 on the second car data card will contain the sequence number of the train in the experiment (not in the scanners).

7 and 9. Car Number

Columns 65-69 on the first car data card and columns 5-9 on the second car data card will contain the sequence number of the cars in the experiment.

10. Actual Car Label Number

The actual car label number will be keypunched in columns 10-21 on the second car data card. The first 10 columns will contain the actual label number. The next two columns will contain the parity check number. For example, the actual car label number might be 0721230750. This number is keypunched, exactly as it appears here, in columns 10 to 21 on the second car data card. The sources of the actual car label numbers, in order of priority, will be the visual inspection reported in the audio channel of the video tape and the still pictures of each car.

11. Oscillogram Label Number

In case the label number from Scanner #2 and #3 is a non-read, the label number from the oscillogram for that scanner will be keypunched onto the second car data in columns 22-23. If the oscillogram cannot be interpreted, nothing will be keypunched for Scanner #3 in columns 22 and 33 on the second car data card.

12. Scanner Source for Oscillogram

If both Scanner #2 and Scanner #3 read a given label number, a 0 will be keypunched in column 34 on the second car data card. If Scanner #2 read a given car label number but Scanner #3 could not read the label at all, a 3 will be keypunched in column 34. If Scanner #3 read a car label but Scanner #2 could not read the label at all, a 2 will be keypunched in column 34.

13. Diagnosis of Non-Read and Error-Read Causes

Diagnosis	Code Number
Dirt	1
Damage	2
Misapplication (wrong module)	3
Other (label burned off, etc.)	4
Undetermined	5
Phosphate accumulation	6
Modules fading	7
Module damage	8
New/Old Modules	9
Rusted background	10
Low and bent	11
Low and dirty	12

Diagnosis	Code Number
Black anodized failure	13
NO LABEL	14

The source of information for the diagnosis will be, in order of priority, the oscillogram, the photograph of the car, the TV image of the car and the reporting by an observer recorded in the audio channel of the video tape. Columns 35-36 on the second car data card will be for causes that affect the non-reads on side 1 and columns 37-38 on the second car data card the causes that affect non-reads on side 2.

14. Car Type

This information will be retrieved from the video tape (audio and/or video) and keypunched in columns 39-40 on the second car data card.

Type	Code Number
Box	1
Closed Hopper	2
Open Hopper	3
Flatcar	4
Car Carrier	5
No Information	6
Gondola	7
Tank	8
Other	9

15. Code for Instrumentation Related Problems

The code for instrumentation-related problems is given in Table D-2. There are four columns on the second car data card designated for this code (columns 41-44).

These columns correspond to the four categories of problems:

Problem Category	Column
Electrical	41
Mechanical	42
Optical	43
Other	44

Table D-2. Code for Instrumentation-Related Problems.

Code Number	Electrical (Power Failure)	Mechanical (Breakage or Vandalism)	Optical (Absence From Post)	Other
0	OK	OK	OK	OK
1	Scanner #1	Scanner #1	Scanner #1	Out of Tape (TV)
2	Scanner #2	Scanner #2	Scanner #2	Out of Film (Still Picture Camera)
3	Scanner #3	Scanner #3	Scanner #3	Train Speed Changes
4	Scanner #4	Scanner #4	Scanner #4	Train Stops
5	Scanner #5	Scanner #5	Scanner #5	Train Reverses Direction
6	General Power	Train Derailment		Scanners #2 &3 Electrical Failure
7	Bio-Motion Power Failure	Bio-Motion		
8	TV Camera #1	TV Camera #1	TV Camera #1	
9	TV Camera #2	TV Camera #2	TV Camera #2	
*	Tape Recorder (Sony,	Tape Recorder (Sony)		
/	Tape Recorder (Panasonic)	Tape Recorder (Panasonic)		
-	Special Effects Generator	Special Effects Generator		
?	Wheel Counters	Wheel Counters		
#	Still Picture Camera	Still Picture Camera	Still Picture Camera	

APPENDIX E

COMPUTER PROGRAM TO ANALYZE THE OACI CHICAGO TEST DATA *

E.1 INTRODUCTION

A program was written to analyze the OACI Chicago Test data. It was compiled and executed with 6K core on the DEC system-10, and the language used was FORTRAN IV. A listing is given in Section 4.

The program was designed to read input data which was recorded on computer cards according to the specifications given in Appendix C. It was designed also to produce printouts of data accumulations according to the formats given in Section 5.

The writing unit was specified with the following two statements which may not be adaptable to all computer systems:

```
CALL ASSDEV (3, 'DSK')
CALL OFILE (3, 'OUT')
```

The reading unit also may not be adaptable to all computer systems. It was selected by the following statement:

```
CALL ASSDEV (2, 'DSK')
```

Since three decode statements were used in this program, the program can be executed without modification only on computer systems which accept the decode statement.

---

* Written by Carolyn Zimmermann, computer programmer, Kentron Hawaii Ltd., ADP Support Services Project, Contract DOT-TSC-297, 1975.

E.2 CAR-BY-CAR PRINTOUTS

The main purpose of the OACI field test data analysis program was to determine how well each of the five scanners at the test site read the labels on the train cars used in the test. The degree of reading accuracy was limited to the following three categories:

1. Read — a particular scanner read each digit of the label number correctly.
2. Read Error — a particular scanner read some, but not all, of the digits of the label number correctly.
3. Non-Read — a particular scanner was completely unable to read the label.

To determine how well a particular scanner read a car label, a digit by digit comparison was made between the actual label number and the label number interpreted by the scanner. The results of each comparison on a car-by-car basis were given in the Label-Scanner Readability Limit Per Car printout. No difference between the actual label number and the label number interpreted by the scanner was recorded as a 0. If no difference existed between all the digits of the actual label number and all the digits of the label number interpreted by the scanner, the reading accuracy category was a Read. Any difference greater than 0 was recorded as a 1 and indicated either a Non-Read or Read Error.

A Non-Read was distinguished from a Read Error by the fact that all zeroes were recorded for all digits of the label number interpreted by a given scanner. For each Non-Read case, an 'X' was printed in the Non-Read column of the Label-Scanner Readability Limit Per Car printout. For both Non-Read and Read Error cases, the corresponding cause of illegibility of the label number was printed.

The parity check number was the last digit of the actual label number. If a particular scanner did not read this digit correctly, the error was defined to be a parity error. A question mark and the number interpreted for the actual digit were printed in the Label-Scanner Readability Limit Per Car printout. If the parity check number was read correctly, only the number was printed.

An effort was made to test the hypothesis that reading accuracy increases when two scanners - one on each side of the railroad track - are used to read car labels. In the OACI field test, Scanners #2 and 3 were used for that purpose. The best information from Scanner #2 or Scanner #3 was recorded on the Label-Scanner Readability Limit Per Car printout. The best information was defined to be the following in the order of decreasing reading accuracy:

1. A Read by Scanner #2.
2. A Read by Scanner #3.
3. A parity error but other digits of a label number correctly read by Scanner #2.
4. A parity error but other digits of a label number correctly read by Scanner #3.
5. Read Error by Scanner #2.
6. Read Error by Scanner #3.
7. Read Error and parity error by Scanner #3.
8. Read Error and parity error by Scanner #2.
9. Non-Read by Scanner #2.

E.3 TRAIN-BY-TRAIN PRINTOUTS

The three different reading accuracy categories and parity errors were accumulated on a train-by-train basis for each scanner, and for the condition of the most accurate information from either Scanner #2 or 3. The percentages of accurately read car labels were calculated using the following formulas:

$$\text{Proportion of Labels Read} = \frac{\text{Total car labels read correctly}}{\text{Total number of cars with labels on the side facing a given scanner}}$$

$$\text{Proportion of Cars Read} = \frac{\text{Total car labels read correctly}}{\text{Total cars in a given train}}$$

The results of the above accumulations and calculations were given in the Operational System Evaluation Per Train printouts.

Two oscilloscopes - one for Scanner #2 and one for Scanner #3 - were included in the test equipment in order to obtain a car label number when their corresponding scanner was completely unable to read a car label. The increase in reading accuracy due to the use of an oscilloscope and a scanner for reading car labels was determined by comparing the increase in the proportion of labels read by either Scanner #2 or Scanner #3 and the corresponding oscilloscope to the proportion of labels read by the corresponding scanner alone. The following equation was used:

$$\text{Proportion of labels read by a scanner and its corresponding oscilloscope} = \frac{\text{Total car labels read correctly by a scanner and its corresponding oscilloscope}}{\text{Total number of cars with labels on the side facing a given scanner}}$$

The Label-Scanner Readability Limit Per Train printout contained the results of the calculations for the above proportions and the data necessary to make the calculations.

Further accumulations on a train-by-train basis included the number of times each scanner read a particular number for the actual label number. A printout for each scanner gave the accumulations for each train.

The last printout for each train included the accumulations by car type and by scanner of the total number of cars scanned, the number of Reads, and the combined total of the number of Read Errors and Non-Reads. The accumulations by car type, and by scanner of the Non-Read and Read Error causes were also given. The car type divisions were "flat" and "other."

E.4 COMPUTER PROGRAM LISTING

The following is a listing of the computer program to analyze OACI Chicago Test data.

```
******************************************************************************
*                                                                            *
******************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKB:TRAIN.F4   [4156,527] 14-Oct-75     *
******************************************************************************
C                              LIST OF VARIABLES
C
C CAR--CAR TYPE
C CAUSE(K,L)--NON-READ AND READ ERROR CAUSES FOR SCANNER K AND CAR TYPE
C ICARD(16)--DUMMY VARIABLES USED TO READ ENTIRE DATA CARD IN A FORMAT
C ICARSC(K)--THE NUMBER OF CARS OF CAR TYPE K SCANNED IN A GIVEN TRAIN
C IDATA(1),IDATA(2),....,IDATA(10)--THE CAR LABEL # READ BY SCANNER 1
C IDATA(11)--THE PARITY CHECK NUMBER READ BY SCANNER 1
C IDATA(12),IDATA(13),....,IDATA(21)--THE CAR LABEL # READ BY SCANNER 2
C IDATA(22)--THE PARITY CHECK NUMBER READ BY SCANNER 2
C IDATA(23),IDATA(24),....,IDATA(32)--THE CAR LABEL # READ BY SCANNER 3
C IDATA(33)--THE PARITY CHECK NUMBER READ BY SCANNER 3
C IDATA(34),IDATA(35),....,IDATA(43)--THE CAR LABEL # READ BY SCANNER 4
C IDATA(44)--THE PARITY CHECK NUMBER READ BY SCANNER 4
C IDATA(45),IDATA(46),....,IDATA(54)--THE CAR LABEL # READ BY SCANNER 5
C IDATA(55)--THE PARITY CHECK NUMBER READ BY SCANNER 5
C IDATA(56),IDATA(57),....,IDATA(65)--THE ACTUAL CAR LABEL #
C IDATA(66)--THE ACTUAL PARITY CHECK NUMBER
C IDATA(67),IDATA(68),....,IDATA(76)--THE CAR LABEL # READ BY
C    OSCILLOGRAM
C IDATA(77)--THE PARITY CHECK NUMBER READ BY OSCILLOGRAM
C IDATA(78)--TRAIN #
C IDATA(79)--CAR #
C IDATA(80)--TRAIN #
C IDATA(81)--CAR #
C IDATA(82)--SCANNER SOURCE FOR OSCILLOGRAM
C IDATA(83)--THE NON-READ OR READ ERROR CAUSE FOR SCANNERS 1,3,4,OR 5
C IDATA(84)--THE NON-READ OR READ ERROR CAUSE FOR SCANNER 2
C IDATA(85)--CAR TYPE
C IDATA(86)--CODE FOR THE ELECTRICAL PROBLEMS
C IDATA(87)--CODE FOR THE MECHANICAL PROBLEMS
C IDATA(88)--CODE FOR THE OPTICAL PROBLEMS
C IDATA(89)--CODE FOR OTHER PROBLEMS
C IDIFF(1),IDIFF(2),...,IDIFF(10)--THE DIGIT BY DIGIT DIFFERENCE BETWEEN
C    THE ACTUAL CAR LABEL # AND THE CAR LABEL # READ BY SCANNER #1
C IDIFF(11),IDIFF(12),....,IDIFF(20)--THE DIGIT BY DIGIT DIFFERENCE
C    BETWEEN THE ACTUAL CAR LABEL # AND THE CAR LABEL # READ BY SCANNER
C    #2
C IDIFF(21),IDIFF(22),....,IDIFF(30)--THE DIGIT BY DIGIT DIFFERENCE
C    BETWEEN THE ACTUAL CAR LABEL # AND THE CAR LABEL # READ BY SCANNER
C    #3
C IDIFF(31),IDIFF(32),....,IDIFF(40)--THE DIGIT BY DIGIT DIFFERENCE
C    BETWEEN THE ACTUAL CAR LABEL # AND THE CAR LABEL # READ BY SCANNER
C    #4
C IDIFF(41),IDIFF(42),....,IDIFF(50)--THE DIGIT BY DIGIT DIFFERENCE
```

```
*******************************************************************************
*                                                                             *
*******************************************************************************
C   BETWEEN THE ACTUAL CAR LABEL # AND THE CAR LABEL # READ BY SCANNER
C   #5
C IDIFF(51),IDIFF(52),...,IDIFF(60)--THE DIGIT BY DIGIT DIFFERENCE
C   BETWEEN THE ACTUAL CAR LABEL # AND THE CAR LABEL # READ BY AN
C   OSCILLOGRAM
C IHDR(1)--A SLASH (/) TO INDICATE A NEW TRAIN
C IHDR(2)--TRAIN NUMBER
C IHDR(3)--JULIAN DATE
C IHDR(4)--HOUR WHEN THE FIRST CAR PASSES THE SCANNERS
C IHDR(5)--MINUTE OF THE HOUR WHEN THE FIRST CAR PASSES THE SCANNERS
C IHDR(6)--TRAIN DIRECTION
C IHDR(7)--USED AT ONE TIME BUT NOW REPRESENTS NO VARIABLE
C IHDR(8)--TRAIN SPEED
C IHDR(9)--WEATHER CONDITIONS
C IHDR(10)--NUMBER OF CARS IN TRAIN
C IHDR(11)--NUMBER OF LABELED CARS IN TRAIN (SIDE 1)
C IHDR(12)--NUMBER OF LABELED CARS IN TRAIN (SIDE 2)
C IHDR(13)--SEQUENCE NUMBER OF THE FIRST CAR IN THE TRAIN
C IHDR(14)--SEQUENCE NUMBER OF THE LAST CAR IN THE TRAIN
C IRDER(K,L)--THE NUMBER OF READ ERRORS FOR A GIVEN TRAIN, A GIVEN
C   SCANNER K, AND A CAR TYPE L WHERE L=1 FOR FLAT CARS AND L=2 FOR
C   OTHER CAR TYPES   .
C IRDNOR--THE NUMBER OF CARS WITH LABELS WHICH WERE READ CORRECTLY FOR A
C   GIVEN TRAIN BY AT LEAST ONE SCANNER ON SIDE 1
C IRDSTH--THE NUMBER OF CARS WITH LABELS WHICH WERE READ CORRECTLY FOR A
C   GIVEN TRAIN BY SCANNER 2
C IREAD--THE NUMBER OF SCANNERS ON SIDE 1 WHICH CORRECTLY READ A
C   GIVEN LABEL
C IREAD6--THE NUMBER OF TIMES FOR A GIVEN TRAIN, THE BEST INFORMATION
C   READ BY SCANNER 2 OR SCANNER 3 INCLUDED A CORRECTLY READ LABEL #
C ISDATA--SUM OF DIGITS FOR A GIVEN LABEL NUMBER
C ISRD(K)--THE NUMBER OF CAR LABELS FOR A GIVEN TRAIN WHICH WERE READ
C   CORRECTLY BY A GIVEN SCANNER K
C ITPER(K)--THE NUMBER OF TIMES FOR A GIVEN TRAIN, SCANNER K INCORRECTLY
C   READ THE PARITY CHECK NUMBER WHERE K=1,5
C ITPER(6)--THE NUMBER OF TIMES FOR A GIVEN TRAIN THE BEST INFORMATION
C   READ BY SCANNER 2 OR 3 INCLUDED AN INCORRECTLY READ PARITY CHECK
C   NUMBER
C ITRD(K,L)--THE NUMBER OF TIMES FOR A GIVEN TRAIN AND CAR TYPE L WHERE
C   L=1 FOR FLAT CARS AND L=2 FOR OTHER CAR TYPES, SCANNER K READ A CAR
C   LABEL CORRECTLY
C ITRDOS(K)--THE NUMBER OF TIMES FOR A GIVEN TRAIN, OSCILLOSCOPE K READ
C   A CAR LABEL CORRECTLY
C ITTCAR--THE NUMBER OF CARS SCANNED IN A GIVEN TRAIN
C ITTNRC(K,L)--THE NUMBER OF NON-READS AND READ ERRORS DUE TO THE LTH
C   NON-READ OR READ ERROR CAUSE FOR A GIVEN TRAIN AND A GIVEN SCANNER K
C MISRD(K,L,M)--THE NUMBER OF TIMES SCANNER K READ A NUMERICAL VALUE M
```

```
***********************************************************************
*                                                                     *
***********************************************************************
C   FOR THE ACTUAL NUMERMICAL VALUE L.   L MAY EQUAL M AND THEY EACH
C   MAY HAVE THE FOLLOWING VALUES:  0,1,2,3,4,5,6,7,8,9,10.
C NERR(K,L)--THE NUMBER OF NON-READS AND READ ERRORS FOR A GIVEN TRAIN,
C   A GIVEN SCANNER K, AND A CAR TYPE L WHERE L=1 FOR FLAT CARS AND L=2
C   FOR OTHER CAR TYPES
C NNERR(K)--THE NUMBER OF NON-READS AND READ ERRORS FOR A GIVEN TRAIN
C   AND A GIVEN SCANNER K
C NRCAUS(K,L,M)--THE NUMBER OF TIMES FOR A GIVEN TRAIN AND CAR TYPE M
C   WHERE M=1 FOR FLAT CARS AND M=2 FOR OTHER CARS, SCANNER K COULD NOT
C   READ A CAR LABEL AT ALL OR COULD NOT READ THE LABEL CORRECTLY DUE
C   TO THE LTH NON-READ OR READ ERROR CAUSE
C NRD(K)--THE NUMBER OF TIMES FOR A GIVEN TRAIN, SCANNER K WAS
C   COMPLETELY UNABLE TO READ (NON-READ) A CAR LABEL , WHERE K=1,5
C NRD(6)--THE NUMBER OF TIMES FOR A GIVEN TRAIN, THE BEST INFORMATION
C   READ BY SCANNER 2 OR 3 INCLUDED A NON-READ
C NRDER(K)--THE NUMBER OF READ ERRORS FOR A GIVEN TRAIN AND A GIVEN
C   SCANNER K
C NREAD(K,L)--THE NUMBER OF TIMES FOR A GIVEN TRAIN AND CAR TYPE L WHERE
C   L=1 FOR FLAT CARS AND L=2 FOR OTHER CAR TYPES, SCANNER K COULD NOT
C   READ A CAR LABEL AT ALL (NON-READ)
C PLBRD(K)--THE PROPORTION OF LABELS SCANNER K READ
C PLBRD(6)--PROPORTION OF LABELS READ UNDER THE CONDITION OF BEST
C   INFORMATION FROM SCANNER 2 OR SCANNER 3
C POSSC2--PROPORTION OF LABELS READ BY SCANNER 2 AND OSCILLOGRAM #1
C POSSC3--PROPORTION OF LABELS READ BY SCANNER 3 AND OSCILLOGRAM #2
C PRD(K)--THE PROPORTION OF CARS SCANNER K READ
C PRD(6)--THE PROPORTION OF CARS READ UNDER THE CONDITION OF BEST
C   INFORMATION FROM SCANNER 2 OR SCANNER 3
C RCAR--COARSER BREAKDOWN OF CAR TYPE
C TRDIR--TRAIN DIRECTION
C WTHR--WEATHER CONDITIONS
      DOUBLE PRECISION WTHR(3,9),CAR(9)
      DIMENSION IHDR(14),PLBRD(6),PRD(6),IDATA(89),ICARSC(2),IDIFF(60),
     1MISRD(5,11,11),ITPER(6),ISDIF(10),NRDER(6),NRD(6),NRCAUS(5,17,2),
     2ITRD(5,2),CAUSE(5,17),ITRDOS(2),TRDIR(2),RCAR(3),ISRD(5),
     3NREAD(5,2),ITTNRC(5,15),ICARD(16),NERR(5,2),IRDER(5,2),NNERR(5)
      DATA WTHR/'CLEAR, BRI','GHT AND SU','NNY       ','CLOUDY AND',' BR
     1IGHT   ','          ','OVERCAST  ','          ','          ','LIGH
     2T DRIZ','ZLE       ','          ','RAIN      ','          ','
     3     ','HEAVY RAIN','          ','          ','FOG       ','
     4     ','          ','HAIL OR SL','EET       ','          ','THICK S
     5MOK','E OR AIR P','OLLUTION  '/,CAR/'   BOX    ',' C HOPPER ',' O
     6HOPPER ',' FLATCAR   ','C CARRIER ',' NO INFO  ',' GONDOLA  ','   T
     7ANK    ','  OTHER   '/,TRDIR/'WEST ','EAST '/,CAUSE/'      NO',' CODE'
     8,'      ','      ','      ','      ','DIRT ','      ','      ','
     9   D','AMAGE','      ','      ','      ','MISAP','PLICA','TION ','
     1   ','      ','      ','OTHER','      ','      ','      ',' UNDE','TERM
```

```
**********************************************************************
*                                                                    *
**********************************************************************
     2I','NED  ','      ','      ','PHOSP','HATE ','ACCUM','ULATI',
     3'ON    ',
     4 'MODUL','ES FA','DING ','      ','      ',' MODU','LE DA','MAGE ',
     5'      ','      ','NEW/O','LD MO','DULES','      ','      ','RUSTE',
     6'D BAC','KGROU','ND    ','      ',' LOW ','AND B','ENT  ','      ',
     7'      ',' LOW ','AND D','IRTY ','      ','      ','BLACK',' ANOD',
     8'IZED ','FAILU','RE    ','    NO',' LABE','L     ','      ','      ',
     9'SCANN','ER EL','ECTRI','CAL P','ROB  ','SC 26',' 3--E','LEC F',
     1'AILUR','E     '/
      DATA RCAR/'FLAT ','OTHER','TOTAL'/
      CALL ASSDEV(3,'DSK')
      CALL OFILE(3,'OUT')
      IRDNOR=0
      IREAD6=0
      DO 10 JLL=1,6
      ITPER(JLL)=0
      NRDER(JLL)=0
   10 NRD(JLL)=0
      DO 20 JLL=1,5
      ISRD(JLL)=0
      NNERR(JLL)=0
      DO 20 KLL=1,2
      IRCER(JLL,KLL)=0
      ITRD(JLL,KLL)=0
      NREAD(JLL,KLL)=0
   20 CONTINUE
      DO 30 NLL=1,2
      ICARSC(NLL)=0
      ITRDOS(NLL)=0
      DO 30 LLL=1,5
      DO 30 MLL=1,17
   30 NRCAUS(LLL,MLL,NLL)=0
      DO 40 NO=1,5
      DO 40 NP=1,11
      DO 40 NS=1,11
   40 MISRD(NO,NP,NS)=0
      ITTCAR=0
      DO 50 NSC=1,5
      DO 50 IC=1,15
   50 ITTNRC(NSC,IC)=0
      CALL ASSDEV(2,'DSK')
C READ FIRST CARD WHICH IS A HEADER CARD
      READ(2,60) (IHDR(I),I=1,14)
   60 FORMAT(A1,2I3,2I2,2I1,I2,I1,3I3,3X,2I6)
C READ NEXT CARD AND CHECK FOR HEADER CARD
   70 READ(2,80,END=1690)(ICARD(I),I=1,16)
   80 FORMAT(16A5)
```

```
***********************************************************************
*                                                                     *
***********************************************************************
      DECODE(1,90,ICARD(1)) ICOL
   90 FORMAT(A1)
      IF(ICOL.NE.'/') GO TO 430
C MAKE CALCULATIONS FOR ONE ENTIRE TRAIN AND PRINT ACCUMULATIONS FOR THE
C    TRAIN
      DO 100 IJK=1,5
      ISRD(IJK)=0
  100 ISRD(IJK)=ITRD(IJK,1)+ITRD(IJK,2)
      PLBRD(1)=FLOAT(ISRD(1))/IHDR(11)
      PLBRD(2)=FLOAT(ISRD(2))/IHDR(12)
      DO 110 IJK=3,5
  110 PLBRD(IJK)=FLOAT(ISRD(IJK))/IHDR(11)
  120 DO 130 IJK=1,5
  130 PRD(IJK)=FLOAT(ISRD(IJK))/IHDR(10)
      WRITE(3,140)
  140 FORMAT(1H1,51X,'OPERATIONAL SYSTEM EVALUATION'/52X,29(1H-)/62X,'PE
     1R TRAIN'/62X,9(1H-))
      IWTHR=IHDR(9)+1
      IDIR=IHDR(6)+1
      DO 150 KSC=1,5
  150 NRDER(KSC)=IRDER(KSC,1)+IRDER(KSC,2)
      WRITE(3,160)IHDR(2),(WTHR(II,IWTHR),II=1,3),IHDR(3),IHDR(10),IHDR(
     14),IHDR(5)
  160 FORMAT(/33X,'TRAIN #:  ',I3,19X,'WEATHER:  ',3A10//33X,'DATE:  ',I
     13,22X,'TOTAL CARS:  ',I3//33X,'TIME:  ',I2,':',I2)
      PRD(6)=FLOAT(IREAD6)/IHDR(10)
      IF(IHDR(11).GT.IHDR(12)) GO TO 170
      PLBRD(6)=FLOAT(IREAD6)/IHDR(12)
      GO TO 180
  170 PLBRD(6)=FLOAT(IREAD6)/IHDR(11)
  180 WRITE(3,190)IHDR(11),IHDR(8),IHDR(12),TRDIR(IDIR),IRDNOR,ISRD(2)
      WRITE(3,200)(IK,ISRD(IK),NRD(IK),NRDER(IK),ITPER(IK),             P
     1LBRD(IK),PRD(IK),IK=1,5)
      WRITE(3,210)IREAD6,NRD(6),NRDER(6),ITPER(6),PLBRD(6),PRD(6)
  190 FORMAT(1H+,64X,'TOTAL LABELED CARS (NORTH):  ',I3//33X,'SPEED:  ',
     1I2,'MPH',19X,'TOTAL LABELED CARS (SOUTH):  ',I3//33X,'TRAIN DIRECT
     2ION:  ',A5,9X,'TOTAL LABELS READ CORRECTLY'/65X,'BY SCANNER #1,3,4
     3,5 (NORTH):  ',I3//65X,'TOTAL LABELS READ CORRECTLY'/65X,'BY SCANN
     4ER #2 (SOUTH):  ',I3//31X,':',14X,':',12X,':  READ   :  PARITY  :
     5 PROPORTION OF  :  PROPORTION OF'/20X,'SCANNER #  :  TOTAL READ  :
     6  NON-READ  :  ERROR  :  ERROR   :  LABELS READ   :  CARS READ'/2
     70X,94(1H-))
  200 FORMAT((20X,I1,'   :   ',I5,6X,':   ',I5,5X,': ',I5,'   : ',I5,4X,
     1':',6X,F4.2,7X,':',4X,F4.2/20X,94(1H-)))
  210 FORMAT(26X,'263   :   ',I5,6X,':   ',I5,5X,': ',I5,'   : ',I5,'   :
     1',6X,F4.2,7X,':',4X,F4.2,/20X,94(1H-))
      POSSC2=FLOAT(ISRD(2)+ITRDOS(1))/IHDR(12)
```

```
*******************************************************************
*                                                                 *
*******************************************************************
      POSSC3=FLOAT(ISRD(3)+ITRDOS(2))/IHDR(11)
      WRITE(3,220)
      WRITE(3,230)IHDR(2),ISRD(2),ISRD(3),IHDR(3),ITRDOS(1),ITRDOS(2),IH
     1DR(4),IHDR(5),PLBRD(2),PLBRD(3),IHDR(11),IHDR(12),POSSC2,POSSC3
  220 FORMAT(1H1,50X,'LABEL-SCANNER READABILITY LIMIT'/51X,31(1H-)/62X,'
     1PER TRAIN'/62X,9(1H-))
  230 FORMAT(10X,'TRAIN #:  ',I3,24X,'TOTAL READ BY SCANNER #2:  ',I3,10
     1X,'TOTAL READ BY SCANNER #3:  ',I3//10X,'DATE:  ',I3,27X,'TOTAL RE
     2AD BY OSCILLOGRAM #1:  ',I3,6X,'TOTAL READ BY OSCILLOGRAM #2:  ',I
     33//10X,'TIME:  ',I2,':',I2,25X,'PROPORTION OF LABELS READ',15X,'PR
     4OPORTION OF LABELS READ'/49X,'BY SCANNER #2:  ',F4.2,21X,'BY SCANN
     5ER #3:  ',F4.2/10X,'TOTAL LABELED CARS (NORTH):  ',I3/47X,'PROPORT
     6ION OF LABELS READ BY',12X,'PROPORTION OF LABELS READ BY'/10X,'TOT
     7AL LABELED CARS (SOUTH):  ',I3,7X,'SCANNER #2 & OSCILLOGRAM #1: ',
     8F4.2,7X,'SCANNER #3 & OSCILLOGRAM #2: ',F4.2)
  240 DO 290 KSC=1,5
      IF(KSC.EQ.2.OR.KSC.EQ.4) GO TO 250
      WRITE(3,1530)
  250 WRITE(3,260)KSC
  260 FORMAT(//,47X,'THE NUMBER OF TIMES SCANNER ',I1,' READ A'/47X,
     136(1H-)/43X,'PARTICULAR NUMBER FOR THE ACTUAL LABEL NUMBER'/43X,
     245(1H-)/62X,'PER TRAIN'/62X,9(1H-))
      WRITE(3,270)IHDR(2)
  270 FORMAT(62X,'TRAIN #:  ',I3//10X,'ACTUAL NUMBERS :',43X,'NUMBERS RE
     1AD'/21X,'ON LABEL    :  0   :  1   :  2   :  3   :  4   :  5
     2  :  6   :  7   :  8   :  9   :  10'/10X,106(1H-))
      DO 290 KROW=1,11
      INDEX=KROW-1
      WRITE(3,280)INDEX,(MISRD(KSC,KROW,KCOL),KCOL=1,11)
  280 FORMAT(24X,I2,7X,11(':',I6,1X))
  290 CONTINUE
      DO 310 IJ=1,2
      ITTCAR=ITTCAR+ICARSC(IJ)
      DO 310 NSC=1,5
      DO 300 IC=2,15
  300 ITTNRC(NSC,IC)=ITTNRC(NSC,IC)+NRCAUS(NSC,IC,IJ)
  310 CONTINUE
      DO 320 KSC=1,5
      DO 320 IJ=1,2
      NERR(KSC,IJ)=NREAD(KSC,IJ)+IRDER(KSC,IJ)
  320 NNERR(KSC)=NNERR(KSC)+NERR(KSC,IJ)
      WRITE(3,330)
  330 FORMAT(1H1,51X,'OPERATIONAL SYSTEM EVALUATION'/52X,29(1H-)/63X,'PE
     1R TRAIN'/63X,9(1H-))
      WRITE(3,340)(RCAR(IJ),ICARSC(IJ),ITRD(1,IJ), NERR(1,IJ),          (
     1NRCAUS(1,IC,IJ),IC=2,15),IJ=1,2),RCAR(3),ITTCAR,ISRD(1),NNERR(1),(
     2ITTNRC(1,IC),IC=2,15)
```

```
*****************************************************************
*                                                               *
*****************************************************************
  340 FORMAT(70X,'# OF ERRORS DUE TO NON-READ AND READ ERROR CAUSES'/
     170X,49(1H-)/38X,':# OF LABELS:'/7X,'CAR TYPE: : TOTAL :# OF LABEL
     2S::NON-READ AND:'                 ,39X,':N/O:',18X,':ANOD:NO'/6X,'SCANNE
     3R #1 : CARS  :READ           ;READ ERROR  :DIRT:DAM:MIS:OTHER:UND:PHO
     4S:M FAD:M DAM:MOD:RUST:L BENT:L DIRT:FAIL:LABEL'/6X,119(1H-)
     5/3(6X,A5,6X,':',I5,'  :',I7,5X,':',I7,5X,':',I3,
     6' :',I3,':',I3,':',I4,' :',I3,2(':',I4),' :',I4,' :',I3,2(':',I4),
     72('  :',I4),':',I4,/6X,119(1H-)/),6X,119(1H-))
      DO 360 NSC=2,5
      WRITE(3,350)NSC,(RCAR(IJ),ICARSC(IJ),ITRD(NSC,IJ), NERR(NSC,IJ), (
     1NRCAUS(NSC,IC,IJ),IC=2,15),IJ=1,2),RCAR(3),ITTCAR,ISRD(NSC),
     2NNERR(NSC),(ITTNRC(NSC,IC),IC=2,15)
  350 FORMAT(7X,'CAR TYPE: :',/6X,'SCANNER #',I1,' :'/6X,119(1H-)/3(6X,A
     15,6X,':',I5,'  :',I7,5X,':',I7,5X,':',I3,' :',I3,':',
     2I3,':',I4,' :',I3,2(':',I4),' :',I4,' :',I3,2(':',I4),2('  :',I4),
     3':',I4,/6X,119(1H-)/),6X,119(1H-))
  360 CONTINUE
C INITIALIZE VARIABLES TO BE ACCUMULATED FOR THE NEXT TRAIN
      IPDNOR=0
      IREAD6=0
      DO 370 JLL=1,6
      ITPER(JLL)=0
      NRDER(JLL)=0
  370 NRD(JLL)=0
      DO 380 JLL=1,5
      ISRD(JLL)=0
      NNERR(JLL)=0
      DO 380 KLL=1,2
      ITPD(JLL,KLL)=0
      NREAD(JLL,KLL)=0
      IRDER(JLL,KLL)=0
  380 CONTINUE
      DO 390 NLL=1,2
      ICARSC(NLL)=0
      ITRDOS(NLL)=0
      DO 390 LLL=1,5
      DO 390 MLL=1,17
  390 NRCAUS(LLL,MLL,NLL)=0
      DO 400 NO=1,5
      DO 400 NP=1,11
      DO 400 NS=1,11
  400 MISRD(NO,NP,NS)=0
      ITTCAR=0
      DO 420 NSC=1,5
      DO 410 IC=1,15
  410 ITTNRC(NSC,IC)=0
  420 CONTINUE
```

```
************************************************************************
*                                                                      *
************************************************************************
      ICOUNT=0
      WRITE(3,1530)
C VALUES ON HEADER CARD ARE STORED STARTING IN LOCATION IHDR(1)
      DECODE(40,60,ICARD(1))(IHDR(I),I=1,14)
      GO TO 70
  430 CONTINUE
C VALUES ON CAR DATA CARD ARE STORED STARTING IN LOCATION IDATA(1)
      DECODE(69,440,ICARD(1))(IDATA(I),I=1,55),IDATA(78),IDATA(79)
  440 FORMAT(5(10I1,I2),I4,I5)
C READ THE SECOND CAR DATA CARD
      READ(2,450)IDATA(80),IDATA(81),(IDATA(I),I=56,77),(IDATA(I),I=82,8
     19)
  450 FORMAT(I4,I5,2(10I1,I2),I1,2I2,1X,5I1)
C DETERMINE IF THE TWO CAR DATA CARDS FOR ONE CAR ARE IN THE APPROPRIATE
C    ORDER
      IF(IDATA(78).EQ.IDATA(80).AND.IDATA(79).EQ.IDATA(81).AND.IDATA(78)
     1.EQ.IHDR(2)) GO TO 470
      WRITE(3,460)
  460 FORMAT(1H1,'CARDS NOT IN ORDER')
      GO TO 1690
C DETERMINE CAR TYPE CATEGORY
  470 IF(IDATA(85).EQ.4) GO TO 480
      ICAR=2
      GO TO 490
  480 ICAR=1
C ACCUMULATE THE NUMBER OF CARS SCANNED
  490 ICARSC(ICAR)=ICARSC(ICAR)+1
      ITYPE=IDATA(85)
  500 WRITE(3,510)(IDATA(I),I=56,66),IHDR(2),IDATA(79),CAR(ITYPE)
  510 FORMAT(//51X,'LABEL-SCANNER READABILITY LIMIT'/51X,31(1H-)/58X,'
     1  PER CAR       '/62X, 7(1H-)/52X,'ACTUAL LABEL #: ',10I1,'-',I2/52X
     2,'TRAIN #:   ',I3/52X,'CAR #:   ',I5/
     3                   52X,'CAR TYPE:  ',A10//39X,':  READ      :  ACTUAL
     4 LABEL #  :  PARITY  :',12X,':'/28X,'SCANNER #  :  LABEL #  :  -RE
     5AD LABEL #  :  CHECK   :  NON-READ  :     CAUSES'/23X,94(1H-))
C DETERMINE THE DIFFERENCES BETWEEN WHAT THE SCANNERS
C    READ AND THE ACTUAL LABEL #
      DO 520 I=1,50
      IDIFF(I)=0
      IF(IDATA((55-(((I-1)/10)*10))+I).EQ.IDATA(I+((I-1)/10))) GO TO 520
      IDIFF(I)=1
  520 CONTINUE
C DETERMINE HOW MANY OSCILLOSCOPES WERE USED TO READ CAR LABELS
      IF(IDATA(82).EQ.0) GO TO 990
      DO 810 K=1,5
      IF(K.NE.2.AND.K.NE.3) GO TO 550
      IF(K.EQ.3.AND.IDATA(82).NE.3) GO TO 550
```

```
*************************************************************************
*                                                                       *
*************************************************************************
      IF(K.EQ.2.AND.IDATA(82).NE.2) GO TO 550
C BOTH OSCILLOSCOPES WERE USED AND THE DESCRIPTION OF WHAT THEY READ
C    WILL BE PRINTED AT THE BOTTOM OF THE 'LABEL READABILITY LIMIT PER
C    NON-READ CAR' PRINTOUT
  530 WRITE(3,540) K
  540 FORMAT(36X,I1,'  :',11X,':',18X,':',10X,':',12X,':')
      GO TO 810
  550 WRITE(3,560)K,(IDATA(II+((K-1)*11)),II=1,10)
  560 FORMAT(36X,I1,'  :',10I1,' :     ')
      WRITE(3,570)(IDIFF(JJ+((K-1)*10)),JJ=1,10)
  570 FORMAT(1H+,55X,10I1)
C DETERMINE IF A PARITY CHECK ERROR EXISTS, ACCUMULATE THE NUMBER OF
C    PARITY CHECK ERRORS, AND WRITE THE PARITY CHECK #
  580 IF(IDATA(K*11).EQ.IDATA(66)) GO TO 600
      ITPER(K)=ITPER(K)+1
      WRITE(3,590) IDATA(K*11)
  590 FORMAT(1H+,65X,'    :   ?',I2,4X,':',5X)
      IF(K.NE.2.AND.K.NE.3) GO TO 640
      GO TO 620
  600 WRITE(3,610) IDATA(K*11)
  610 FORMAT(1H+,65X,'    :     ',I2,4X,':',5X)
C DETERMINE IF LABEL WAS INCORRECTLY READ (READ ERROR)
  620 ISDIF(K)=0
      DO 630 I=1,10
  630 ISDIF(K)=ISDIF(K)+IDIFF(I+((K-1)*10))
      IF(ISDIF(K).EQ.0.AND.IDATA(K*11).EQ.IDATA(66)) GO TO 750
C DETERMINE THE CAUSE OF THE NON-READ OR READ ERROR AND THEN DETERMINE
C    IF LABEL WAS NOT READ AT ALL (NON-READ), AND ACCUMULATE THE
C    NUMBER OF NON-READS, READ ERRORS, AND THE ASSOCIATED CAUSES
  640 IF(IDATA(86).EQ.3.AND.K.EQ.3) GO TO 650
      IF(IDATA(89).EQ.6.AND.K.EQ.3.OR.IDATA(89).EQ.6.AND.K.EQ.2) GO TO 6
     160
      GO TO 670
  650 ICAUSE=16
      GO TO 690
  660 ICAUSE=17
      GO TO 690
  670 IF(K.EQ.2) GO TO 680
      ICAUSE=IDATA(83)+1
      GO TO 690
  680 ICAUSE=IDATA(84)+1
  690 ISDATA=0
      DO 700 IK=1,10
  700 ISDATA=ISDATA+IDATA(IK+((K-1)*11))
      IF(ISDATA.EQ.0) GO TO 720
      IRDER(K,ICAR)=IRDER(K,ICAR)+1
      NRCAUS(K,ICAUSE,ICAR)=NRCAUS(K,ICAUSE,ICAR)+1
```

```
********************************************************************************
*                                                                              *
********************************************************************************
      WRITE(3,710)(CAUSE(IND,ICAUSE),IND=1,5)
  710 FORMAT(1H+,93X,':',5A5)
      GO TO 780
  720 NRD(K)=NRD(K)+1
C ACCUMULATE THE NUMBER OF TIMES A LABEL WAS NOT READ AT ALL DUE TO A
C   PARTICULAR NON-READ CAUSE
      NRCAUS(K,ICAUSE,ICAR)=NRCAUS(K,ICAUSE,ICAR)+1
      NREAD(K,ICAR)=NREAD(K,ICAR)+1
      IF(IDATA(K+11).EQ.IDATA(66)) GO TO 730
      WRITE(3,1110)(CAUSE(IND,ICAUSE),IND=1,5)
      GO TO 810
  730 ITPER(K)=ITPER(K)+1
      WRITE(3,740)(CAUSE(IND,ICAUSE),IND=1,5)
  740 FORMAT(1H+,73X,'?',12X,'X',6X,':',5A5)
      GO TO 810
C ACCUMULATE THE NUMBER OF LABELS WHICH WERE READ CORRECTLY
  750 ITRD(K,ICAR)=ITRD(K,ICAR)+1
      IF(K.EQ.2) GO TO 760
C ACCUMULATE THE NUMBER OF SCANNERS ON SIDE 1 WHICH READ A GIVEN LABEL
C   CORRECTLY
      IREAD=IREAD+1
  760 WRITE(3,770)
  770 FORMAT(1H+,86X,7X,':')
C   ACCUMULATE THE NUMBER OF TIMES A PARTICULAR NUMBER WAS READ FOR THE
C   ACTUAL LABEL DIGIT
  780 DO 800 JJ=1,11
  790 IROW=IDATA(55+JJ)+1
      ICOL=IDATA(JJ+((K-1)*11))+1
      MISRD(K,IROW,ICOL)=MISRD(K,IROW,ICOL)+1
  800 CONTINUE
  810 CONTINUE
C DETERMINE THE NUMBER OF OSCILLOSCOPES USED
      IF(IDATA(82).EQ.2) GO TO 820
      IK=3
      GO TO 830
  820 IK=2
C WRITE THE NUMBER OF THE OSCILLOSCOPE AND THE LABEL NUMBERS A GIVEN
C   OSCILLOSCOPE READ
  830 WRITE(3,840) IK,(IDATA(JJ),JJ=67,76)
  840 FORMAT(23X,'OSCILLOGRAM #',I1,'  :',10I1,' :     ')
C DETERMINE IF LABEL DIGITS WERE INCORRECTLY READ (READ ERROR)
      DO 850 I=51,60
      IDIFF(I)=0
      IF(IDATA(I+16).EQ.IDATA(I+5)) GO TO 850
      IDIFF(I)=1
  850 CONTINUE
      WRITE(3,570)(IDIFF(JJ),JJ=51,60)
```

```
*********************************************************************
*                                                                   *
*********************************************************************
C DETERMINE IF A PARITY CHECK ERROR EXISTS AND THEN WRITE THE PARITY
C    CHECK NUMBER A GIVEN OSCILLOSCOPE READ
       IF(IDATA(77)          .EQ.IDATA(66)) GO TO 860
       WRITE(3,590) IDATA(77)
       GO TO 890
  860 WRITE(3,610) IDATA(77)
C DETERMINE IF LABEL WAS INCORRECTLY READ (READ ERROR)
  870 ISDIF(IK)=0
       DO 880 LL=51,60
  880 ISDIF(IK)=ISDIF(IK)+IDIFF(LL)
       IF(ISDIF(IK).EQ.0) GO TO 960
C DETERMINE THE CAUSE OF THE NON-READ OR READ ERROR
C    ALL OF THE NON-READ AND READ ERROR CAUSES AS CODED FOR IDATA(83) AND
C    IDATA(84) HAVE BEEN INCLUDED IN THE LIST OF POTENTIAL NON-READ OR
C    READ ERROR CAUSES, BUT ONLY THE INSTRUMENTATION-RELATED PROBLEMS
C    THAT WERE ACTUALLY ENCOUNTERED IN THE ACI FIELD TEST HAVE BEEN
C    INCLUDED IN THE LIST OF POTENTIAL NON-READ OR READ ERROR CAUSES
  890 IF(IDATA(86).EQ.3.AND.IK.EQ.3) GO TO 900
       IF(IDATA(89).EQ.6.AND.IK.EQ.3.OR.IDATA(89).EQ.6.AND.IK.EQ.2) GO TO
      1910
       GO TO 920
  900 ICAUSE=16
       GO TO 940
  910 ICAUSE=17
       GO TO 940
  920 IF(IK.EQ.2) GO TO 930
       ICAUSE=IDATA(83)+1
       GO TO 940
  930 ICAUSE=IDATA(84)+1
C DETERMINE IF A GIVEN OSCILLOSCOPE DID NOT READ THE LABEL AT ALL
C    (NON-READ)
  940 ISDATA=0
       DO 950 LL=67,76
  950 ISDATA=ISDATA+IDATA(LL)
       IF(ISDATA.NE.0) GO TO 970
C WRITE THE CAUSE OF THE NON-READ
       WRITE(3,710)(CAUSE(IND,ICAUSE),IND=1,5)
       GO TO 980
C ACCUMULATE THE NUMBER OF TIMES A GIVEN OSCILLOSCOPE CORRECTLY READ A
C    CAR LABEL
  960 ITRDOS(IK)=ITRDOS(IK)+1
       WRITE(3,770)
       GO TO 980
  970 WRITE(3,710)(CAUSE(IND,ICAUSE),IND=1,5)
  980 CONTINUE
C DETERMINE WHETHER SCANNER 2 OR SCANNER 3 READ THE MOST INFORMATION
C    CORRECTLY FROM A GIVEN CAR LABEL
```

```
*************************************************************************
*                                                                       *
*************************************************************************
      IF(IDATA(82).EQ.3) GO TO 1580
      IF(IDATA(82).EQ.2) GO TO 1560
  990 DO 1170 K=1,5
C NO OSCILLOSCOPES WERE USED TO READ LABELS
C WRITE THE NUMBERS A GIVEN SCANNER READ FOR THE ACTUAL LABEL NUMBERS
      WRITE(3,560)K,(IDATA(II+((K-1)*11)),II=1,10)
      WRITE(3,570)(IDIFF(JJ+((K-1)*10)),JJ=1,10)
C DETERMINE IF A PARITY CHECK ERROR EXISTS, ACCUMULATE THE NUMBER
C   OF PARITY CHECK ERRORS, AND WRITE THE PARITY CHECK #
      IF(IDATA(K*11).EQ.IDATA(66)) GO TO 1000
      ITPER(K)=ITPER(K)+1
      WRITE(3,590) IDATA(K*11)
      IF(K.NE.2.AND.K.NE.3) GO TO 1060
      GO TO 1010
 1000 WRITE(3,610) IDATA(K*11)
C DETERMINE IF LABEL WAS INCORRECTLY READ (READ ERROR)
 1010 ISDIF(K)=0
      DO 1020 I=1,10
 1020 ISDIF(K)=ISDIF(K)+IDIFF(I+((K-1)*10))
      IF(ISDIF(K).EQ.0.AND.IDATA(K*11).EQ.IDATA(66)) GO TO 1130
C DETERMINE THE CAUSE OF THE NON-READ OR READ ERROR
C  ALL OF THE NON-READ AND READ ERROR CAUSES AS CODED FOR IDATA(83) AND
C   IDATA(84) HAVE BEEN INCLUDED IN THE LIST OF POTENTIAL NON-READ OR
C   READ ERROR CAUSES, BUT ONLY INSTRUMENTATION-RELATED PROBLEMS THAT
C   WERE ACTUALLY ENCOUNTERED IN THE ACI FIELD TEST HAVE BEEN INCLUDED
C   IN THE LIST OF POTENTIAL NON-READ OR READ ERROR CAUSES
      IF(IDATA(86).EQ.3.AND.K.EQ.3) GO TO 1030
      IF(IDATA(89).EQ.6.AND.K.EQ.3.OR.IDATA(89).EQ.6.AND.K.EQ.2) GO TO
     11040
      GO TO 1050
 1030 ICAUSE=16
      GO TO 1080
 1040 ICAUSE=17
      GO TO 1080
 1050 IF(K.EQ.2) GO TO 1070
 1060 ICAUSE=IDATA(83)+1
      GO TO 1080
 1070 ICAUSE=IDATA(84)+1
C DETERMINE IF A GIVEN SCANNER DID NOT READ THE LABEL AT ALL
 1080 ISDATA=0
      DO 1090 IK=1,10
 1090 ISDATA=ISDATA+IDATA(IK+((K-1)*11))
      IF(ISDATA.EQ.0) GO TO 1100
C ACCUMULATE THE NUMBER OF READ ERRORS AND THE NUMBER OF TIMES
C   A LABEL WAS READ INCORRECTLY DUE TO A PARTICULAR NON-READ CAUSE
      IRDER(K,ICAR)=IRDER(K,ICAR)+1
      NRCAUS(K,ICAUSE,ICAR)=NRCAUS(K,ICAUSE,ICAR)+1
```

```
************************************************************************
*                                                                      *
************************************************************************
      WRITE(3,710)(CAUSE(IND,ICAUSE),IND=1,5)
      GO TO 1150
C ACCUMULATE THE NUMBER OF NON-READS AND THE NUMBER OF TIMES A LABEL
C    WAS NOT READ AT ALL DUE TO A PARTICULAR NON-READ CAUSE
 1100 NRD(K)=NRD(K)+1
      NRCAUS(K,ICAUSE,ICAR)=NRCAUS(K,ICAUSE,ICAR)+1
      NREAD(K,ICAR)=NREAD(K,ICAR)+1
      IF(IDATA(K*11).EQ.IDATA(66)) GO TO 1120
      WRITE(3,1110)(CAUSE(IND,ICAUSE),IND=1,5)
 1110 FORMAT(1H+,86X,'X',6X,':',5A5)
      GO TO 1170
 1120 ITPER(K)=ITPER(K)+1
      WRITE(3,740)(CAUSE(IND,ICAUSE),IND=1,5)
      GO TO 1170
C ACCUMULATE THE NUMBER OF TIMES A GIVEN SCANNER CORRECTLY READ A CAR
C    LABEL
 1130 ITRD(K,ICAR)=ITRD(K,ICAR)+1
      IF(K.EQ.2) GO TO 1140
C ACCUMULATE THE NUMBER OF SCANNERS ON SIDE 1 WHICH READ A GIVEN
C    LABEL CORRECTLY
      IREAD=IREAD+1
 1140 WRITE(3,770)
 1150 DO 1160 JJ=1,11
C ACCUMULATE THE NUMBER OF TIMES A PARTICULAR NUMBER WAS READ FOR THE
C    ACTUAL LABEL DIGIT
      IROW=IDATA(55+JJ)+1
      ICOL=IDATA(JJ+((K-1)*11))+1
      MISRD(K,IROW,ICOL)=MISRD(K,IROW,ICOL)+1
 1160 CONTINUE
 1170 CONTINUE
C DETERMINE WHETHER SCANNER 2 OR SCANNER 3 READ THE MOST INFORMATION
C    CORRECTLY FROM A GIVEN CAR LABEL
 1180 IF(ISDIF(2).EQ.0.AND.IDATA(22).EQ.IDATA(66)) GO TO 1380
      IF(ISDIF(3).EQ.0.AND.IDATA(33).EQ.IDATA(66)) GO TO 1400
      IF(ISDIF(2).EQ.0) GO TO 1410
      IF(ISDIF(3).EQ.0) GO TO 1470
      ISUM=0
      DO 1190 ISM=23,32
 1190 ISUM=ISUM+IDATA(ISM)
C IF SCANNER 2 DID NOT READ THE LABEL AT ALL, DETERMINE IF SCANNER 3
C    READ ANY INFORMATION FROM THE LABEL AND IF IT DID WRITE THAT
C    INFORMATION
      IF(IDATA(22).NE.IDATA(66).AND.ISUM.NE.0) GO TO 1270
      ISDATA=0
      DO 1200 ISM=12,21
 1200 ISDATA=ISDATA+IDATA(ISM)
      IF(IDATA(89).EQ.6) GO TO 1210
```

```
**********************************************************************
*                                                                    *
**********************************************************************
      GO TO 1220
 1210 ICAUSE=17
      GO TO 1230
 1220 ICAUSE=IDATA(84)+1
 1230 IF(ISDATA.EQ.0) GO TO 1260
      IF(IDATA(22).NE.IDATA(66)) GO TO 1670
 1240 NRDER(6)=NRDER(6)+1
C WRITE THE LABEL READ BY SCANNER 2, THE DIGITS INDICATING WHETHER THE
C    LABEL DIGITS WERE READ CORRECTLY OR NOT, AND THE PARITY CHECK NUMBER
C    READ BY SCANNER 2
      WRITE(3,1250)(IDATA(LMN),LMN=12,21),(IDIFF(JKL),JKL=11,20),IDATA(2
     12),(CAUSE(IND,ICAUSE),IND=1,5)
 1250 FORMAT(34X,'263  :',10I1,' :     ',10I1,'      :     ',I2,4X,':',12X,'
     1:',5A5)
      GO TO 1520
 1260 IF(ISUM.EQ.0) GO TO 1630
C WRITE THE LABEL READ BY SCANNER 3 AND THE DIGITS INDICATING WHETHER
C    THE LABEL DIGITS WERE READ CORRECTLY OR NOT
 1270 WRITE(3,1280)(IDATA(LMN),LMN=23,32),(IDIFF(JKL),JKL=21,30)
 1280 FORMAT(34X,'263  :',10I1,' :     ',10I1)
      IF(IDATA(86).EQ.3)GO TO 1290
      IF(IDATA(89).EQ.6) GO TO 1300
      GO TO 1310
 1290 ICAUSE=16
      GO TO 1320
 1300 ICAUSE=17
      GO TO 1320
 1310 ICAUSE=IDATA(83)+1
 1320 NRDER(6)=NRDER(6)+1
C DETERMINE IF PARITY CHECK ERROR EXISTS AND WRITE THE PARITY CHECK
C    NUMBER SCANNER 3 READ
      IF(IDATA(33).EQ.IDATA(66)) GO TO 1340
      WRITE(3,1330) IDATA(33),(CAUSE(IND,ICAUSE),IND=1,5)
 1330 FORMAT(1H+,65X,'     :   Y',I2,4X,':',12X,':',5A5)
C ACCUMULATE THE NUMBER OF PARITY ERRORS UNDER THE CONDITION OF THE BEST
C    INFORMATION FROM SCANNER 2 OR SCANNER 3
      ITPER(6)=ITPER(6)+1
      GO TO 1520
 1340 WRITE(3,1350) IDATA(33),(CAUSE(IND,ICAUSE),IND=1,5)
 1350 FORMAT(1H+,65X,'     :     ',I2,4X,':',12X,':',5A5)
      GO TO 1520
C ACCUMULATE THE NUMBER OF NON-READS UNDER THE CONDITION OF THE BEST
C    INFORMATION FROM SCANNER 2 OR SCANNER 3
 1360 NRD(6)=NRD(6)+1
C WRITE THE LABEL READ BY SCANNER 3, THE DIGITS INDICATING WHETHER THE
C    LABEL DIGITS WERE READ CORRECTLY OR NOT, THE PARITY CHECK DIGIT
C    READ BY SCANNER 3 AND THE CAUSE OF THE NON-READ
```

```
*****************************************************************
*                                                               *
*****************************************************************
      WRITE(3,1640)(IDATA(LMN),LMN=23,32),(IDIFF(JKL),JKL=21,30)
      WRITE(3,1650)IDATA(33),(CAUSE(IND,ICAUSE),IND=1,5)
      ITPER(6)=ITPER(6)+1
      GO TO 1520
 1370 FORMAT(1H+,65X,'     :     ',I2,4X,':',5X,'X',6X,':',5A5)
      GO TO 1520
C WRITE THE LABEL READ BY SCANNER 2, THE DIGITS INDICATING WHETHER THE
C    LABEL DIGITS WERE READ CORRECTLY OR NOT, AND THE PARITY CHECK NUMBER
C    READ BY SCANNER 2
 1380 WRITE(3,1390)(IDATA(LMN),LMN=12,21),(IDIFF(JKL),JKL=11,20),IDATA(2
     12)
 1390 FORMAT(34X,'263  :',10I1,' :    ',10I1,'    :    ',I2,4X,':',12X,'
     1:')
C ACCUMULATE THE NUMBER OF TIMES A CAR LABEL WAS READ CORRECTLY UNDER
C    THE CONDITION OF THE BEST INFORMATION FROM SCANNER 2 OR SCANNER 3
      IREAD6=IREAD6+1
      GO TO 1520
C WRITE THE LABEL READ BY SCANNER 3, THE DIGITS INDICATING WHETHER THE
C    LABEL DIGITS WERE READ CORRECTLY OR NOT, AND THE PARITY CHECK NUMBER
C    READ BY SCANNER 3
 1400 WRITE(3,1390)(IDATA(LMN),LMN=23,32),(IDIFF(JKL),JKL=21,30),IDATA(3
     13)
C ACCUMULATE THE NUMBER OF TIMES A CAR LABEL WAS READ CORRECTLY UNDER
C    THE CONDITION OF THE BEST INFORMATION FROM SCANNER 2 OR SCANNER 3
      IREAD6=IREAD6+1
      GO TO 1520
C ACCUMULATE THE NUMBER OF READ ERRORS AND PARITY ERRORS UNDER
C    THE CONDITION OF THE BEST INFORMATION FROM SCANNER 2 OR SCANNER 3
 1410 NRDER(6)=NRDER(6)+1
      ITPER(6)=ITPER(6)+1
 1420 IF(IDATA(89).EQ.6) GO TO 1430
      GO TO 1440
 1430 ICAUSE=17
      GO TO 1450
 1440 ICAUSE=IDATA(84)+1
C WRITE THE LABEL READ BY SCANNER 2, THE DIGITS INDICATING WHETHER THE
C    LABEL DIGITS WERE READ CORRECTLY OR NOT, THE PARITY CHECK NUMBER
C    READ BY SCANNER 2, AND THE CAUSE OF THE READ ERROR
 1450 WRITE(3,1460)(IDATA(LMN),LMN=12,21),(IDIFF(JKL),JKL=11,20),IDATA(2
     12),(CAUSE(IND,ICAUSE),IND=1,5)
 1460 FORMAT(34X,'263  :',10I1,' :    ',10I1,'    :    ',I2,4X,':',12X,'
     1:',5A5)
      GO TO 1520
 1470 NRDER(6)=NRDER(6)+1
      ITPER(6)=ITPER(6)+1
      IF(IDATA(86).EQ.3) GO TO 1480
      IF(IDATA(89).EQ.6) GO TO 1490
```

```
*****************************************************************************
*                                                                           *
*****************************************************************************
      GO TO 1500
 1480 ICAUSE=16
      GO TO 1510
 1490 ICAUSE=17
      GO TO 1510
 1500 ICAUSE=IDATA(83)+1
 1510 WRITE(3,1460)(IDATA(LMN),LMN=23,32),(IDIFF(JKL),JKL=21,30),IDATA(3
     13),(CAUSE(IND,ICAUSE),IND=1,5)
C DETERMINE IF MAXIMUM OF THREE PRINTOUTS PER PAGE OF THE 'LABEL
C    READABILITY LIMIT PER NON-READ CAR' HAS BEEN REACHED
 1520 ICOUNT=ICOUNT+1
      IF(ICOUNT.LT.3) GO TO 1540
      WRITE(3,1530)
 1530 FORMAT(1H1)
      ICOUNT=0
C DETERMINE IF AT LEAST ONE SCANNER ON SIDE 1 READ THE GIVEN CAR
C    LABEL CORRECTLY
 1540 IF(IREAD.EQ.0) GO TO 70
 1550 IRDNOR=IRDNOR+1
      IREAD=0
      GO TO 70
C OSCILLOGRAM 2 WAS USED, SO SCANNER 3 OBTAINED MORE INFORMATION FROM
C    THE GIVEN LABEL THAN SCANNER 2
 1560 IF(ISDIF(3).EQ.0.AND.IDATA(33).EQ.IDATA(66)) GO TO 1400
      IF(ISDIF(3).EQ.0) GO TO 1470
      ISUM=0
      DO 1570 I=23,32
 1570 ISUM=ISUM+IDATA(I)
      IF (ISUM.EQ.0) GO TO 1360
      GO TO 1270
C OSCILLOGRAM 3 WAS USED, SO SCANNER 2 OBTAINED MORE INFORMATION
C    FROM THE GIVEN LABEL THAN SCANNER 3
 1580 IF(ISDIF(2).EQ.0.AND.IDATA(22).EQ.IDATA(66)) GO TO 1380
      IF(ISDIF(2).EQ.0) GO TO 1410
      ISDATA=0
      DO 1590 ISM=12,21
 1590 ISDATA=ISDATA+IDATA(ISM)
C DETERMINE THE CAUSE OF THE NON-READ OR READ ERROR
      IF(IDATA(89).EQ.6) GO TO 1600
      GO TO 1610
 1600 ICAUSE=17
      GO TO 1620
 1610 ICAUSE=IDATA(84)+1
 1620 IF(ISDATA.NE.0) GO TO 1660
 1630 NRD(6)=NRD(6)+1
      ITPER(6)=ITPER(6)+1
      WRITE(3,1640)(IDATA(LMN),LMN=12,21),(IDIFF(JKL),JKL=11,20)
```

```
***************************************************************************
*                                                                         *
***************************************************************************
 1640 FORMAT(34X,'263  :',10I1,' :     ',10I1)
      WRITE(3,1650) IDATA(22),(CAUSE(IND,ICAUSE),IND=1,5)
 1650 FORMAT(1H+,65X,'     :   ?',I2,4X,':',5X,'X',6X,':',5A5)
      GO TO 1520
 1660 IF(IDATA(22).EQ.IDATA(66)) GO TO 1240
 1670 WRITE(3,1680)(IDATA(LMN),LMN=12,21),(IDIFF(JKL),JKL=11,20),IDATA(2
     12),( CAUSE(IND,ICAUSE),IND=1,5)
 1680 FORMAT(34X,'263  :',10I1,' :     ',10I1,'     :   ?',I2,4X,':',12X,'
     1:',5A5)
      NRDER(6)=NRDER(6)+1
      ITPER(6)=ITPER(6)+1
      GO TO 1520
C PRINTOUTS FOR THE LAST TRAIN
C DETERMINE THE NUMBER OF TIMES FOR A GIVEN TRAIN, SCANNER K READ
C    A CAR LABEL CORRECTLY
 1690 DO 1700 IJK=1,5
      ISRD(IJK)=0
 1700 ISRD(IJK)=ITRD(IJK,1)+ITRD(IJK,2)
C CALCULATE THE PROPORTION OF LABELS WHICH WERE READ CORRECTLY
      PLBRD(1)=FLOAT(ISRD(1))/IHDR(11)
      PLBRD(2)=FLOAT(ISRD(2))/IHDR(12)
      DO 1710 IJK=3,5
 1710 PLBRD(IJK)=FLOAT(ISRD(IJK))/IHDR(11)
 1720 DO 1730 IJK=1,5
C CALCULATE THE PROPORTION OF CARS WHICH WERE READ CORRECTLY
 1730 PRD(IJK)=FLOAT(ISRD(IJK))/IHDR(10)
      WRITE(3,140)
      IWTHR=IHDR(9)+1
      IDIR=IHDR(6)+1
      DO 1740 KSC=1,5
 1740 NRDER(KSC)=IRDER(KSC,1)+IRDER(KSC,2)
      WRITE(3,160)IHDR(2),(WTHR(II,IWTHR),II=1,3),IHDR(3),IHDR(10),IHDR(
     14),IHDR(5)
      PRD(6)=FLOAT(IREAD6)/IHDR(10)
      IF(IHDR(11).GT.IHDR(12)) GO TO 1750
      PLBRD(6)=FLOAT(IREAD6)/IHDR(12)
      GO TO 1760
 1750 PLBRD(6)=FLOAT(IREAD6)/IHDR(11)
 1760 WRITE(3,190)IHDR(11),IHDR(8),IHDR(12),TRDIR(IDIR),IRDNOR,ISRD(2)
      WRITE(3,200)(IK,ISRD(IK),NRD(IK),NRDER(IK),ITPER(IK),             P
     1LBRD(IK),PRD(IK),IK=1,5)
      WRITE(3,210)IREAD6,NRD(6),NRDER(6),ITPER(6),PLBRD(6),PRD(6)
      POSSC2=FLOAT(ISRD(2)+ITRDOS(1))/IHDR(12)
      POSSC3=FLOAT(ISRD(3)+ITRDOS(2))/IHDR(11)
      WRITE(3,220)
      WRITE(3,230)IHDR(2),ISRD(2),ISRD(3),IHDR(3),ITRDOS(1),ITRDOS(2),IH
     1DR(4),IHDR(5),PLBRD(2),PLBRD(3),IHDR(11),IHDR(12),POSSC2,POSSC3
```

```
*********************************************************************
*                                                                   *
*********************************************************************
 1770 DO 1790 KSC=1,5
      IF(KSC.EQ.2.OR.KSC.EQ.4) GO TO 1780
      WRITE(3,1530)
 1780 WRITE(3,260)KSC
      WRITE(3,270)IHDR(2)
      DO 1790 KROW=1,11
      INDEX=KROW-1
      WRITE(3,280)INDEX,(ISRD(KSC,KROW,KCOL),KCOL=1,11)
 1790 CONTINUE
 1800 DO 1820 IJ=1,2
      ITTCAR=ITTCAR+ICARSC(IJ)
      DO 1820 NSC=1,5
      DO 1810 IC=2,15
 1810 ITTNRC(NSC,IC)=ITTNRC(NSC,IC)+NRCAUS(NSC,IC,IJ)
 1820 CONTINUE
      DO 1830 KSC=1,5
      DO 1830 IJ=1,2
      NERR(KSC,IJ)=NREAD(KSC,IJ)+IRDER(KSC,IJ)
 1830 NNERR(KSC)=NNERR(KSC)+NERR(KSC,IJ)
      WRITE(3,330)
      WRITE(3,340)(RCAR(IJ),ICARSC(IJ),ITRD(1,IJ), NERR(1,IJ),             (
     1NRCAUS(1,IC,IJ),IC=2,15),IJ=1,2),RCAR(3),ITTCAR,ISRD(1),NNERR(1),(
     2ITTNRC(1,IC),IC=2,15)
      DO 1840 NSC=2,5
      WRITE(3,350)NSC,(RCAR(IJ),ICARSC(IJ),ITRD(NSC,IJ), NERR(NSC,IJ), (
     1NRCAUS(NSC,IC,IJ),IC=2,15),IJ=1,2),RCAR(3),ITTCAR,ISRD(NSC),
     2NNERR(NSC),(ITTNRC(NSC,IC),IC=2,15)
 1840 CONTINUE
      STOP
      END
```

E.5 COMPUTER OUTPUT FORMAT

The following is the computer output format for OACI Chicago Test data analysis.

OPERATIONAL SYSTEM EVALUATION

PER TRAIN

Train No.:

Date:

Time:

Train Speed:

Train Direction:

Weather:

Total Cars:

Total Labeled Cars (North):

Total Labeled Cars (South):

No. of Labels Read Correctly by Scanner #1, 3, 4, 5 (North):

No. of Labels Read Correctly by Scanner #2 (South):

Scanner #	Total Read	Total Non-Read	Read Errors	Parity Errors	Proportion of Labels Read	Proportion of Cars Read
1						
2						
3						
4						
5						
2 & 3						

OPERATIONAL SYSTEM EVALUATION

PER ENTIRE EXPERIMENT

Car Type: Scanner #1	Total Cars	No. of Labels: Read	No. of Labels: Non-Read	No. of Cars: No Label	Dirt	Damage	Non-Read Causes Misapplication	Other	Undetermined
Flat									
Other									
Total									
Car Type: Scanner #4									
Flat									
Other									
Total									

LABEL-SCANNER READABILITY LIMIT

PER NON-READ CAR

Scanner #	Read Label #	Actual Label # Read Label #	Parity Check	Non-Read	Car Type	Causes
1						
2						
3						
4						
5						
Oscillogram						

LABEL-SCANNER READABILITY LIMIT

PER TRAIN

Train No.:

Date:

Time:

Total Labeled Cars (North):

Total Labeled Cars (South):

Total Read by Scanner #3:

Total Read by Oscillogram:

Proportion of Labels Read by Scanner #3:

Proportion of Labels Read by Scanner #3 and Oscillogram:

APPENDIX F

COMMENTS ON THE PARAMETERS USED IN THE CHICAGO TEST

An important consideration in an assessment of the utilization of a parameter (such as readability) as an indicator of a trend, is the method of data collection and processing. All data must be compatible so that intercomparisons between parameters will have statistical significance. To this end, we will begin with an assessment of the derivation of the parameters used.

F.1 READABILITY

Readability is a measurement of scanner operational system performance, or an indicator of the ability of a scanner to read labels. It is based on the number of cars scanned, disregarding locomotives, cabooses and non-labeled cars. The expression of readability is given by Equation (1) in Section 4.5.

A readability can be derived from every train scanned. If, as in the Chicago Test, a number of scanners scan the same labels, their readabilities for each train can be compared.* For a number of trains, all read by these scanners, the mean readabilities of the different scanners can be compared, and since the labels scanned are the same for each scanner, differences in mean readabilities reflect a difference between scanner operational system performance. From these results, decisions regarding the cost-effectiveness of modifications to the standard scanner or multiplexing of scanners can be reached. It is important that the mean readabilities be derived in the same manner for all scanners. A weighted mean readability is expressed by

---

*Note that Scanners #1, 3, 4 and 5 scanned the same label population. Scanner #2 scanned the label population on the other side of the cars.

$$\bar{R} = \frac{\sum_{i=1}^{N} A_i}{\sum_{i=1}^{N} (T_i - a_i)} \qquad \text{(F-1)}$$

where A_i = total number of freight cars correctly read in train i

T_i = total number of freight cars scanned in train i

a_i = total number of unlabelled freight cars in train i

The arithmetic mean readability is expressed by:

$$\bar{R} = \sum_{i=1}^{N} \frac{R_i}{N} \qquad \text{(F-2)}$$

where R_i is the readability of each one of the total number N of trains scanned. Although in the Chicago Test data, the difference between these two means is not large (at most a few tenths of one percent), the difference in other cases can be significant. As an illustration of this fact, consider three trains A, B, and C with 100, 25 and 20 labelled freight cars scanned. Suppose the numbers of these cars read correctly are 90, 5 and 10 respectively. The readabilities of each train are 90%, 20% and 50%, giving an arithmetic mean of 53.3%. However, taking the weighted mean, the readability is 72.4%.

The difference between the weighted mean and the arithmetic mean in this case is large. The arithmetic mean implies that the scanner reads only about half of the cars correctly, or about 77 of the cars in the trains, whereas 105 of these cars are actually read correctly. The mean and standard deviation of R for each scanner takes into account "all the cars in all the trains" rather than "all the trains" (which would wrongly imply all trains had the same number of cars).

Taking into account all the trains in the Chicago Test, the weighted mean and arithmetic mean for Scanner #1 are 85.5 and 85.6 percent, respectively, that means a difference of only 0.1 percent. The difference between these two values corresponding to Scanner #2 is less than 0.1 percent; to Scanner #3, 0.3 percent; to Scanner #4, 0.1 percent; and to Scanner #5, 0.2 percent. That means that the results given in this report came out practically the same using the weighted or arithmetic mean. If in general the weighted mean readability is more representative of the operational system performance than the arithmetic mean values then why was the latter used at the Chicago Test? The answer is that the results of the test were reported in a quasi-real time to the RPI/AAR/FRA Steering Committee. Therefore, we had to reduce the data on a train-by-train basis. A benefit of computing on a train basis is also that we could relate readabilities and characteristics of trains.

F.2 LABEL-SCANNER READABILITY

The label scanner readability, R', is given by Equation (5). The difference R' - R gives an indication of how much information can be obtained from labels not within the specifications of the AAR. O is as defined for Equation (5).

$$R' - R = \frac{A + O}{T - a} - \frac{A}{T - a} = \frac{O}{T - a} \qquad \text{(F-3)}$$

The same considerations made on the arithmetic and weighted mean $\bar{R}$ are applicable to $\bar{R}'$.

F.3 SCANNER-SYSTEM PERFORMANCE LIMIT

The scanner system performance limit R_{limit} given by Equation (6) evaluates capabilities of OACI as a principle of operation. The percentage of non-read and error-read related to the operating environment is given by $100 - R_{limit}$. The percentage of non-read and error-read related to management is given by $R_{limit} - R'$.

The same considerations made on the arithmetic and weighted mean $\bar{R}$ are applicable to $\bar{R}_{limit}$.

APPENDIX G

PHOTOGRAPHS OF OACI LABELS AFFECTED BY NON-READ AND/OR ERROR-READ CAUSES

From the OACI label photographs obtained at the Chicago Test and from labels sent to TSC by different railroads, representative cases of non-read and error-read causes which affected the labels are given. The classification given in Section 4.8 is used to identify the causes.

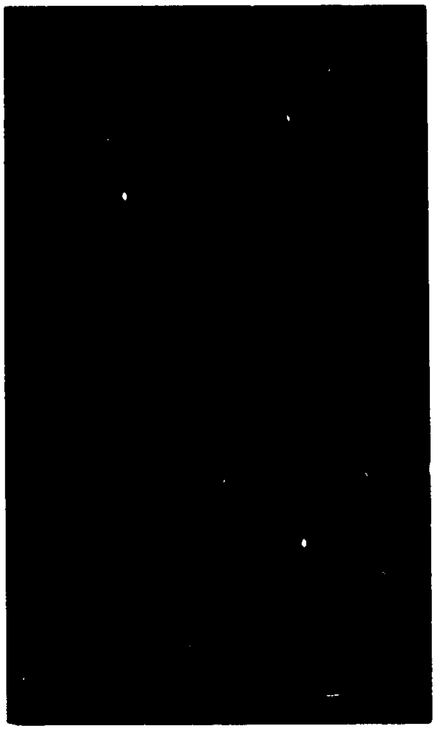

Figure G-1. Label affected by heavy reddish dirt (Cause #4). The new S.ART module at the bottom of the label was added for comparison purposes. (Label courtesy of the Canadian National Railroad.)

Reproduced from best available copy.

Figure G-2. Label affected by dirt (Cause #4). This label was mounted on u hopper car dedicated to coal service. The new START module was added at the bottom of the labe! for comparison purposes. (Label courtesy of the Chicago and North Western Transportation Company.)

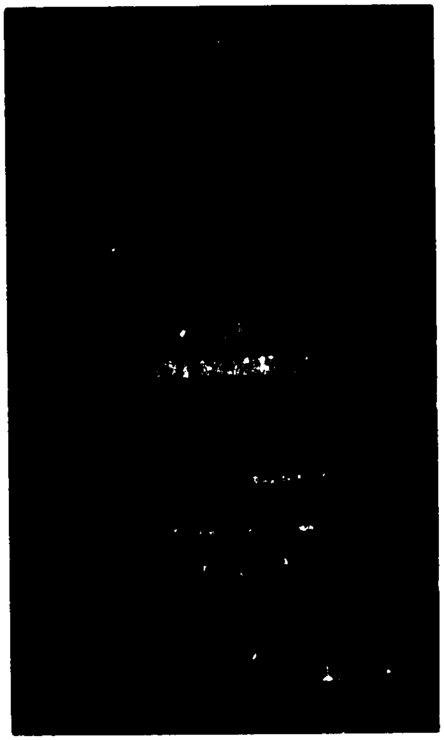

Figure G-3. Label affected by dirt (Cause #4). (Label courtesy of Atchison, Topeka and Santa Fe Railway Company.)

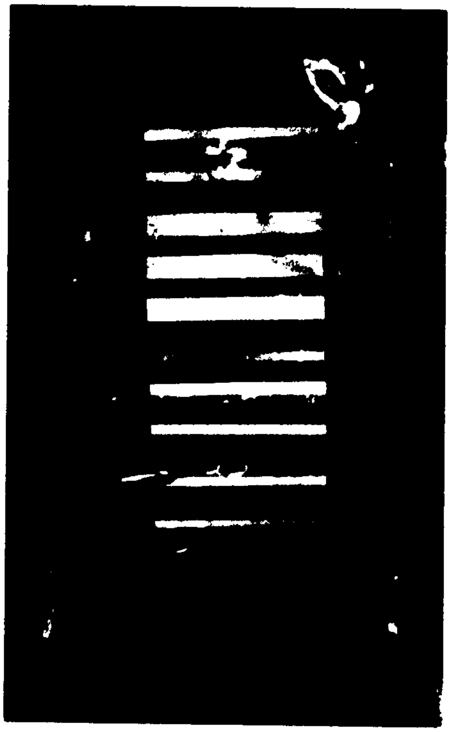

Figure G-4. Label affected by damage on label as well as damage on backing plate (Cause #5). This label was mounted on a gondola. (Label courtesy of Atchison, Topeka and Santa Fe Railway Company.)

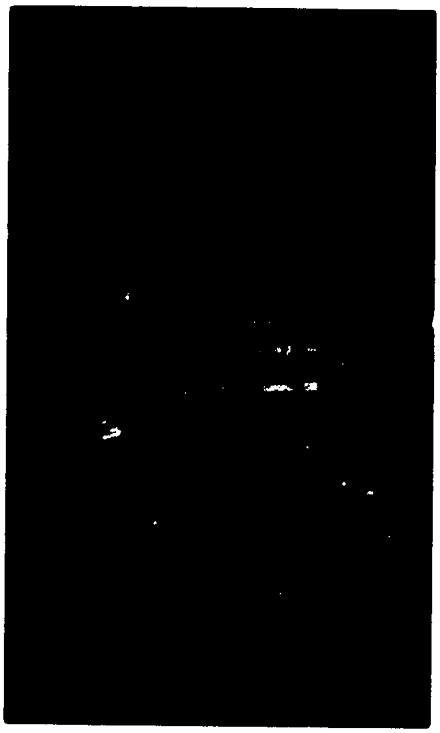

Figure G-5. Label affected by damage (Cause #5). This label was mounted on a tank car. (Label courtesy of Norfolk and Western Railroad.)

Reproduced from best available copy.

Figure G-6. Label affected by damage (Cause #5). The damage consists of a deep scratch crossing all modules from the top to the bottom of the label. This label was mounted on a box car. (Label from the OACI Chicago Test.)

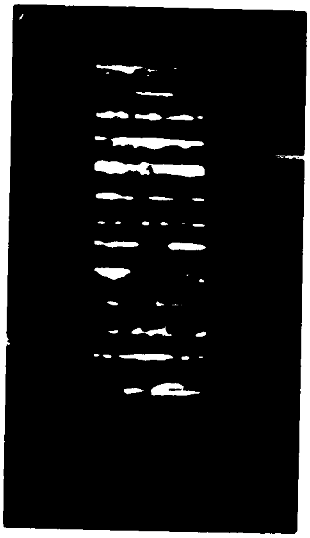

Figure G-7. Label affected by severe burns (Cause #7) when the car was heated in an oven. This label was mounted on a gondola. (Label from Train #15, OACI Chicago Test.)

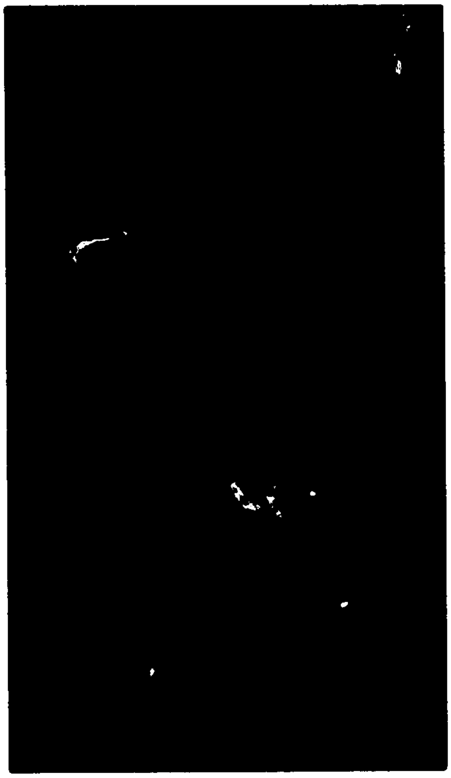

Figure G-8. Label affected by phosphate accumulation (Cause #9) partially cleaned on the central portion. (Label courtesy of the Canadian Pacific Railroad.)

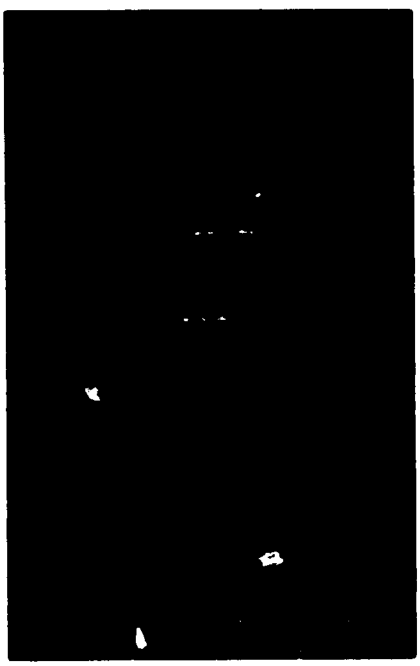

Figure G-9. Label affected by fading due to excessive cleaning (Cause #10). Notice the effect of cleaning around the back plate. This label was mounted on a box car. (Label from Train #10, OACI Chicago Test.)

Reproduced from best available copy.

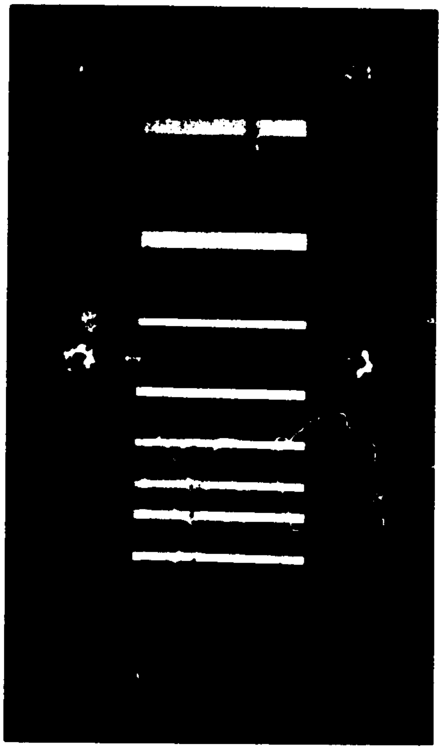

Figure G-10. Label affected by damaged modules (Cause #11). This label was mounted on a box car. (Label courtesy of the Atchison, Topeka and Santa Fe Railway Company).

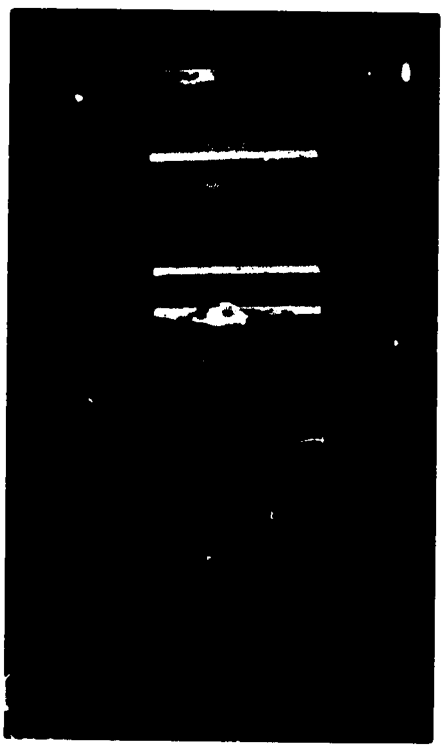

Figure G-11. Label affected by damaged modules (Cause #11). (Label courtesy of the Atchison, Topeka and Santa Fe Railway Company.)

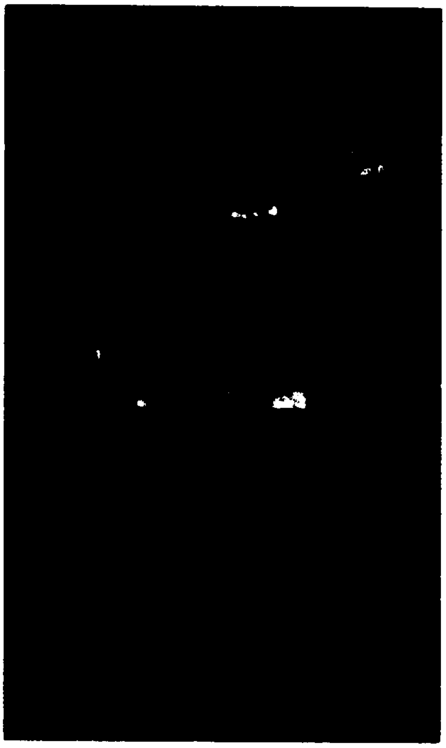

Figure G-12. Label affected by the replacement of three full modules (Cause #12). The new modules are, counting from the top, the first red, the first blue and the second white. This label was mounted on a car carrier. (Label courtesy of Norfolk and Western Railroad.)

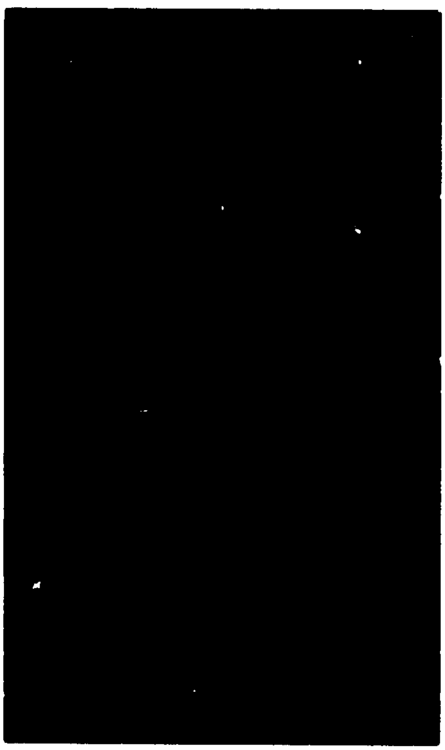

Figure G-13. Label affected by rusted backing plate (Cause #13). This label was mounted on a covered hopper car. (Label courtesy of Canadian National Railroad.)

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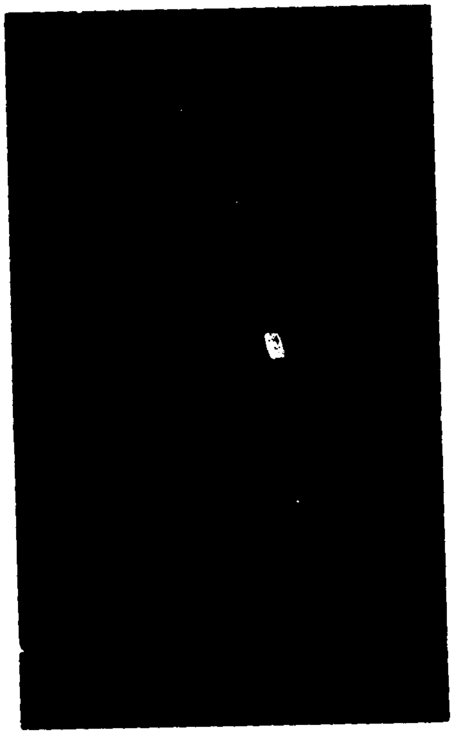

Figure G-14. Label affected by bent back plate and dirt (Cause #14). The new START module at the bottom of the label was added for comparison purposes. This label was mounted on a flat car. (Label courtesy of Chicago and North Western Transportation Company.)

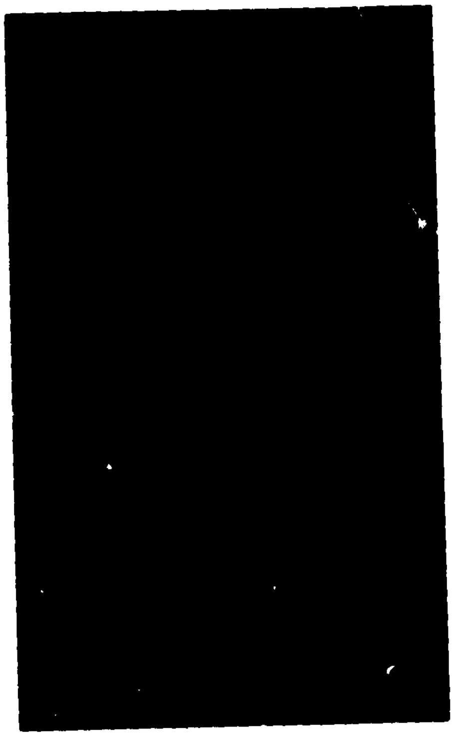

Figure G-15. Label affected by dirt (Cause #15). The new START module at the bottom of the label was added for comparison purposes. This label was mounted on a flat car. (Label courtesy of Chicago and North Western Transportation Company.)

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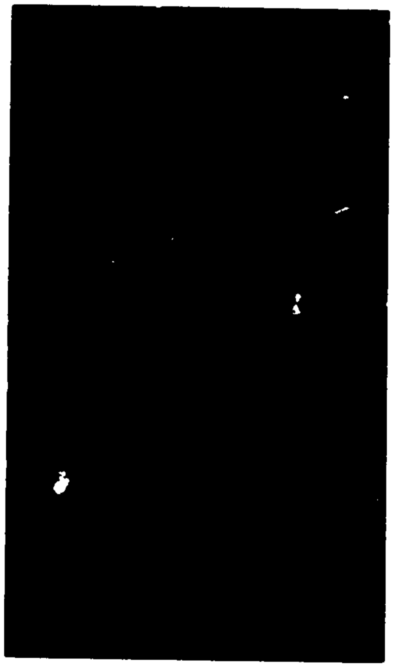

Figure G-16. Black anodize failure on backing plate (Cause #16). This label was mounted on a box car. (Label from OACI Chicago Test.)