MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

25 G - 11

DATA TRANSMISSION TESTING FROM DONNELLY FLATS, ALASKA, TO SUNNYVALE, CALIFORNIA OVER A NETWORK OF CARRIER EQUIPMENT

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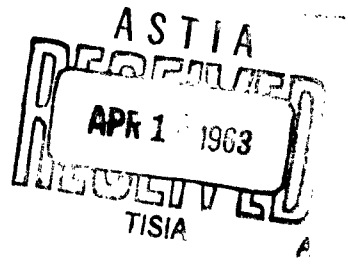
LEXINGTON MASSACHUSETTS



ABSTRACT

This report presents the summary of data measurements made from 27 June 1962 to 28 July 1962 evaluating the coded biphase data modem over a combination of K-carrier, TD-2 (microwave), and submarine cable from Donnelly Flats, Alaska, to Sunnyvale, California.

Occurrence of errors is related as much as possible to the daily log and the record of equipment failures, interruptions, and circuit failures.

Introduction

The circuit was a combination of K-carrier, TD-2 (microwave), and submarine cable, from Donnelly Flats, Alaska, to Sunnyvale, California. It was under test to establish error rates from the period 27 June to 28 July 1962.

The Automatic Digital Data Error Recorder (ADDER)[1] was used to record error distributions.

The data transmission modem was COBI (coded biphase) with a data rate of 1200 bits per second with a 16-bit block length.

All testing was accomplished with the cooperation of the American Telephone and Telegraph Company and the Alaskan Telephone Company.

Testing was performed for a 24-hour-per-day period.

The ADDER was internally self-tested to check its performance daily.

The resultant punched paper tape was processed by the 7090 computer to obtain the averages and time distribution of errors.

Figure 1 describes the error rates obtained on a daily basis.

Included are:

(1) The dates during which statistics were measured,

(2) Total time of operation,

(3) The block error rate in blocks in error per minute,

(4) The bit error rate in bits in error per 10^5 bits transmitted,

(5) The average number of bits in error in a block in error,

(6) Average block error per minute,

(7) Gained syncs per minute,

(8) Lost syncs per minute, and

(9) Gained totals of the previous quantities.

Although no criterion of goodness has been established for the average error rate of the data system, it is generally agreed that an error rate of one bit error per 10^5 bits is representative and satisfactory for comparison.

Description of Circuit

A complete layout of the circuit used for the test is shown in Fig. 2. Digital data were transmitted from

(a) Donnelly Flats via Delta Junction over 19H44 cable, a distance of 16.3 miles.

(b) Delta Junction via Smugglers Cove over TD-2 (microwave) and tropospheric scatter equipments, a distance of 1,341.5 miles.

(c) Smugglers Cove via Annette Island over TD-2, a distance of 5.6 miles.

(d) Annette Island via Port Angeles over L-carrier on the Alaskan submarine cable, a distance of 877 miles.

(e) Port Angeles via Seattle over TD-2, a distance of 25 miles.

(f) Seattle via Oakland on K- and L-carrier on coaxial cable, a distance of 359.2 miles.

(g) Oakland via San Jose on L-carrier on coaxial cable, a distance of 42.5 miles.

(h) San Jose to Sunnyvale on 19H88 and 22H88 cable, a distance of 13.9 miles.

The receiving equipment was located at Sunnyvale.

The control station for the over-all circuit was at San Jose.

The complete circuit length was 2,680 miles.

COBI Data System

The COBI transmitter was located at Donnelly Flats. A fixed word was obtained using the Transword generator. The receiver was located at Sunnyvale, with ADDER as shown in Fig. 3.

A complete description of the COBI modem is given in Lincoln Laboratory Technical Report 263.[2]

Test Conditions

The output of the COBI transmitter was set at 0 dbm. The receiver level was set at -12 dbm to -15 dbm.

Operation throughout the test was at 1200 bits per second with 16 bits per block.

Processing

Recording of the error data was accomplished with the ADDER.

The ADDER revealed the following information about a block in error:

1. the 16 bits of the incorrect block,
2. time of occurrence,
3. the loss or gain of sync pulses in the sync channel of the output of the COBI receiver, and
4. additional information about the performance of external error detectors (such as parity).

Dropout Measurements

Dropouts were measured throughout the test. Level, signal, time of dropout occurrence were recorded by a Brush oscillograph for a 24-hour-per-day period.

Figure 4 shows the number of dropouts for a particular date, total time of dropouts in seconds, and the number of blocks lost due to this dropout phenomena.

Analysis

Processing

Error data were accumulated over a period of one month for a total of 609.8 hours.

The resulting punched paper tape from the ADDER was processed by the IBM 7090 computer to obtain totals, averages, and time distributions of the errors.

Error Rates

Figure 1 shows the error rates obtained on a daily basis. Included are:

(1) The dates on which measurements were taken,

(2) The total time of operations,

(3) The block error rate in blocks in error per minute,

(4) The block error rate in bits in error per 10^5 bits transmitted,

(5) The average of bits in errors in a block in error, and

(6) The grand averages of totals of the foregoing quantities.

Daily and Weekly Distribution of Errors

Error Rate

Both the bit and block error rates tabulated in Fig. 1 are re-plotted as bar graphs in Figs. 5 and 6. The error patterns revealed are interesting. Peaks, which correspond to high-error days, appear to be

random on all curves. The curves representing bit error rates are similar in shape to corresponding curves for block error rates.

Bit Errors per Block Error

Figure 7 shows the percentage (obtained from daily averages) of block errors as a function of bit errors per block.

The averages represented are weighted.

It will be noted that a single bit error per block error occurs most frequently.

Temporal Analysis

Figure 8 shows the variation of block error rate with the day of the week. The minimum and maximum curves represent the lowest and highest values, respectively.

Minute-by-Minute Distribution

In order to describe the characteristics of a burst, the data were analyzed in intervals of twenty minutes.

Figure 9 shows the block error rate as a function of the time of day. Figure 10 shows the block errors as a function of the length of the test.

The occurrence of consecutive minutes in error is shown in Fig. 11. The occurrence of consecutive error-free periods is shown in Fig. 12.

Consecutive Block Error Analysis

The average number of bit errors per block error is described as a function of error rate in Fig. 13.

Bit Error Distribution

The percentage of occurrence of consecutive bits in error within a block is plotted in Fig. 14.

Figures 15 and 16 show the probabilities of a bit lost or a bit gained as a function of bit position.

A gained bit is defined as a conversion from a space (zero) to a mark (one). A lost bit is the converse. The probability of a bit being lost or gained depends on the position of the bit block being transmitted. These probabilities for lost or gained bits are reflected in the graphs.

Block Start Errors

Figure 17 shows the variation of block start error day by day. A lost start is defined as a missing block start. A gained block start is a spurious or additional block start signal.

Parity Analysis

An analysis of the blocks in error was made in order to determine the effectiveness of a simple parity check. (See Fig. 18.) For this test a simple parity check would have been 64 percent effective in detecting block errors of two blocks per minute.

Acknowledgement

The Laboratory is indebted to the Alaskan Communication Service, the Pacific Telephone and Telegraph Company, and the American Telephone and Telegraph Company for their full cooperation and for their permission to publish these results.

REFERENCES

1. E. J. Hofmann, "Automatic Digital-Data-Error Recorder," IRE Transactions on Instrumentation, I-10, No. 1, pp. 27-31 (June, 1961).

2. K. H. Morey, "The COBI Data Transmission Modem," Lincoln Laboratory Technical Report No. 263 (23 May 1962).

PLG:jmc

APPENDIX

Log of Donnelly Flats, Alaska, to Sunnyvale, California

GD-70183 - 6/27/62 to 7/28/62

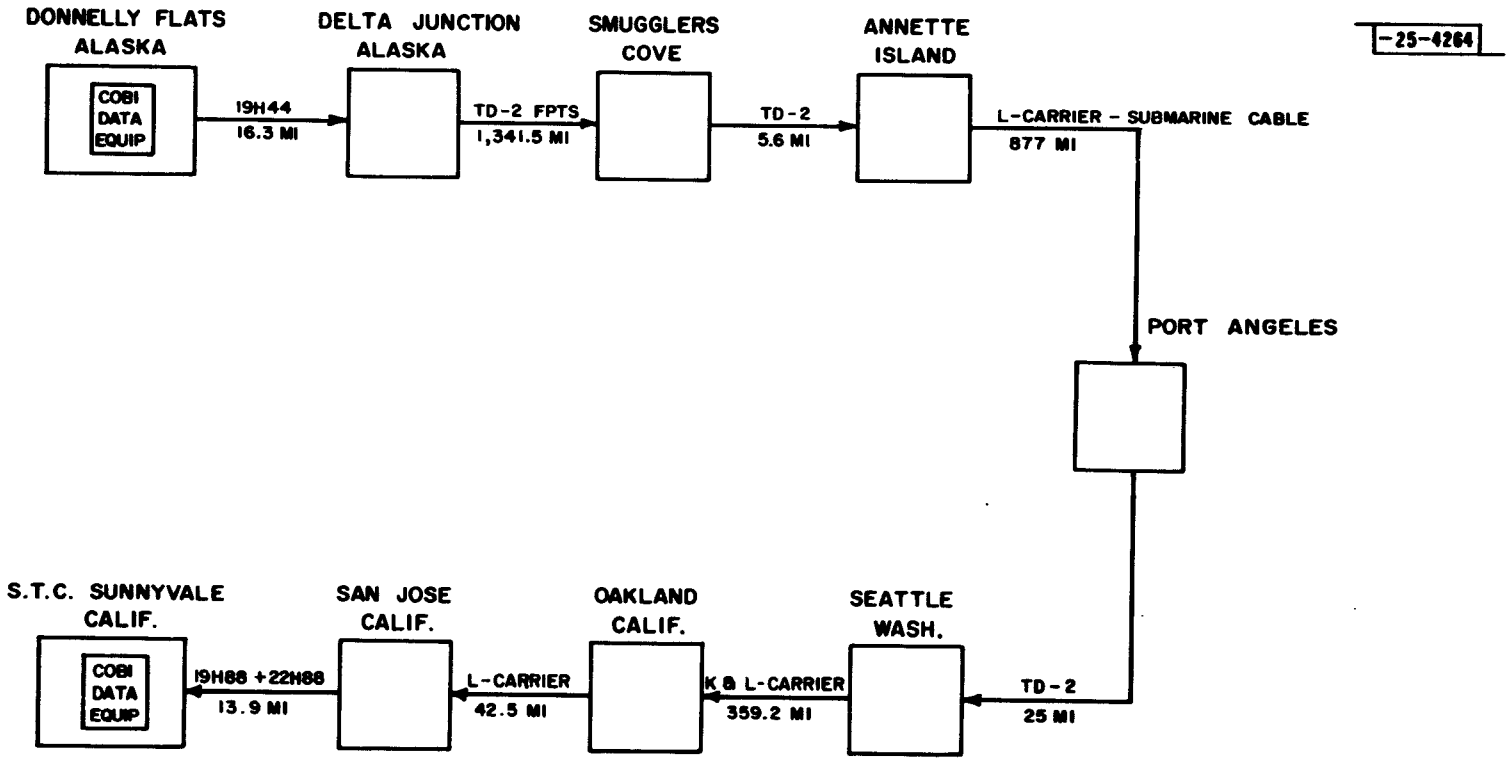
Date	Time	Comment
6/27/62	1300	Test started
6/28/62	0955	Loss of power, failure of circuit breaker.
	1015	Restarted test
6/29/62	0830	Stopped test
	0835	Restarted test
6/30/62	0845	Stopped test
	0850	Restarted test
7/2/62	0845	Stopped test, punch clutch sticking.
	0930	Restarted test
	1305	Signal level low 0.1 to 0.15 volt peak to peak. Telephone Company notified.
7/3/62	0915	Stopped test
	0925	Restarted test
	1305	Line out; reported trouble to San Jose toll test center.
	1415	Line returned. K-carrier failure between Oakland and Seattle, reported by San Jose toll test center.
7/4/62	1015	Stopped test
	1020	Restarted test
	1030	Brush recorder in trouble, drive wheel worn.
7/5/62	0930	Punch running open due to power failure. Stopped test.
	1000	Restarted test
7/6/62	1005	Stopped test
	1015	Restarted test
7/7/62	0915	Stopped test
	0920	Restarted test
7/8/62	1100	Stopped test
	1105	Restarted test

Date	Time	Comment
7/9/62	0955	Stopped test
	1000	Restarted test
7/10/62	0840	Stopped test. Power failure during night.
	0845	Restarted test
7/11/62	1335	Released circuit to San Jose toll center for change of carrier equipment at the Telephone Company's request.
	1445	Circuit returned, faulty carrier equipment between Seattle and Oakland.
7/13/62	1010	Stopped test
	1015	Restarted test
7/14/62	0710	Stopped test
	1715	Restarted test
7/15/62	0955	Stopped test
	1000	Restarted test
7/16/62	0925	Stopped test
	0930	Restarted test
7/17/62	0940	Stopped test
	0945	Restarted test
7/18/62	0945	Stopped test
	0950	Restarted test
	2150	Stopped test. Punch running open in ADDER due to circuit breaker overload caused from local office coffee pot being plugged in.
	2155	Restarted test
7/19/62	0840	Stopped test
	0845	Restarted test
	1455	Stopped test
	1503	Reset ADDER and restarted test
	2055	Stopped test, punch running open circuit breaker overload.
	2100	Restarted test
7/20/62	0910	Stopped test
	0915	Restarted test
	1915	Stopped test, pickup reel full.
	1920	Restarted test
7/21/62	1425	Stopped test
	1430	Restarted test

Date	Time	Comment
7/22/62	1325	Stopped test
	1335	Restarted test
7/23/62	0910	Stopped test, punch running away because of power failure.
	0915	Restarted test
7/24/62	0905	Stopped test
	0910	Restarted test
7/25/62	0910	Stopped test, punch operating continuously.
	0920	Restarted test
7/26/62	0915	Stopped test, tape broken sometime during the night.
	0920	Restarted test
	1400	Stopped test, punch running open
	1405	Restarted test
7/27/62	0905	Stopped test
	0915	Restarted test
7/28/62	0200	Stopped test. Equipment to be ready for packing.

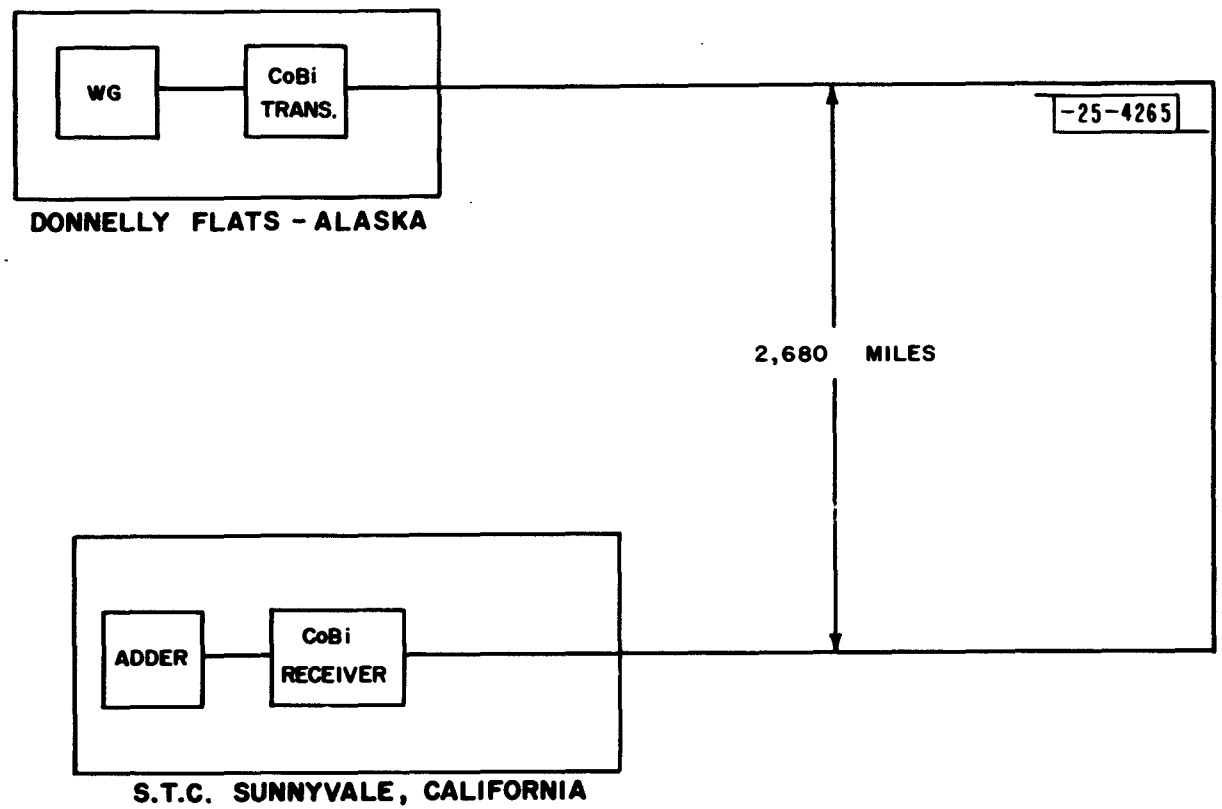
Date	Time Hours	Block Errors	L.S.	G.S.	Average bits in Error per Block in Error	Average bit error rate in parts in 10^5
6/26-27/62	17.9	0.427	0.261	0.090	7.014	4.157
6/27-28/62	23.4	0.311	0.151	0.047	5.152	2.222
6/28-29/62	16.1	0.273	0.175	0.058	6.141	2.327
6/29-30/62	24.5	0.363	0.090	0.100	3.727	1.881
6/30 7/2/62	47.9	0.106	0.021	0.024	2.659	0.391
7/2-3/62	24.3	0.642	0.526	0.051	7.246	6.465
7/3-4/62	24.1	0.334	0.254	0.041	7.248	3.360
7/4-5/62	7.5	0.027	0.002	0.002	1.747	0.065
7/5-6/62	24.2	0.105	0.019	0.025	2.934	0.427
7/6-7/62	23.0	0.147	0.017	0.038	1.994	0.407
7/7-8/62	25.7	0.031	0.003	0.005	1.770	0.076
7/8-9/62	22.8	0.117	0.009	0.020	1.693	0.275
7/9-10/62	21.3	0.236	0.037	0.047	2.493	0.817
7/10-11/62	24.6	0.155	0.032	0.035	2.535	0.546
7/11-12/62	23.2	0.225	0.027	0.052	2.047	0.639
7/12-13/62	24.5	0.211	0.140	0.033	6.952	2.035
7/13-14/62	20.8	0.330	0.053	0.068	2.497	1.143
7/14-15/62	25.3	0.532	0.051	0.103	2.105	1.554
7/15-16/62	23.6	2.013	0.368	0.442	3.015	8.427
7/16-17/62	24.4	0.325	0.072	0.078	3.436	1.551
7/17-18/62	23.9	0.144	0.032	0.022	3.351	0.670
7/18-19/62	10.8	0.130	0.051	0.037	4.748	0.855
7/19-20/62	12.2	0.301	0.234	0.012	6.964	2.911
7/20-21/62	19.2	0.030	0.003	0.016	2.440	0.100
7/22-23/62	10.9	0.038	0.002	0.009	1.800	0.096
7/23-24/62	22.4	1.200	0.918	0.243	8.305	13.838
7/24-25/62	21.4	0.710	0.173	0.158	4.420	4.357
7/27-28/62	19.5	1.031	0.236	0.346	4.326	6.193
Totals	609.8	0.383	0.141	0.080	4.565	2.247

Figure 1 Error Rates



TOTAL CIRCUIT LENGTH - 2,680. MILES
19H44, 22H88 - ARE CABLES
TD-2 - MICROWAVE
FPTS - FOWARD PROPAGATION TROPOSPHERIC SCATTER
L-CARRIER - ON SUBMARINE AND COXIAL CABLE

Figure 2



WG – WORD GENERATOR
CoBi – CODED BIPHASE
ADDER – AUTOMATIC DIGITAL DATA ERROR RECORDER
S.T.C – SATELITE TEST CENTER

Figure 3

Date	Number of Dropouts	Total Time of Dropouts in Seconds	Number of Blocks lost Due to Dropouts
6/28/62	2	126	9,450
6/29/62	13	1,524	114,300
6/30/62	36	4,616	346,200
7/1/62	4	49	3,675
7/2/62	1	18	1,350
7/3/62	12	402	30,150
7/4/62	1	46	3,450
7/8-10/62	2	516	38,700
7/11/62	4	176	13,200
7/12/62	6	338	25,350
7/13/62	1	12	900
7/14/62	2	62	4,650
7/15/62	1	4	300
7/16/62	7	1,639	122,925
7/17/62	0	0	------
7/18/62	4	442	33,150
7/19/62	7	407	30,525
7/20/62	3	1,047	78,525
7/21/62	3	122	9,150
7/22/62	3	80	6,000
7/23/62	0	0	-----
7/24/62	2	841	63,075
7/25/62	0	0	-----
7/26/62	2	1,807	135,525
Totals	116	11,874	890,550

Figure 4 Dropout Measurements

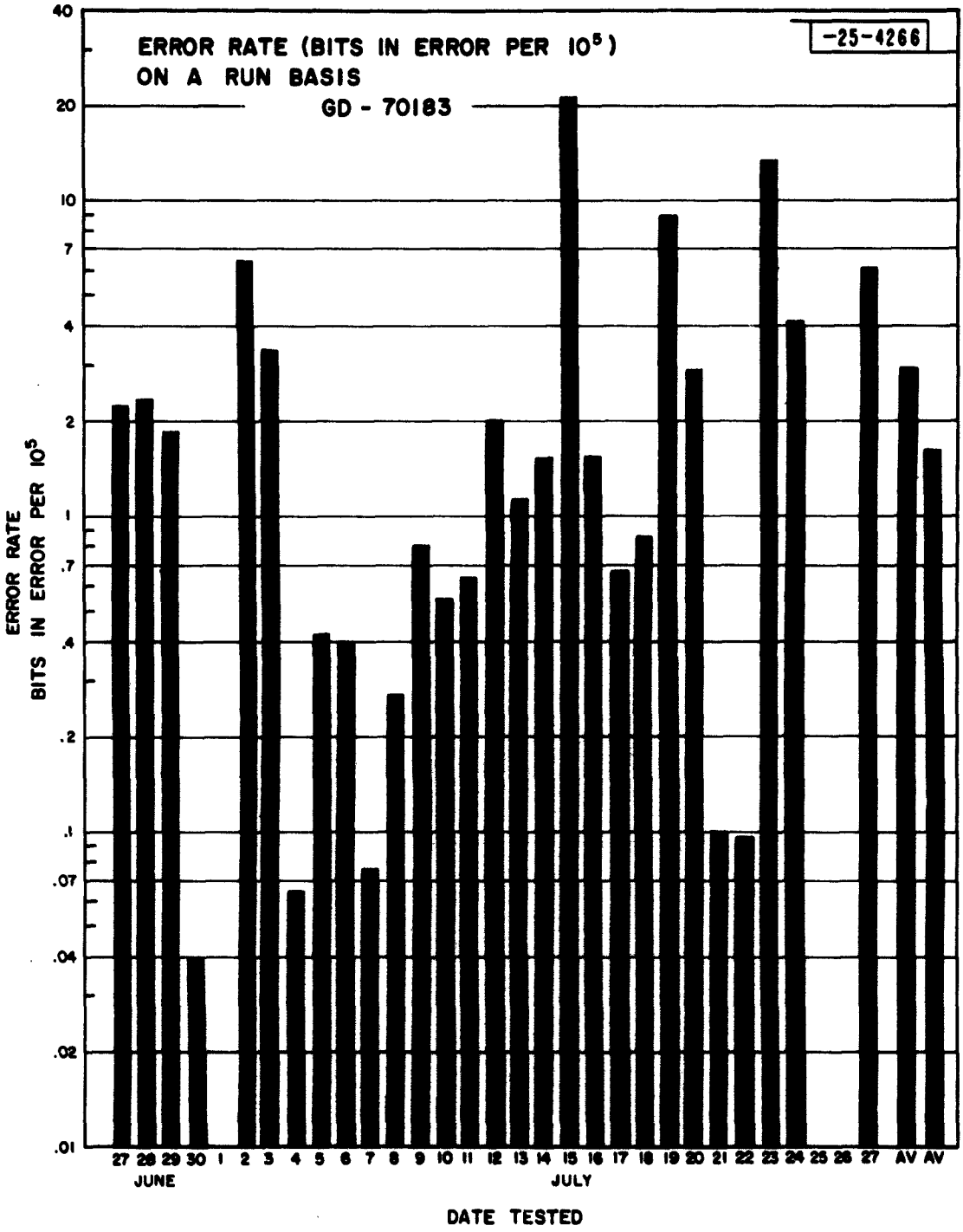

ERROR RATE (BITS IN ERROR PER 10^5)
ON A RUN BASIS
GD - 70183
-25-4266
ERROR RATE
BITS IN ERROR PER 10^5
40
20
10
7
4
2
1
.7
.4
.2
.1
.07
.04
.02
.01
27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 AV AV
JUNE
JULY
DATE TESTED

Figure 5

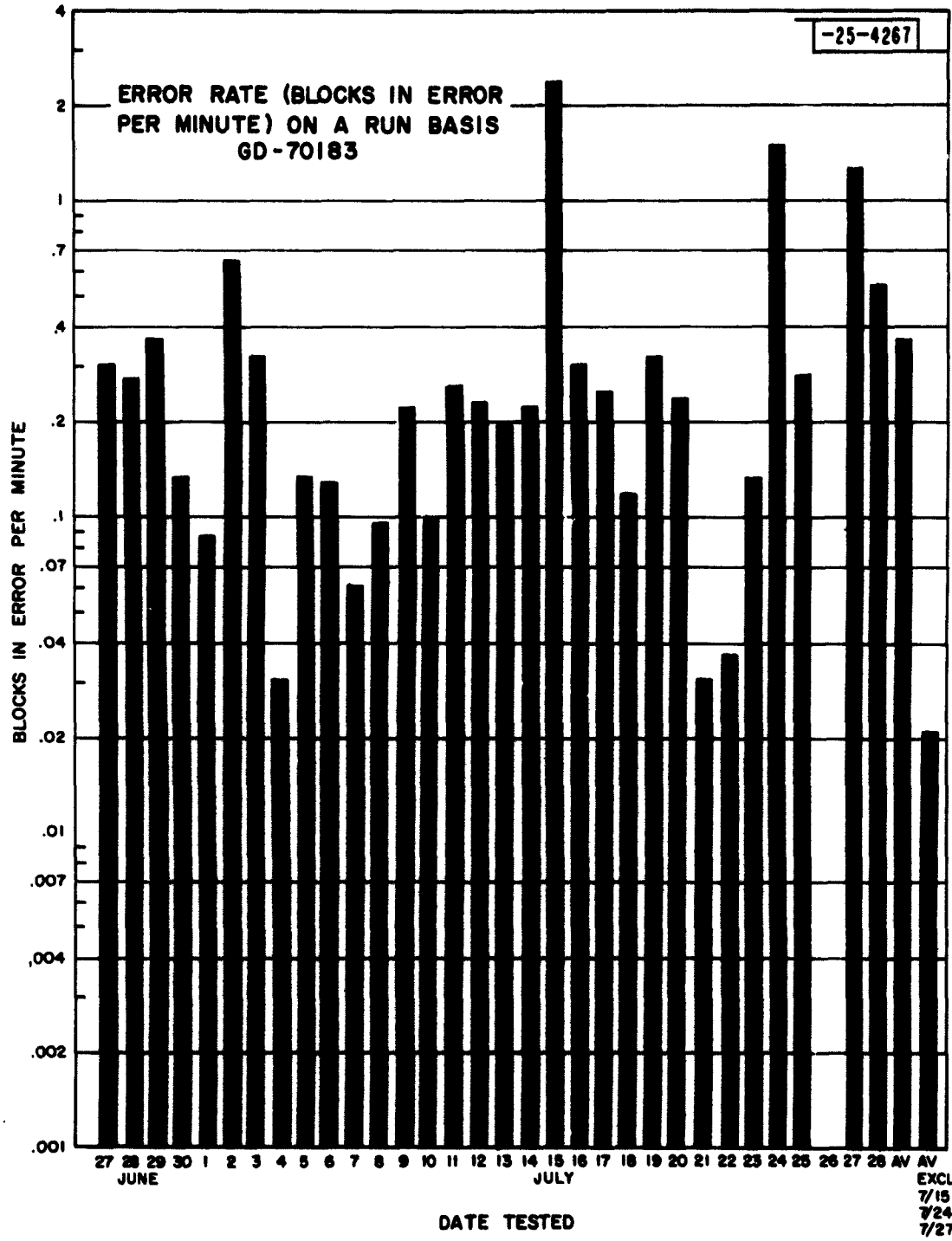

-25-4267
ERROR RATE (BLOCKS IN ERROR PER MINUTE) ON A RUN BASIS
GD-70183
BLOCKS IN ERROR PER MINUTE
4
2
1
.7
.4
.2
.1
.07
.04
.02
.01
.007
.004
.002
.001
27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 AV AV
JUNE
JULY
EXCLD
7/15
7/24
7/27
DATE TESTED

Figure 6

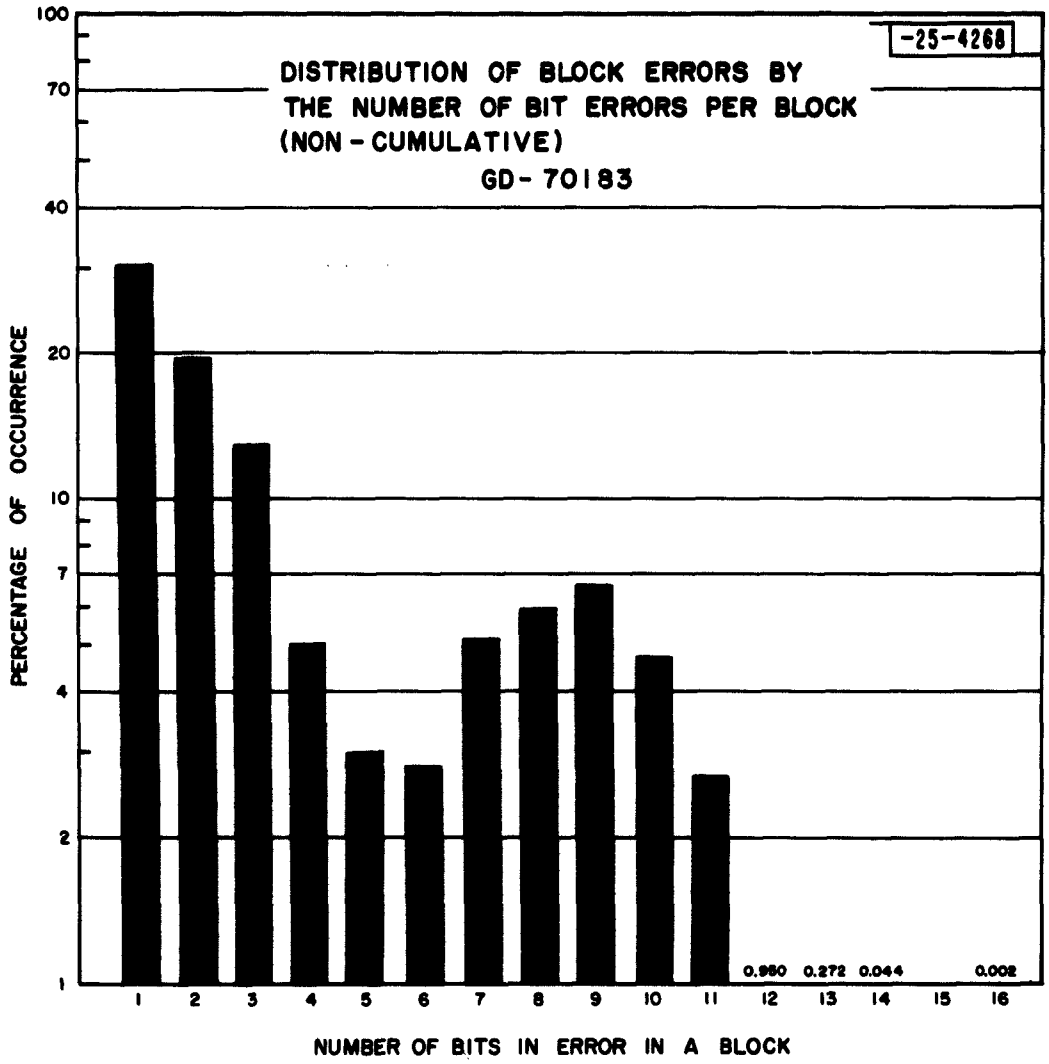

-25-4268
DISTRIBUTION OF BLOCK ERRORS BY
THE NUMBER OF BIT ERRORS PER BLOCK
(NON - CUMULATIVE)
GD - 70183
PERCENTAGE OF OCCURRENCE
100
70
40
20
10
7
4
2
1
0.980
0.272
0.044
0.002
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
NUMBER OF BITS IN ERROR IN A BLOCK

Figure 7

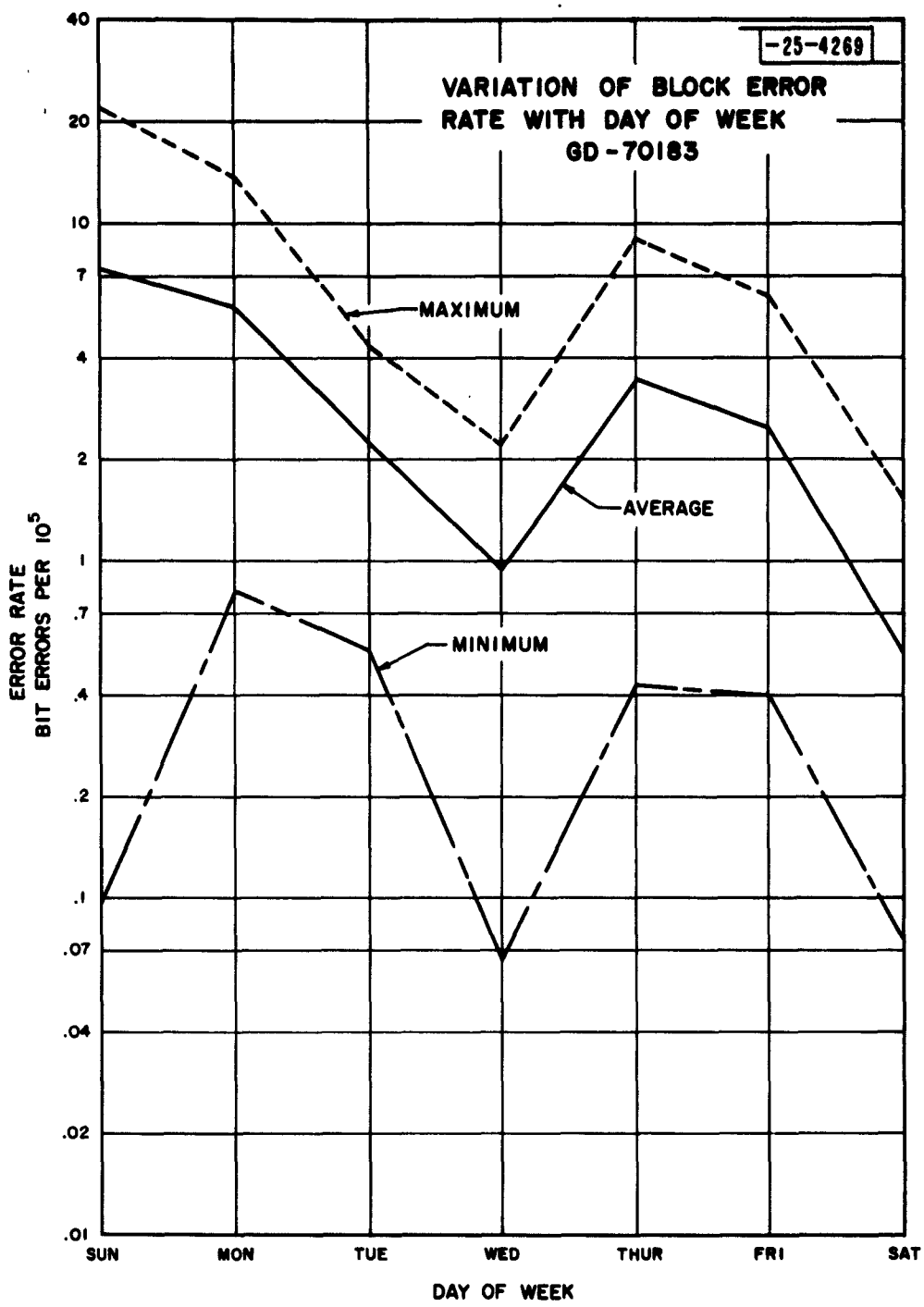

-25-4269
VARIATION OF BLOCK ERROR RATE WITH DAY OF WEEK
GD-70183
MAXIMUM
AVERAGE
MINIMUM
ERROR RATE
BIT ERRORS PER 10^5
40
20
10
7
4
2
1
.7
.4
.2
.1
.07
.04
.02
.01
SUN
MON
TUE
WED
THUR
FRI
SAT
DAY OF WEEK

Figure 8

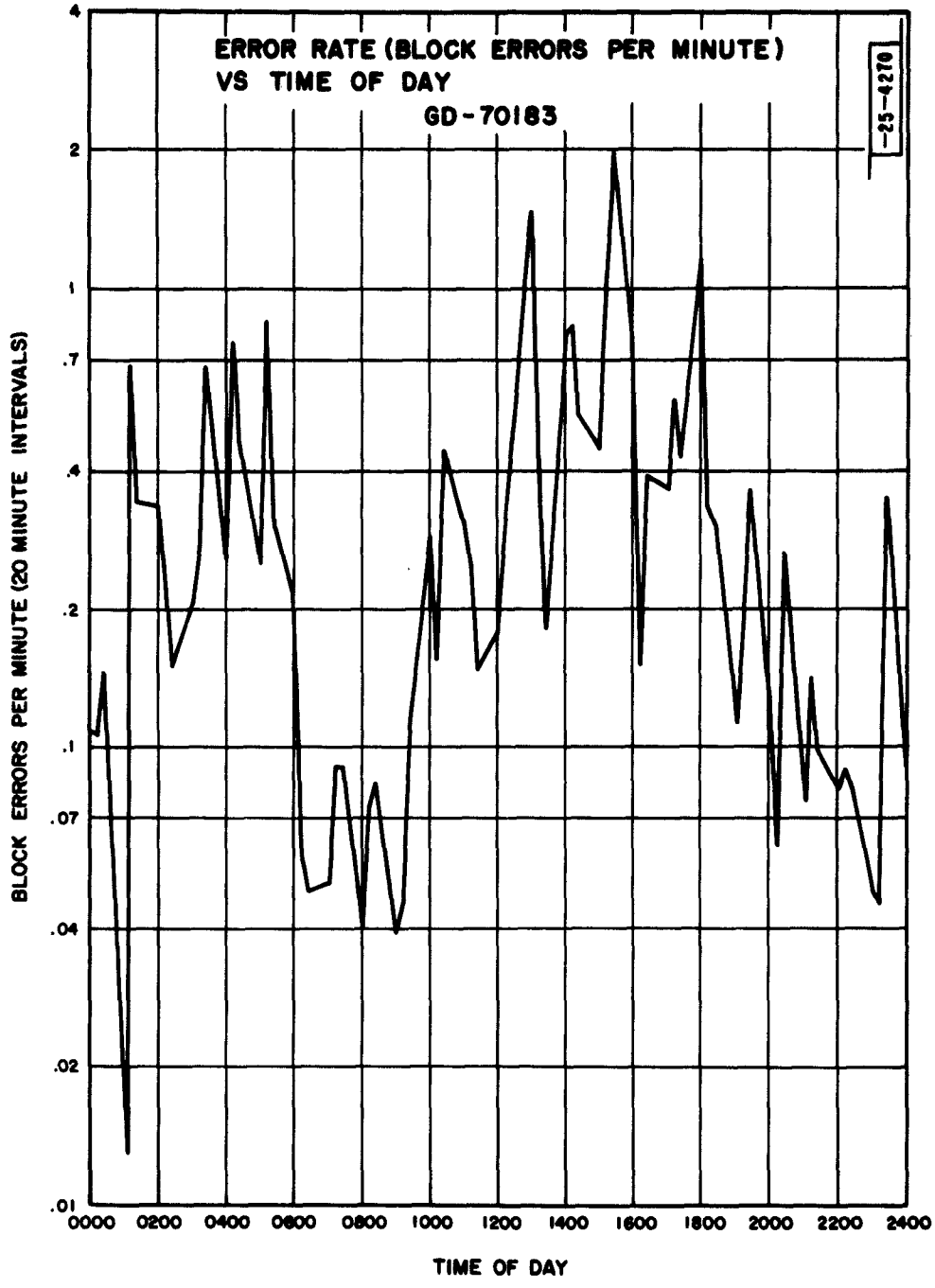

ERROR RATE (BLOCK ERRORS PER MINUTE)
VS TIME OF DAY
GD-70183
-25-4270
BLOCK ERRORS PER MINUTE (20 MINUTE INTERVALS)
4
2
1
.7
.4
.2
.1
.07
.04
.02
.01
0000
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
TIME OF DAY

Figure 9

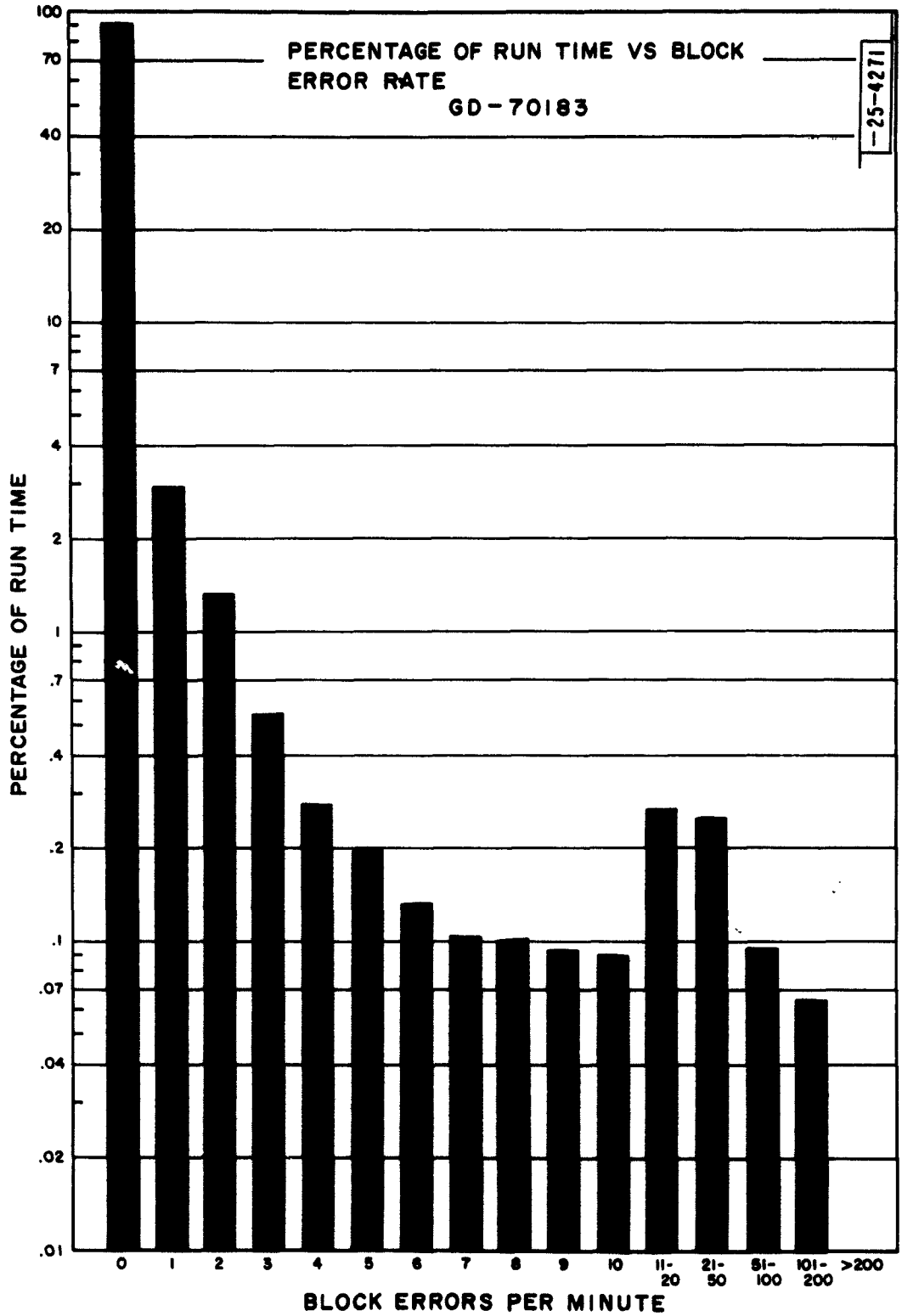

PERCENTAGE OF RUN TIME VS BLOCK ERROR RATE
GD-70183
-25-4271
PERCENTAGE OF RUN TIME
100
70
40
20
10
7
4
2
1
.7
.4
.2
.1
.07
.04
.02
.01
0
1
2
3
4
5
6
7
8
9
10
11-20
21-50
51-100
101-200
>200
BLOCK ERRORS PER MINUTE

Figure 10

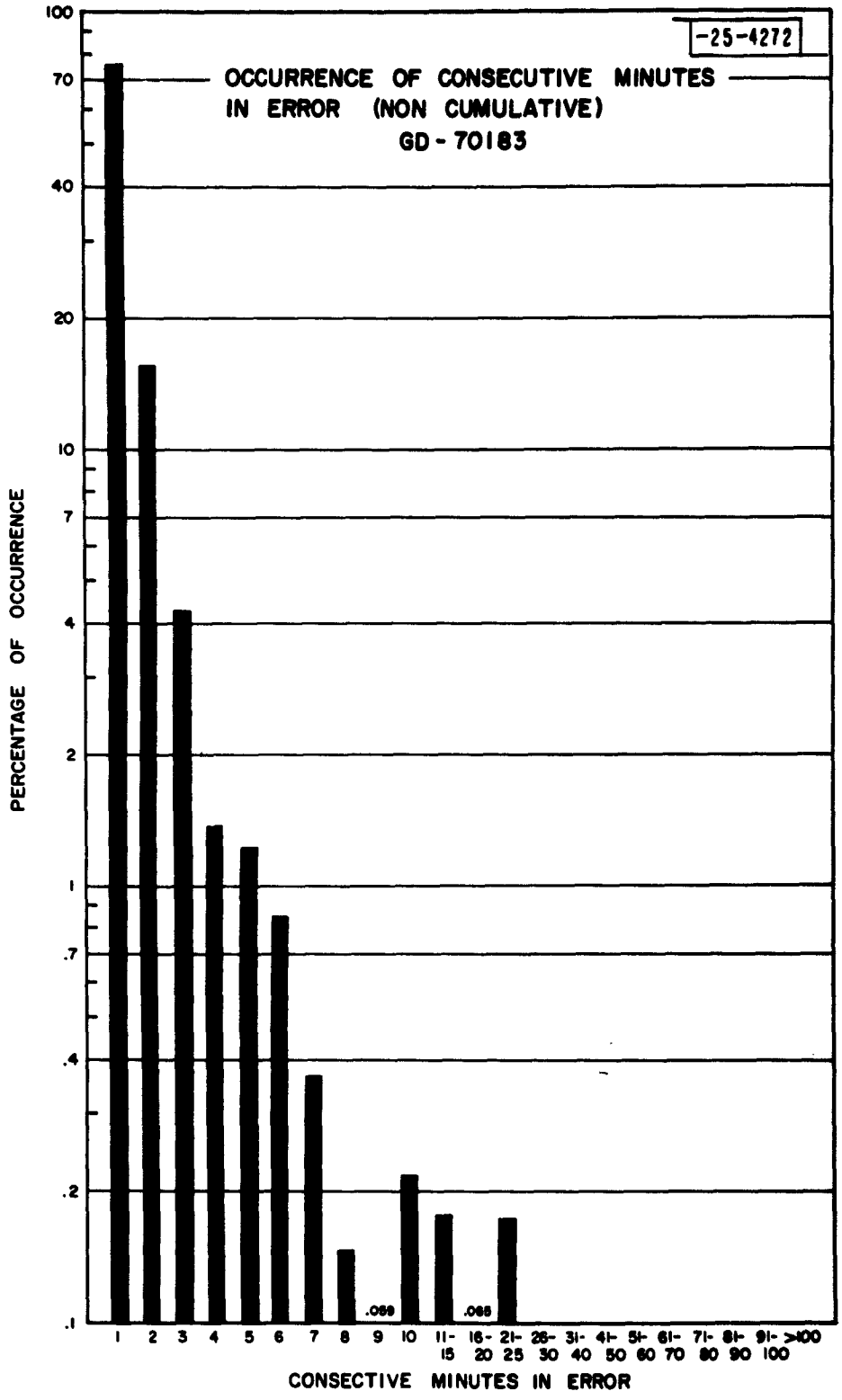

-25-4272
OCCURRENCE OF CONSECUTIVE MINUTES IN ERROR (NON CUMULATIVE)
GD - 70183
PERCENTAGE OF OCCURRENCE
100
70
40
20
10
7
4
2
1
.7
.4
.2
.1
.066
.066
1 2 3 4 5 6 7 8 9 10 11-15 16-20 21-25 26-30 31-40 41-50 51-60 61-70 71-80 81-90 91-100 >100
CONSECTIVE MINUTES IN ERROR

Figure 11

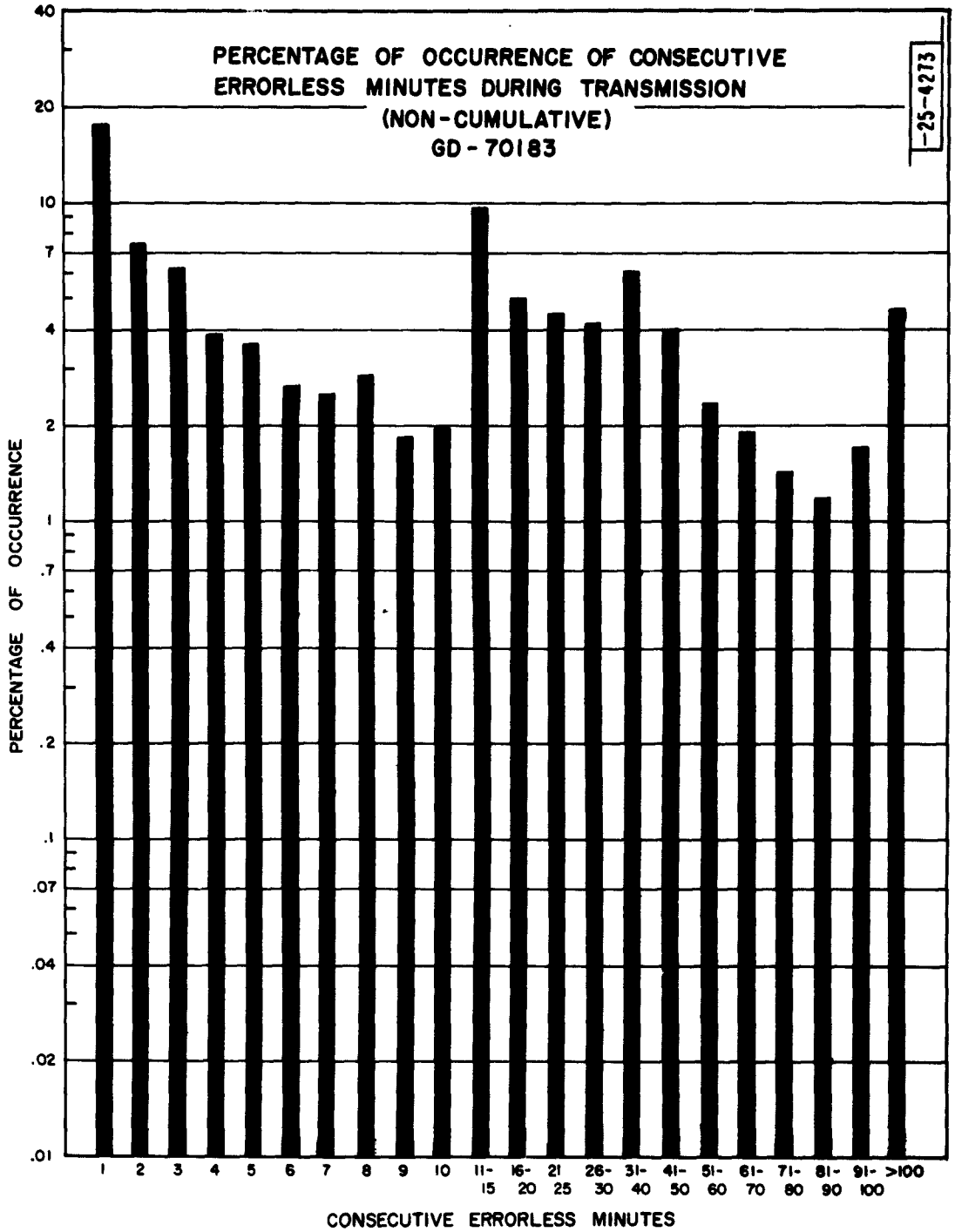

PERCENTAGE OF OCCURRENCE OF CONSECUTIVE
ERRORLESS MINUTES DURING TRANSMISSION
(NON-CUMULATIVE)
GD-70183
-25-4273
PERCENTAGE OF OCCURRENCE
40
20
10
7
4
2
1
.7
.4
.2
.1
.07
.04
.02
.01
1
2
3
4
5
6
7
8
9
10
11-15
16-20
21-25
26-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
>100
CONSECUTIVE ERRORLESS MINUTES

Figure 12

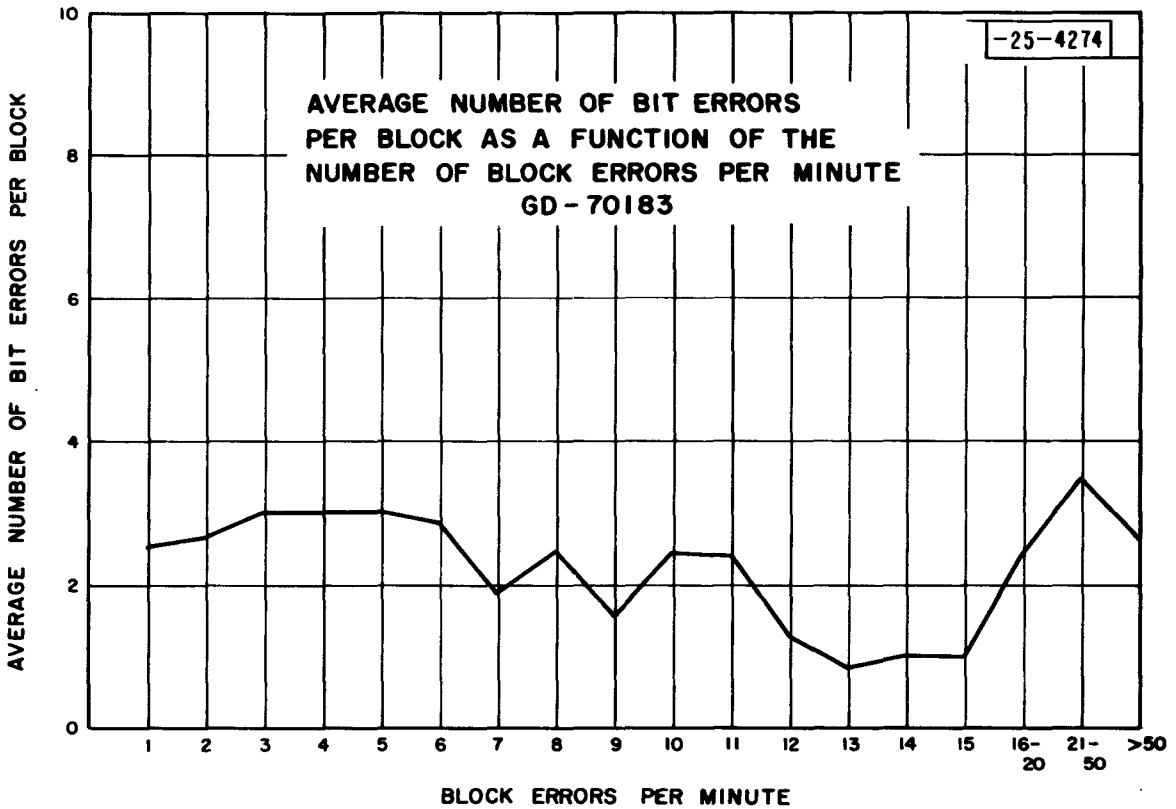

-25-4274
AVERAGE NUMBER OF BIT ERRORS PER BLOCK AS A FUNCTION OF THE NUMBER OF BLOCK ERRORS PER MINUTE
GD-70183
AVERAGE NUMBER OF BIT ERRORS PER BLOCK
0
2
4
6
8
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16-20
21-50
>50
BLOCK ERRORS PER MINUTE

Figure 13

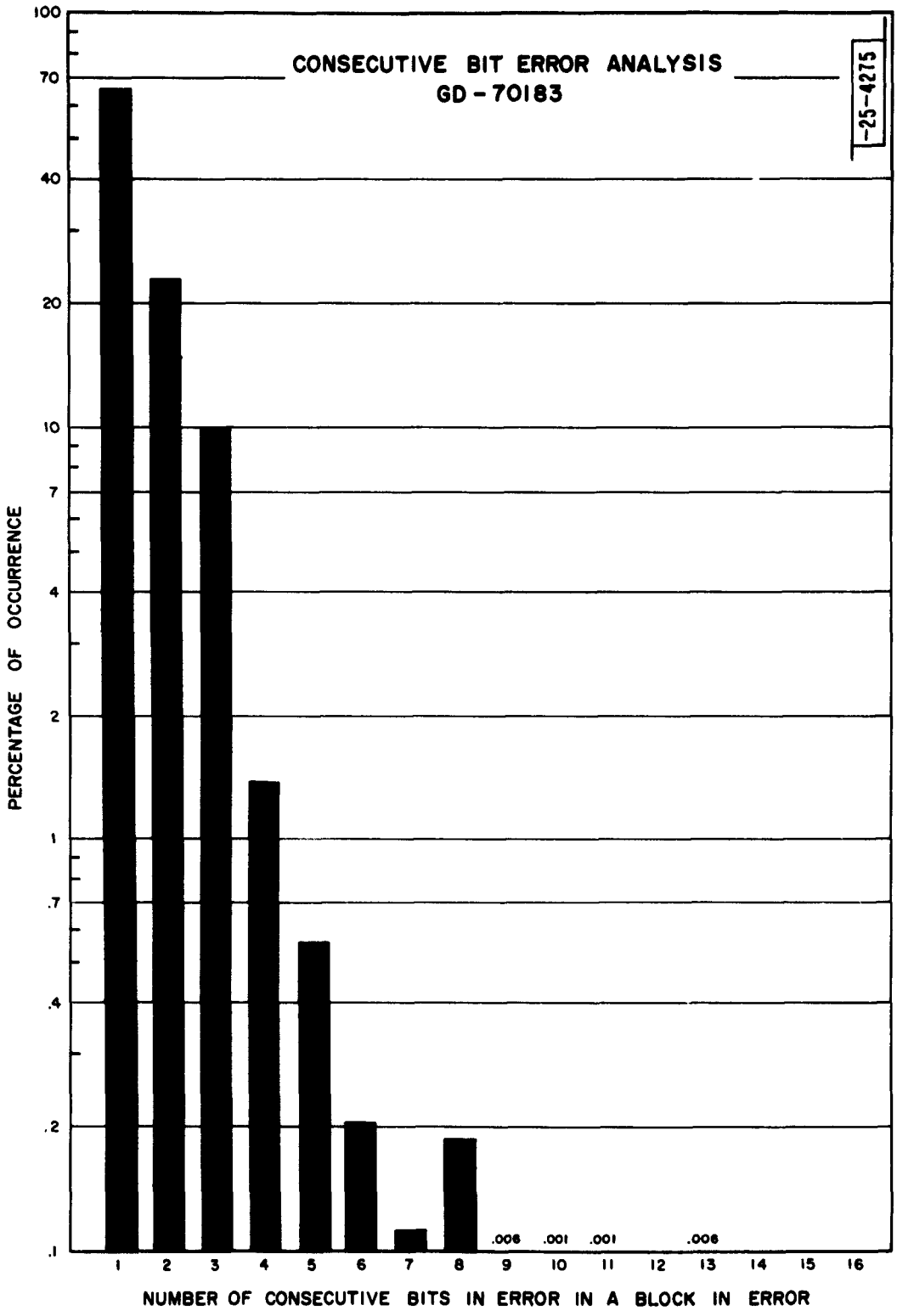

CONSECUTIVE BIT ERROR ANALYSIS
GD - 70183
-25-4275
PERCENTAGE OF OCCURRENCE
100
70
40
20
10
7
4
2
1
.7
.4
.2
.1
.006
.001
.001
.006
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
NUMBER OF CONSECUTIVE BITS IN ERROR IN A BLOCK IN ERROR

Figure 14

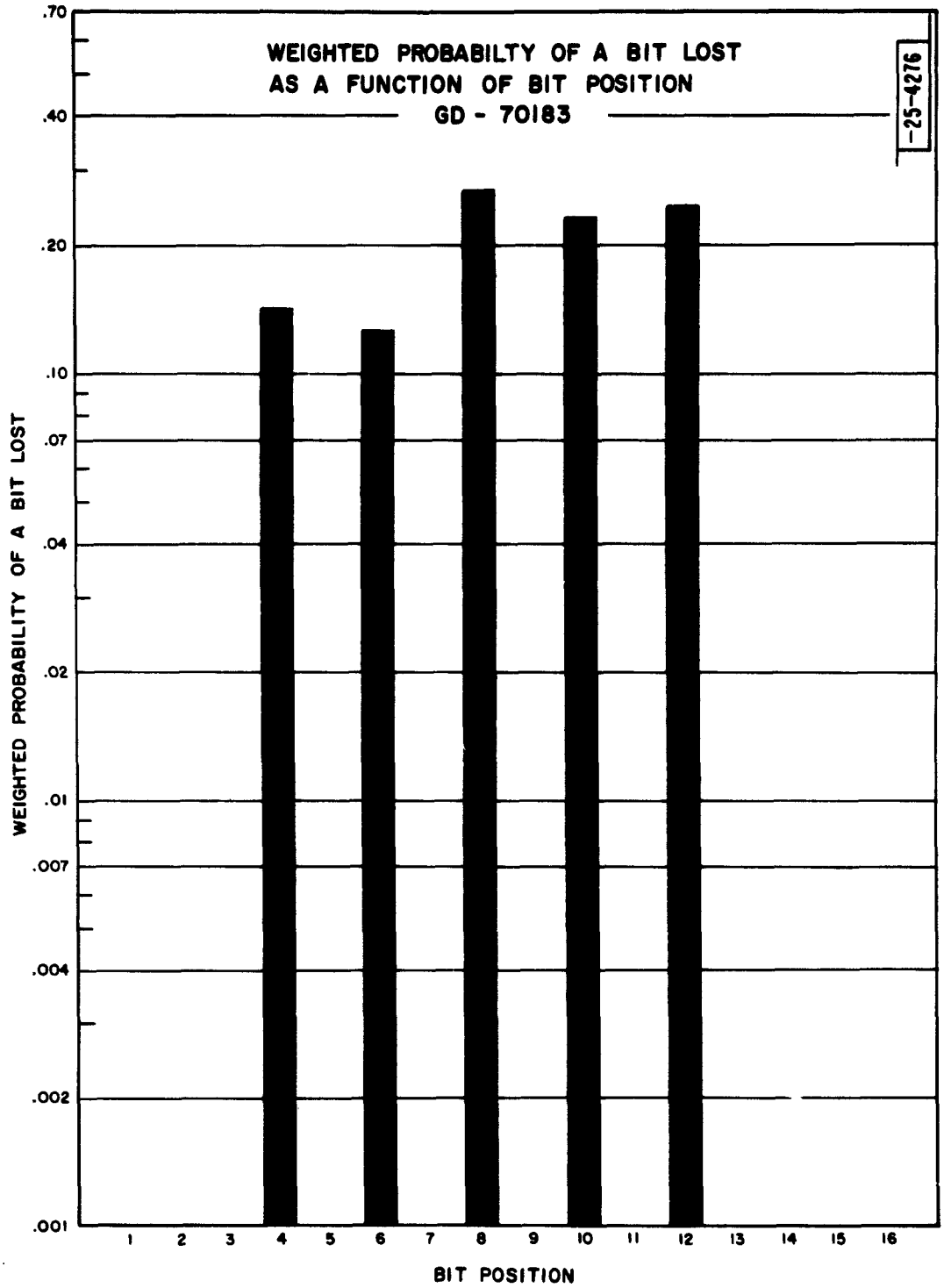

WEIGHTED PROBABILTY OF A BIT LOST
AS A FUNCTION OF BIT POSITION
GD - 70183
-25-4276
WEIGHTED PROBABILITY OF A BIT LOST
.70
.40
.20
.10
.07
.04
.02
.01
.007
.004
.002
.001
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
BIT POSITION

Figure 15

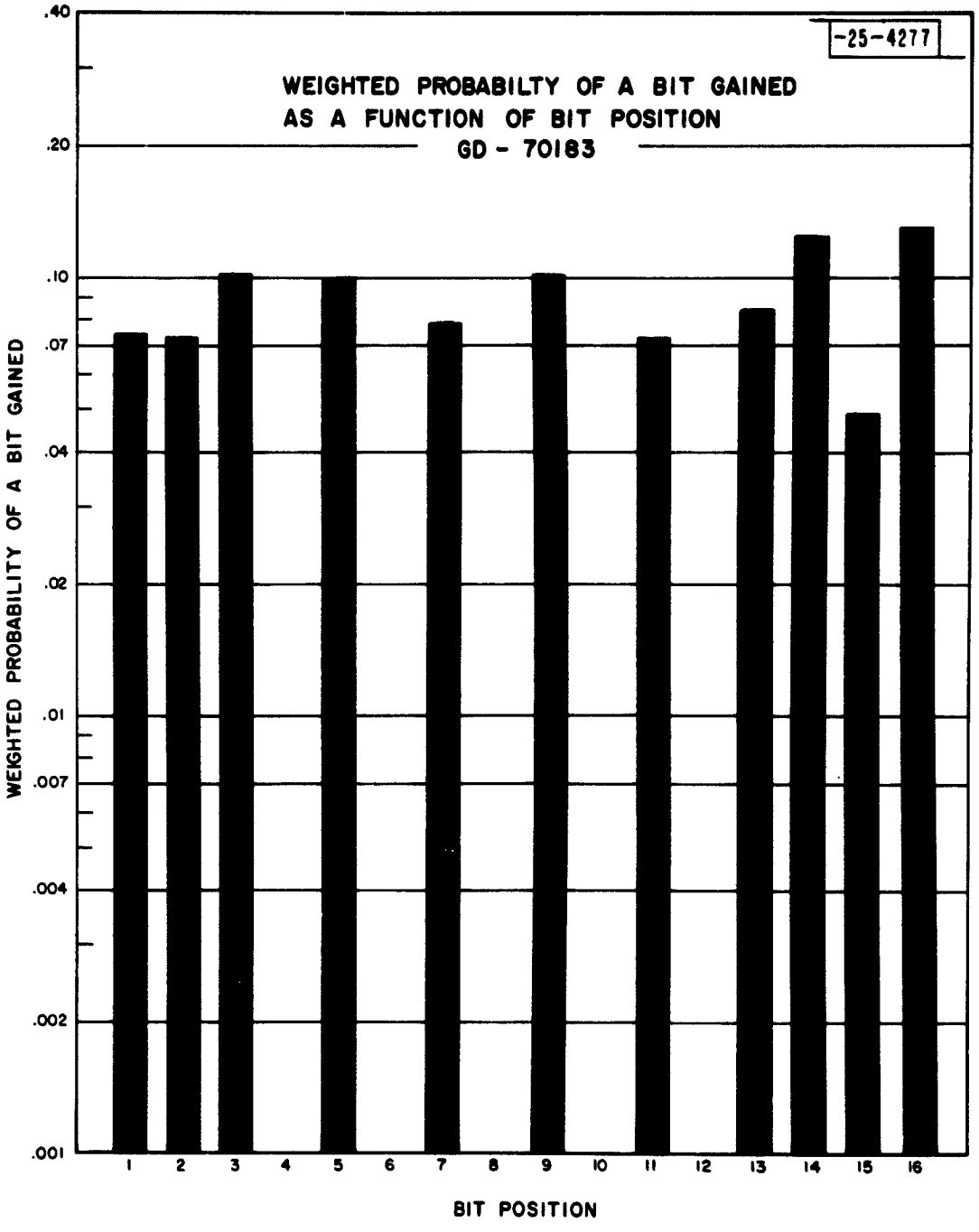

-25-4277
WEIGHTED PROBABILTY OF A BIT GAINED
AS A FUNCTION OF BIT POSITION
GD - 70183
WEIGHTED PROBABILITY OF A BIT GAINED
.40
.20
.10
.07
.04
.02
.01
.007
.004
.002
.001
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
BIT POSITION

Figure 16

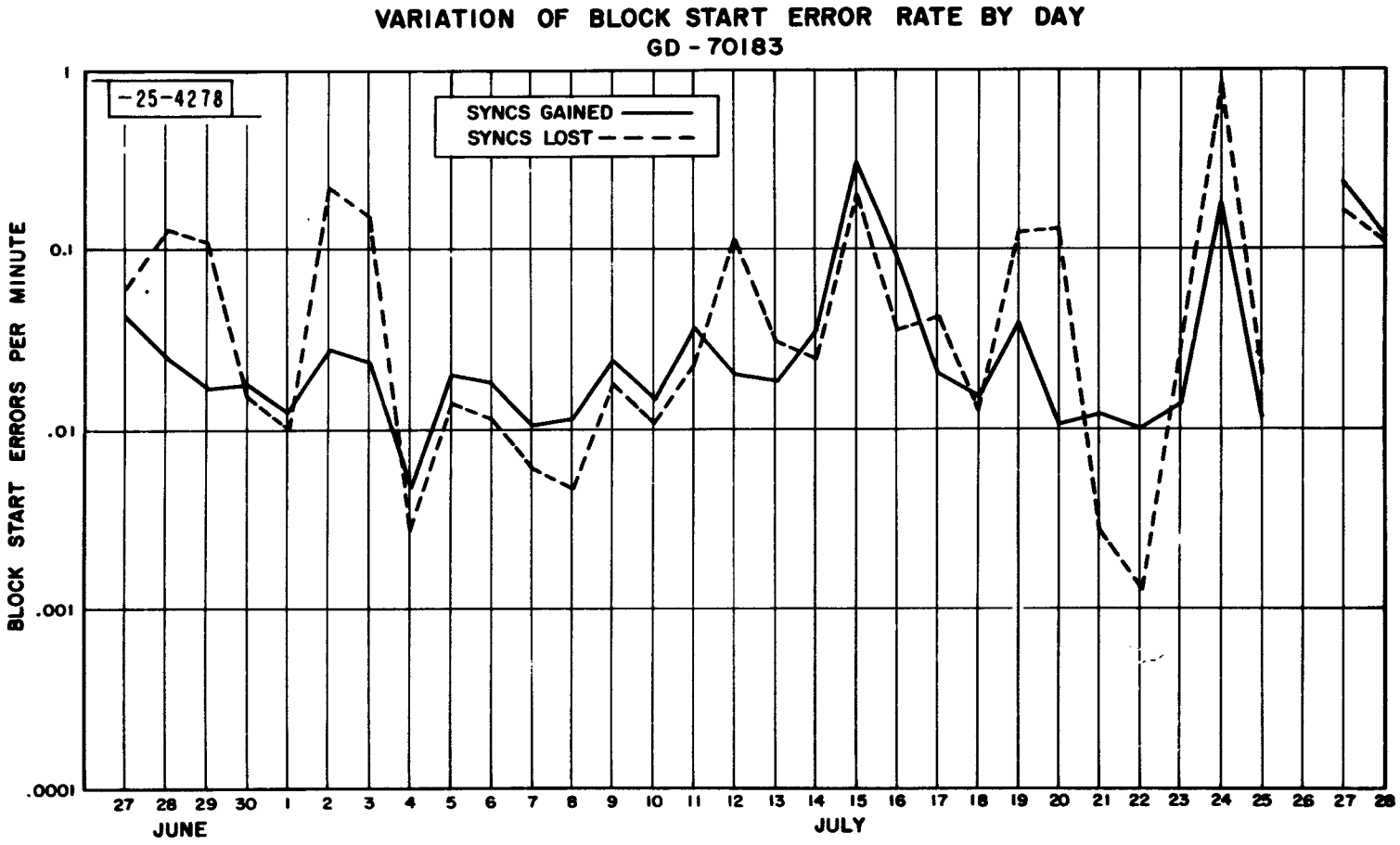

VARIATION OF BLOCK START ERROR RATE BY DAY
GD - 70183
-25-4278
SYNCS GAINED
SYNCS LOST
BLOCK START ERRORS PER MINUTE
1
0.1
.01
.001
.0001
27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
JUNE
JULY

Figure 17

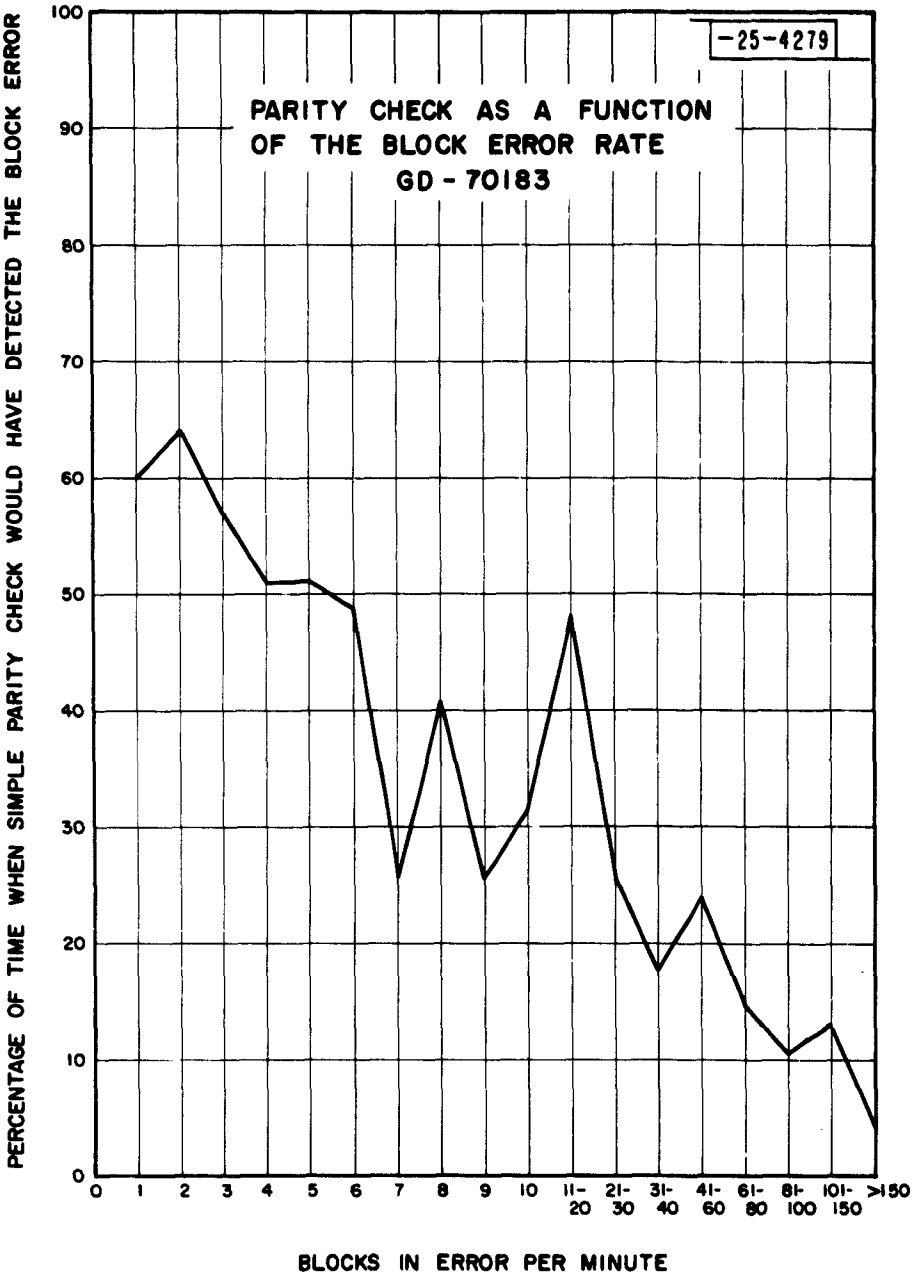

-25-4279
PARITY CHECK AS A FUNCTION
OF THE BLOCK ERROR RATE
GD - 70183
PERCENTAGE OF TIME WHEN SIMPLE PARITY CHECK WOULD HAVE DETECTED THE BLOCK ERROR
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11-20 21-30 31-40 41-60 61-80 81-100 101-150 >150
BLOCKS IN ERROR PER MINUTE

Figure 18

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