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DISTANCE MEASURING EQUIPMENT TRAFFIC-LOADING CAPACITY INVESTIGA--ETC(U)
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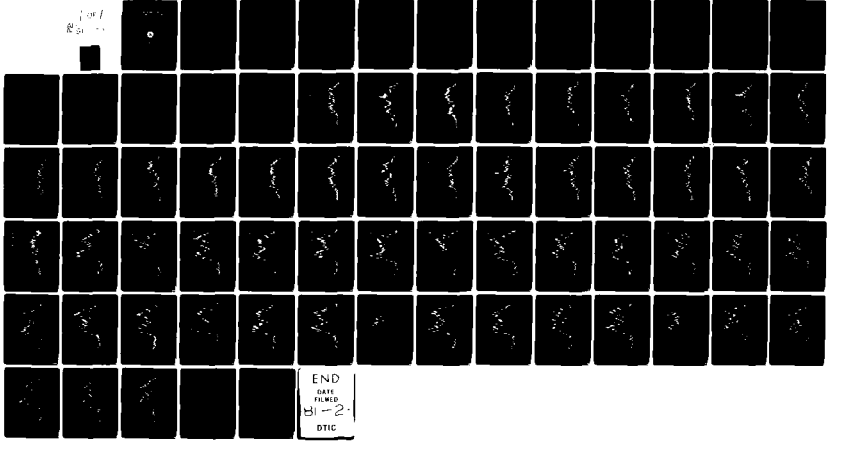

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Report No. FAA-RD--80-100
FAA-CT-80-41

DISTANCE MEASURING EQUIPMENT TRAFFIC-LOADING CAPACITY INVESTIGATION

Harold Postel

FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER
Atlantic City Airport, New Jersey 08405

INTERIM REPORT

OCTOBER 1980

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D. C. 20590

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-80-100	AD-A091977	

4. Title and Subtitle	5. Report Date
DISTANCE MEASURING EQUIPMENT TRAFFIC-LOADING CAPACITY INVESTIGATION.	October 1980
	6. Performing Organization Code
7. Author(s) Harold Postel	8. Performing Organization Report No. FAA-CT-80-41
9. Performing Organization Name and Address Federal Aviation Administration Technical Center Atlantic City Airport, New Jersey 08405	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. 042-306-810
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20590	13. Type of Report and Period Covered Interim rept.
	14. Sponsoring Agency Code

15. Supplementary Notes

73

16. Abstract

This phase of the project was performed in response to a letter from Acting Chief, Navigation and Landing Division, ARD-300, dated January 17, 1980, under Project 81, tactical air navigtional aid (TACAN)/distance measuring equipment (DME) Systems Support 042-306 TACAN/DME Maintenance/Sustaining Engineering. The project was performed to determine the cause of loss of DME service at the O'Hare International Airport, Chicago, Illinois, and the Stapleton International Airport very high frequency omnidirectional radio range tactical air navigational system (VORTAC), Denver, Colorado.

This report covers the findings of the traffic counts of the O'Hare DME and Stapleton VORTAC. The results show that these systems were being interrogated at rates in excess of the systems' capacities.

17. Key Words	18. Distribution Statement
Airport Capacity DME Traffic Loading Air Traffic Survey DME Traffic Count	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	67	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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METRIC CONVERSION FACTORS

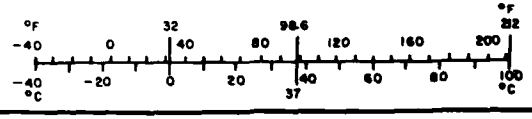
Approximate Conversions to Metric Measures

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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INTRODUCTION

PURPOSE.

The purpose of this effort was to determine the cause of user complaints of loss of distance measuring equipment (DME) service at O'Hare and Stapleton very high frequency omnidirectional radio range (VOR) DME/tactical air navigation (TACAN). This combined system is known as a VORTAC.

BACKGROUND.

Development of a method for recording the number of distance measuring interrogations to a VORTAC was assigned to the Federal Aviation Administration (FAA) Technical Center in March 1970. Report No. FAA-RD-71-109, dated February 1972, "Investigate and Analyze DME Traffic Load," details the method and approach actually developed for collection of data at VORTAC facilities The method utilized at both O'Hare and Stapleton was the same. Application of the method is described in the following reports:

FAA-RD-74-93, "Distance Measuring Equipment and Traffic Loading Capacity Investigation," June 1972.

FAA-78-48-LR, "Distance Measuring Equipment Traffic Loading Capacity Investigation, (1977)," July 1978.

FAA-79-4-LR, "Distance Measuring Equipment Traffic Loading Capacity at Key Biscayne, Florida," February 1979.

FAA-79-36-LR, "Distance Measuring Equipment Traffic Loading Capacity Investigation," April 1979.

DESCRIPTION OF EQUIPMENT.

Distance reply signals are supplied by TACAN or DME ground beacon in response to interrogations from an airborne interrogator. Each airborne interrogator transmits, at the frequency of the radio beacon receiver, a sequence of paired pulses with a random pulse-pair spacing peculiar to itself. These signals are received by the ground-located beacon receiver which will accept, decode, and initiate a reply to as many as 2,700 pulse pairs per second (ppps) without degradation of system performance. At an average interrogation rate per aircraft of 27 per second, this is usually equated to 100 interrogators.

The output of the beacon receiver is controlled by the automatic repetition rate control (ARRC) voltage. The receiver output consists of noise-generated squitter pulses and DME interrogations; the number of squitter pulses varies inversely with the number of interrogations.

TECHNICAL APPROACH.

Tests were conducted to determine the level of traffic loading at both facilities. A graphic computing system utilizing a magnetic tape was programmed to record interrogation rates continuously over a 24-hour period. The program collected 54 samples of data per minute, and then stored the data on the tape. A plot program provided the capability to list and plot the collected data. The test conditions allowed a retriggerable blanking gate to be set at a specific value for the first half of testing and then changed for the final half of the test. The gate width was varied to determine if any change in traffic loading was realized.

TEST CONFIGURATIONS.

The test equipment consisted of a Hewlett-Packard 5328A programmable counter and a Tektronix 4051 graphic computing system with a direct-view-storage cathode ray tube. The graphic system has full American National Standard Code for Information

Interchange (ASCII) character set. A general purpose interface bus and a tape drive consisting of a 3MDC300A cartridge with a capacity of 300K bytes are integral parts of the 4051 graphic system. A Hewlett-Packard 59309AHP-1B digital clock controlled the sampling time of the collected data. The equipment was utilized at each of the two facilities as described below.

1. O'Hare. This facility has installed a Wilcox 596B DME System. The test configuration used at the O'Hare DME site is shown in figure 1. The LOG intermediate frequency (IF) VIDEO OUT, located on the IF sub-assembly 1A2A6, was fed to the Hewlett-Packard 5328A counter A input. The automatic repetition rate control (ARRC) voltage was connected to the voltmeter input of the same counter. The ARRC voltage is a direct current (d.c.) voltage proportional to the interrogation rate that limits the station reply rate to 2,700 ppps. The reference level is adjusted so that the interrogation rate is maintained. As the interrogation rate reaches this level, the ARRC level prevents the system from responding to any further interrogations in excess of 2,700 ppps. This circuit acts as an overload circuit to prevent station shutdown due to over interrogations. A constant pulse repetition frequency (PRF) of 2,700 ppps is maintained, thereby, not allowing any other aircraft to be serviced until such time as the PRF falls below 2,700 ppps.

2. Stapleton. The Stapleton facility is a VORTAC which has istalled a RHO-THETA-Navigation (RTN)-2 beacon. The test configuration utilized is shown in figure 2. The IF amplifier video output from the RTN-2 system was connected to the input of the HP-5328A counter A input. Its output, and that of the HP-5309A clock, were connected to the Tektronix 4051 terminal via an IEEE-488 instrumentation bus. Normally, in the RTN-2 radio beacon equipment, the radiofrequency (RF) signal generator produces simulated interrogation signals which are applied to the transponder at a preset power level via an interrogation overload switch. The number of interrogation responses for the particular power-level setting is used as a measure of receiver sensitivity. The RF signal generator signal, which is set to approximately 45 decibels (dB) lower than the normal interrogation signals, is directed to the receiver sensitivity monitor. When receiver sensitivity is reduced by 1 dB due to high traffic loading, the RF signal generator output is increased to a fixed, preset level by the operation of an interrogation overload relay in the transponder. This prevents an alarm condition.

A modification to prevent false distance lock-on has been installed at this facility (FAA Order AFP 6780.1, chg 224, chapter 229, dated June 30, 1975). When this modification was installed, the interrogation overload circuitry became disabled. Since this modification, a receiver sense alarm would result from an interrogation rate in excess of 5,400 pulse per second (pps), an overload condition. If this condition persisted, the system would shut down and not furnish any DME service.

When the modification was originally installed, the blanking gate portion of this modification was set to 250 microseconds (μs). The result of this modification was that aircraft interrogations exceeding a specific level will generate an additional blanking period, in this case 250 μs. The weaker multipath reflected signals following the direct path interrogation will be eliminated, thus preventing a false lock-on. The retriggerable feature of this modification allowed interrogations exceeding the specific level to generate its own reply. At Denver the triggerable level was -80 decibels above 1 milliwatt (dBm). This was determined by procedures outlined in the installation procedures. At this

level (-80 dBm), almost all aircraft tuned to this station within the service volumn area would generate gates, lowering the traffic handling capability of the facility because of the 250 μs blanking period. A revision (AFP 6780.1, chg 298, chapter 263, dated November 1, 1979) was installed on April 30, 1980, and the blanking gate originally set to 250 μs was reset to 150 μs and the level that generates this gate was -78 dBm.

The programmable counter utilized at both facilities took fifty-four 1-second video output samples per minute. The test points utilized show all interrogations being received before decoding takes place. At these points a count of 5,400 ppps represents a fully loaded system.

FIELD TEST RESULTS.

The method used to record the traffic count was used at both facilities. Graphic displays of the time of day versus percent of traffic loading are shown in figure 3 for O'Hare and figure 4 for Stapleton. A fully loaded system would be indicated by a count of 5,400 ppps. The percent of loading was calculated by dividing the measured interrogation pulses by 54. The data displayed on the graphs were recorded at the rate of 54 samples per minute, averaged, and then stored on magnetic tape.

O'HARE DME. Data collection started at the O'Hare DME facility on February 13, 1980 and was completed on March 11, 1980. Two actual overload conditions did occur during the data collection period. They occurred on February 19, 1980 at 1602 and 1605 hours. Several other near overload conditions were recorded on February 14, 19, 20, and March 2 and 9, 1980. The total number of departures and arrivals and percent loading for these periods are shown in table 1.

The total number of arrivals and departures were obtained from FAA Form 7200-1, Air Traffic Control Log. The DME is located 400 feet from runway 4L-22R, 1,300 feet from 27R-9L, and 1,200 feet from 14L and 32R (figure 5). Previous tests conducted at the FAA Technical Center has shown that the level of continuous wave (CW) being radiated from various types of airborne interrogators is of a level sufficient to cause receiver sense and reply delay alarm. (See Report No. RD-67-7, "TACAN CW Interference.") The proximity of the site to runway 4L-22R makes this facility susceptable to CW interference when it's in use. In all instances shown in the preceeding table, runway 4L or 22R was in use when the near and overload conditions were recorded.

The arrivals and departures shown in column 2 table 2 represents the actual arrivals and departures for the dates indicated during a 10-hour period. The information was obtained from FAA Form 7200-1. The high and low interrogations rates were obtained over a 24-hour period.

During the first half of the test period, February 13 through February 16, 1980, the blanking gate in the Wilcox 596B DME was set at 0 μs. It was reset to 150 μs during the final phase of testing, February 27 through March 11, 1980. This test was performed to determine if any detrimental effect on traffic handling would result from the increased gate width (no significant effect was noted due to gate width change). The range of traffic loading from February 13 through February 26, 1980, was 6 to 64 percent; from February 27 through March 11, 1980, it was 8.5 to 65 percent. To help reduce the traffic loading being experienced by the DME, the Chief, Chicago-O'Hare Air Traffic Control Tower advised air carriers to turn their DME equipment to standby whenever it is not needed.

TABLE 1. RANGE OF TRAFFIC LOADING

Date (1980)	Time	Figure	Percent Traffic Loading	Total Arrivals and Departures
2/14	1630	4	86	150
2/19	1602	9	104	152
2/20	1758	10	88	152
3/2	1443	20	77	145
3/9	1043	27	133	146

The result of the above memo appears to have decreased the interrogation levels to the DME, and user complaints of lack of DME service beyond 25 nmi. Peak traffic hours at this facility are occurring between 1600 and 1800 hours, the times that the two overload conditions were recorded.

STAPLETON VORTAC. Data collection was started at this facility on April 10 and ended on May 20, 1980. The range of traffic loading, actual arrivals, and departures for the times indicated are shown in table 3. The arrivals and departures were obtained from FAA Form 7200-1, Air Traffic Control Log.

There were 14 occurrences of overload conditions recorded during the test period at this facility. One on April 24, 1980 at 1318 hours resulted in a station shutdown. Table 4 shows the dates, times, and percentage of traffic loading for the overload conditions recorded.

From April 10 through April 26, 1980, the retriggerable blanking was set at 250 μs as required by AFP 6780.1. Change 298 to this modification required the resetting of this gate to 150 μs. The range of traffic loading from April 10 to April 26, 1980, as 9.8 to 101 percent; from May 2 to May 20, 1980, was 15 to 98.5 percent.

A memo (similar to the one for O'Hare) has been issued by the United Air Lines Navigation Aids (NAVAIDS) Manager advising pilots to switch both DME systems to "standby" until just prior to takeoff clearance. The location of the Stapleton VORTAC is shown in figure 6.

The beacon under test was placed into a dummy load to determine if internal receiver noise was contributing to the high interrogation rates. A counter was utilized to count the output of the IF video output. The internal pulse generator was set to various PRF's and the count verified. No extraneous counts were noted. The number of blanking gates that were noted were not inconsistent with the traffic levels recorded. An ongoing program to determine the effects of the retriggerable blanking gate on the RTN-2 TACAN beacon is currently in progress. The results of this program will more readily determine the exact effect on traffic loading. Peak traffic periods are occurring at Stapleton, primarily from 1000 and 1100 hours. Ninety percent of the recorded overload condition occurred between 1000 and 1100 hours.

A test to determine if any outside interference source was the cause of the overload conditions was conducted by ARM-406, at the request of ARM-434. The test was conducted on February 19, 1980, 0900 to 1000 hours, during a peak traffic period. No levels of interference could be found that would result in an overload condition.

TABLE 2. RANGE OF TRAFFIC LOADING, O'HARE

Range of Traffic Loading Percent	Total Actual Arrivals and Departures	Day of Week	DATE 1980	Highest Interrogation Rate PPS	Time	Low Interrogation Rate PPS	Time	Figure	μs Blanking Gate Setting
7-55	1638	Wednesday/Thursday	2/13, 14	3003	1855	437	0435	3A	0
5-86	1606	Thursday/Friday	2/14, 15	4681	1633	298	2257	3B	0
7-53	1562	Friday/Saturday	2/15, 16	2868	2016	424	0042	3C	0
7-51	1142	Saturday/Sunday	2/16, 17	2777	1642	399	2250	3D	0
7-60	1311	Sunday/Monday	2/17, 18	3263	1019	356	0317	3E	0
5-61	1549	Monday/Tuesday	2/18, 19	3317	1610	305	0024	3F	0
7-104	1592	Tuesday/Wednesday	2/19, 20	5664	1602	340	0007	3G	0
5-88	1454	Wednesday/Thursday	2/20, 21	4771	1758	225	0304	3H	0
5-59	1575	Friday/Saturday	2/22, 23	3187	1712	252	0006	3I	0
5-44	1337	Saturday/Sunday	2/23, 24	2418	1142	335	2256	3J	0
5-49	1418	Sunday/Monday	2/24, 25	2679	1534	306	2244	3K	0
5-59	697	Monday/Tuesday	2/25, 26	3196	1748	311	0149	3L	0
6-55	1569	Tuesday/Wednesday	2/26, 27	3010	1904	346	0008	3M	150
5-54	1621	Wednesday/Thursday	2/27, 28	2935	1753	315	0030	3N	150
9-53	1577	Thursday/Friday	2/28, 29	2878	1732	499	2318	3O	150
5-61	1742	Friday/Saturday	2/29, 3/1	3383	1922	309	0142	3P	150
7-47	1275	Saturday/Sunday	3/1, 2	2586	1724	380	2202	3Q	150
11-77	1412	Sunday/Monday	3/2, 3	4152	1443	575	2251	3R	150
6-65	1572	Tuesday/Wednesday	3/4, 5	3528	1529	325	0355	3S	150
5-54	1603	Wednesday/Thursday	3/5, 6	2893	1750	277	0005	3T	150
6-51	1604	Thursday/Friday	3/6, 7	2773	1615	433	2222	3U	150
9-133	1274	Saturday/Sunday	3/8, 9	7182	1043	496	0240	3V	150
6-64	1428	Sunday/Monday	3/9, 10	3437	1224	313	0015	3W	150
6-67	1556	Monday/Tuesday	3/10, 11	3659	1954	370	2235	3X	150

TABLE 3. RANGE OF TRAFFIC LOADING

Date (1980)	Time	Percent Traffic Loading	Total Arrivals and Departures	Figure
4/11	1012	102	N/A	56
4/14	1016	103	N/A	53
4/18	1006	111	106	50
4/19	1011	107	N/A	49
4/24	1158	125	96	47
4/25	0957	102	112	46
5/2	1828	109	100	42
5/3	1017	100	104	41
5/4	1007	110	99	40
5/6	1104	100	98	38
5/8	1010	107	80	36
5/12	1031	103	110	33
5/13	1009	117	115	32

N/A = not available

CONCLUSIONS

Based on the test results, it is concluded that:

1. The data collection samples reflect the current distance measuring equipment (DME) interrogation rates at the facilities tested.

2. The effect of the false DME modification on traffic loading could not be determined during this phase of the testing.

3. The Stapleton very high frequency omnidirectional radio range tactical air navigation (VORTAC) facility is being subjected to overload conditions that have caused station shutdown.

4. User complaints of lack of DME service beyond 25 nautical miles are justified, based on the data collected.

5. The proximity of O'Hare DME to runway 4L-22R does subject it to high levels of continuous wave interference from taxiing aircraft when in use.

6. Both facilities are experiencing interrogation rates in excess of system capacity.

RECOMMENDATIONS

It is recommended that:

1. A second generation very high frequency omnidirectional radio range tactical air navigation (VORTAC) system be installed at Stapleton as soon as possible.

2. In the interim, one of the instrument landing system distance measuring equipment (ILS/DME) systems currently installed at Stapleton be changed to a terminal omnidirectional radio range distance measuring equipment (TVOR/DME). This should reduce the traffic loading on the Denver VORTAC.

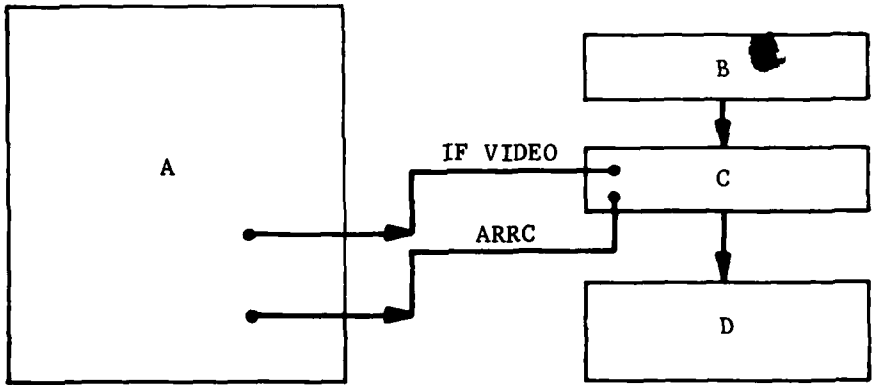
3. Several other VORTAC's in the affected areas be used to provide en route guidance to aircraft utilizing Stapleton and O'Hare Airports as their destination.

TABLE 4. RANGE OF TRAFFIC LOADING, STAPLETON

Range of Traffic Loading Percent	Total Actual Arrivals and Departures	Day of Week	Date (1980)	Highest Interrogation Rate PPS	Time	Low Interrogation Rate PPS	Time	Figure	μs Blanking Gate Seting
3-115	N/A	Wednesday/Thursday	4/9, 10	6228	1016	322	1306	4A	250
9-97	N/A	Thursday/Friday	4/10, 11	5241	0147	466	0147	4B	250
10-102	N/A	Friday/Saturday	4/11, 12	5553	1012	552	0117	4C	250
15-97	N/A	Saturday/Sunday	4/12, 13	5247	1015	810	0004	4D	250
14-94	N/A	Sunday/Monday	4/13, 14	5094	1013	766	0338	4E	250
12-103	N/A	Monday/Tuesday	4/14, 15	5605	1016	657	0318	4F	250
11-87	N/A	Tuesday/Wednesday	4/15, 16	4708	1901	639	2344	4G	250
8-97	N/A	Wednesday/Thursday	4/16, 17	5232	1907	458	0201	4H	250
11-111	1069	Friday/Saturday	4/18, 19	6038	1006	611	0119	4I	250
11-107	N/A	Saturday/Sunday	4/19, 20	5795	1011	575	2250	4J	250
9-94	1087	Sunday/Monday	4/20, 21	5049	1013	461	0443	4K	250
4-125	955	Monday/Tuesday	4/24, 25	6767	1158	245	1144	4L	250
11-102	1041	Tuesday/Wednesday	4/25, 26	5527	0957	603	0314	4M	250
10-88	827	Wednesday/Thursday	4/26, 27	4738	0824	523	0519	4N	250
50-109	1136	Thursday/Friday	5/2, 3	5902	1828	272	1438	4O	250
17-100	913	Friday/Saturday	5/3, 4	5421	1017	937	2236	4P	250
14-110	933	Saturday/Sunday	5/4, 5	5987	1012	809	0045	4Q	250
14-95	1082	Sunday/Monday	5/5, 6	5158	1007	840	0254	4R	250
12-100	1091	Tuesday/Wednesday	5/6, 7	5403	1104	685	0312	4S	250
38-92	1094	Wednesday/Thursday	5/7	4979	1208	2076	1632	4T	250
11-107	1052	Thursday/Friday	5/8, 9	5845	1010	618	0522	4U	250
14-90	1106	Saturday/Sunday	5/9, 10	4855	1154	715	0621	4V	150
12-99	914	Sunday/Monday	5/10, 11	5348	1026	687	0458	4W	150
10-103	1013	Monday/Tuesday	5/12, 13	5587	1031	542	0257	4X	150

4. The presence of nearby taxiing aircraft are a possible source of continuous wave interference and should be considered in the location of additional DME systems.

5. Other facilities be retested to provide further inputs as to trends in traffic increase.



A WILCOX 596B DME SYSTEM

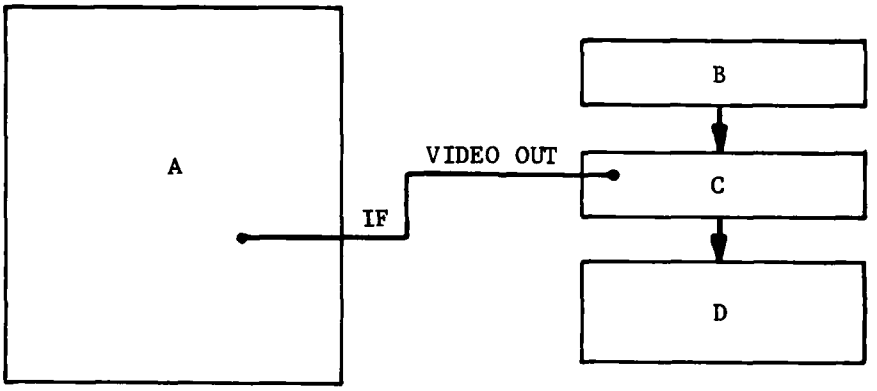
B HEWLETT-PACKARD 59309A HP-IB DIGITAL CLOCK

C HEWLETT-PACKARD 5328A PROGRAMMABLE ELECTRONIC COUNTER

D TEKTRONIX 4051 GRAPHIC COMPUTING SYSTEM

80-41-1

FIGURE 1. CHICAGO (O'HARE) TEST CONFIGURATION



A RTN-2 BEACON

B HEWLETT-PACKARD 59309A HP-IB DIGITAL CLOCK

C HEWLETT-PACKARD 5328A PROGRAMMABLE ELECTRONIC COUNTER

D TEKTRONIC 4051 GRAPHIC COMPUTING SYSTEM

80-41-2

FIGURE 2. DENVER (STAPLETON) TEST CONFIGURATION

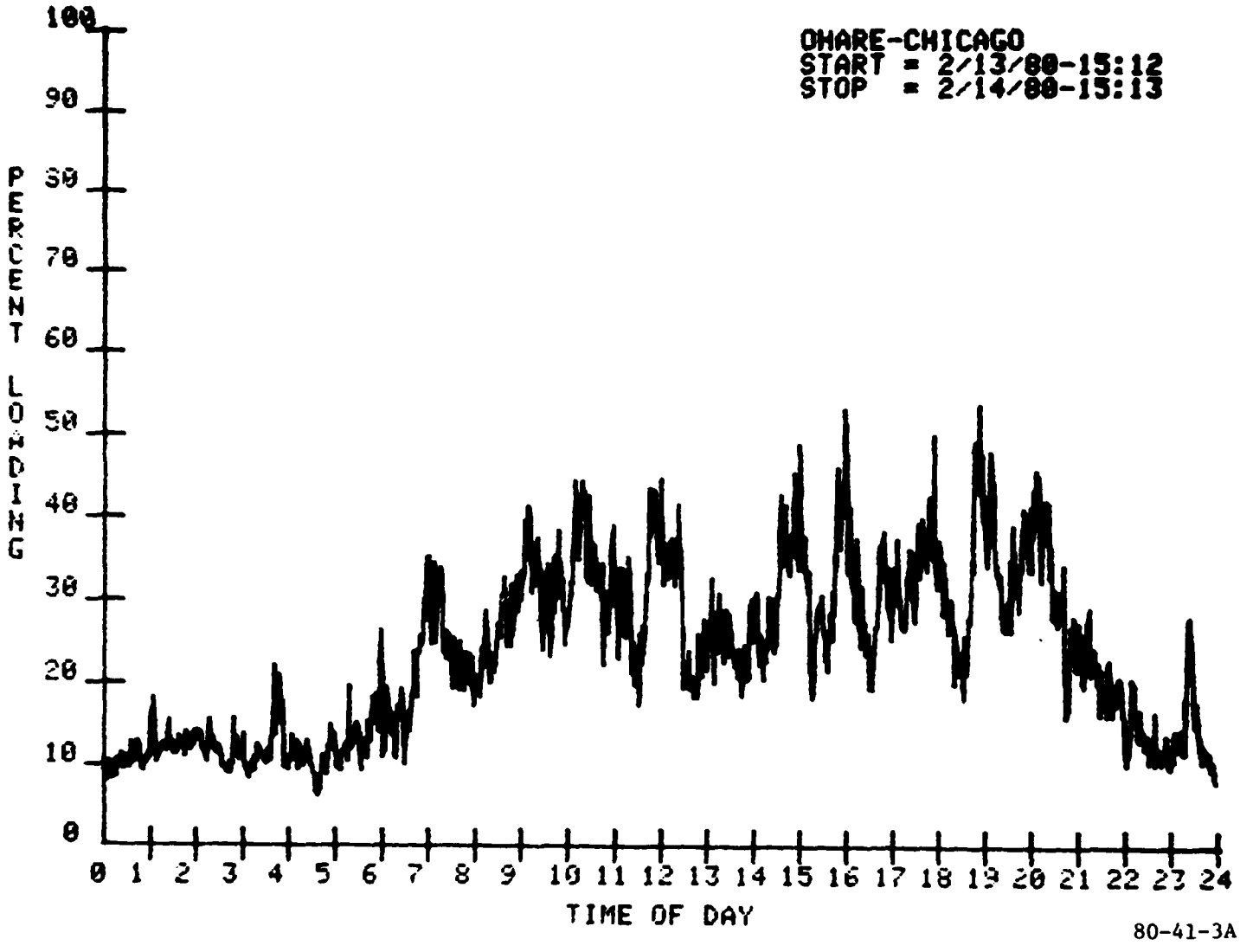


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 1 of 24)

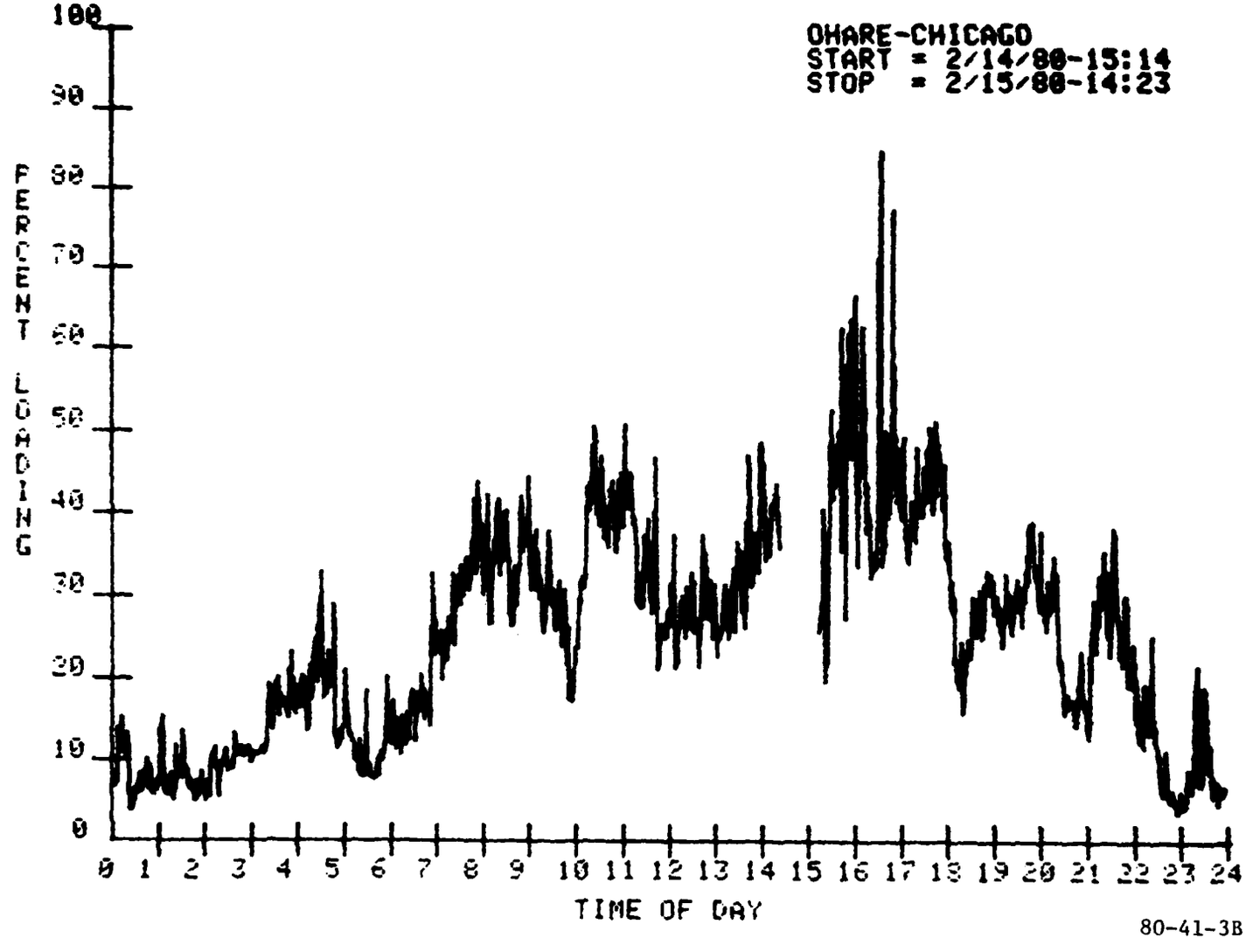


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 2 of 24)

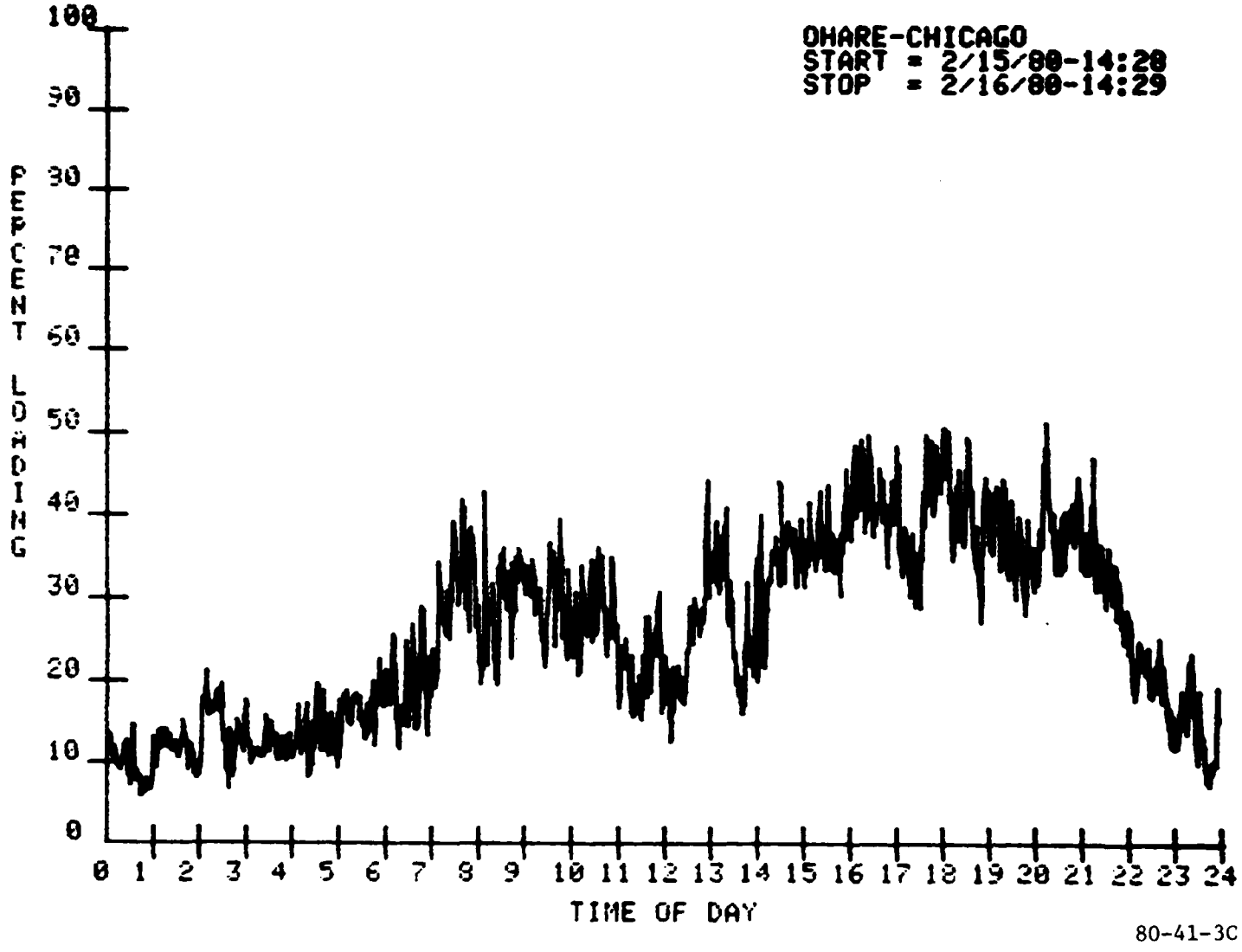


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 3 of 24)

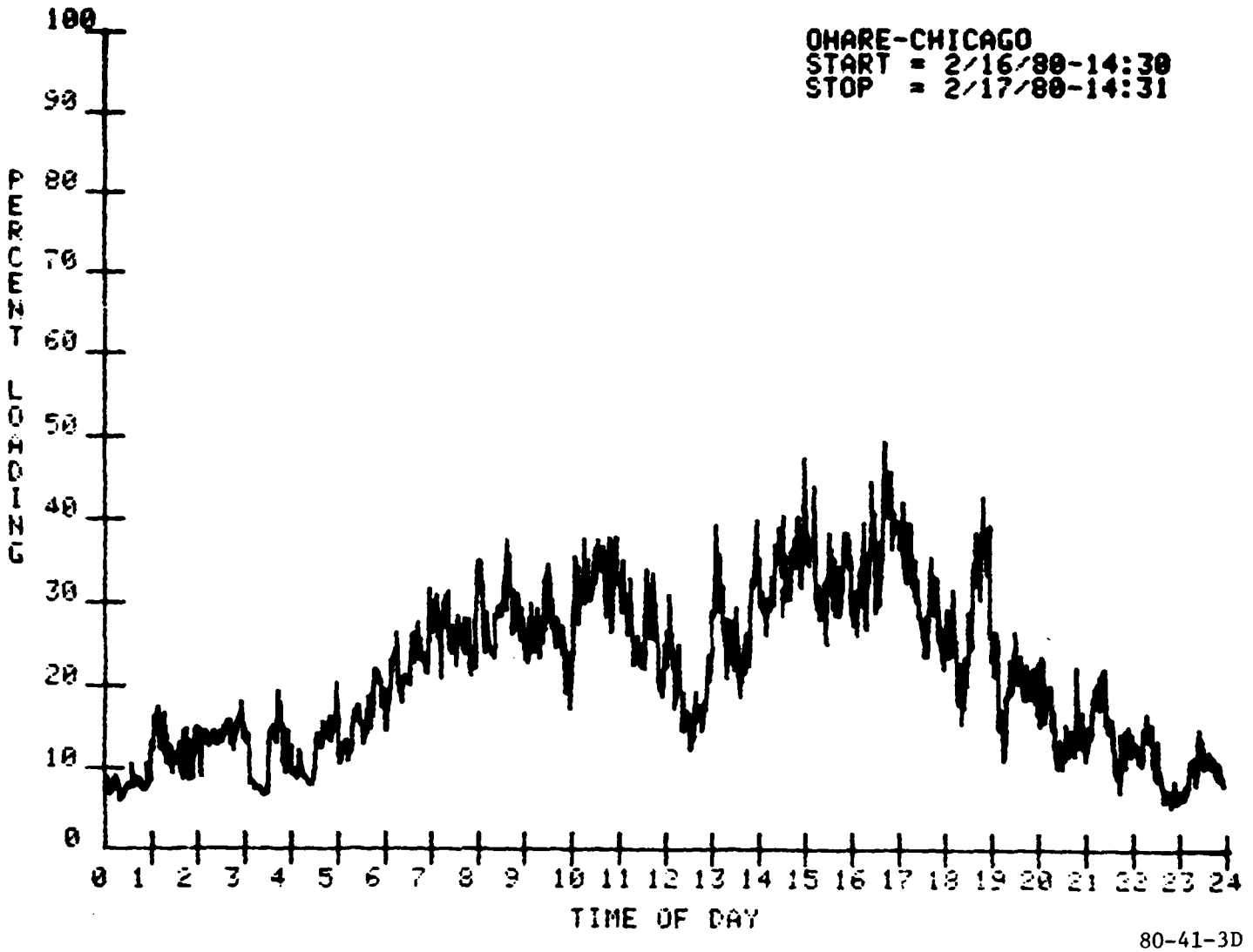


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 4 of 24)

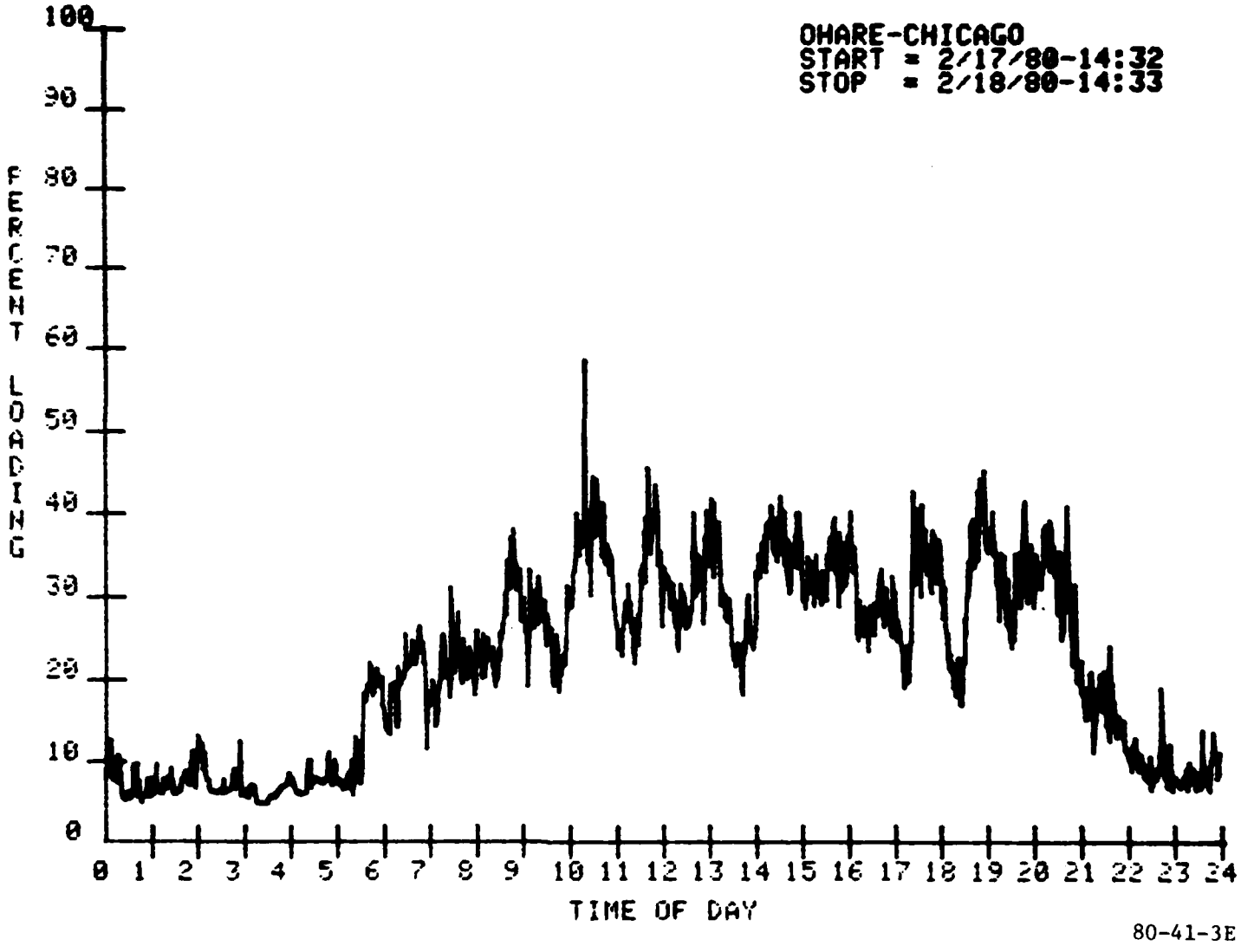


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 5 of 24)

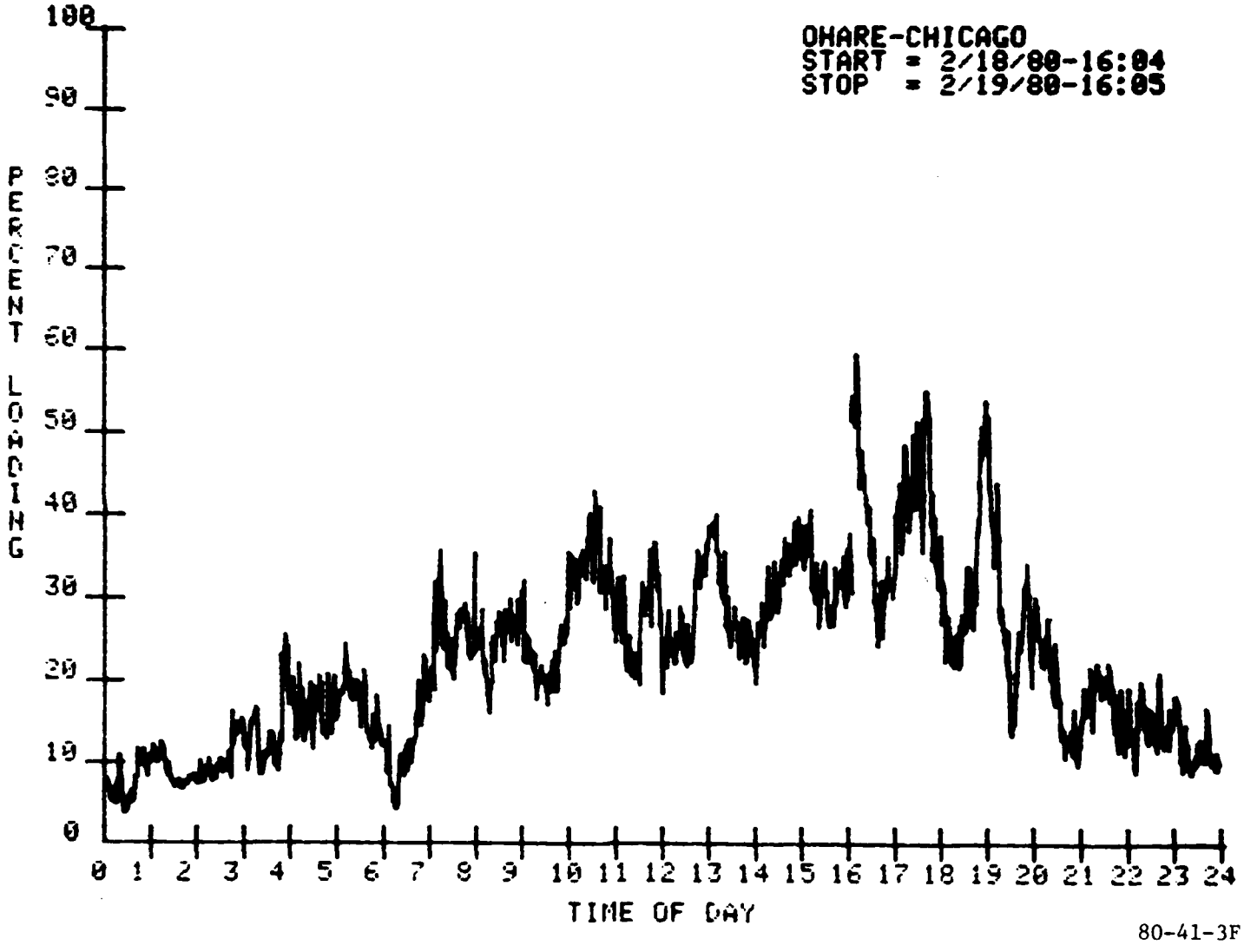


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 6 of 24)

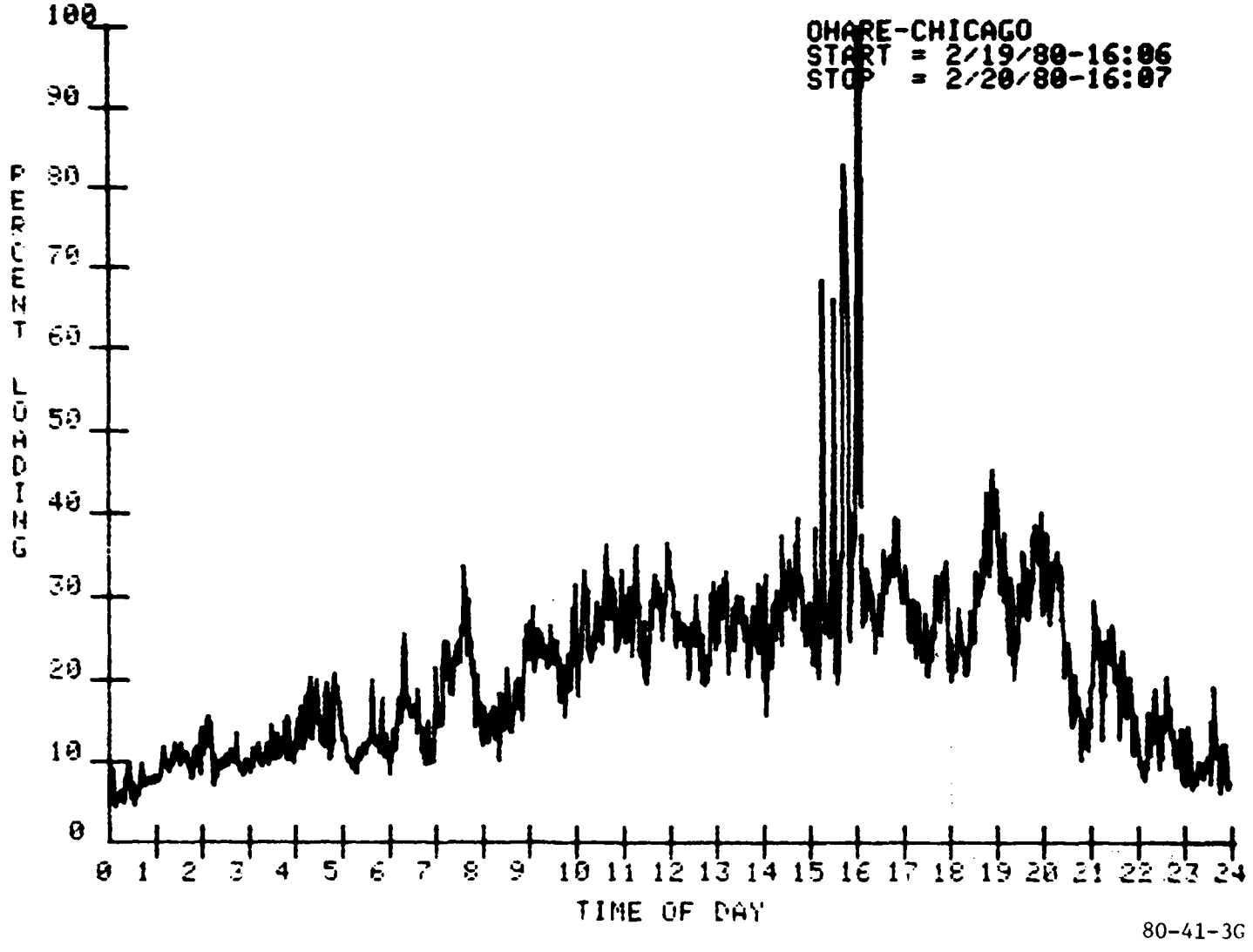


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 7 of 24)

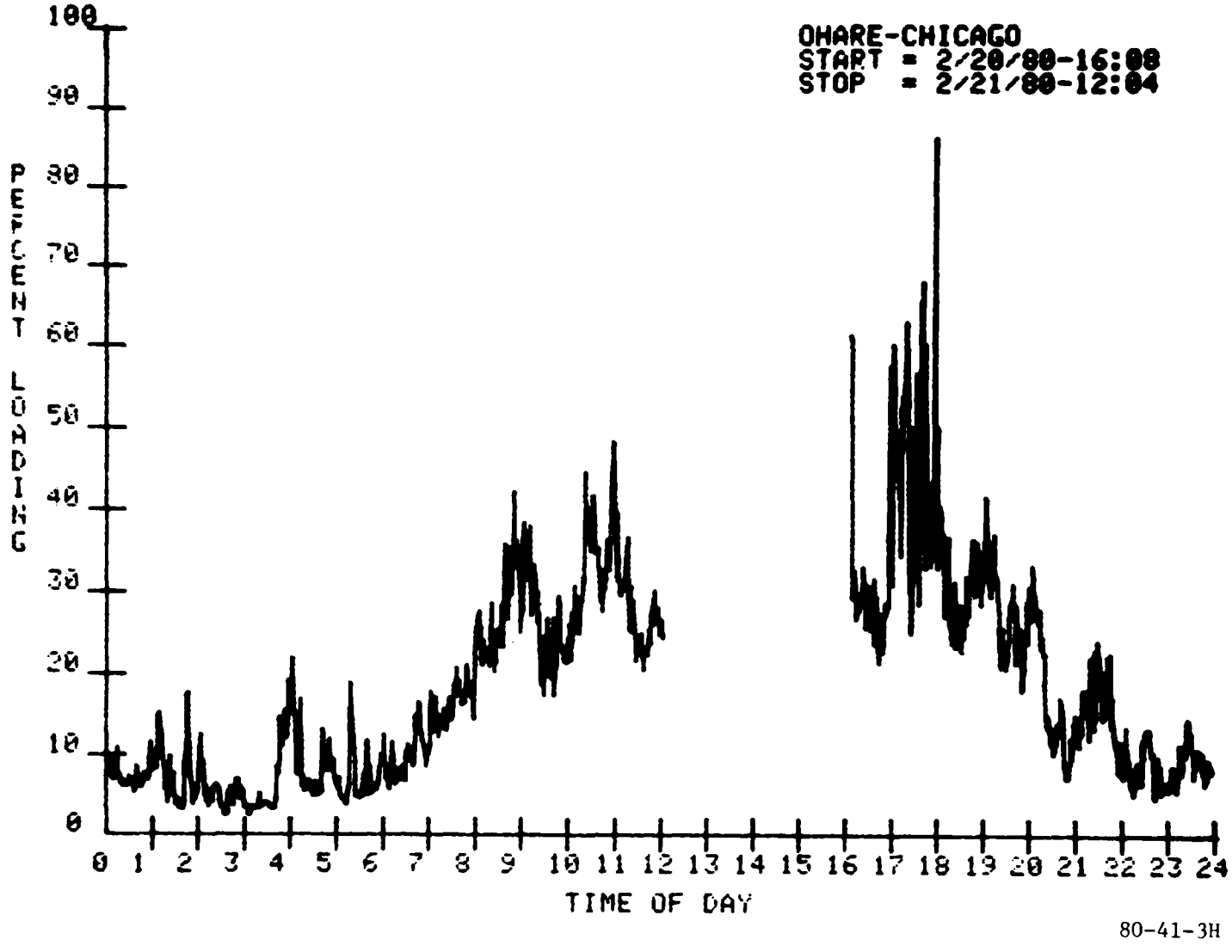


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 8 of 24)

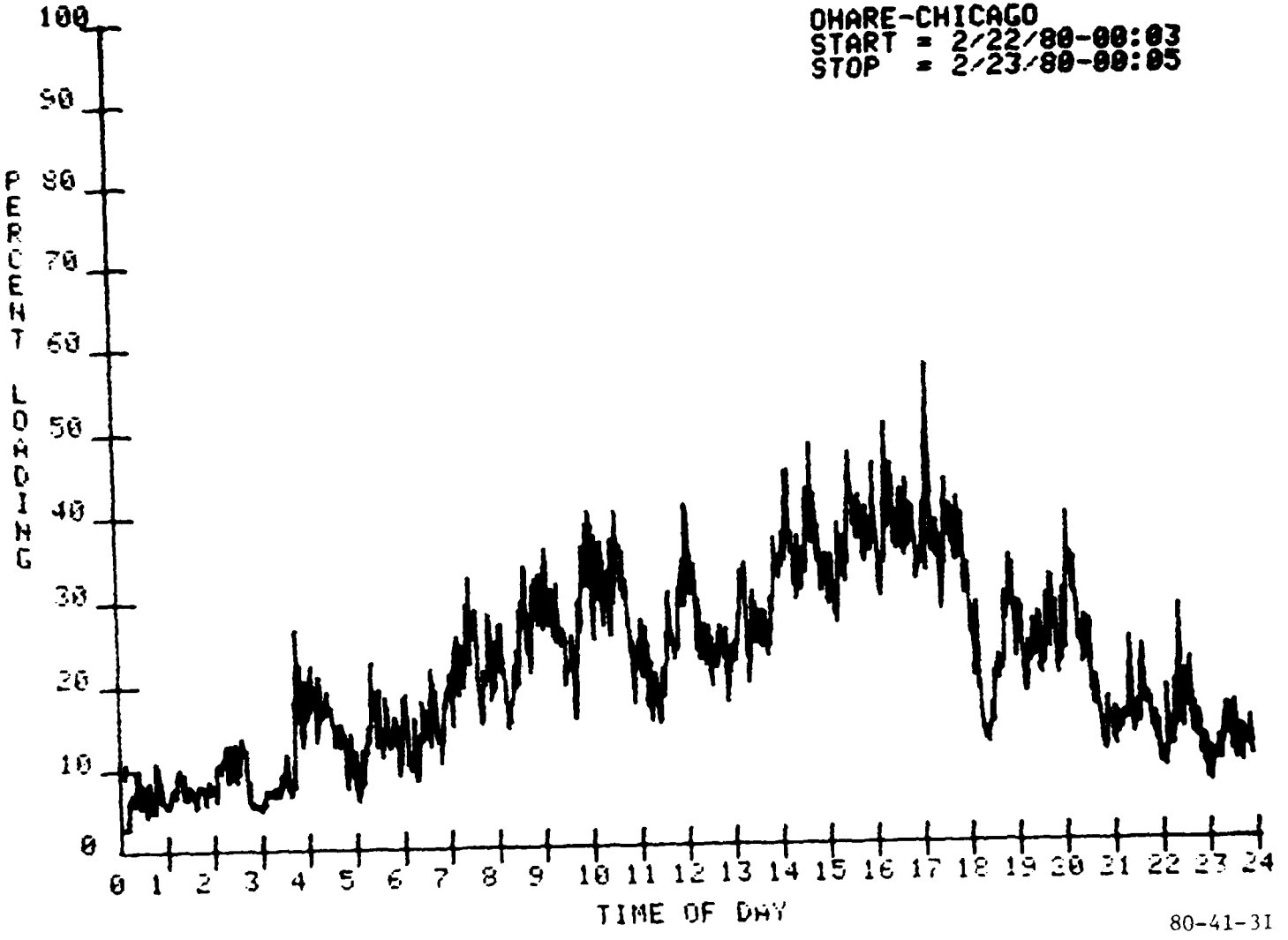


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 9 of 24)

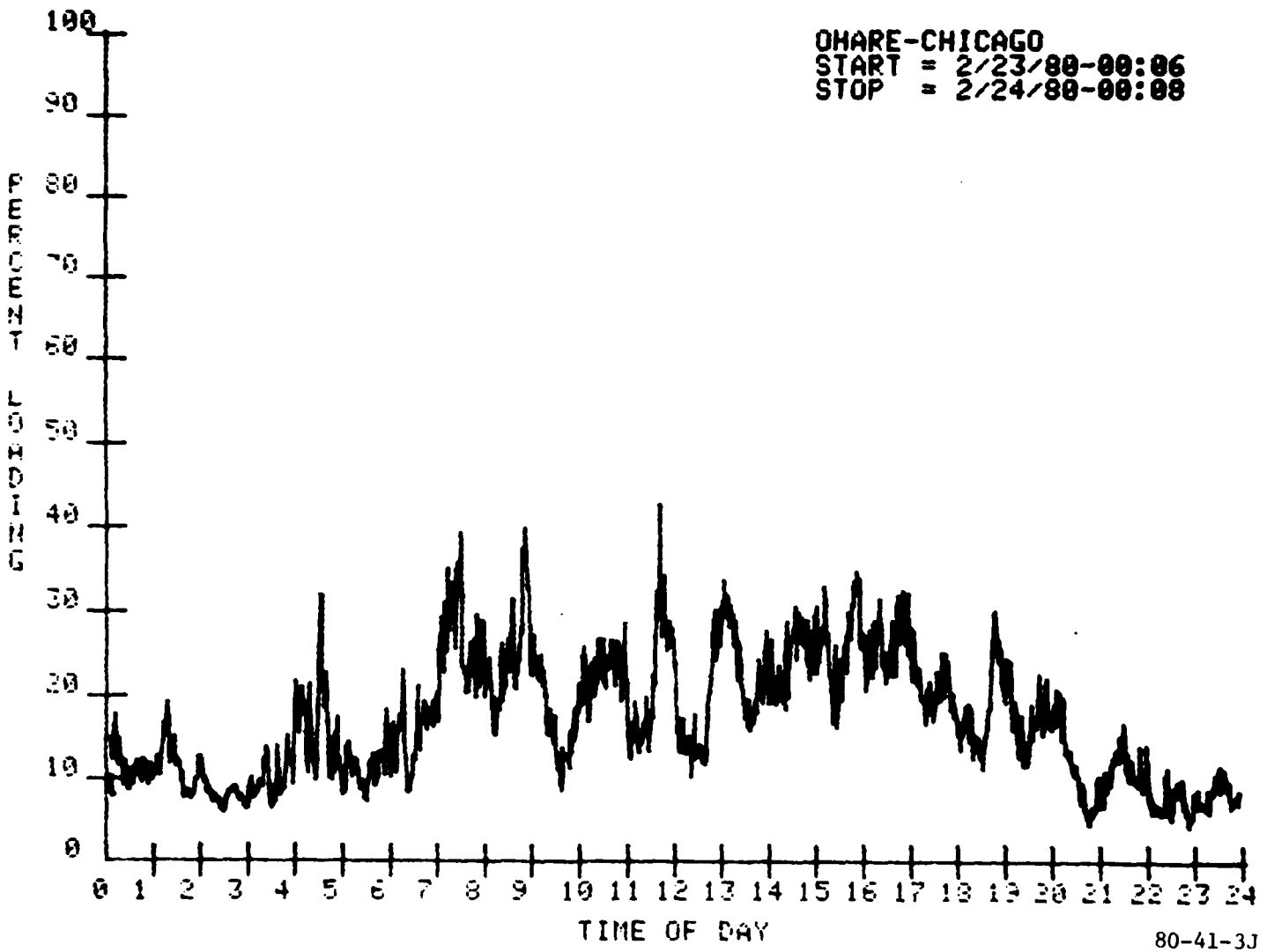


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 10 of 24)

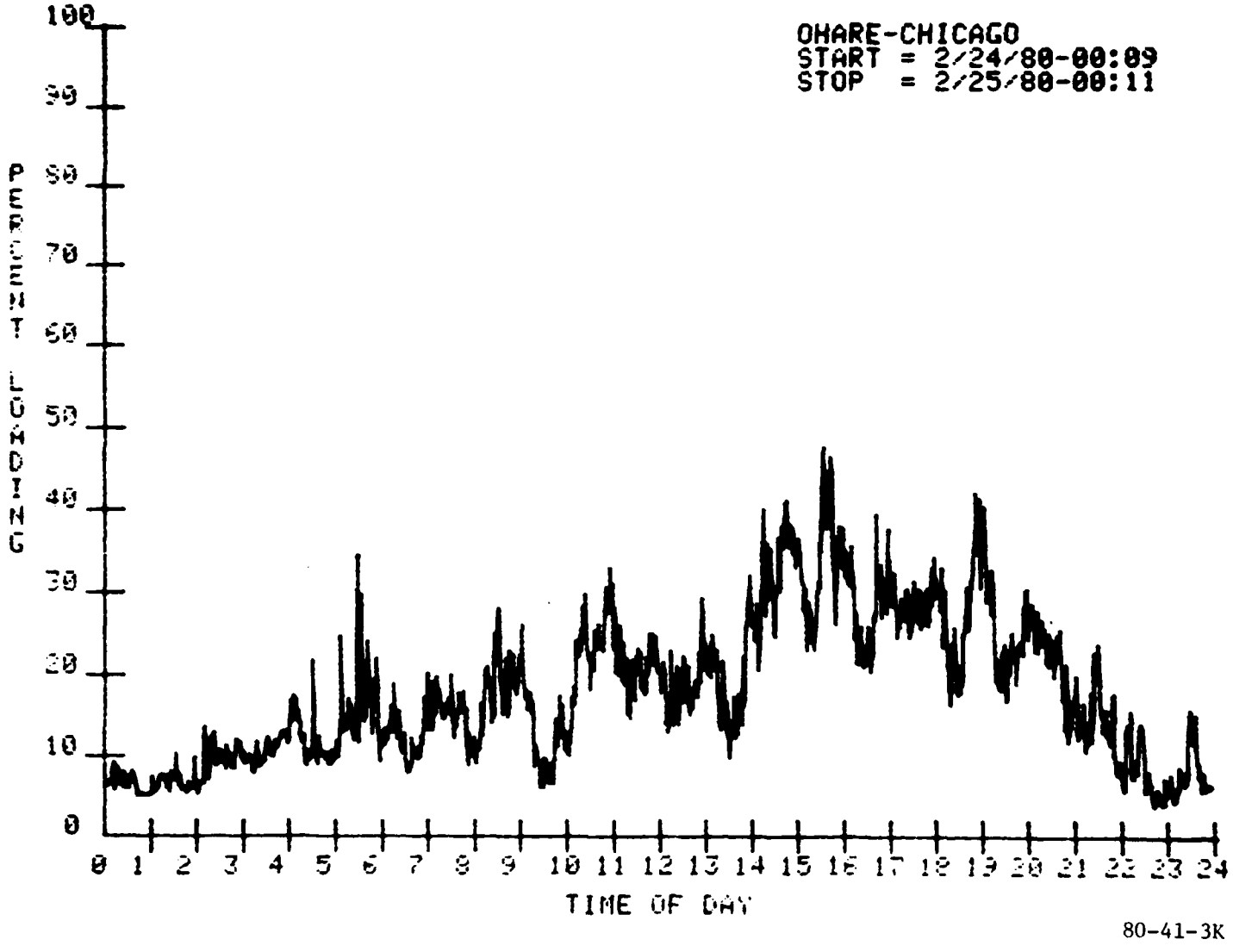


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 11 of 24)

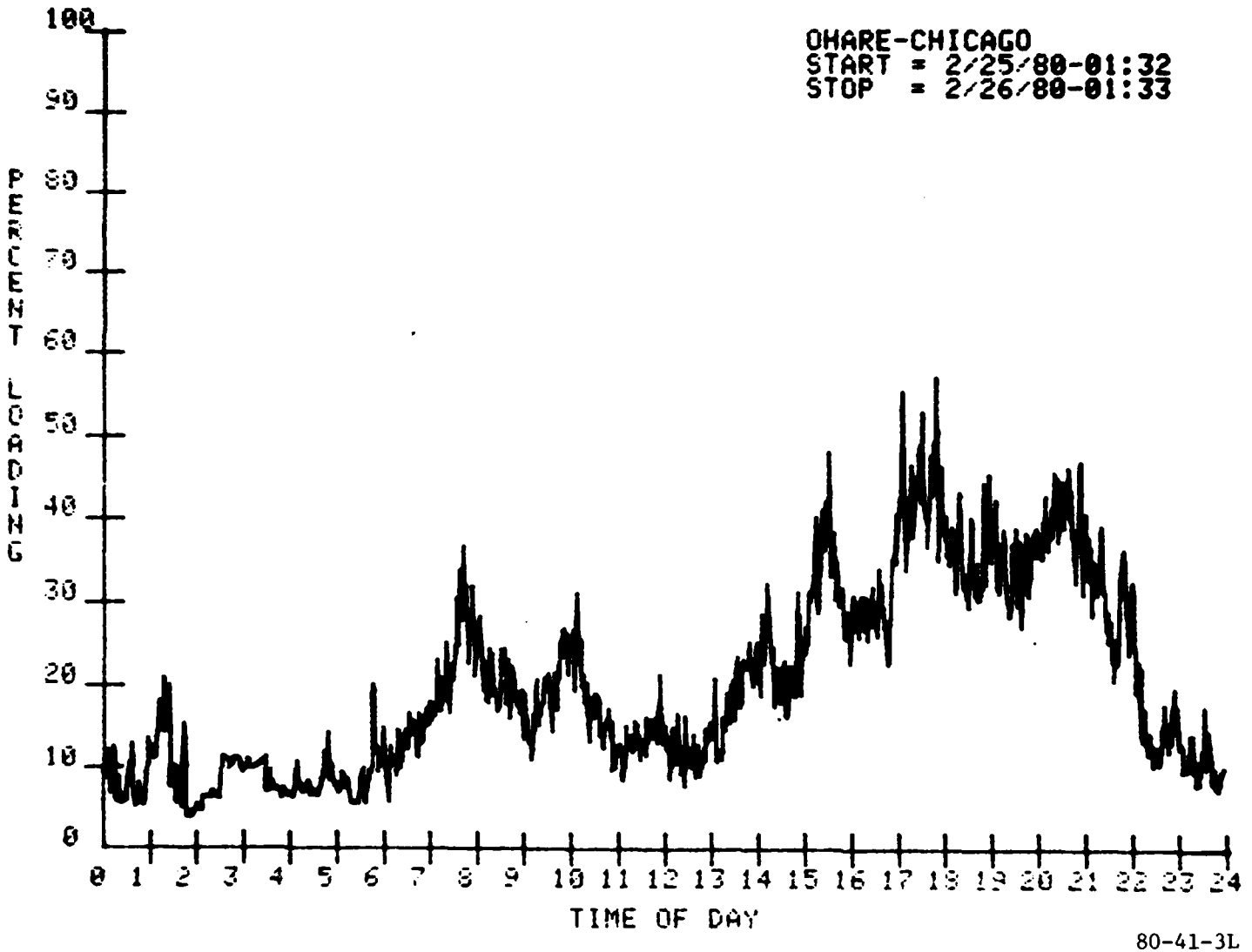


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 12 of 24)

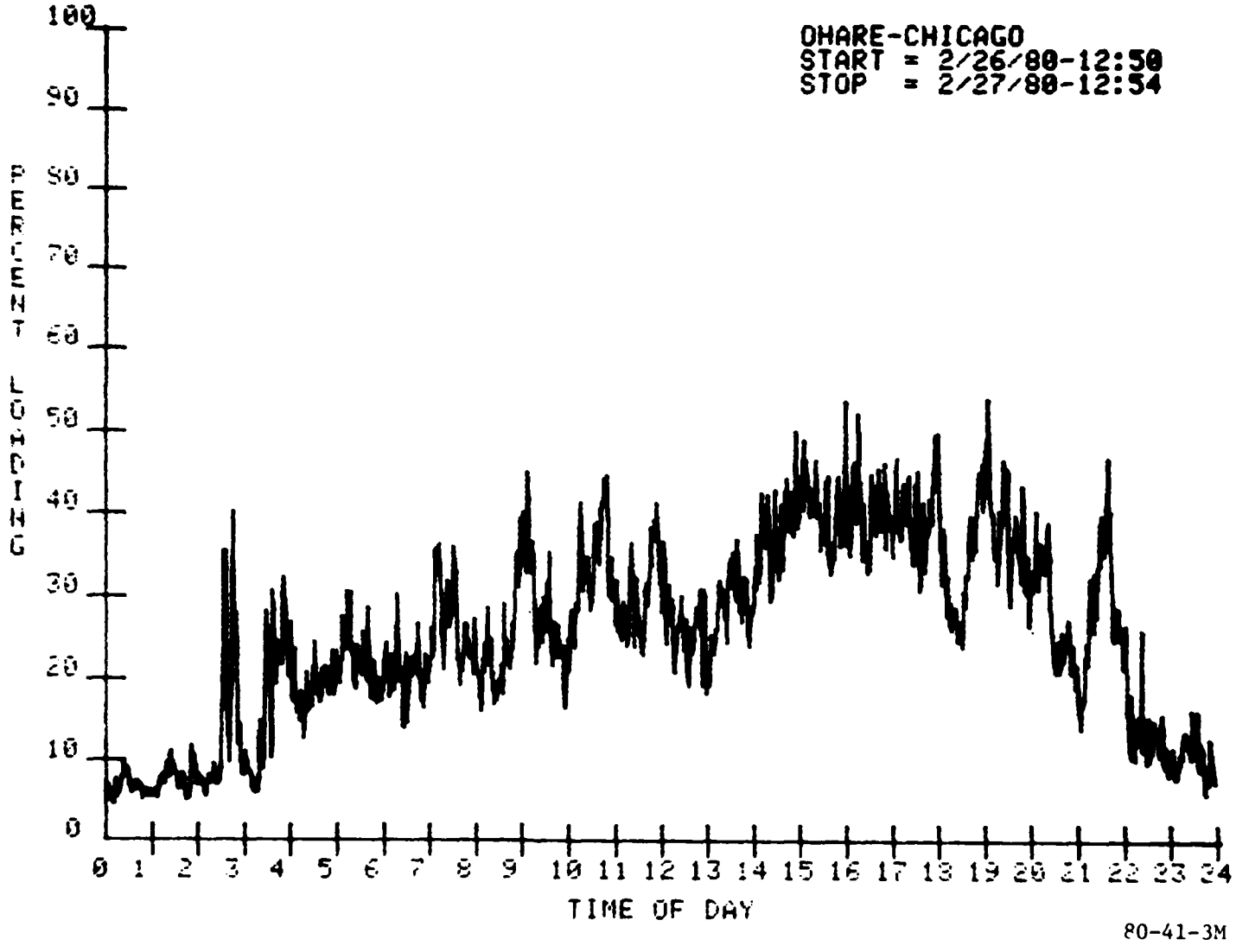


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 13 of 24)

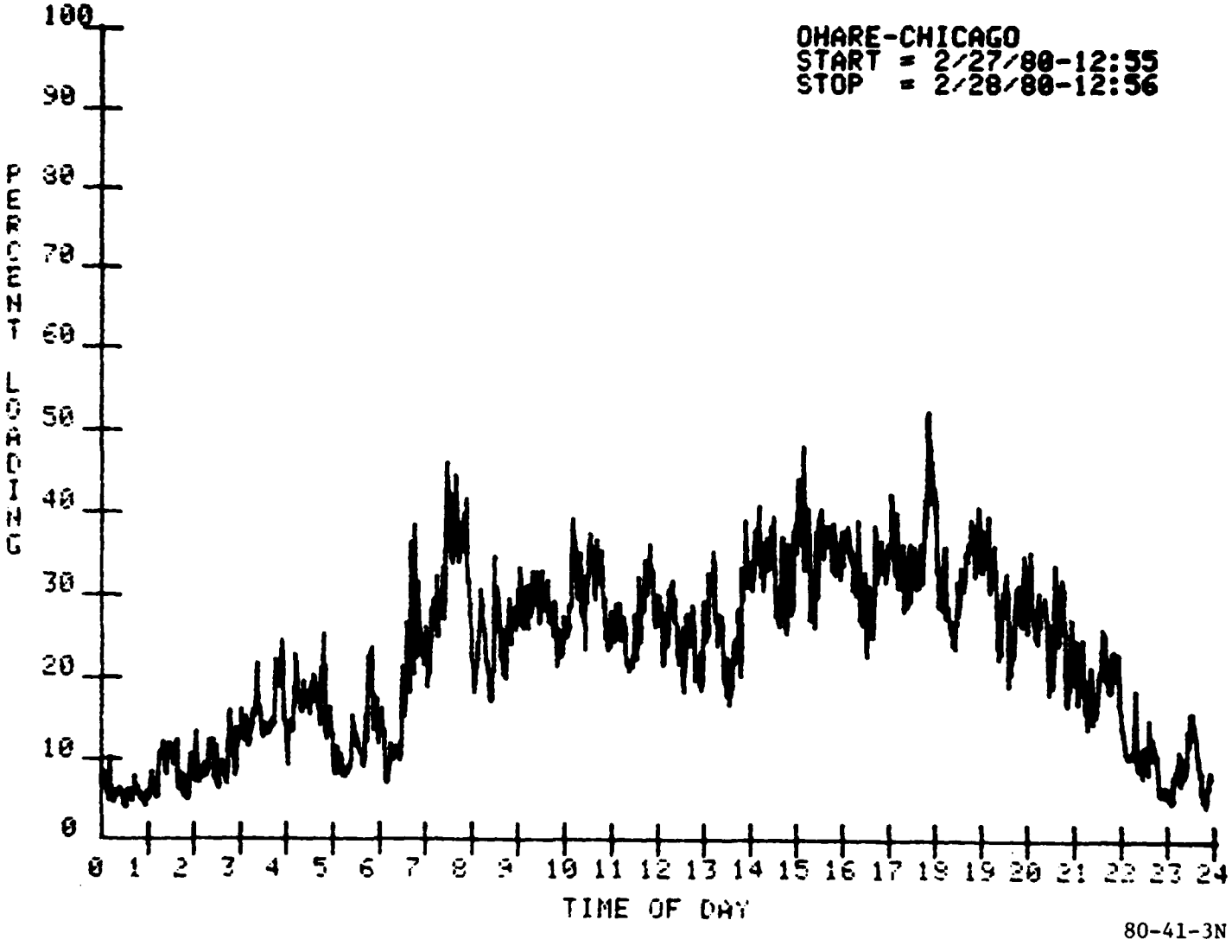


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 14 of 24)

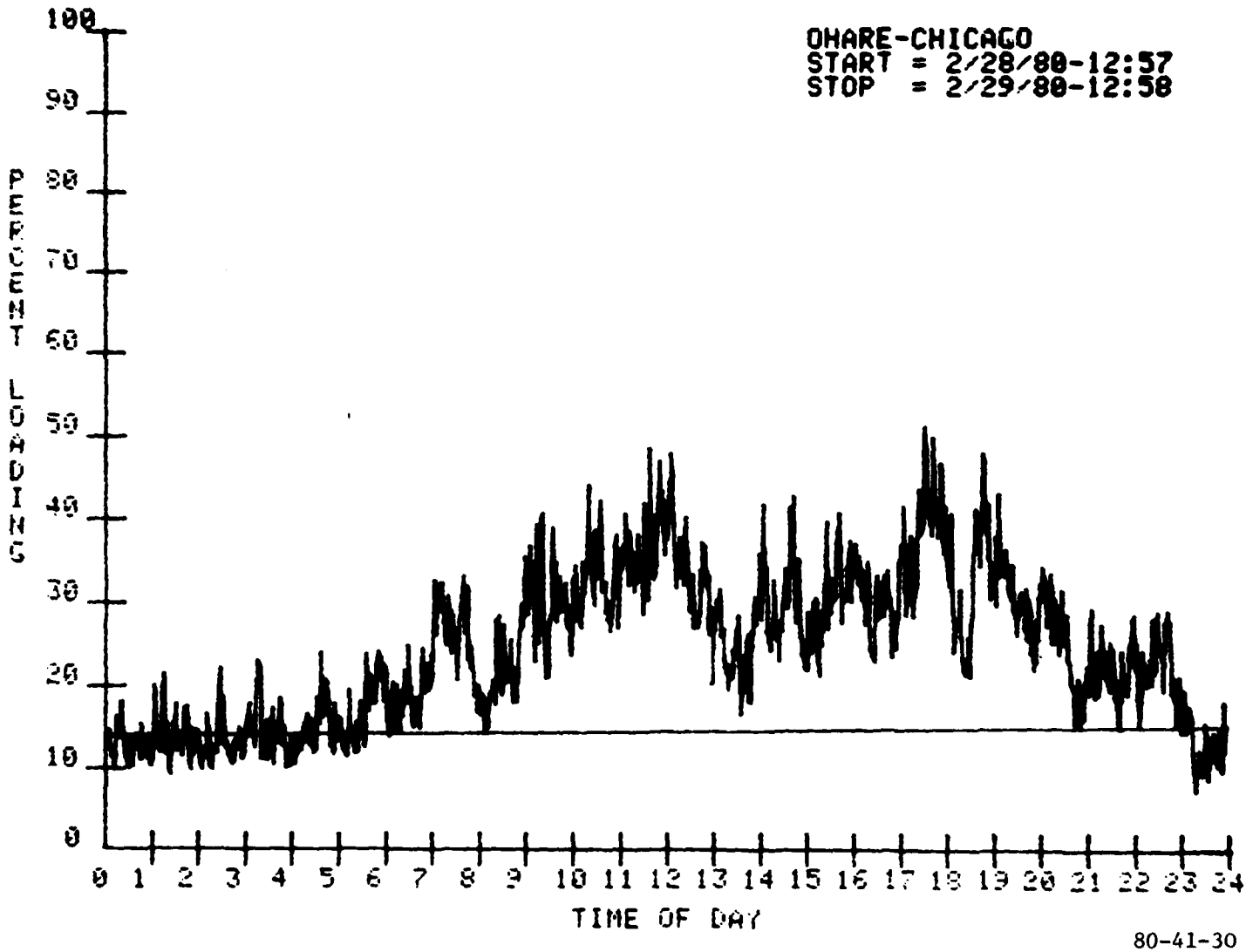


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 15 of 24)

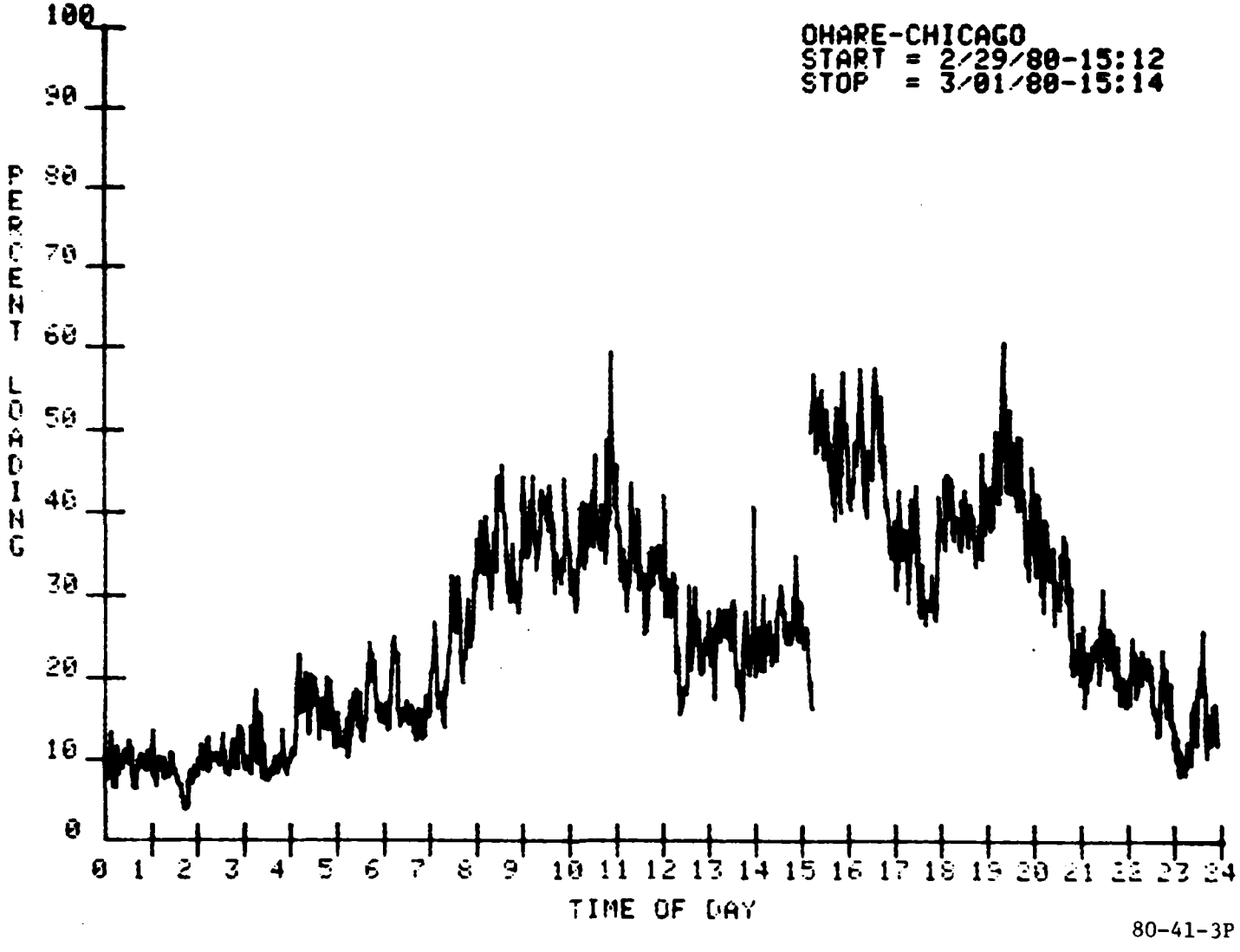


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 16 of 24)

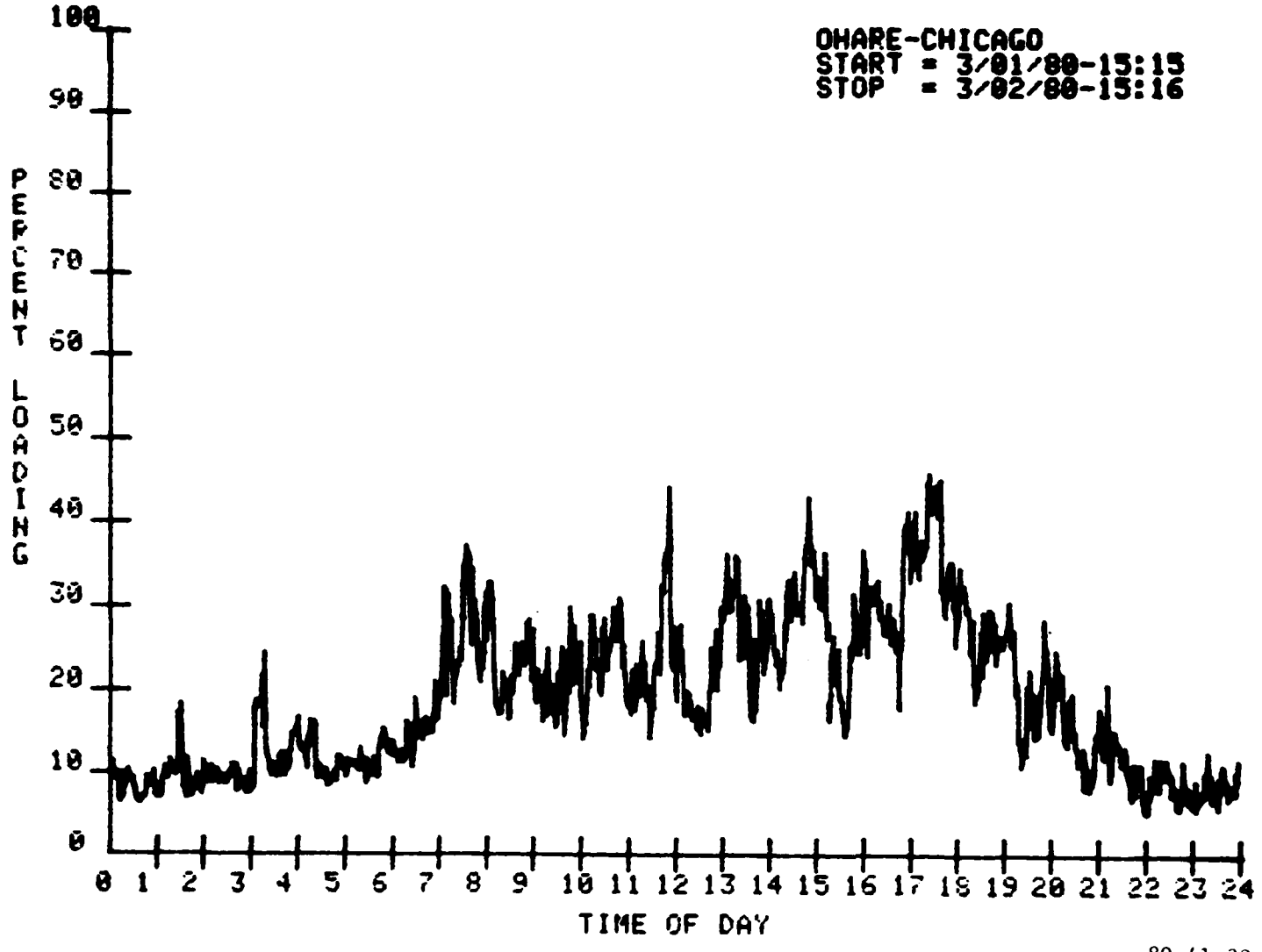


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 17 of 24)

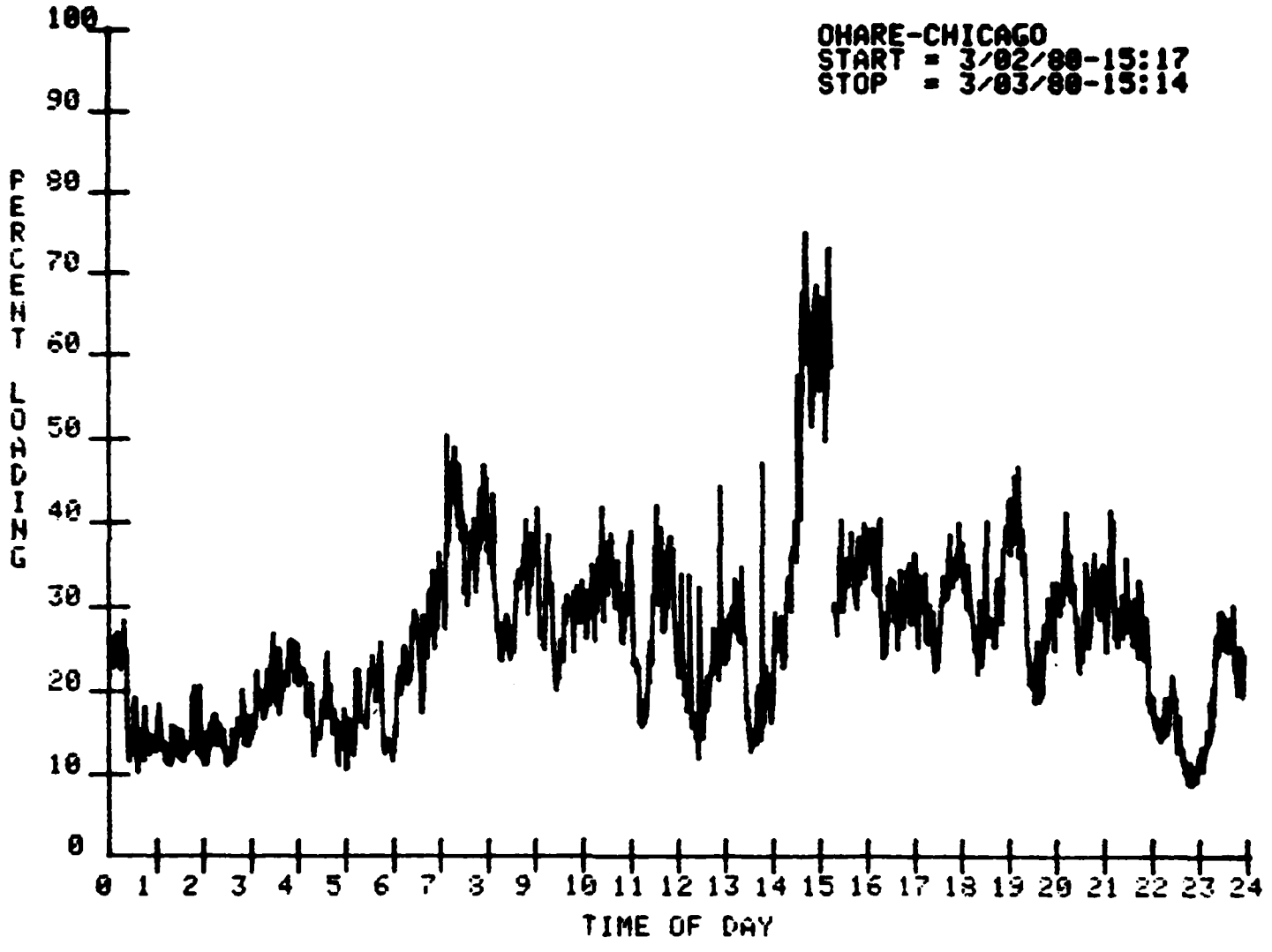


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 18 of 24)

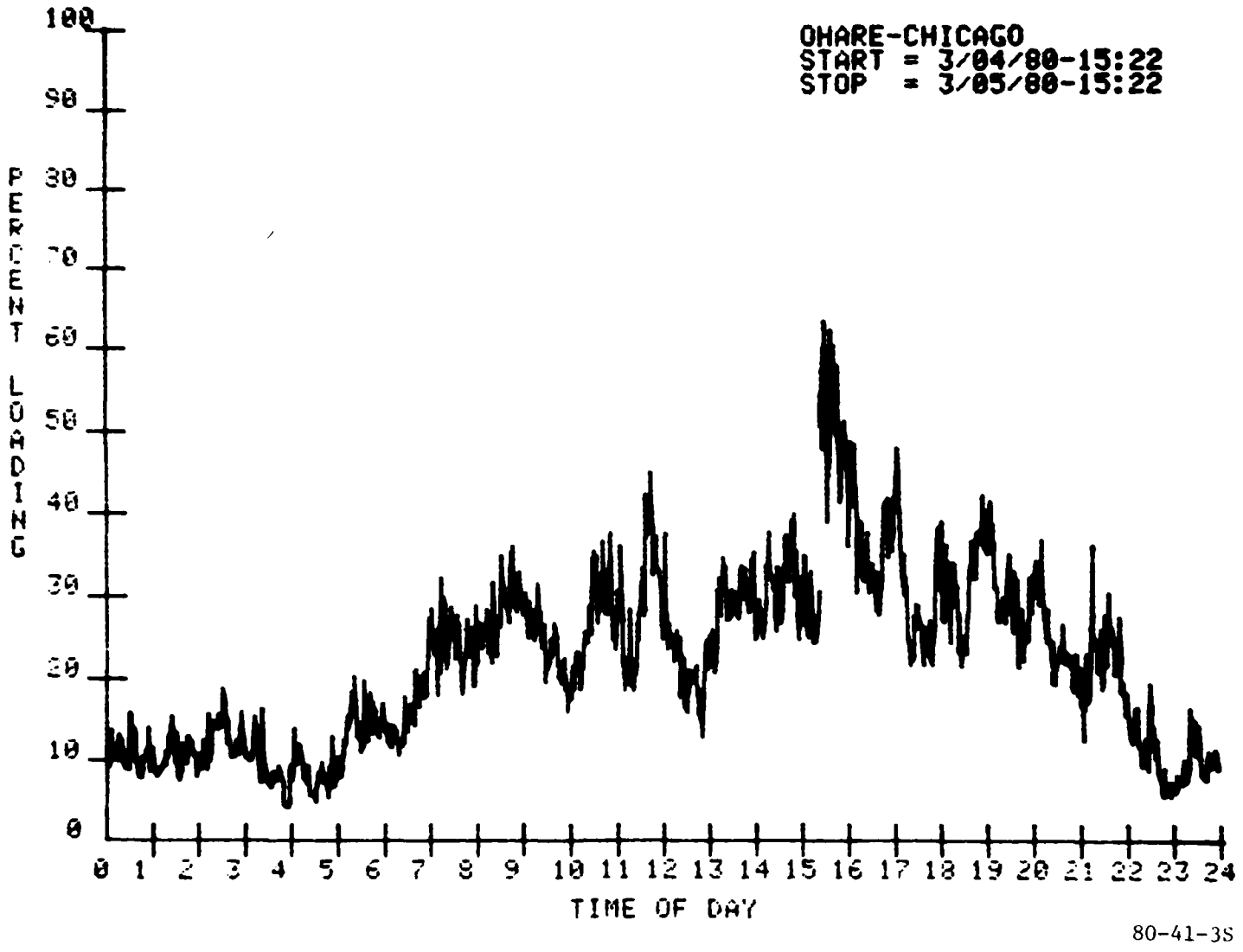


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 19 of 24)

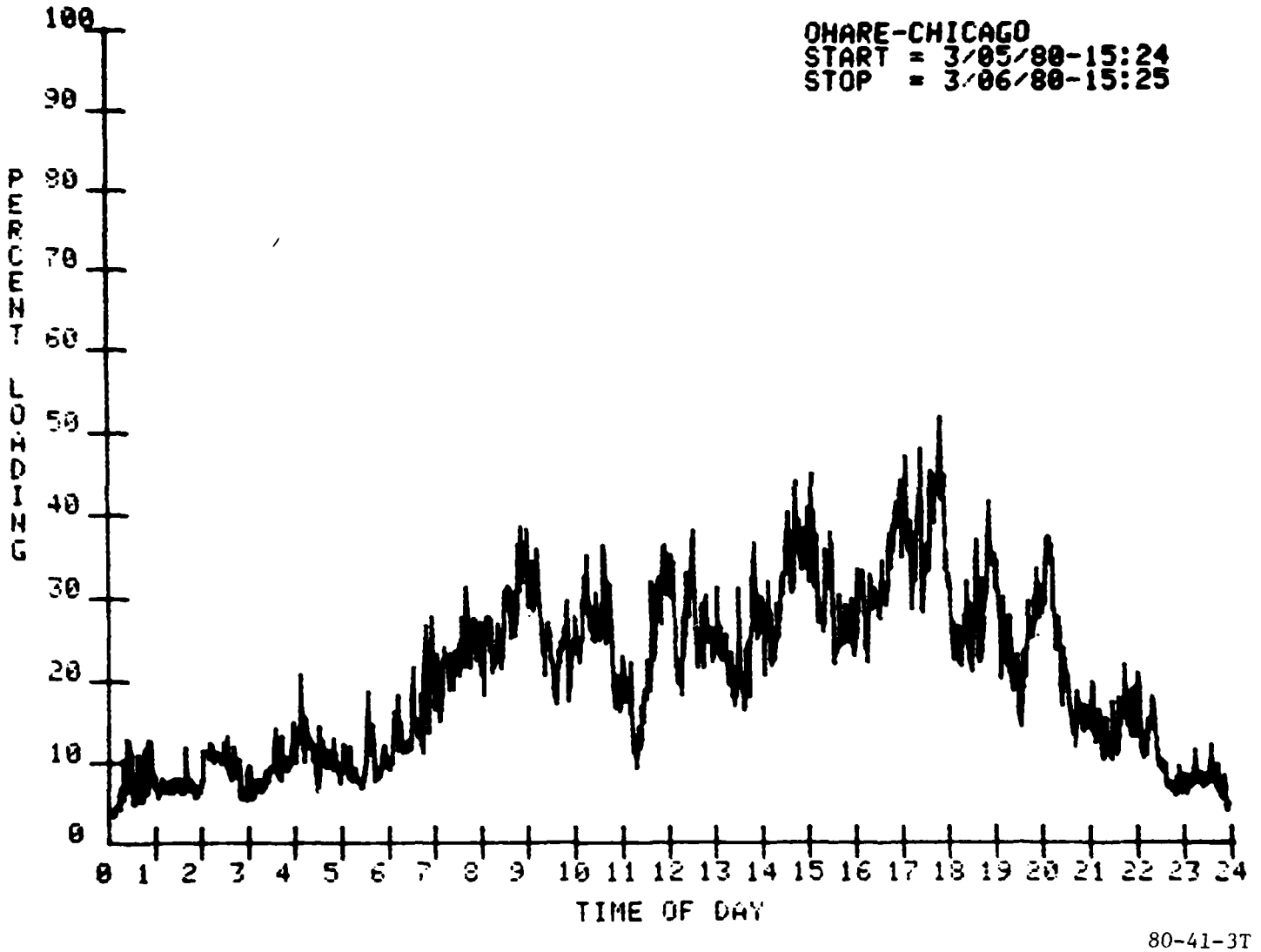


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 20 of 24)

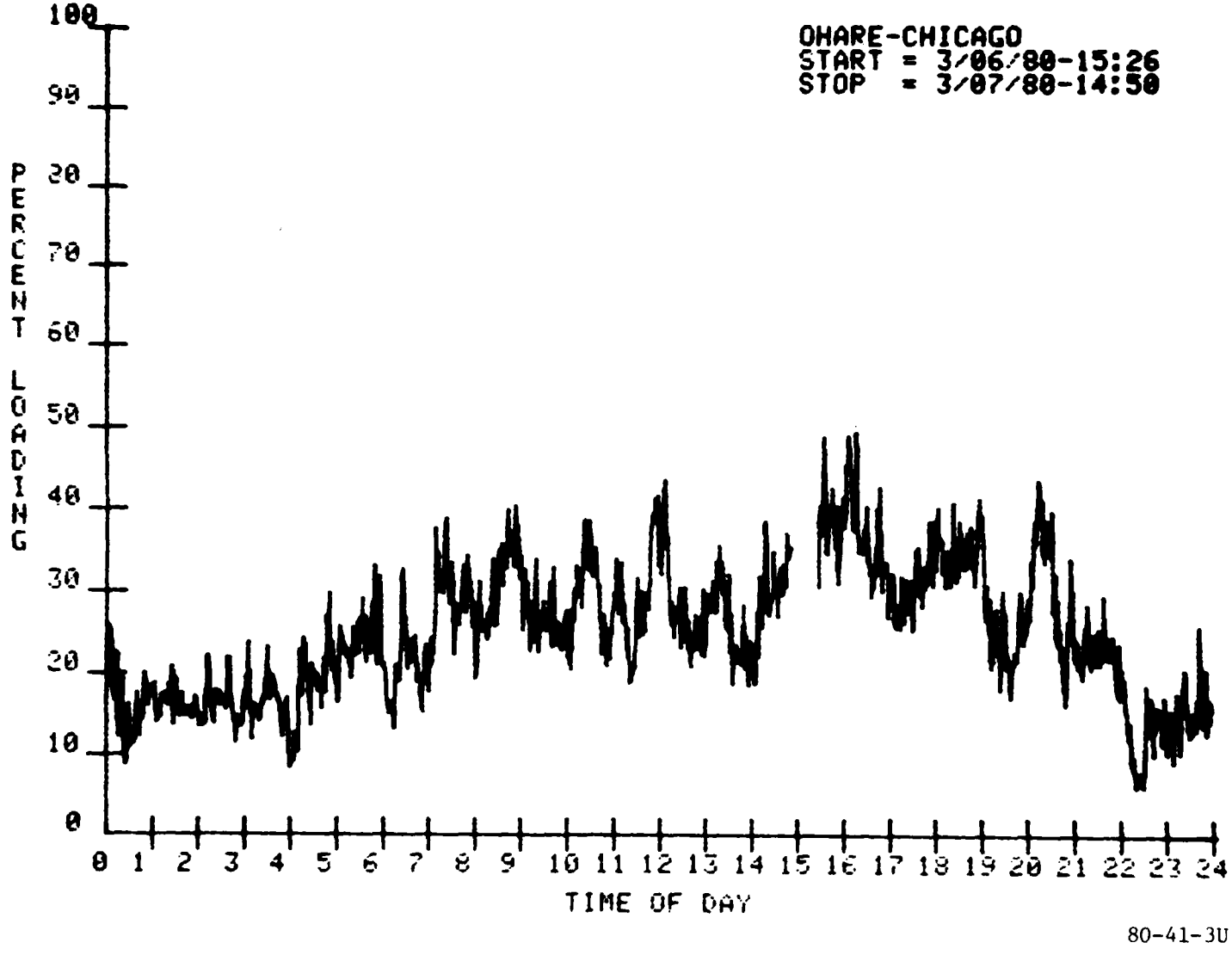


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 21 of 24)

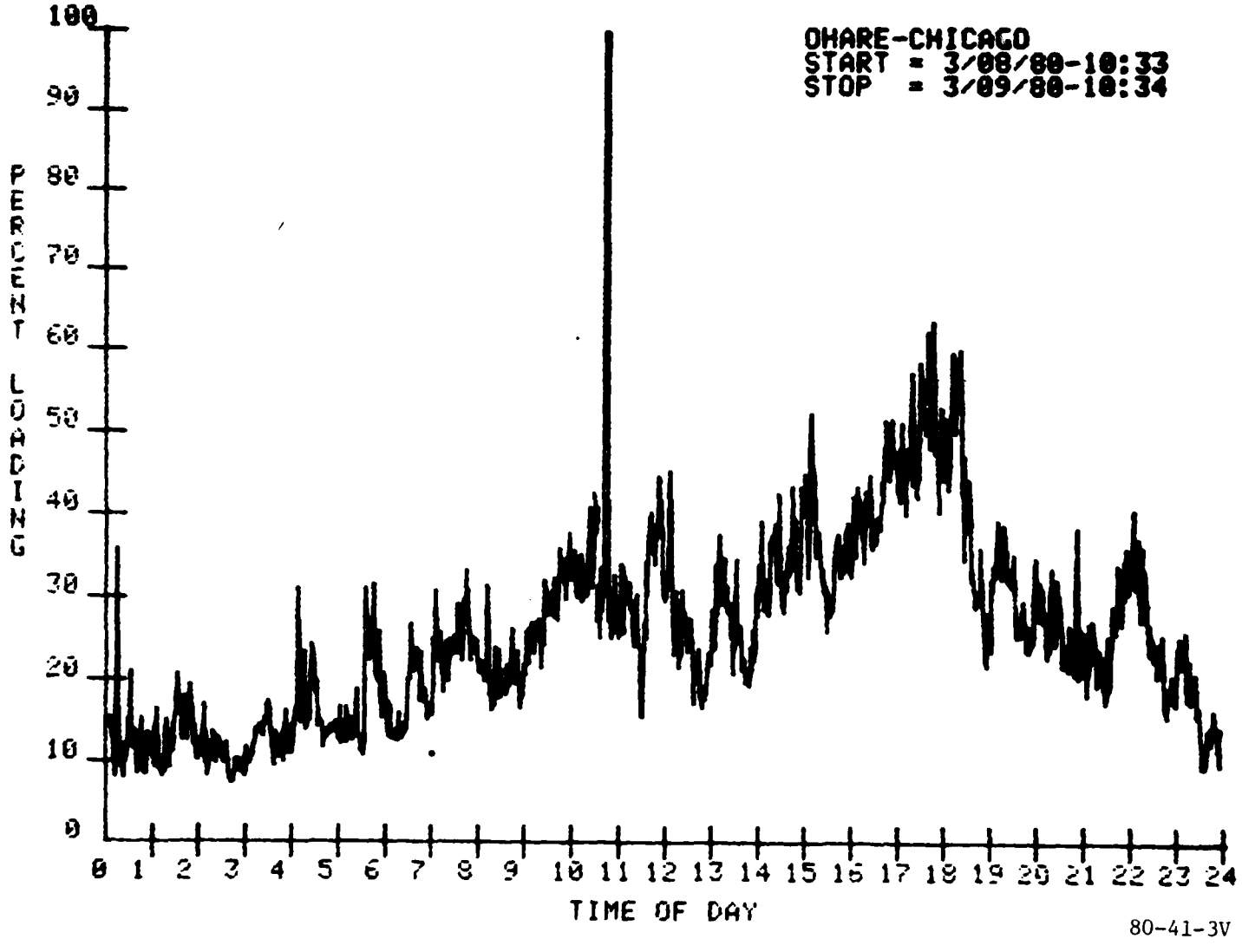


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 22 of 24)

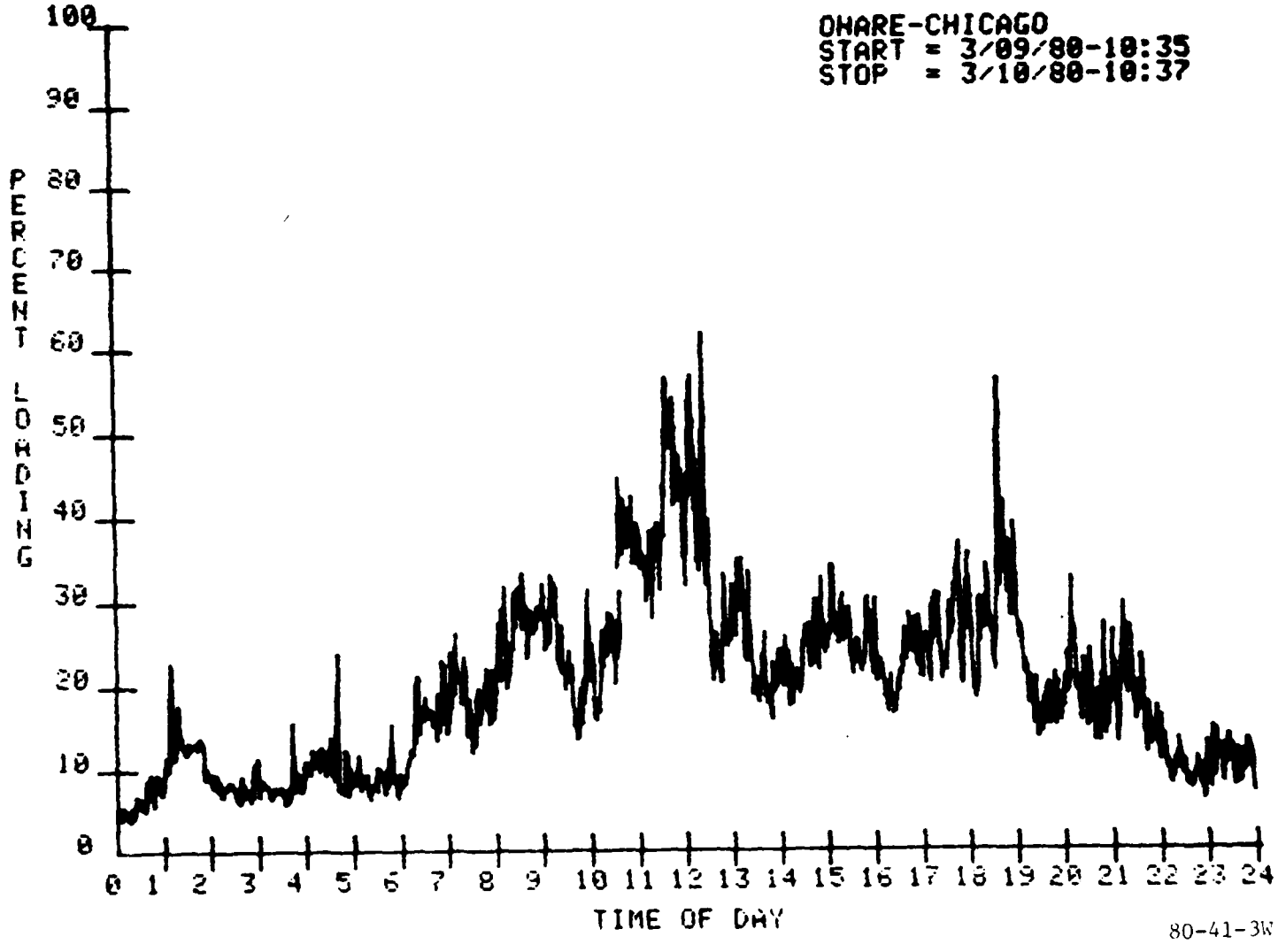


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 23 of 24)

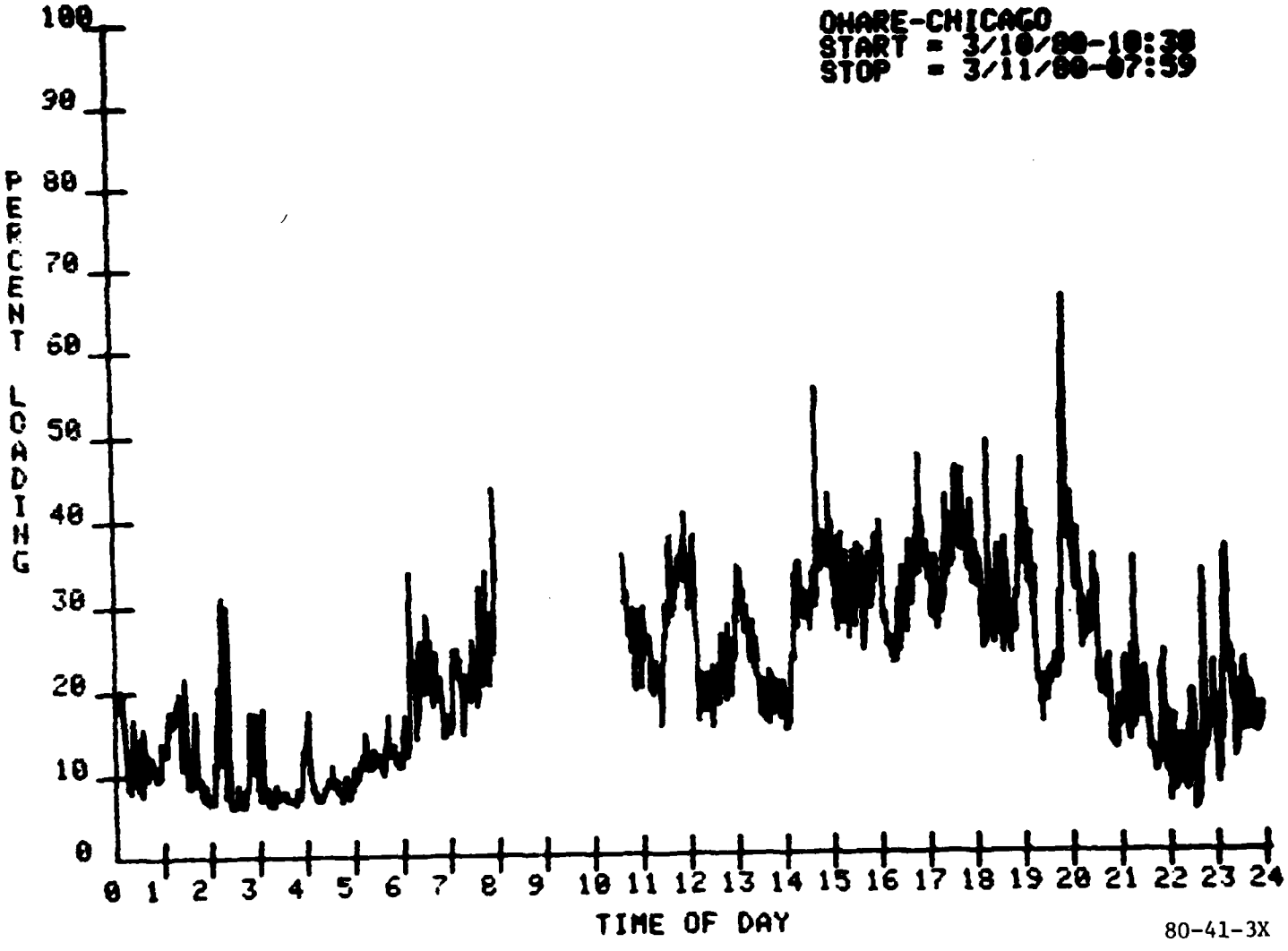


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 24 of 24)

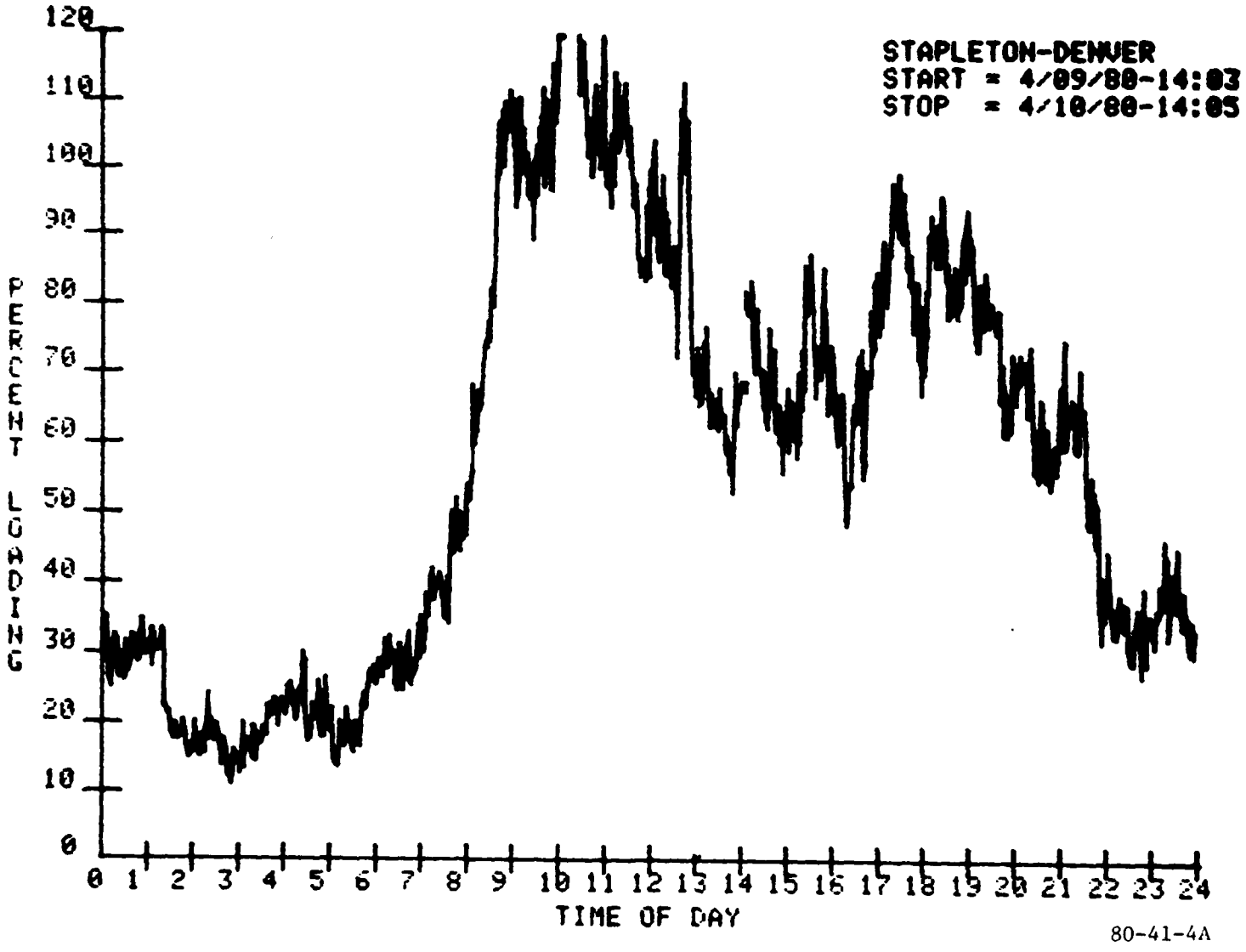


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 1 of 30)

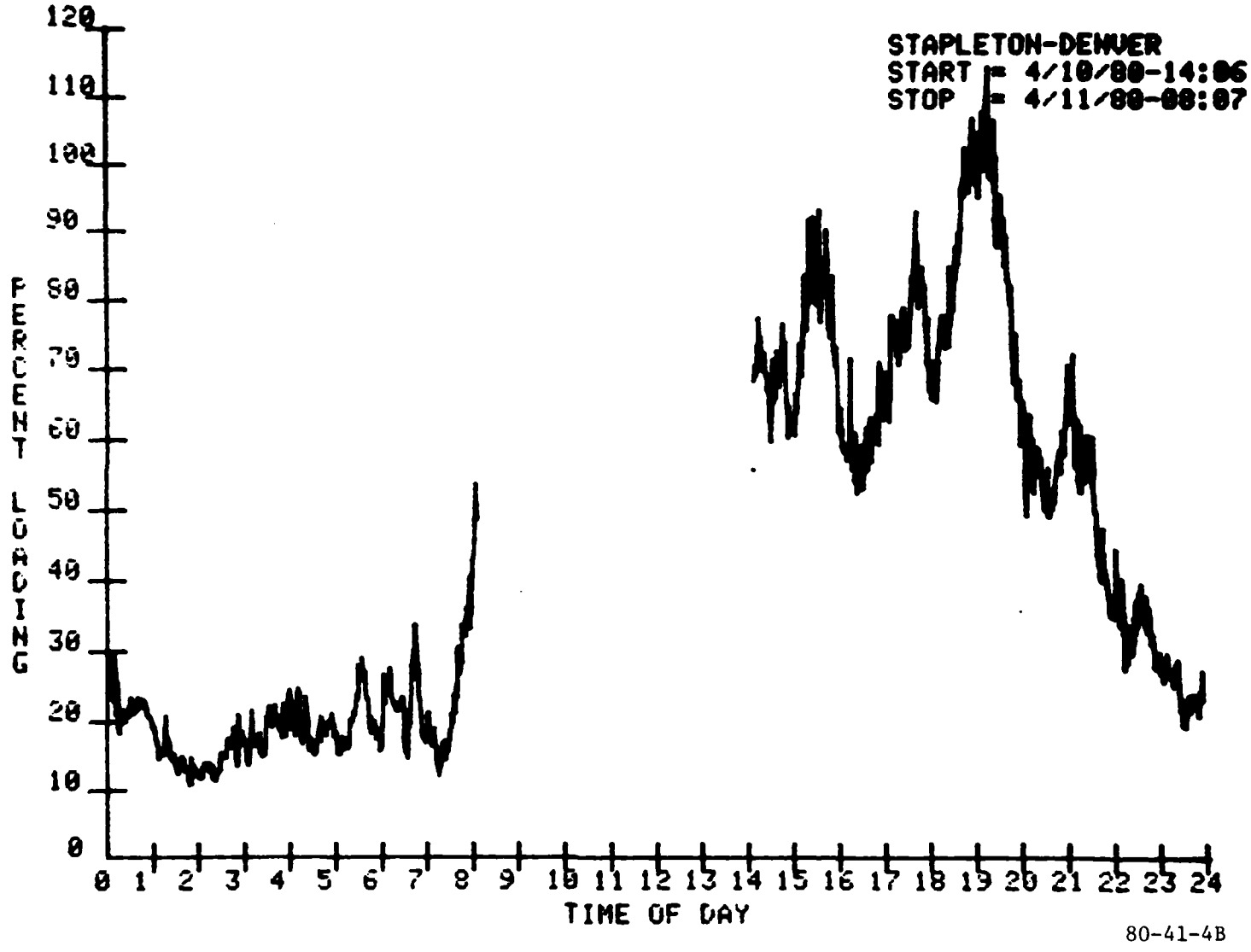


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 2 of 30)

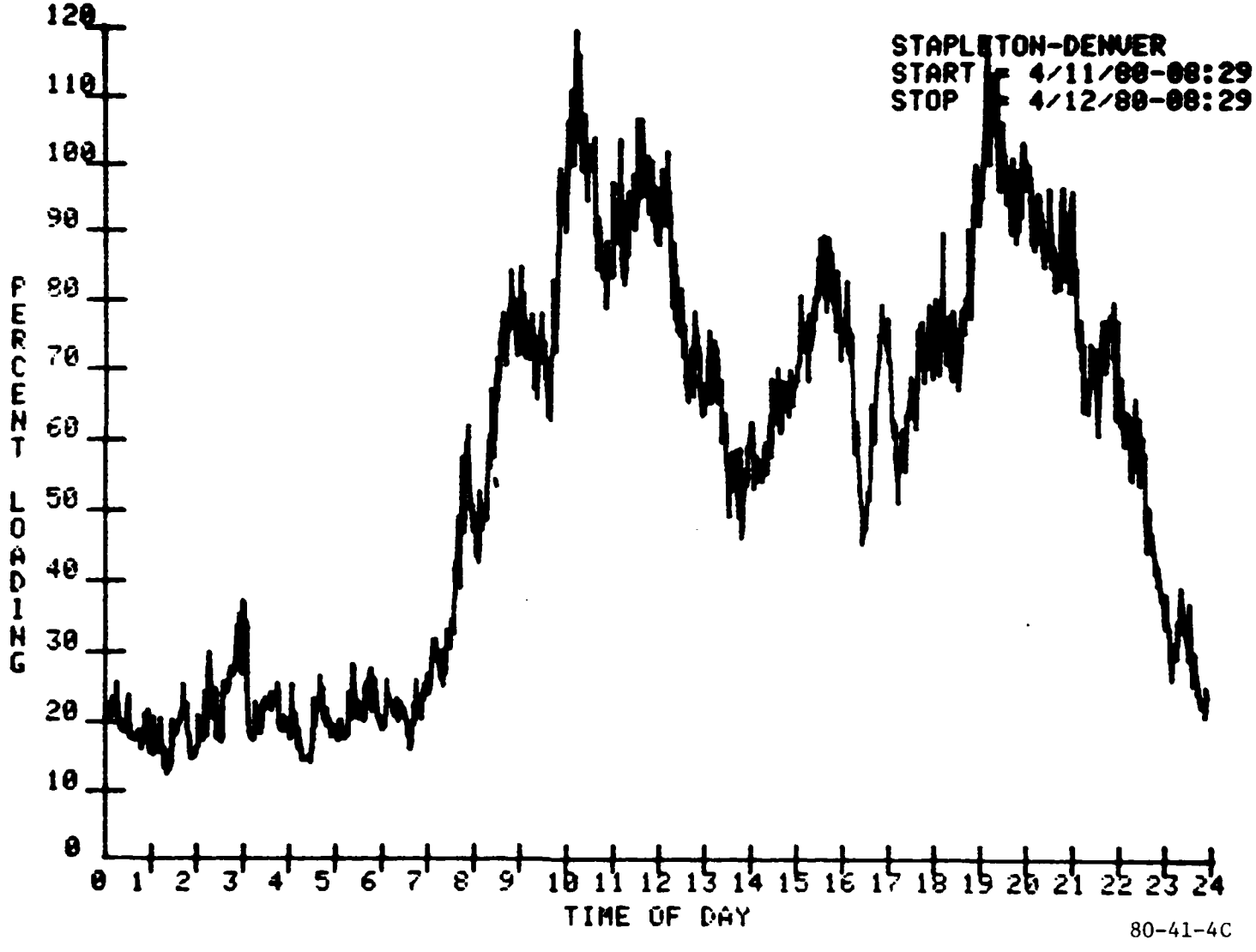


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 3 of 30)

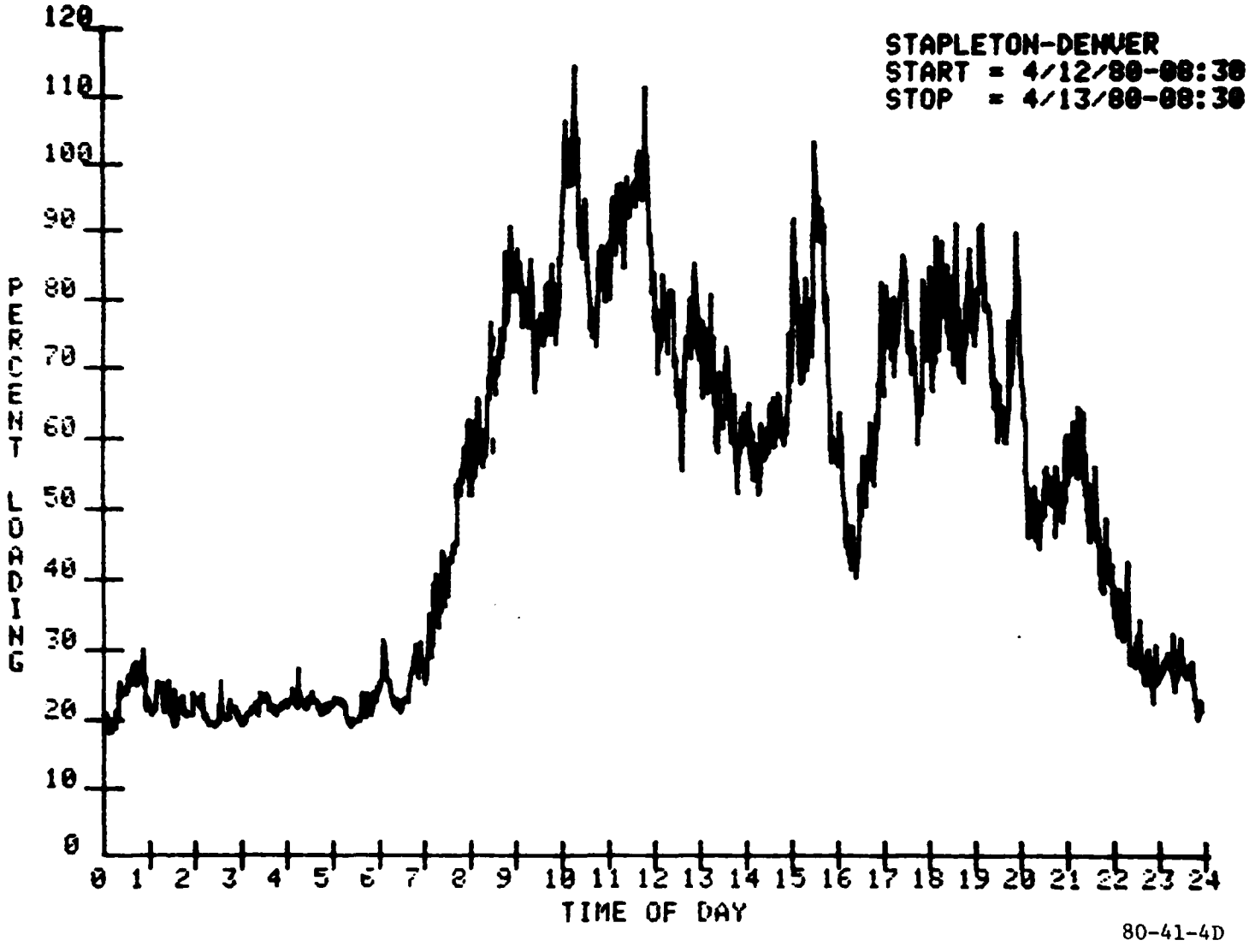


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 4 of 30)

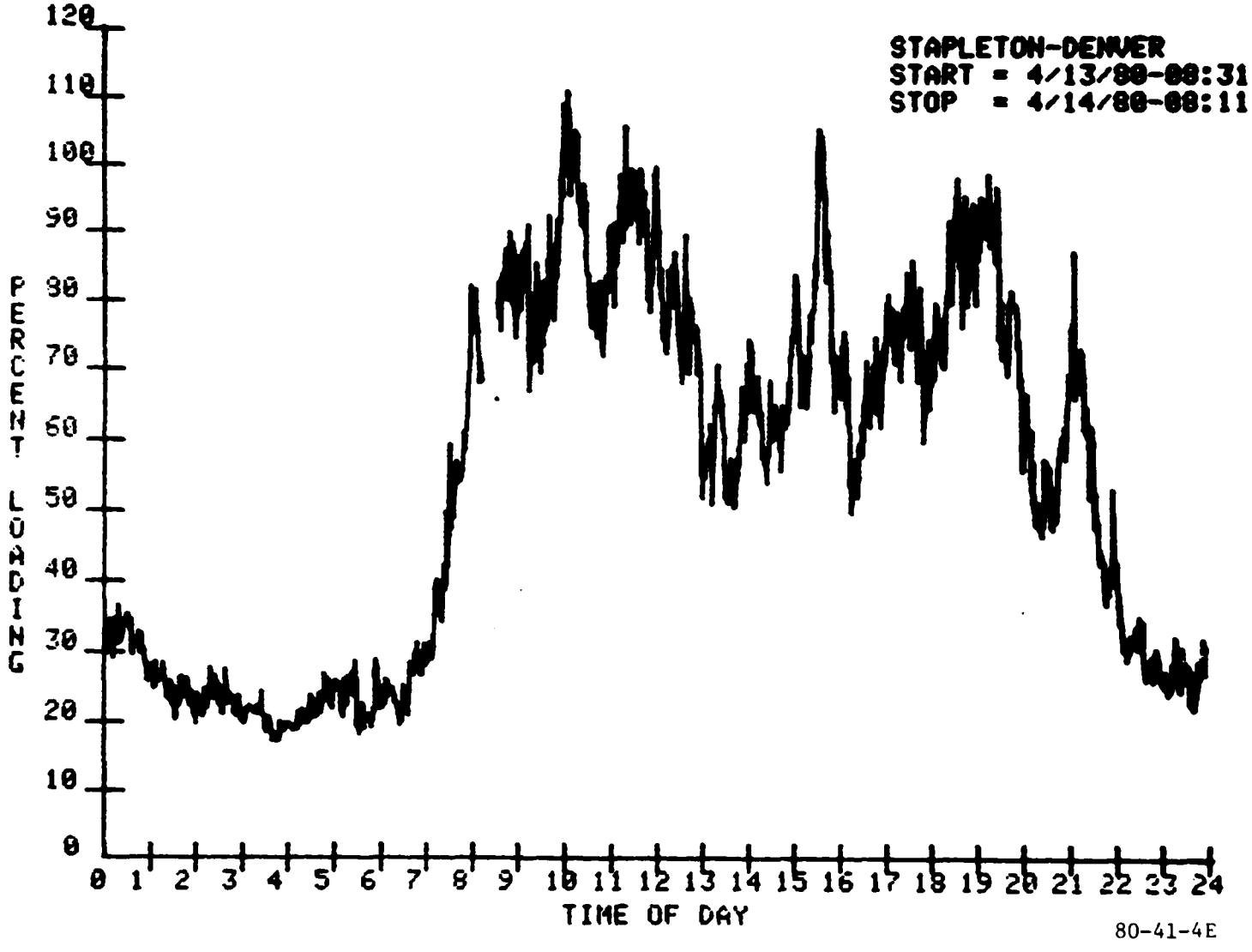


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 5 of 30)

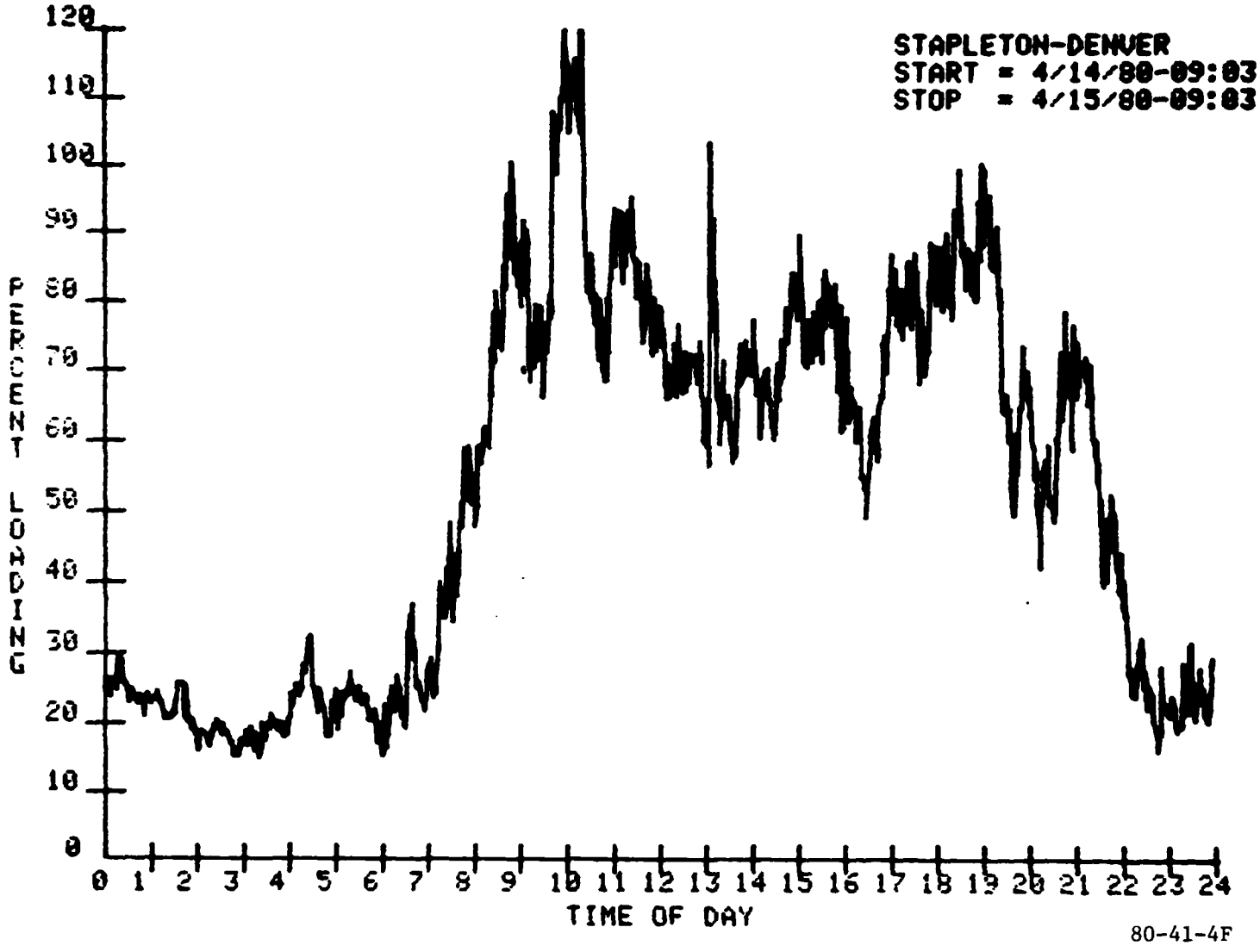


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 6 of 30)

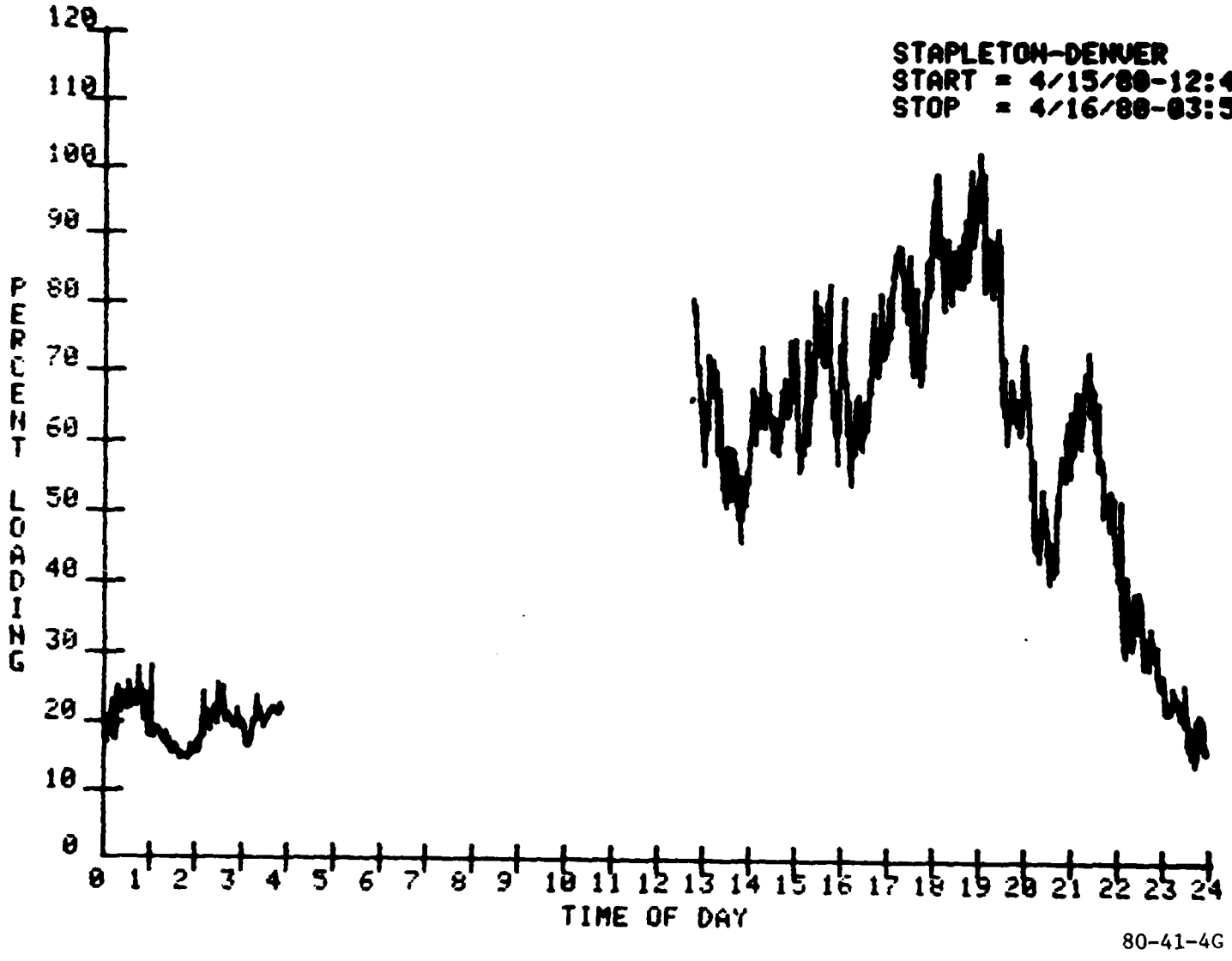


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 7 of 30)

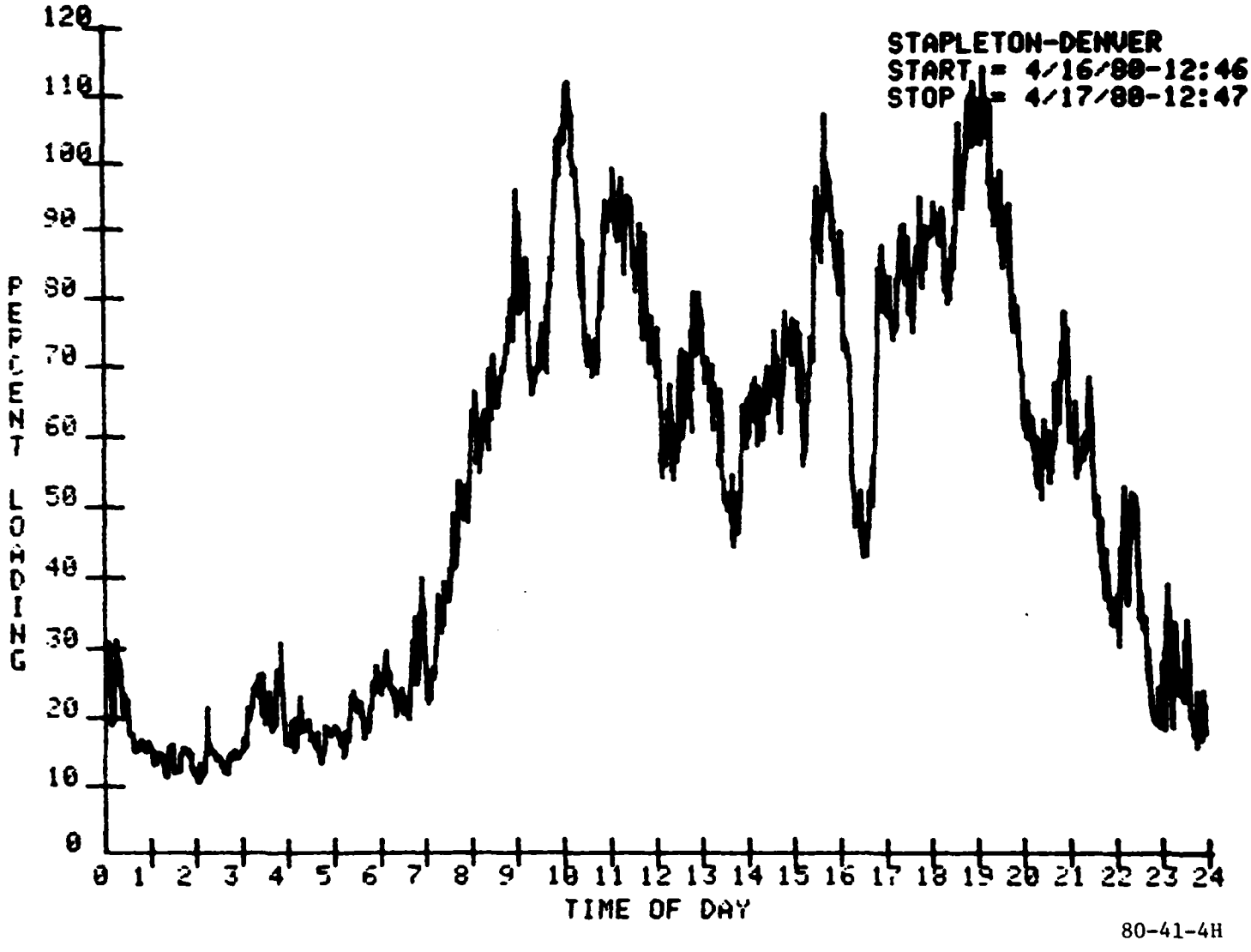


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 8 of 30)

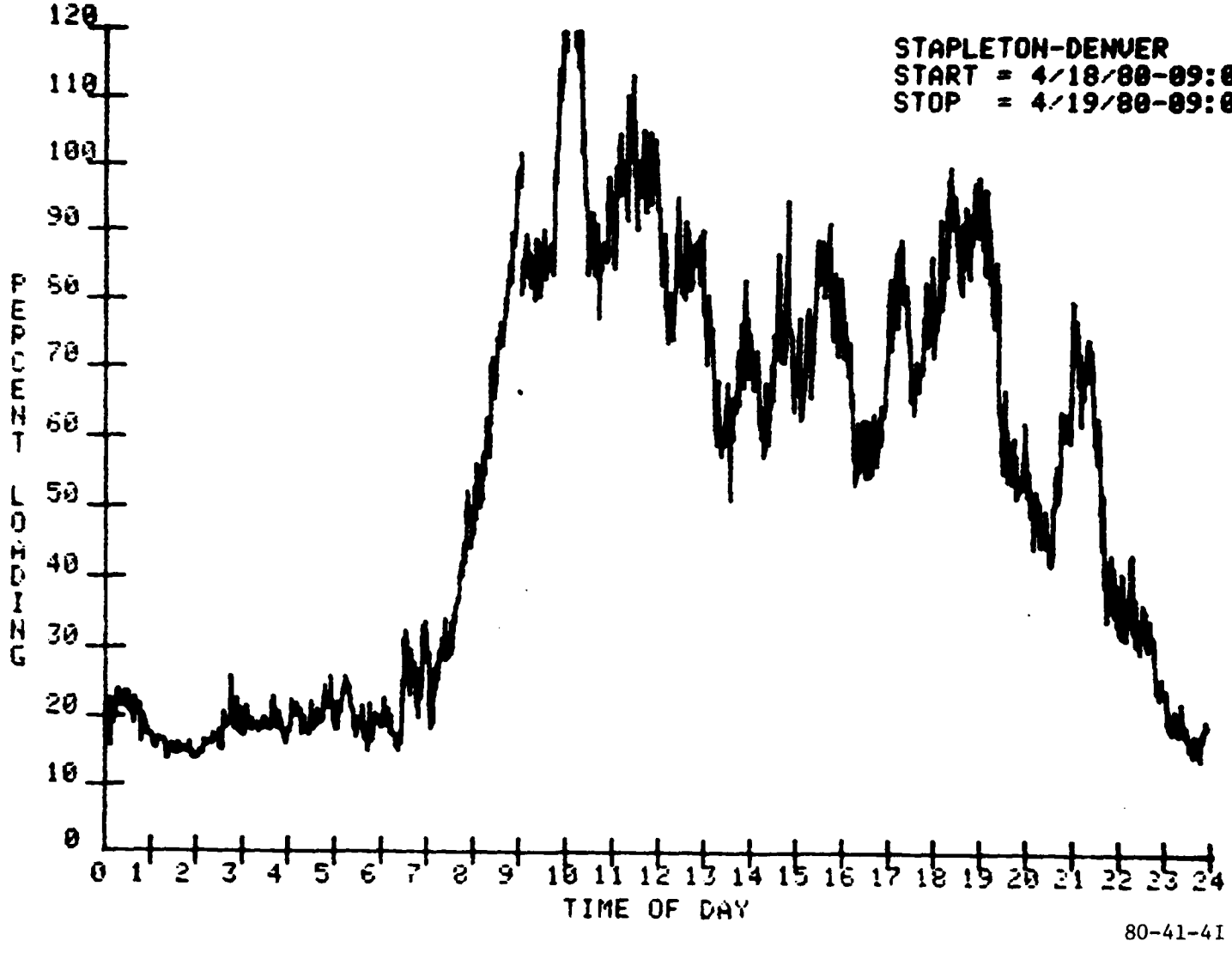


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 9 of 30)

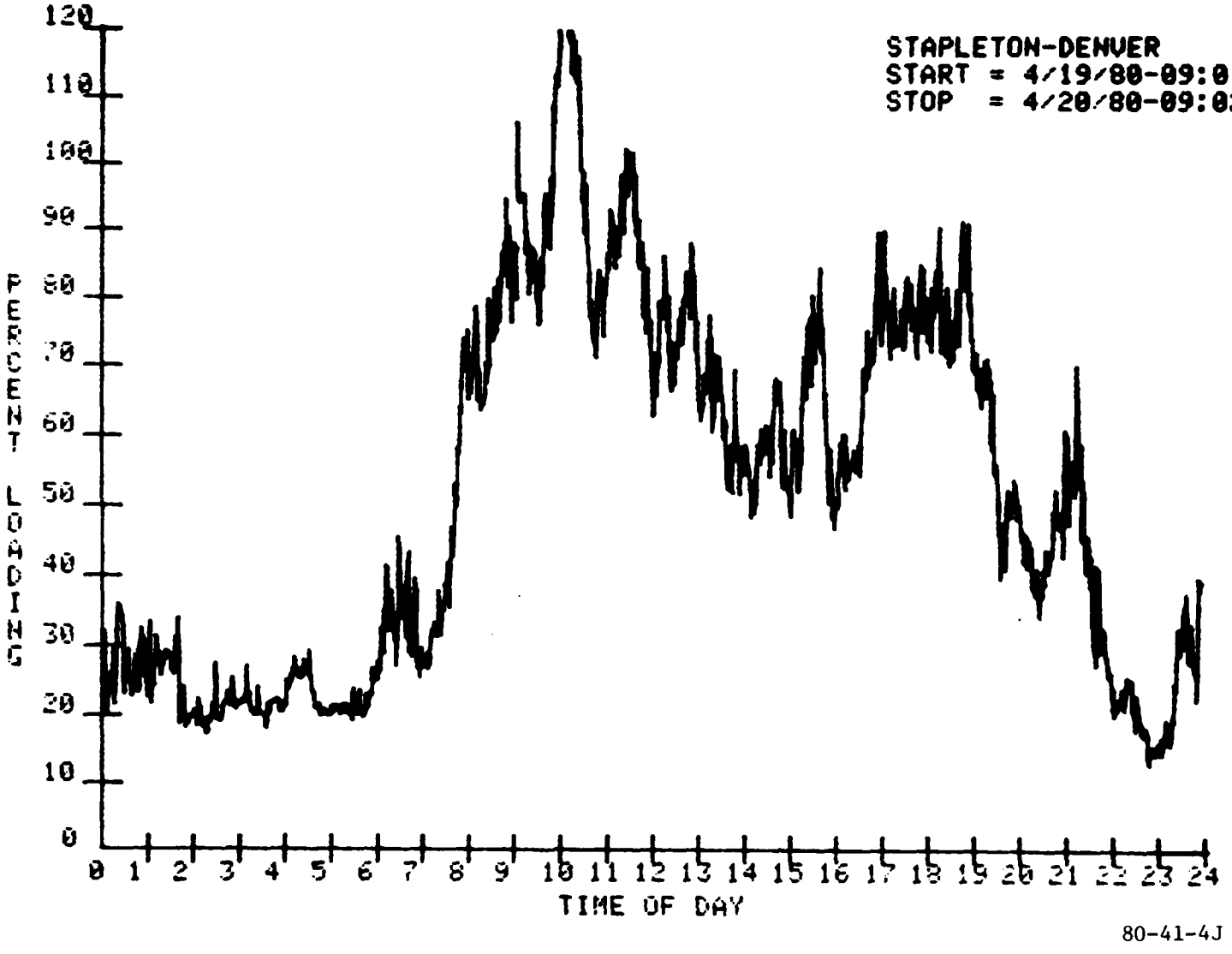


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 10 of 30)

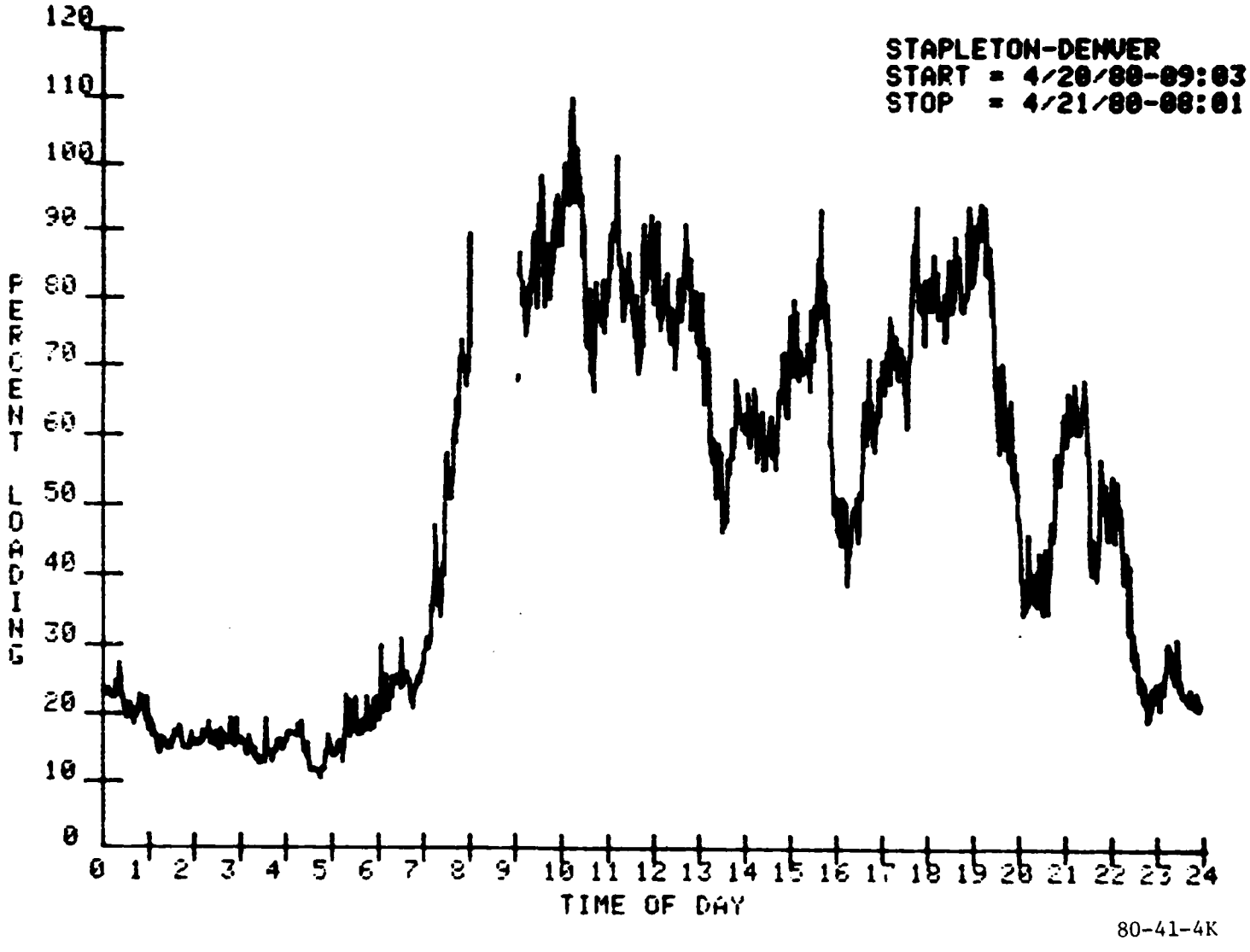


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 11 of 30)

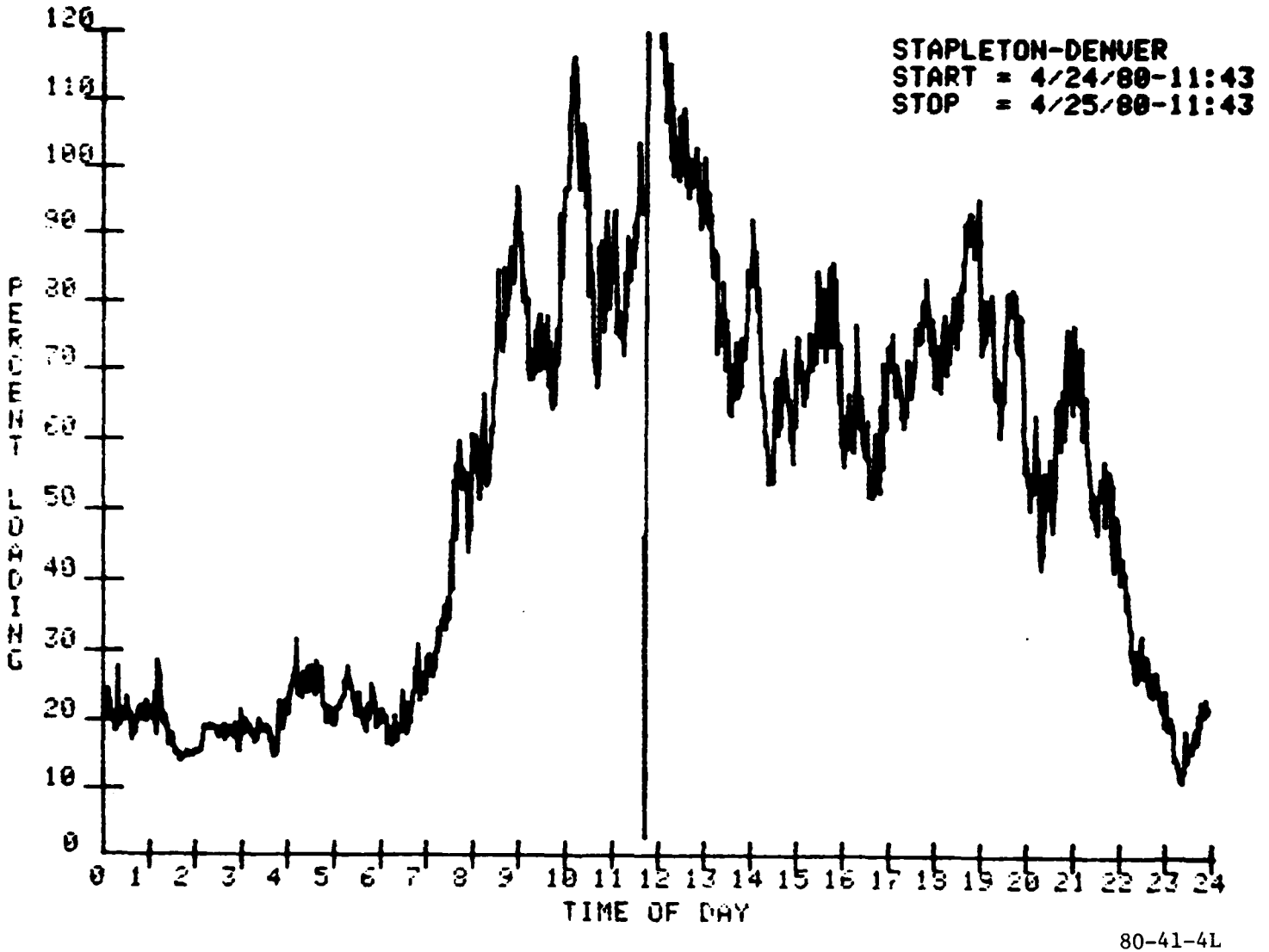


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 12 of 30)

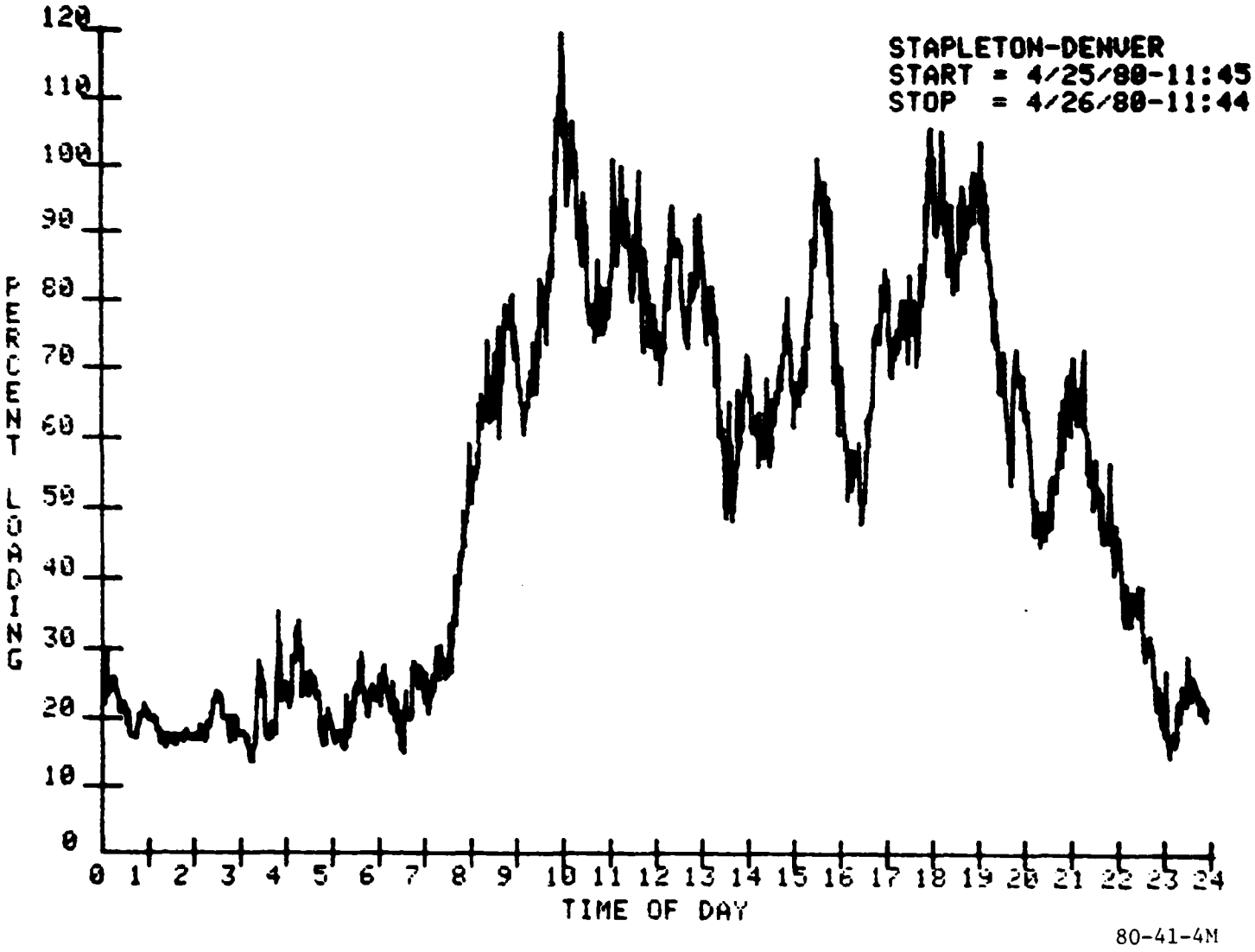


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 13 of 30)

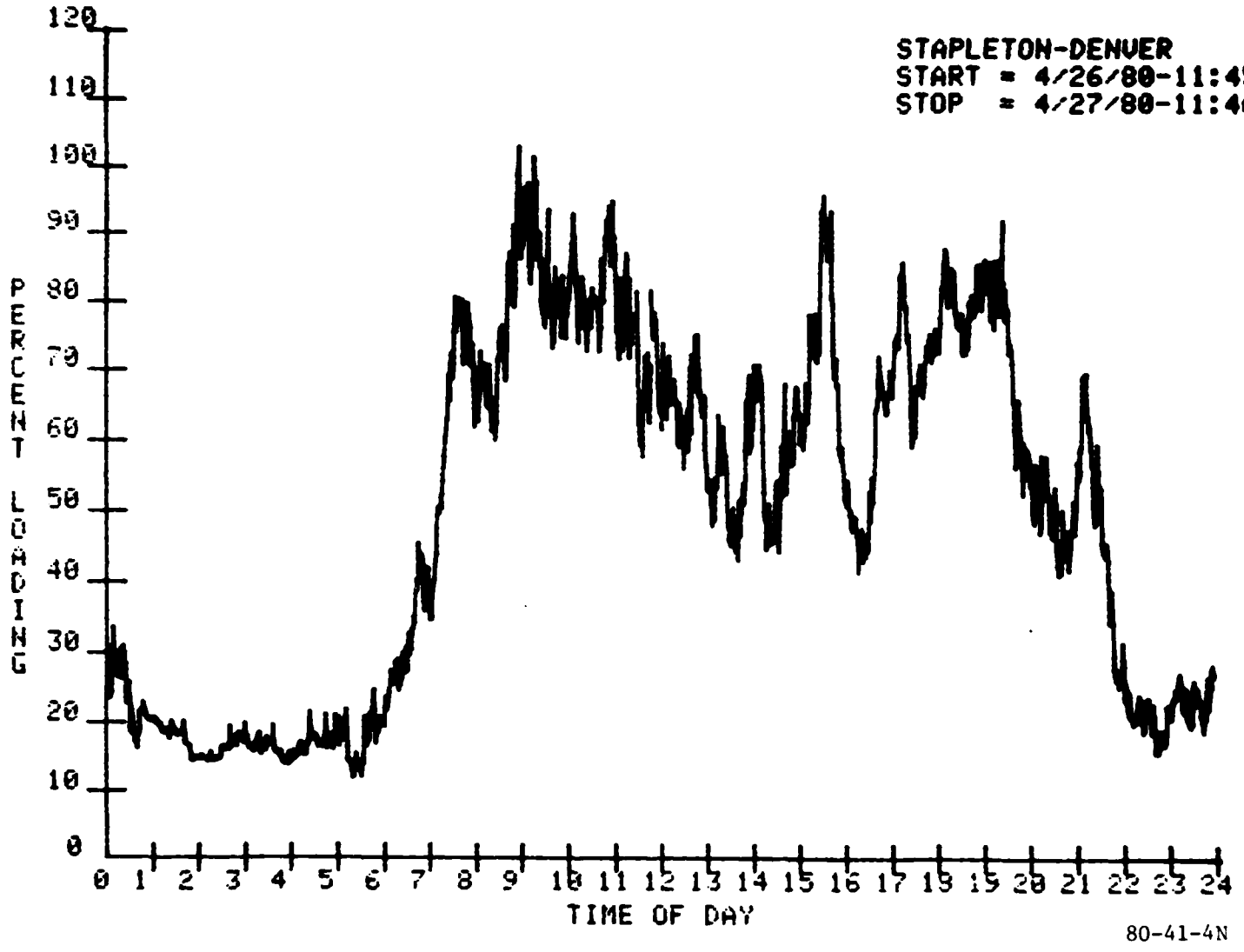


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 14 of 30)

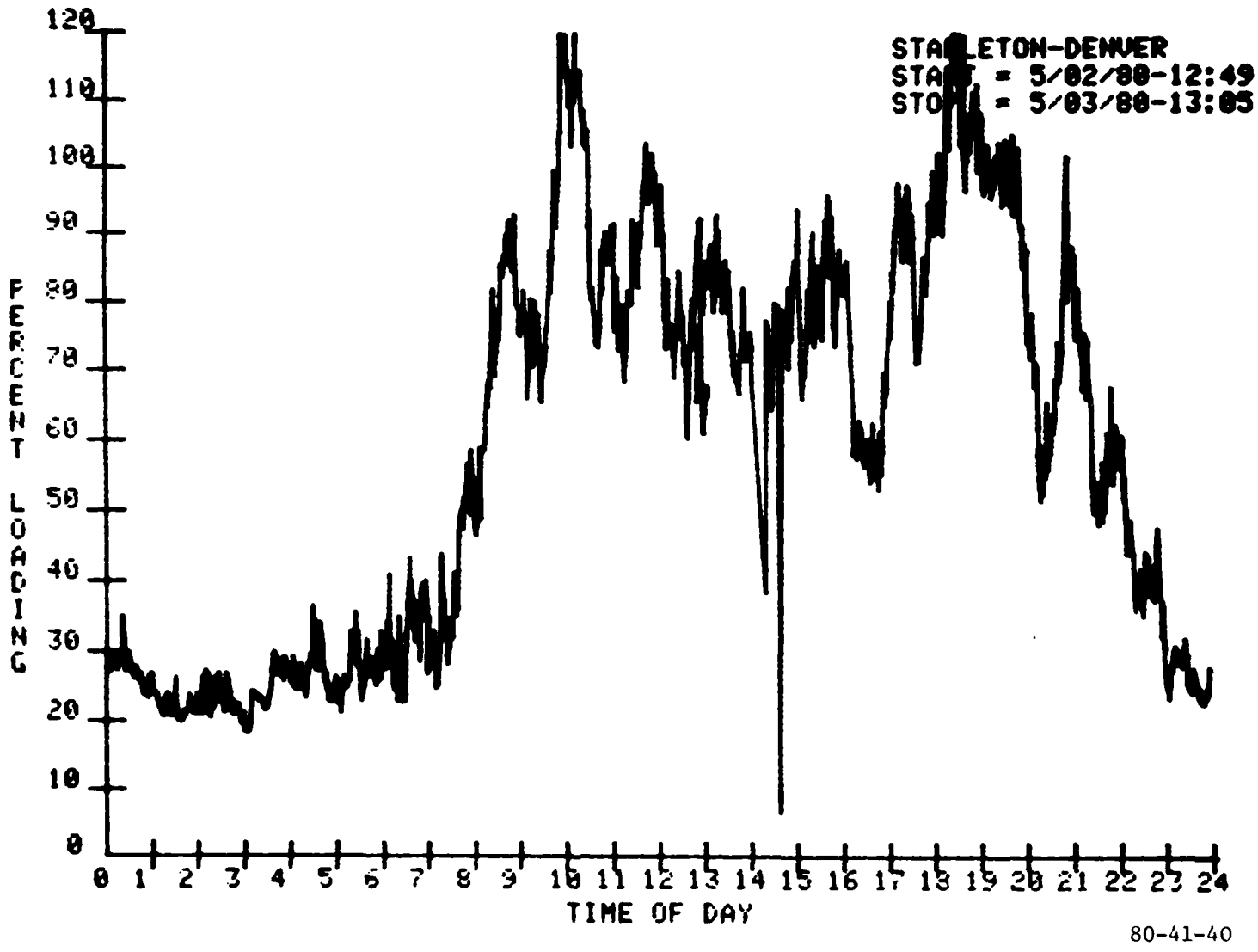


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 15 of 30)

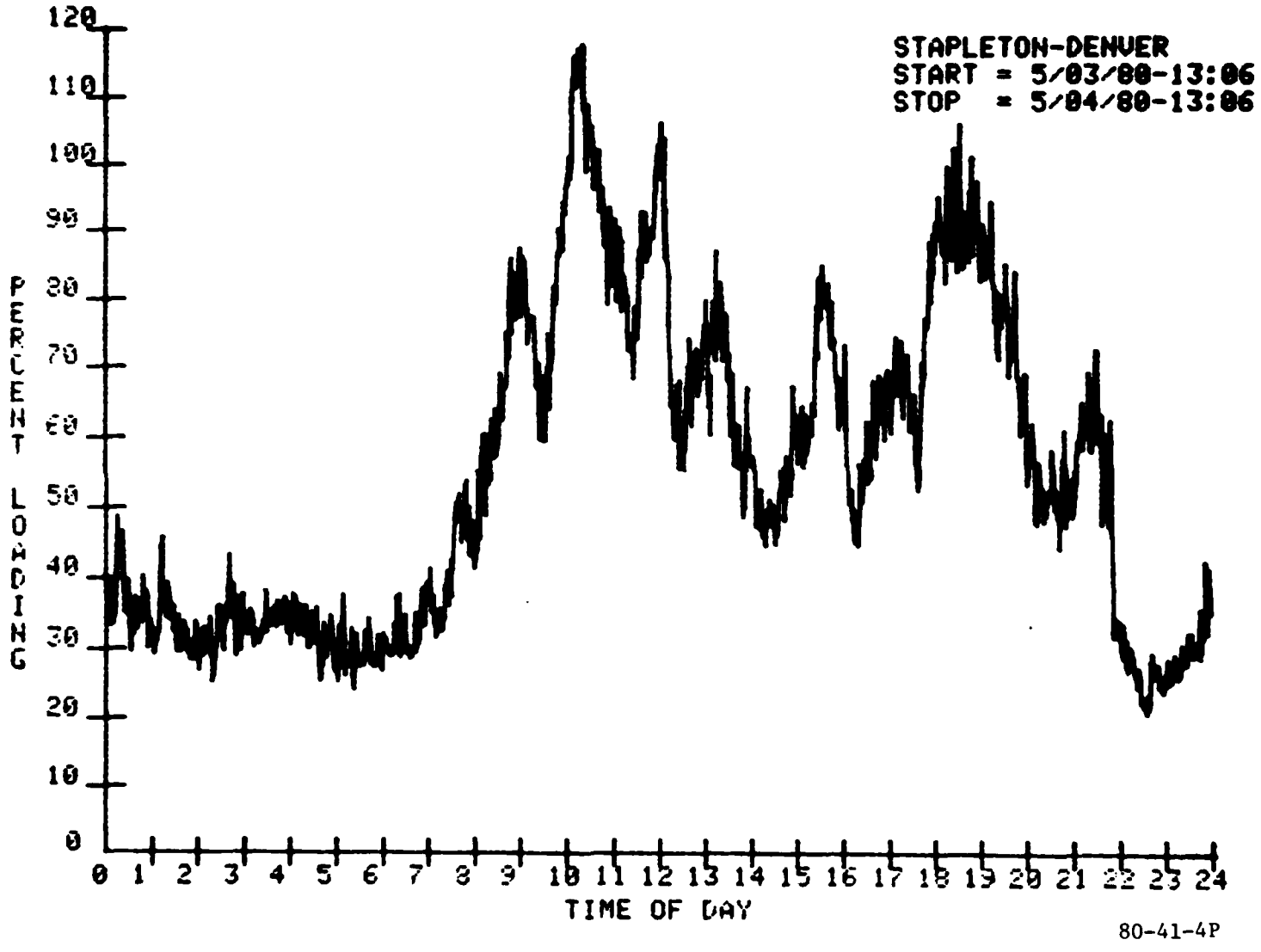


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 16 of 30)

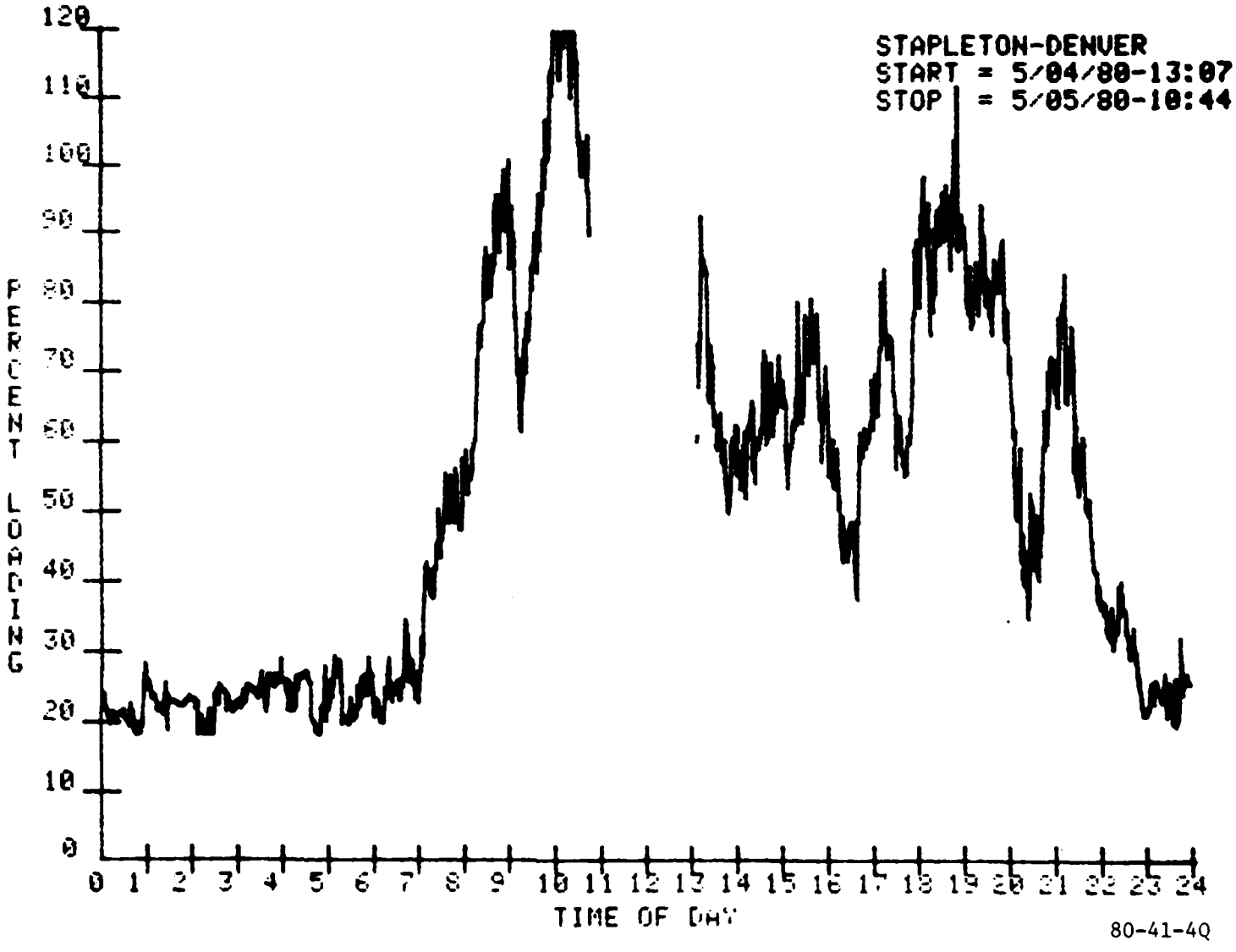


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 17 of 30)

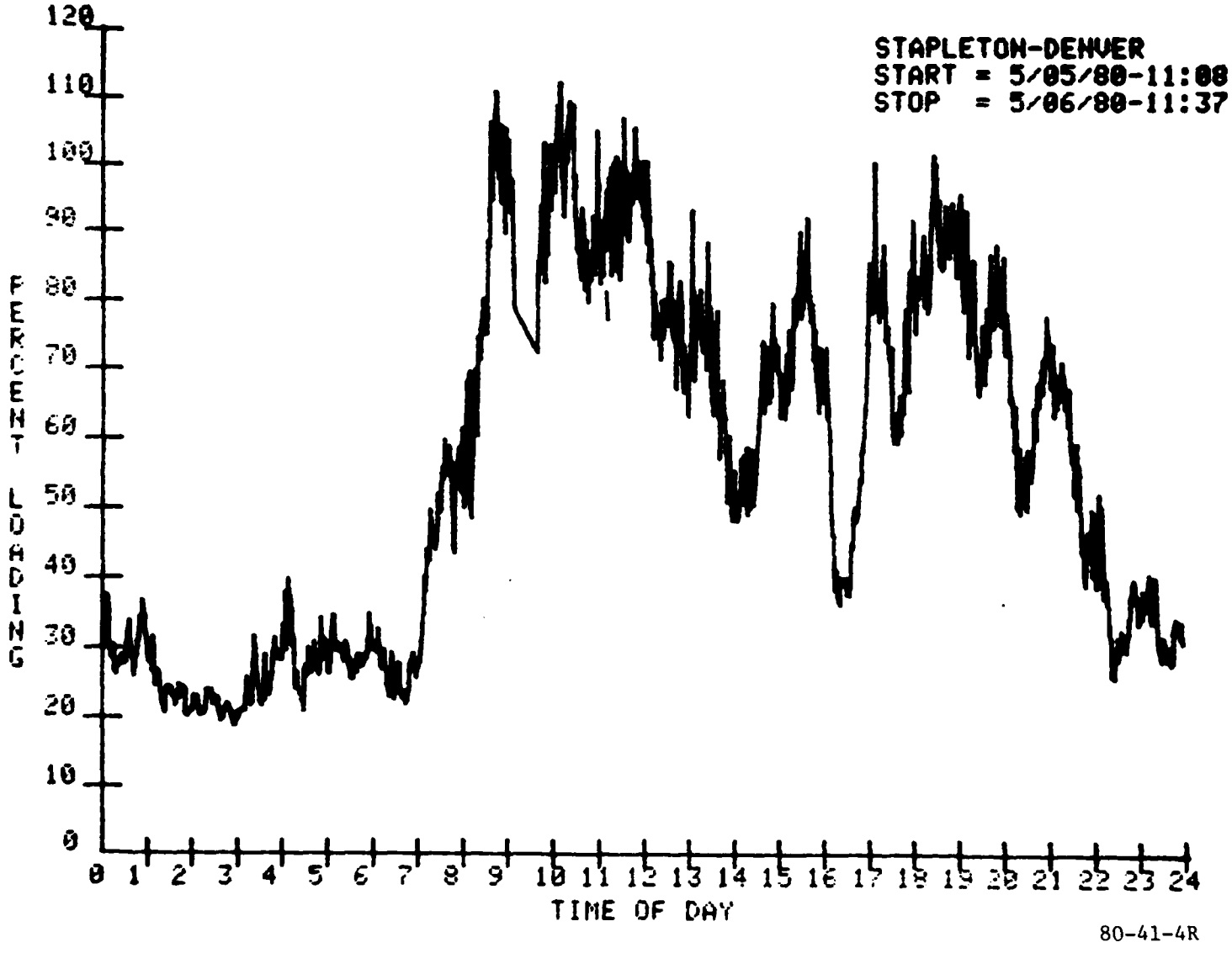


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 18 of 30)

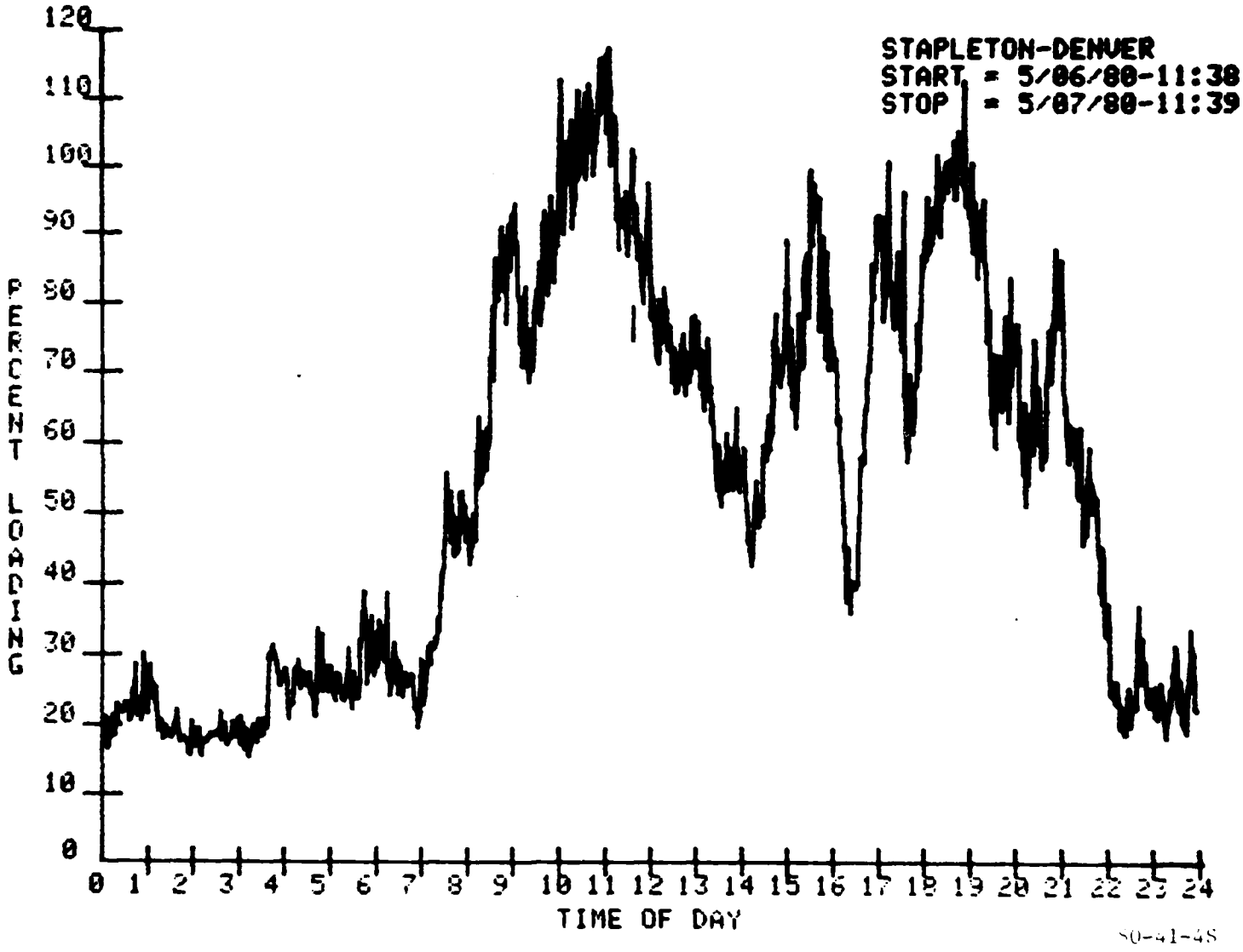


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 19 of 30)

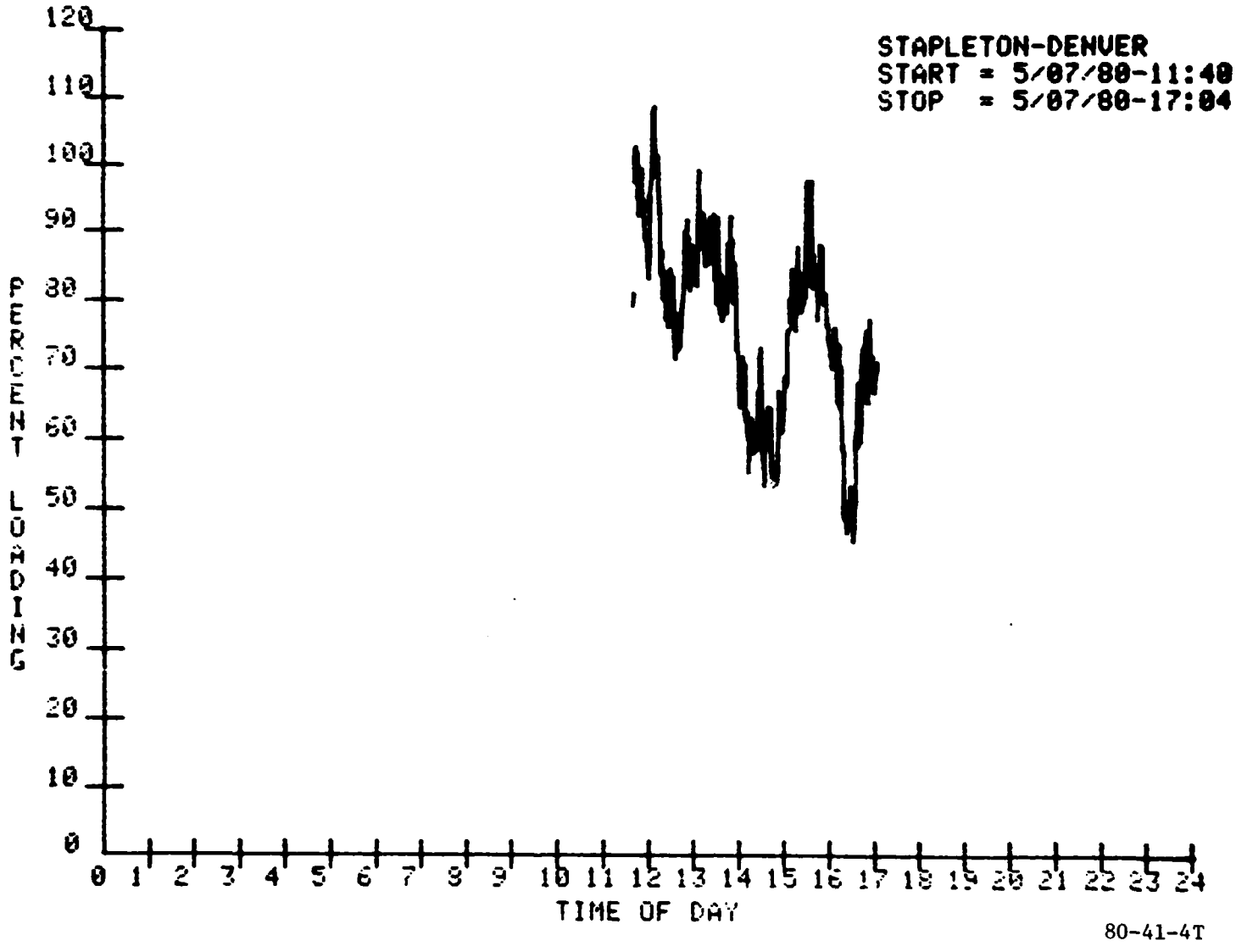


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 20 of 30)

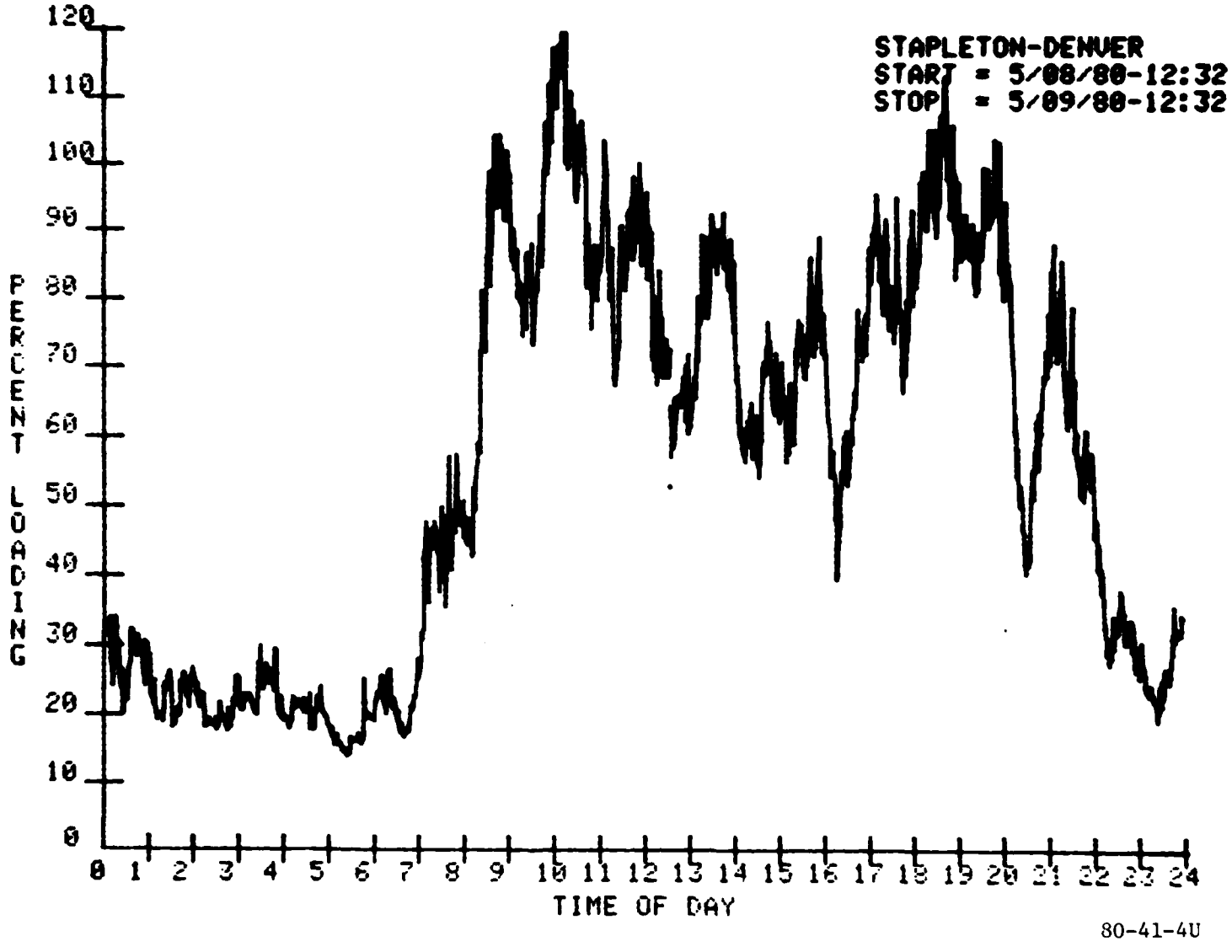


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 21 of 30)

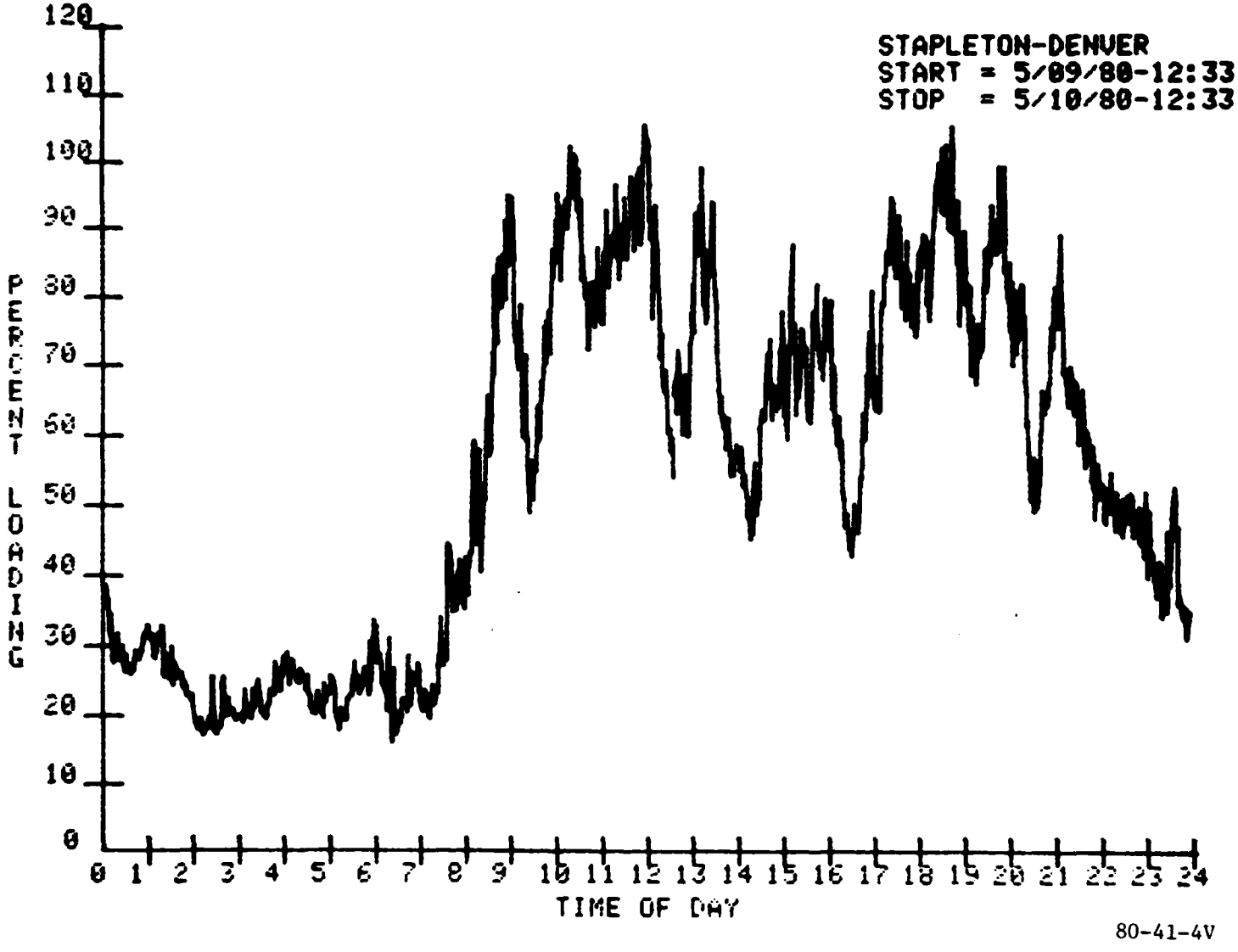


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 22 of 30)

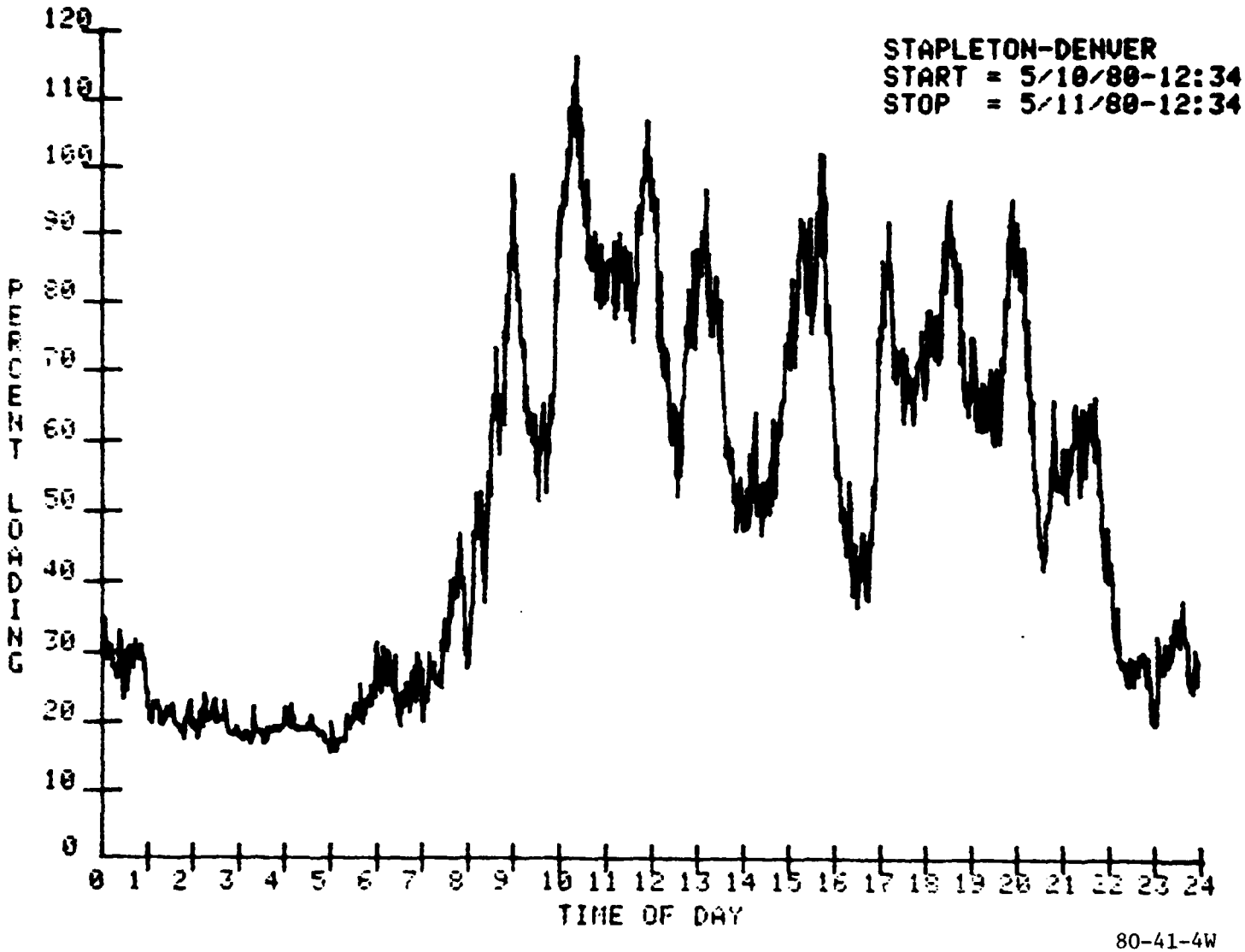


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 23 of 30)

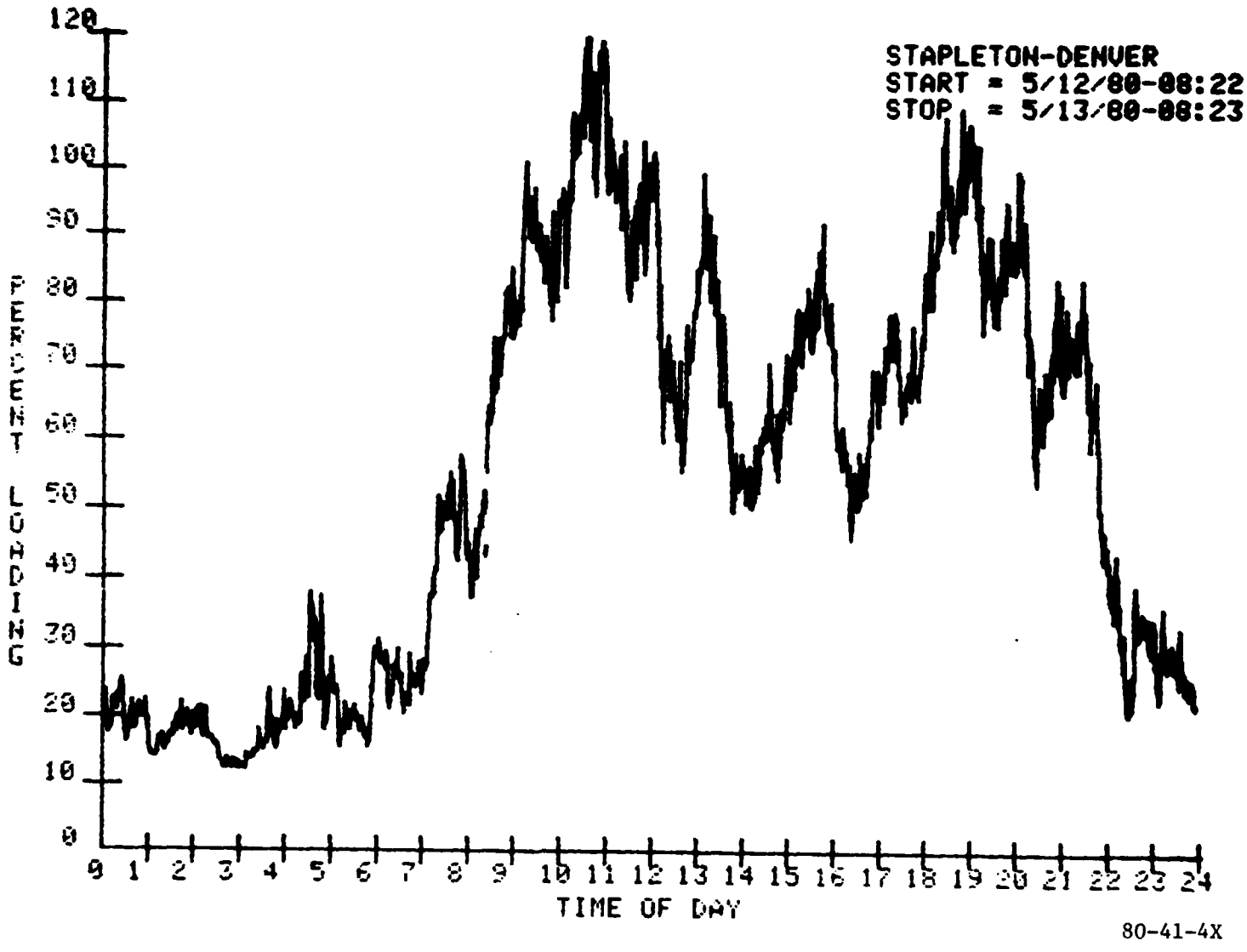


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 24 of 30)

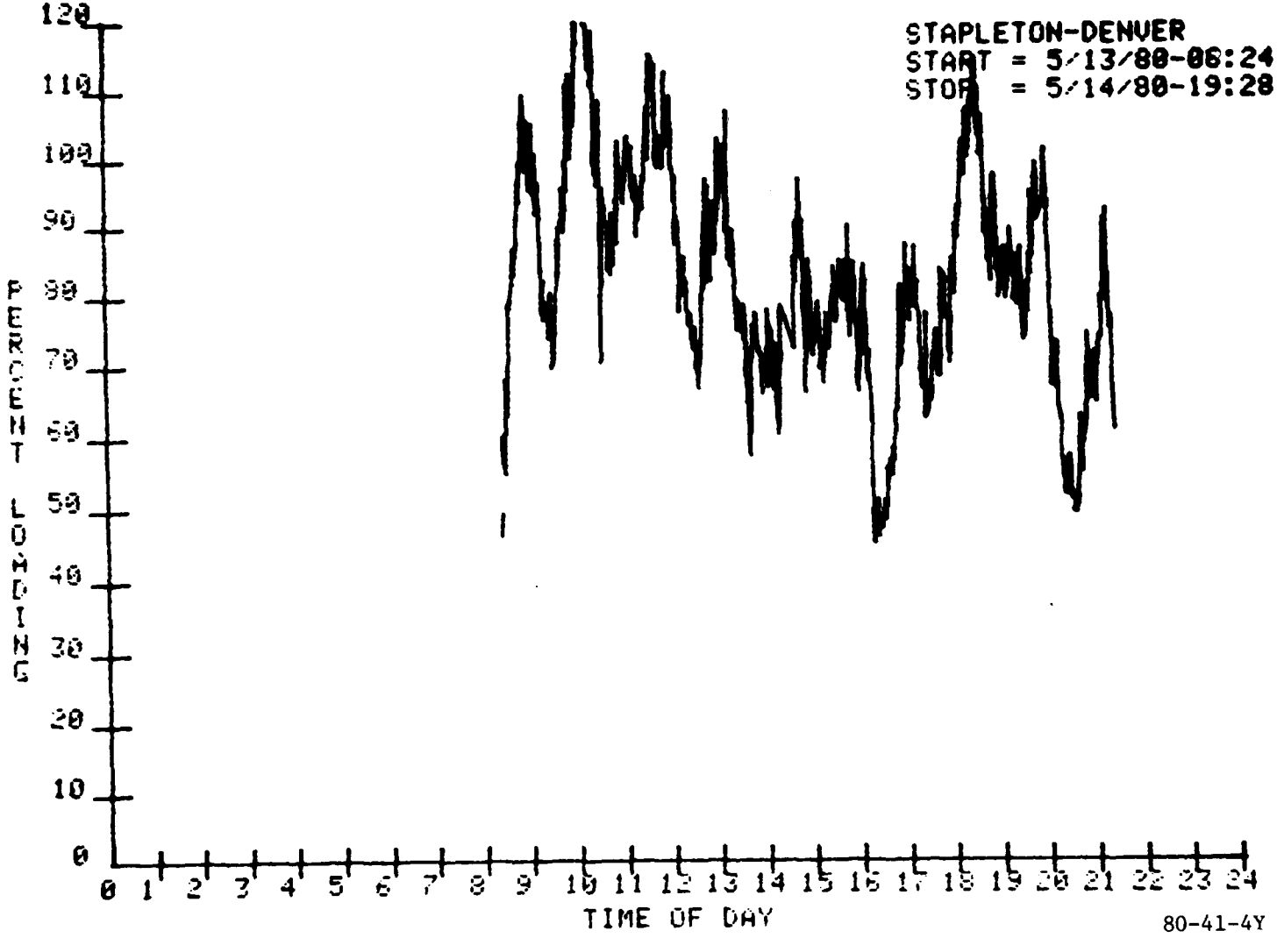


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 25 of 30)

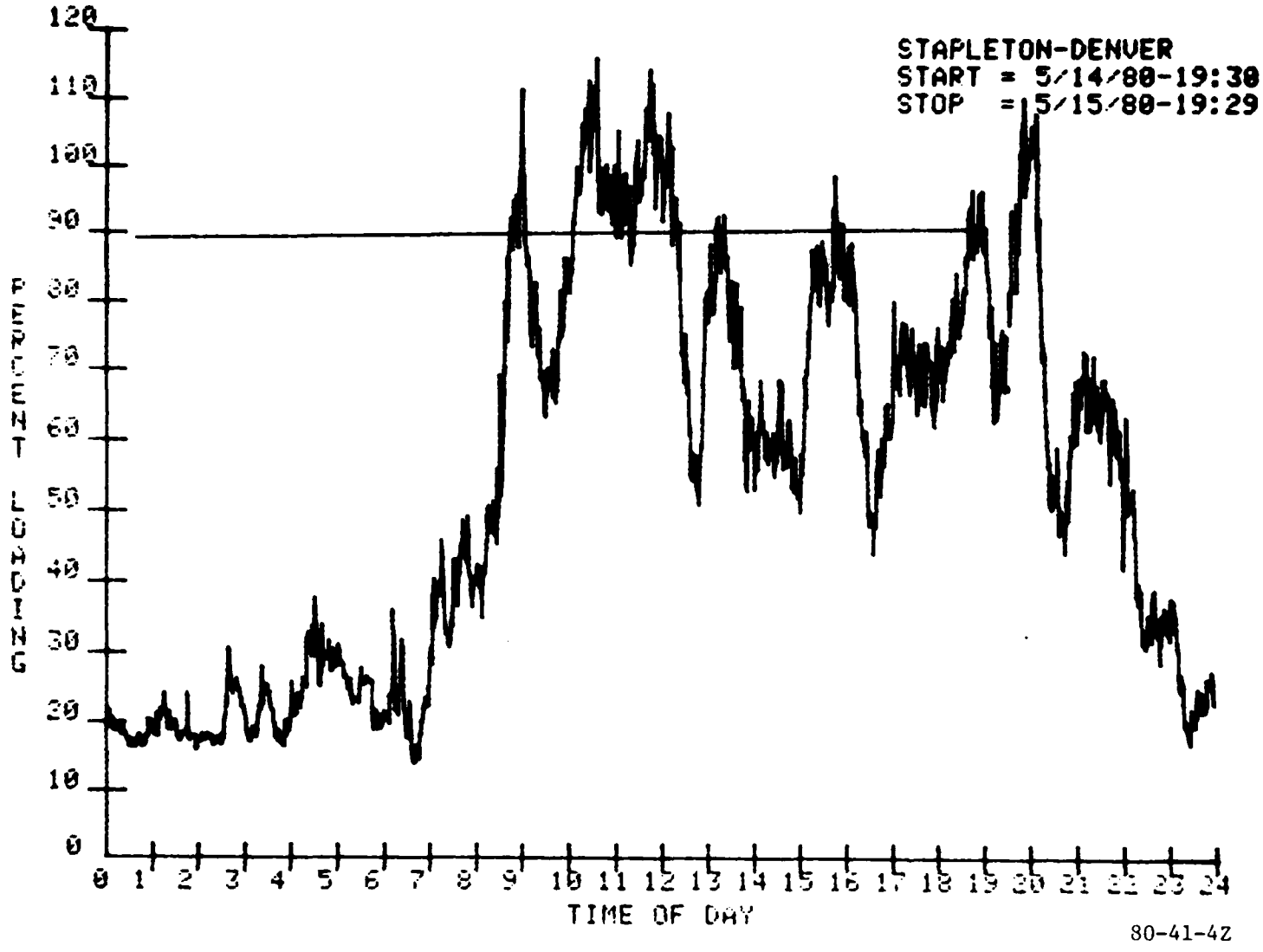


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 26 of 30)

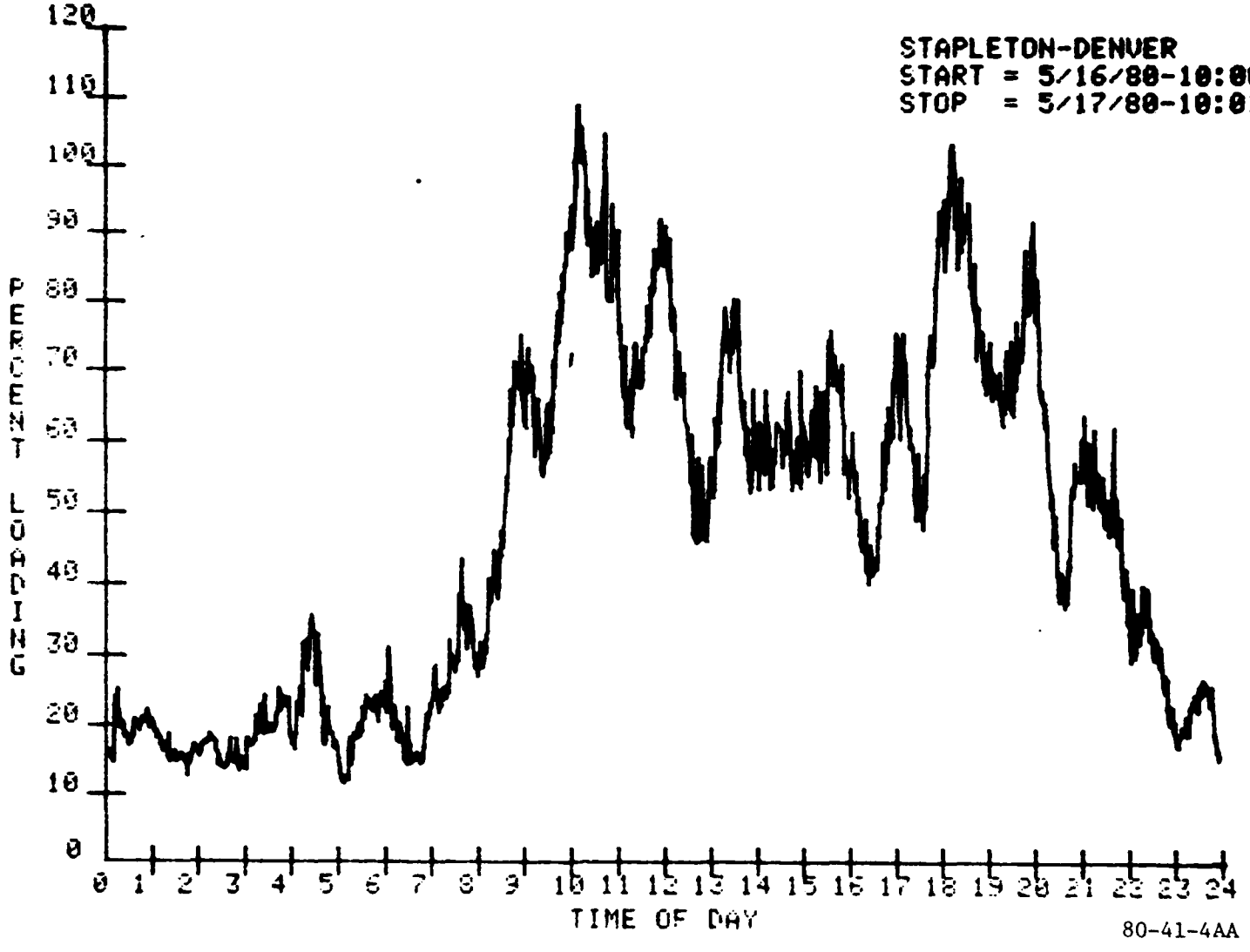


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 27 of 30)

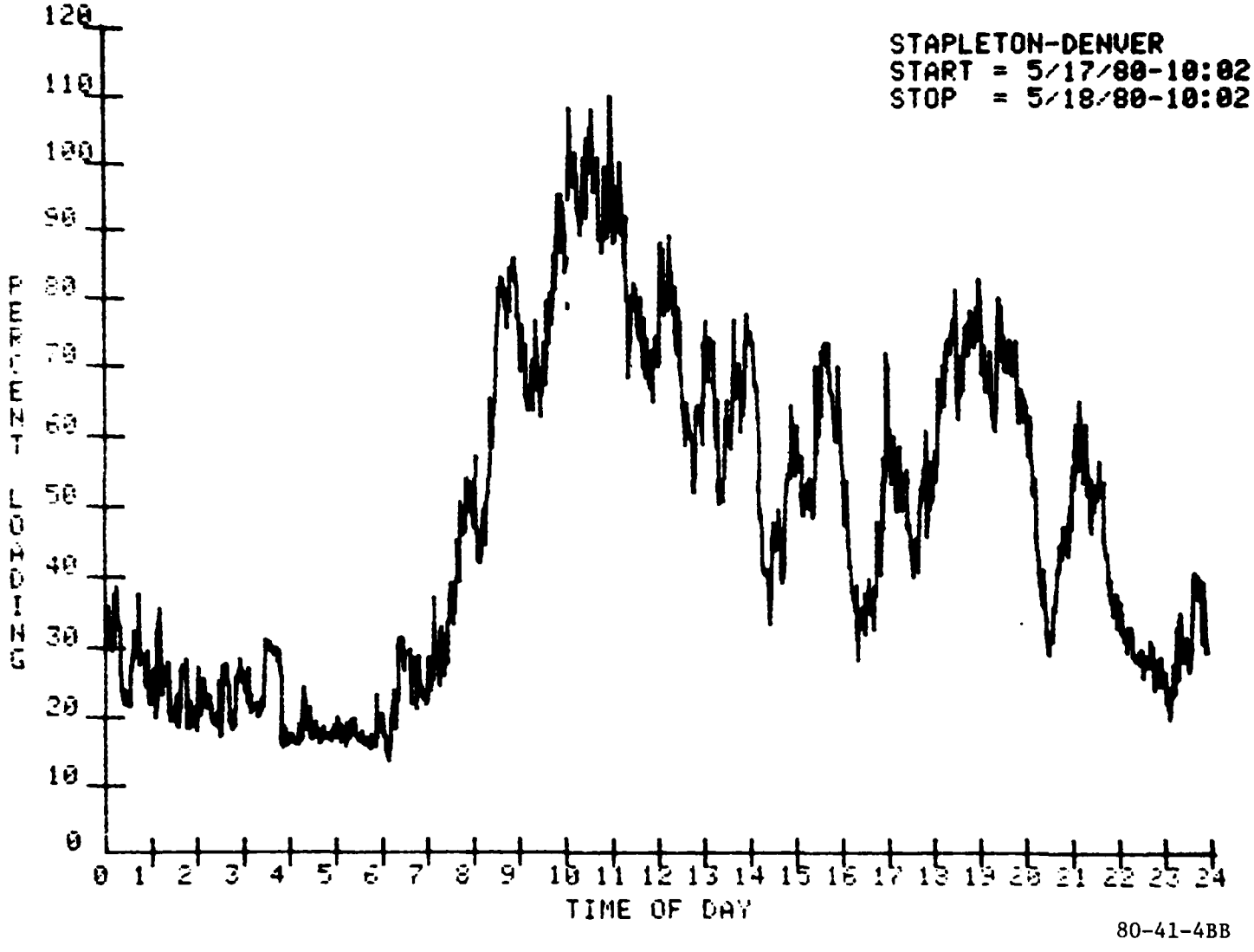


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 28 of 30)

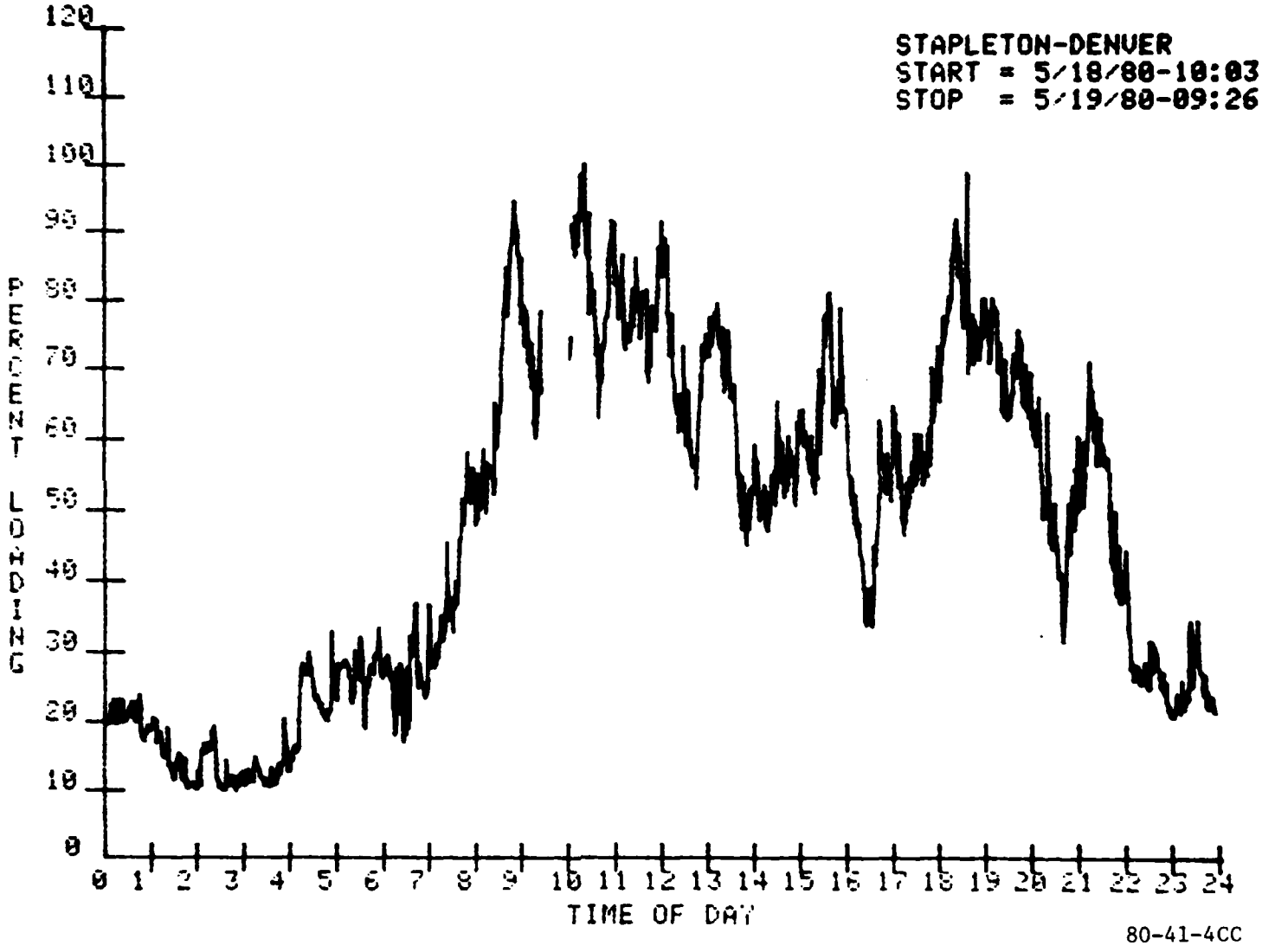


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 29 of 30)

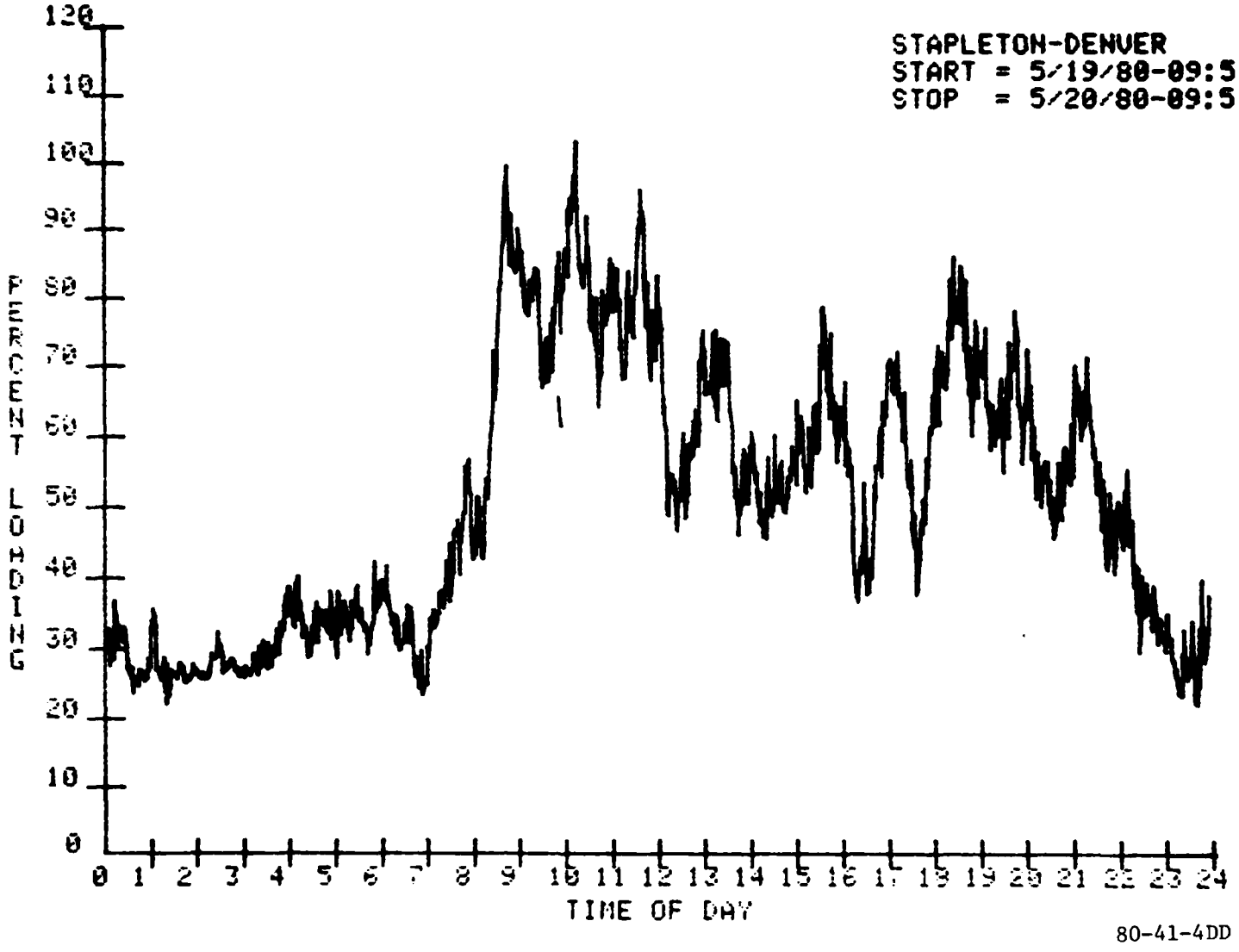


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 30 of 30)

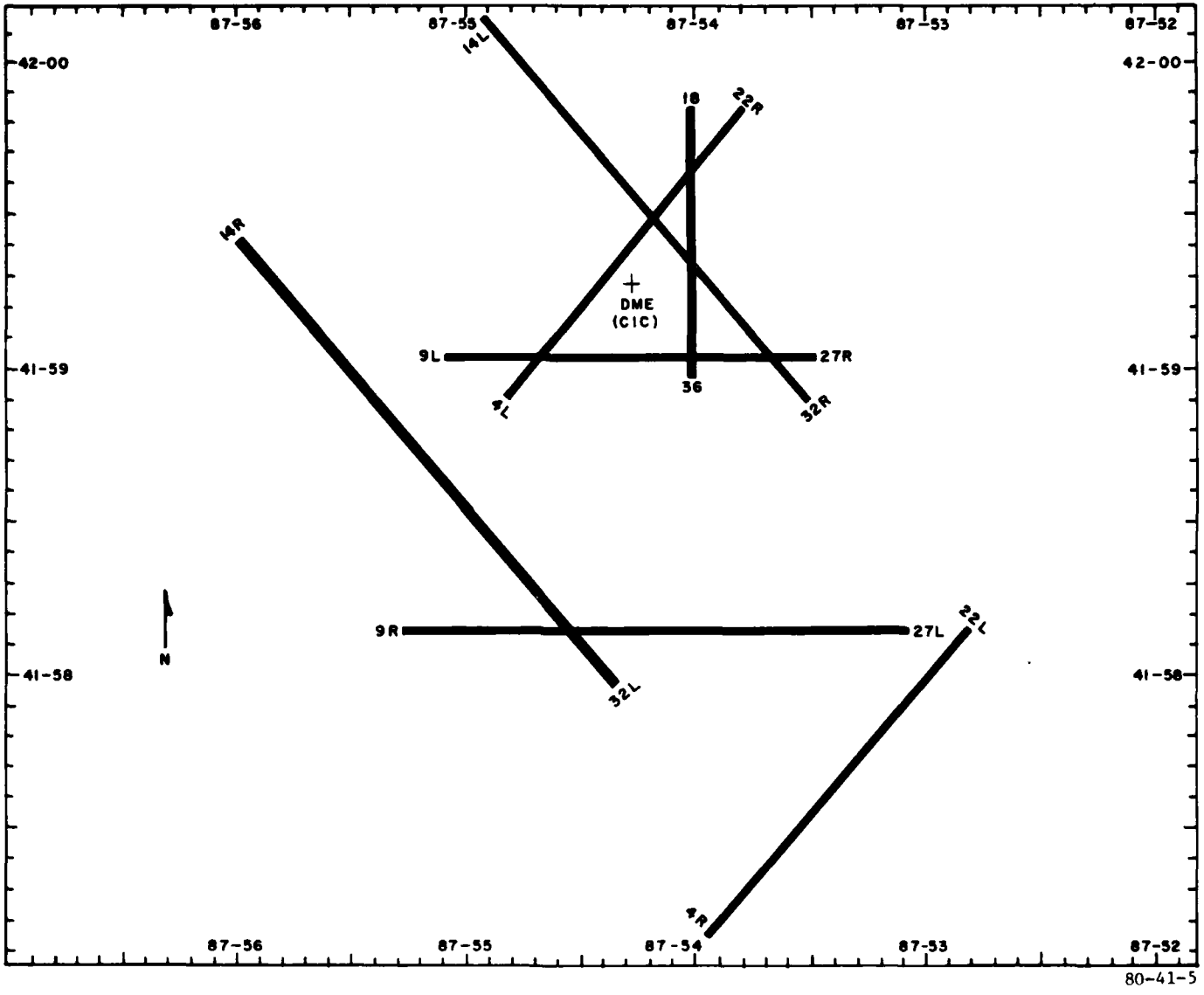


FIGURE 5. AIRPORT MAP CHICAGO, ILLINOIS

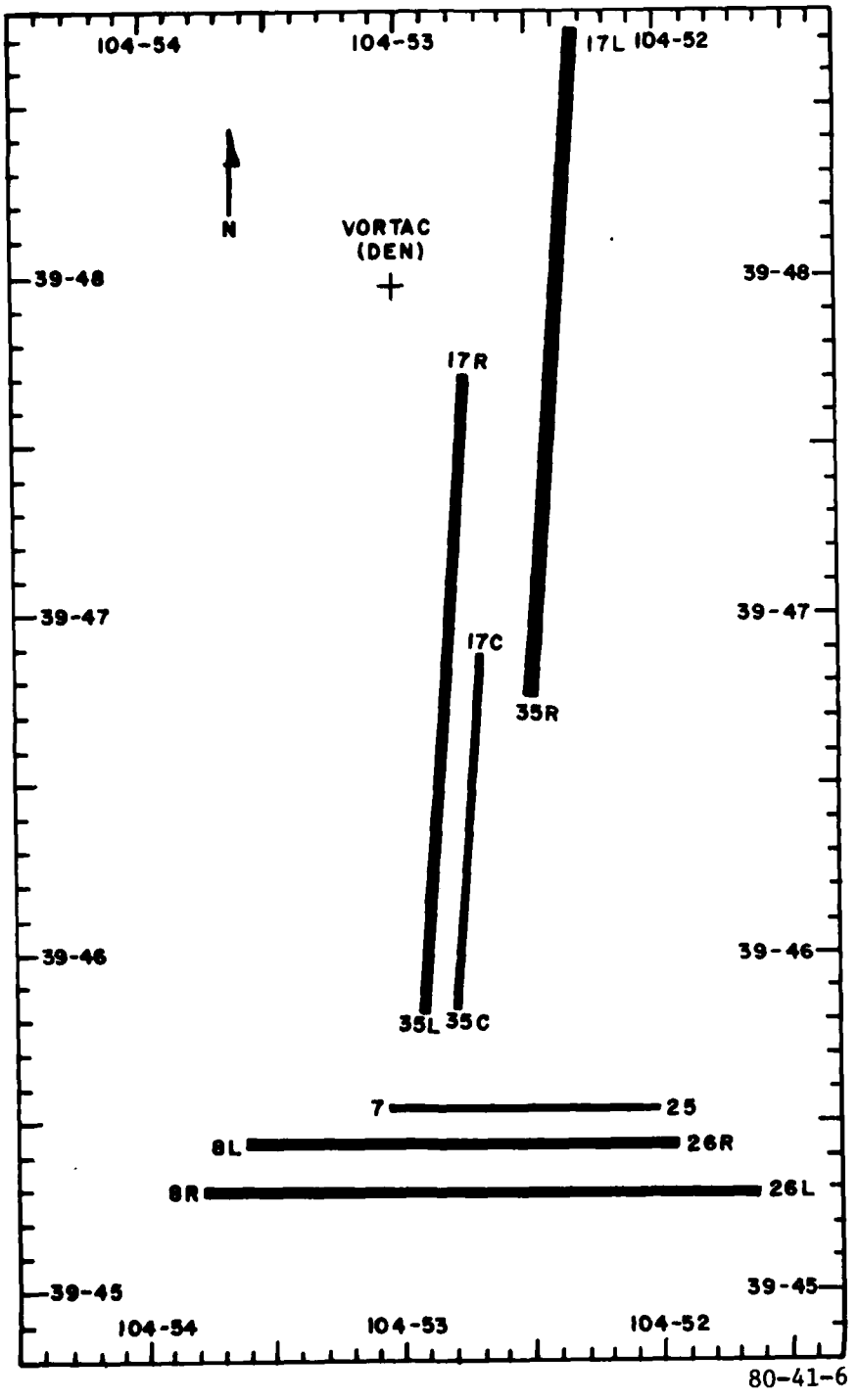


FIGURE 6. AIRPORT MAP DENVER, COLORADO