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NRL Report 6352

An Atlas of the Absorption of the Atmosphere From 8512 to 11,600A

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ABSTRACT

This report presents an atlas of the atmospheric spectral absorption structure of a 10.1-mile sea level path when the atmosphere contained 4.5 cm of precipitable water and when the atmosphere contained 12 cm of precipitable water. A neodymium glass laser spectrum is also included and shown to emit in a spectral region which is particularly free of atmospheric absorption.

PROBLEM STATUS

This is an interim report on one phase of the problem; work on this and other phases is continuing.

AUTHORIZATION

NRL Problem A02-17
Project RR 004-02-42-5152

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AN ATLAS OF THE ABSORPTION OF THE ATMOSPHERE FROM 8512 TO 11,600A

INTRODUCTION

This report is the third in a series of atlases of the absorption structure of the lower atmosphere, made through moderately long air paths of 10 and 17 miles. Previous publications (1-3) have presented the absorption structure in the wavelength intervals 4400 to 5500A and 5400 to 8520A. The present work covers the interval from 8512 to 11,600A, in which normal uncontaminated sea level atmosphere has an absorption structure which is due primarily to water vapor. The optical path was across the Chesapeake Bay, entirely over water, and removed from any industrial area. It is assumed that the atmosphere was free of contaminants and that all the absorption structure observed was caused by water vapor.

PROCEDURE

The spectra were made over a 10.1-statute-mile path across Chesapeake Bay in the winter of 1965. The sloping light path was approximately 50 feet above the water surface at the center of the path. Spectra were made in the wavelength interval 8500A to 11,600A with a Baird, 1-meter, f/10 grating spectrograph. The 15,000-lines-per-inch grating was used in the first order, with a dispersion of about 16 A/mm and a resolution of about 0.25A. A 35-mm film was used to record the spectra and during the course of the work IM and IZ hypersensitized emulsions were used. The dual light source consisted of a 1000-watt projection lamp at the focus of a 60-inch searchlight mirror and a 10,000-watt lamp at the focus of another 60-inch mirror. These searchlights were positioned side by side on Tilghman Island, 10.1 statute miles from the spectrograph across Chesapeake Bay. At the spectrograph end of the optical path the light was collected by a 20-ft, f/13 mirror and was directed to the slit via a 90-degree image rotator which placed both of the images on the vertical slit. Exposure times varied from 1 to 8 hours, depending on the atmospheric transparency in this spectral region and the precipitable water content of the path. The spectra recorded here were made on clear nights when there was no moonlight, through 4.5 and 12 cm of precipitable water, and when the visual meterological range was 20 miles for both exposures. The temperature and relative humidity were 40°F and 43% and 56°F and 65% for the 4.5 and 12 cm of precipitable water respectively.

ATLAS

The spectra were scanned on a Jaco Recording Microphotometer at a speed which gave a chart dispersion of 3A per inch of original chart. For this atlas, the chart trace was redrawn and reproduced in 34, sections (Charts 1-34) each 90A long and approximately with one angstrom overlap between succeeding sections. The numbers on the chart sections refer to wavelengths of the absorbing lines, measured on the original densitometer trace using charts by Minnaert (4) and Mohler (5) and tables by Babcock (6) as references. Many of the sections show two traces; the one of higher density corresponds to 4.5 cm of precipitable water and the one of lower density and more pronounced absorption structure corresponds to 12.5 cm of precipitable water.

The atlas begins at 8511.9A, which comfortably overlaps the previous atlas, which stopped at 8524A. The most intensive absorption structure by water vapor is primarily confined to two spectral regions, from 8900A to 9900A and from 10,800A to the end of the trace at 11,530A. The end of the trace was determined by a lack of film sensitivity beyond the latter region. This is shown by the last six sections of the chart of the spectrum (Charts 35-40), taken over a short path (500 feet), containing only 1.5mm of precipitable water, and extending out only 70A to 11,600A.

Within the resolution limits of the spectra, the absorption structure, discussed in this atlas, is from water vapor. An indication of this is in the charts having two traces, where one trace has a weaker absorption structure at all points because of lower precipitable water in the absorbing path. The weak oxygen absorption structure found in the solar spectrum in the spectral region 10,584 to 10,719A was not detected here presumably because of insufficient O_2 in the 10.1-mile path. Reference 3 indicates that a 200-km air-path is required in order to observe these weak atmospheric oxygen absorption bands.

For optical communication and detection purposes the spectral regions of greatest interest are the windows or regions of minimum absorption. The work of Yates and Taylor (7), as shown in Fig. 1, indicates relatively clear spectral regions at about 8900A and 10,500A. Of greatest concern here is the relatively wide clear region at 10,600A, which is where the neodymium glass laser emits. This is shown in Figs. 2 and 3, which show the spectrum and densitometer trace (3rd exposure) of the neodymium glass laser emission at 10,600A. Neodymium glass lasers are attractive for communication purposes because of the emission in the near infrared spectral regions, where the atmospheric scattering losses are low. However, for maximum transmission, it is also essential that the emission be in a region of low atmospheric absorption.

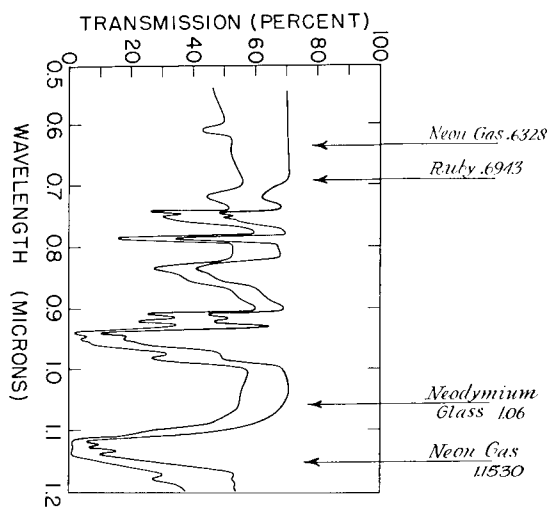

Fig. 1 - Absorption spectrum of the atmosphere from Yates and Taylor (Reference 7)

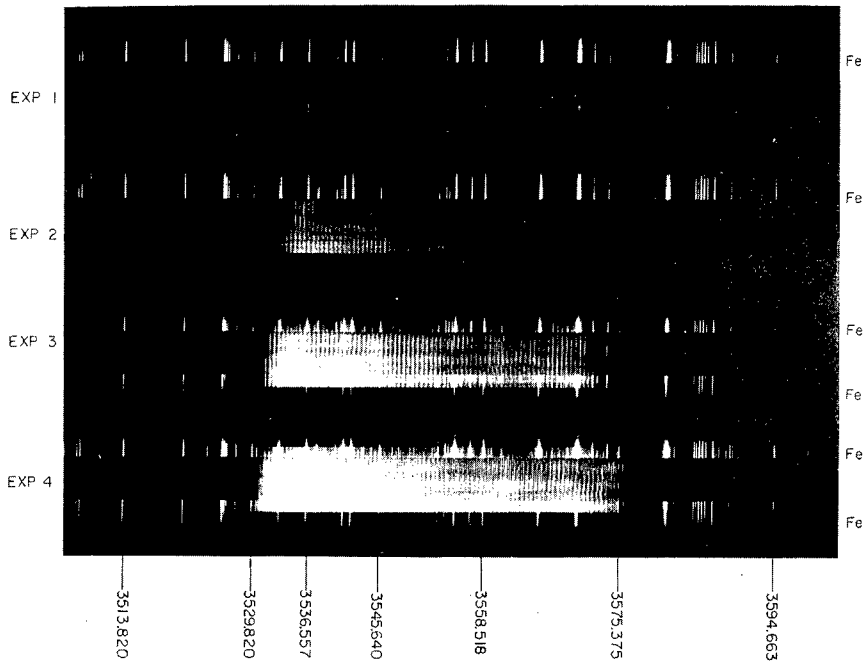

Fig. 2 - Neodymium laser spectrum at various levels of flash tube input

The spectrum of the neodymium laser was obtained on nonhypersensitized Z emulsion with a 3.4-meter Ebert spectrograph at a dispersion of 4.8A per mm. A fixed 50-μ slit was used for all exposures; the central 5-mm length of the slit was illuminated with laser radiation. Flash tube current was provided by a 225-μfd capacitor bank. The four exposures in Fig. 2 consisted of one laser shot each, the capacitor bank being charged to a different voltage for each shot, as shown in Table 1.

Table 1
Electrical Parameters for Laser Exposures

Exposure Number	Supply Voltage (volts)	Flash Tube Energy (joules)	Percentage Above Threshold (%)
1	1,750	345	13
2	2,000	450	43
3	2,250	570	81
4	2,250	703	124

From Fig. 3 it is seen that the neodymium glass laser emission is a series of almost uniformly spaced lines superposed on a continuum, extending for about 140A from 10,590 to 10,730A. This spectral interval is recorded in Charts 23, 24, and 25 of the atlas, and it is seen that for all practical purposes atmospheric absorption losses would be small and negligible, at least for 12 cm of precipitable water.

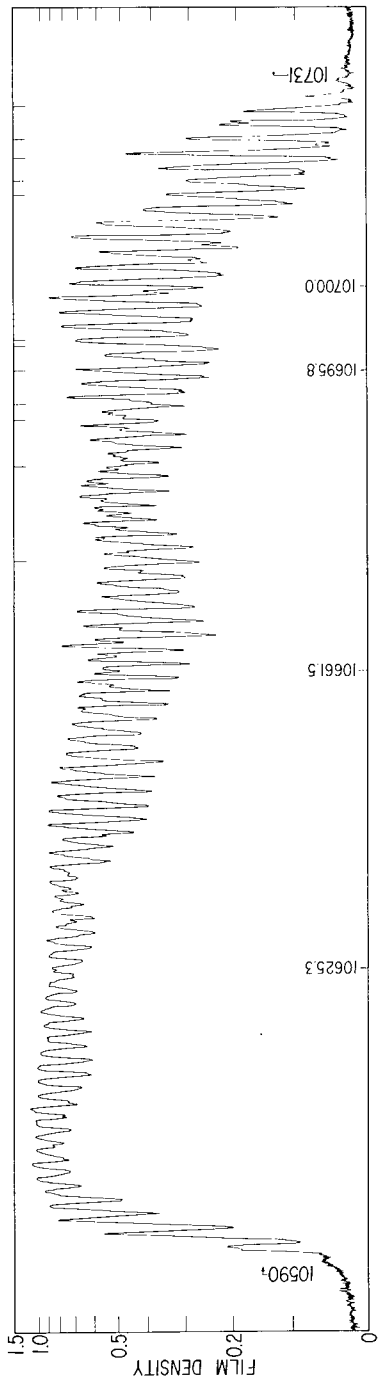

Fig. 3 - Densitometer trace of neodymium lases spectrum when capacitor bank was charged to 2,250 volts

ACKNOWLEDGMENT

We would like to express our thanks to J. T. McDowell, who redrew the traces with painstaking care and expert craftsmanship.

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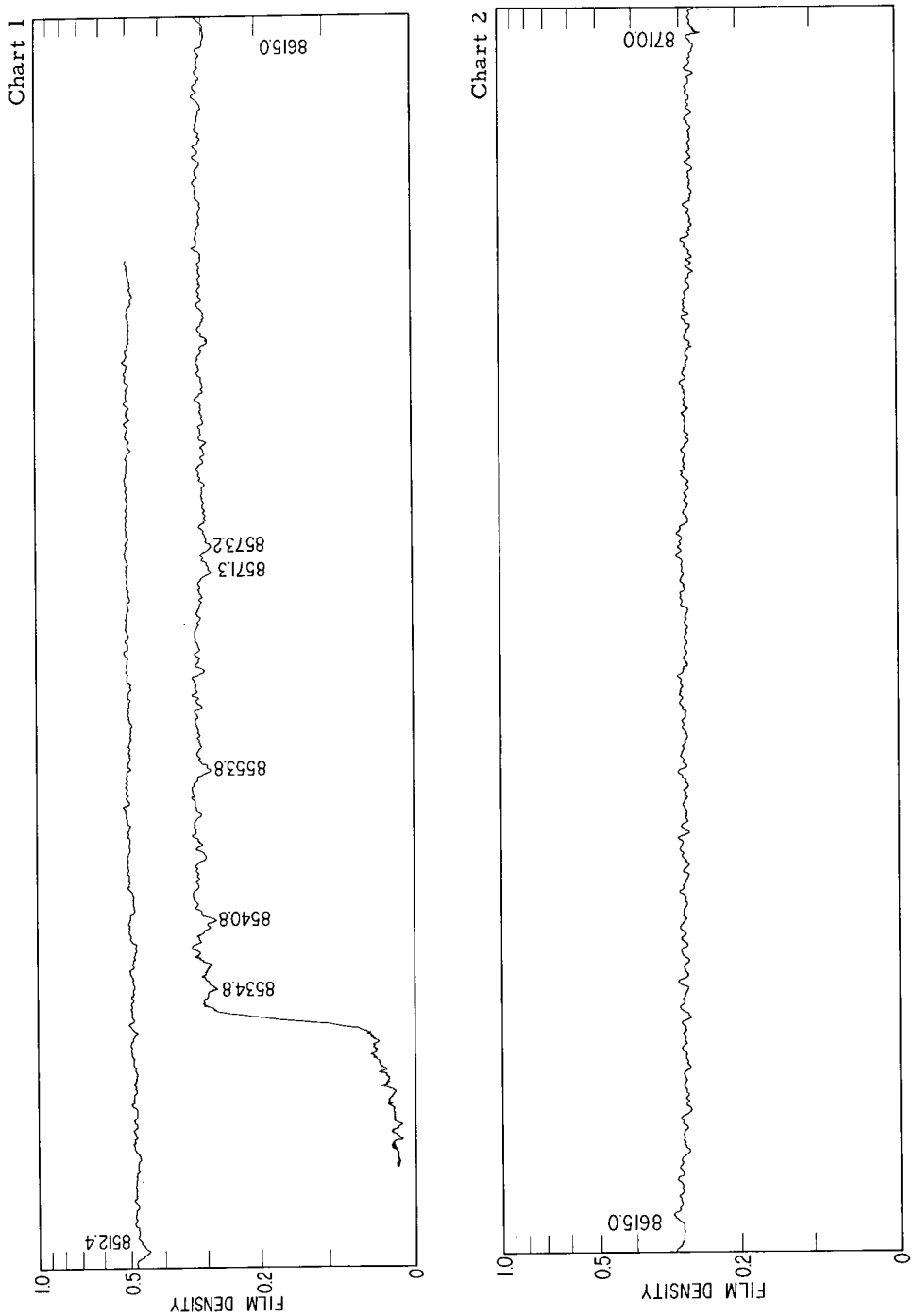
Chart 1
8512.4
8534.8
8540.8
8553.8
8571.3
8573.2
8615.0
FILM DENSITY
1.0
0.5
0.2
0
Chart 2
8615.0
8710.0
FILM DENSITY
1.0
0.5
0.2
0

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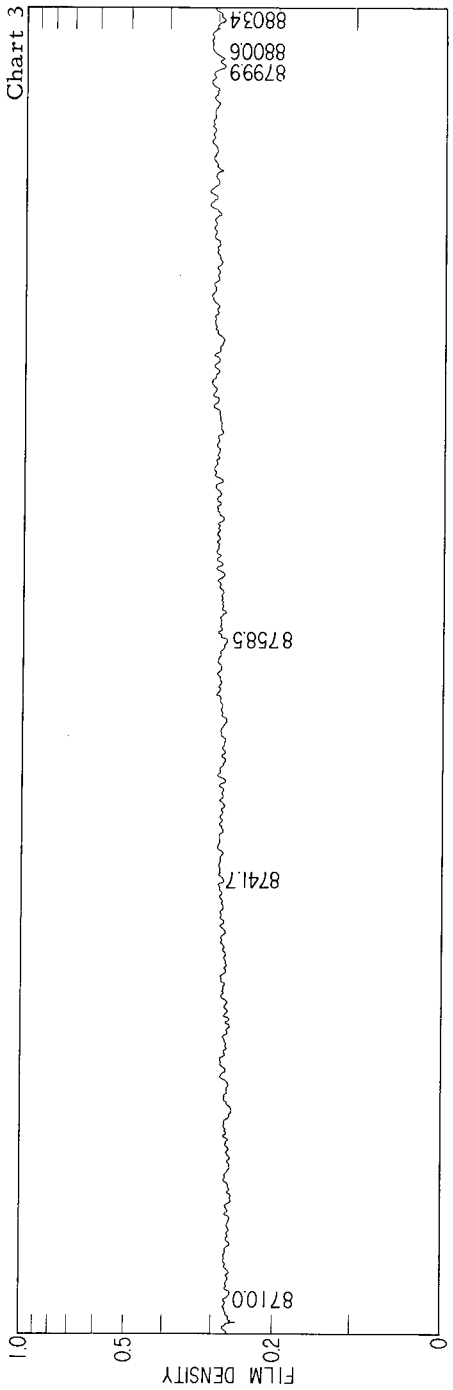

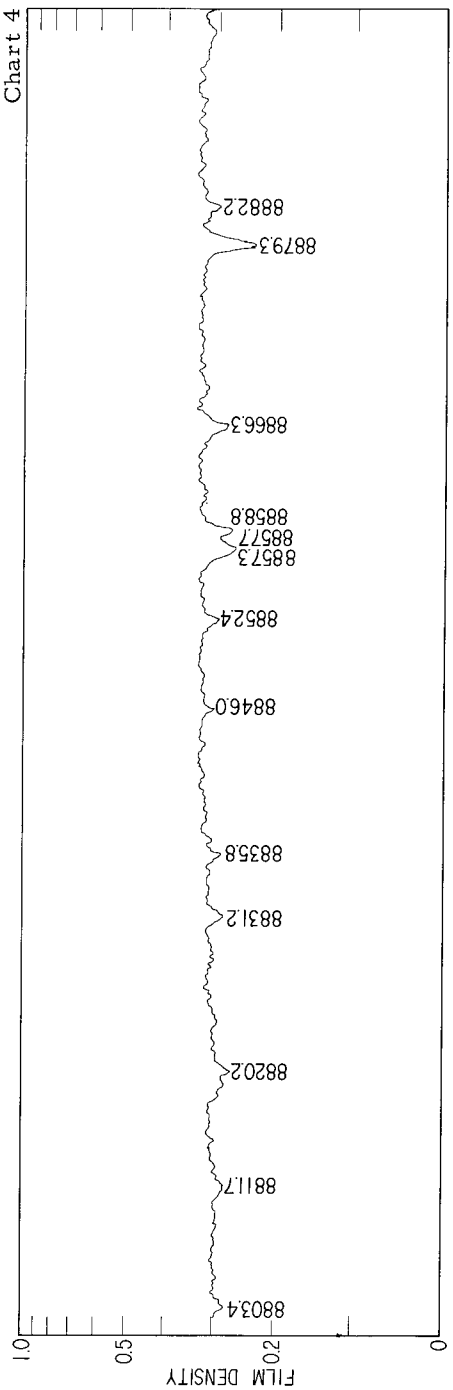

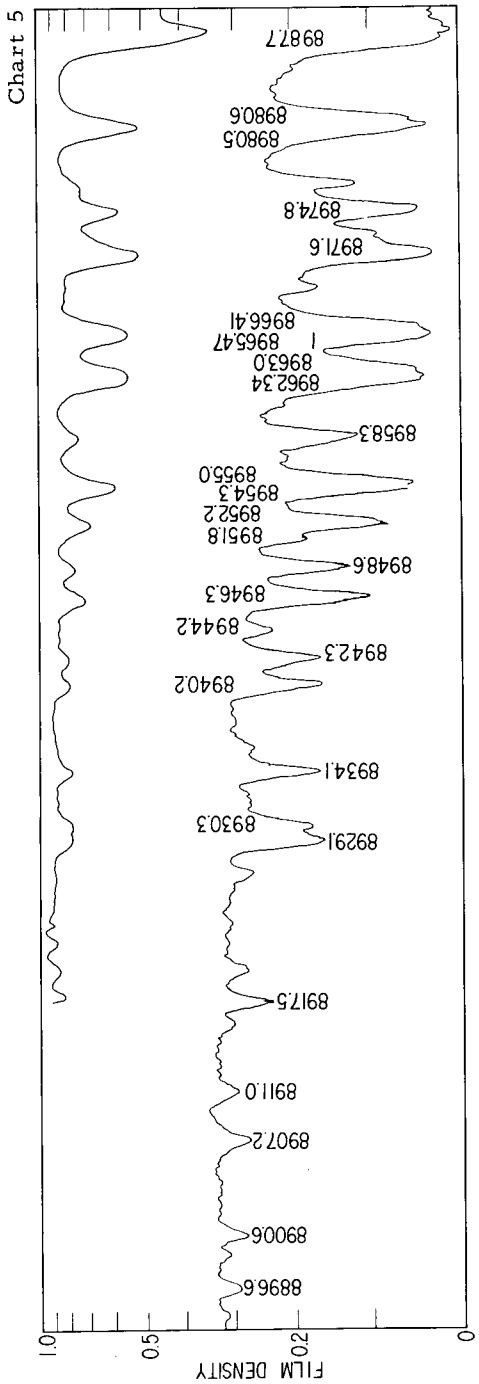
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FILM DENSITY
1.0
0.5
0.2
0
8896.6
8900.6
8907.2
8911.0
8917.5
8929.1
8930.3
8934.1
8940.2
8942.3
8944.2
8946.3
8948.6
8951.8
8952.2
8954.3
8955.0
8958.3
8962.34
8963.0
8965.47
8966.41
8971.6
8974.8
8980.5
8980.6
8987.7

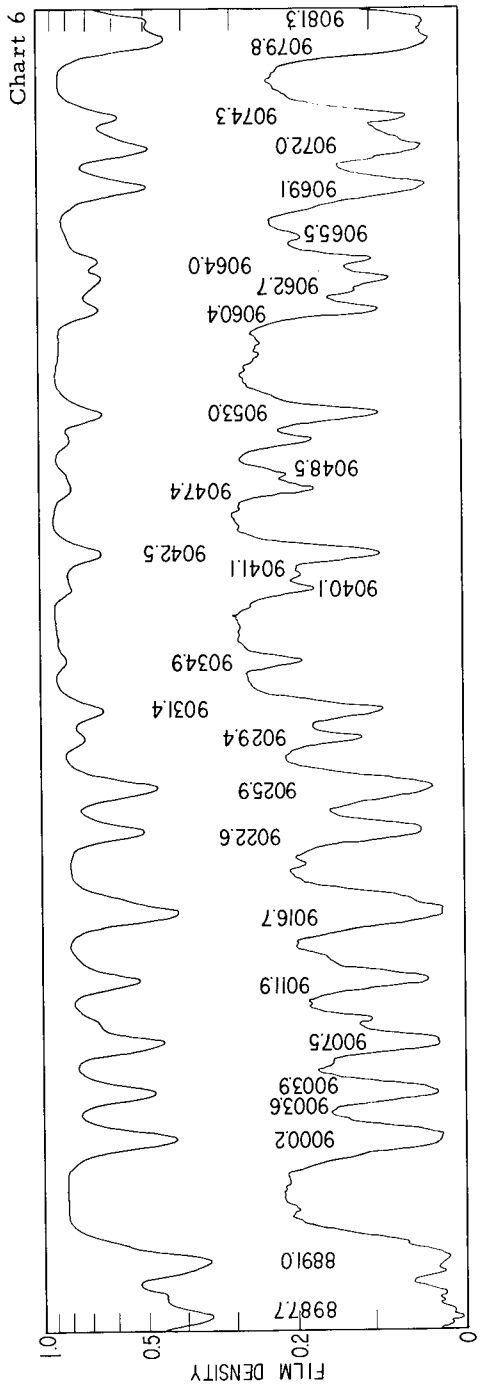
Chart 6
FILM DENSITY
1.0
0.5
0.2
0
8987.7
8991.0
9000.2
9003.6
9003.9
9007.5
9011.9
9016.7
9022.6
9025.9
9029.4
9031.4
9034.9
9040.1
9041.1
9042.5
9047.4
9048.5
9053.0
9060.4
9062.7
9064.0
9065.5
9069.1
9072.0
9074.3
9079.8
9081.3

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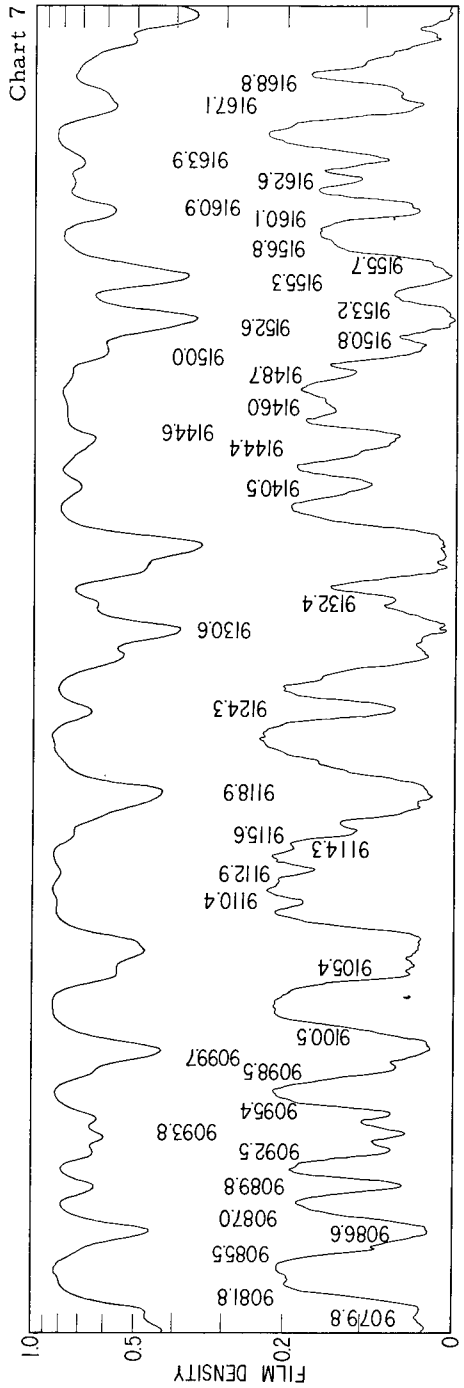

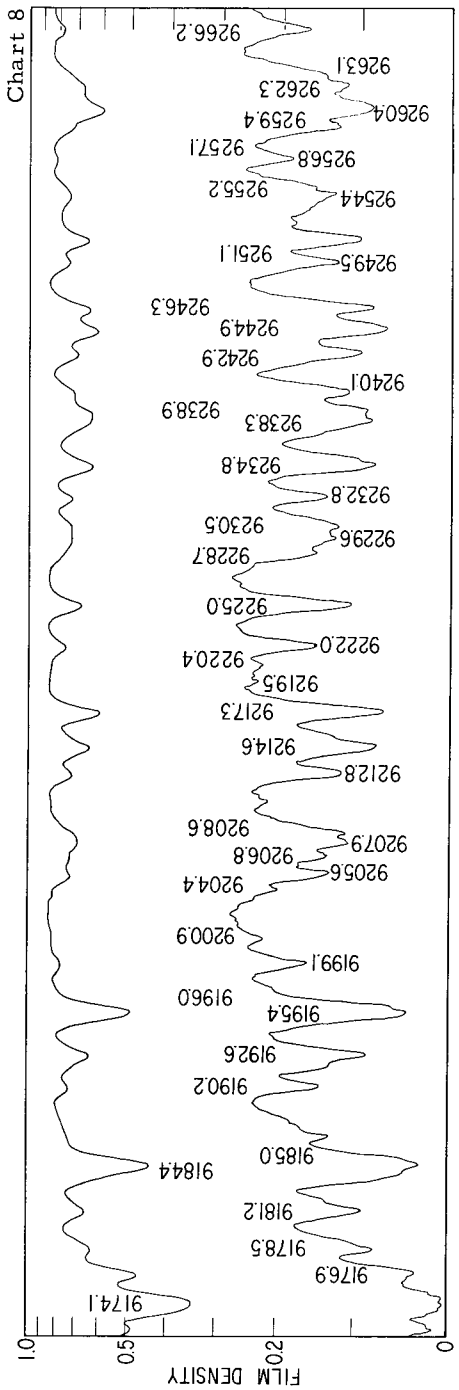

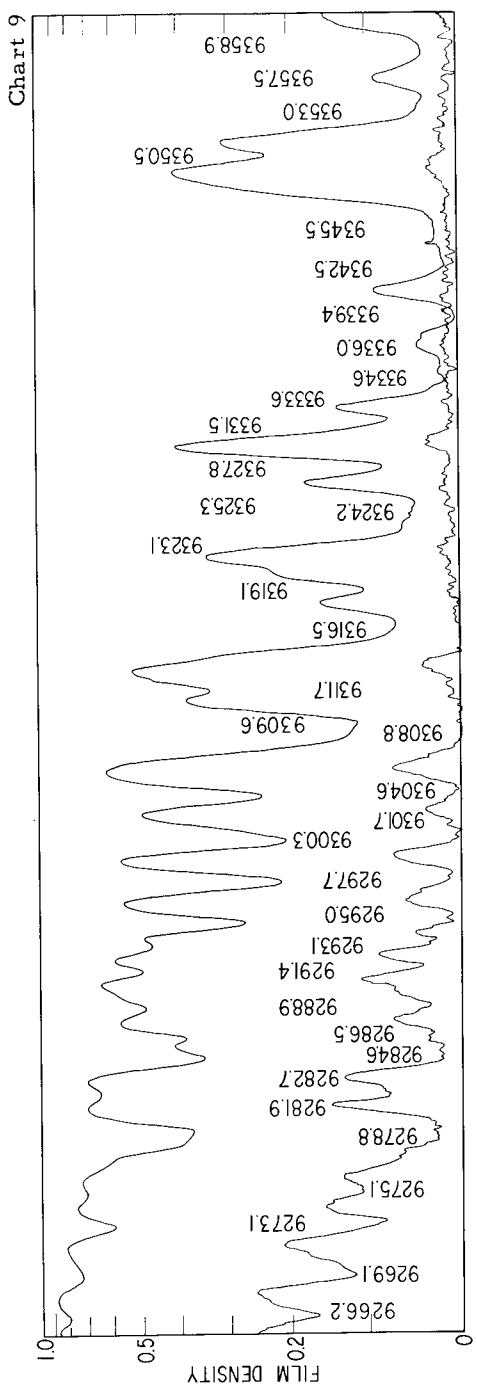
Chart 9
FILM DENSITY
1.0
0.5
0.2
0
9266.2
9269.1
9273.1
9275.1
9278.8
9281.9
9282.7
9284.6
9286.5
9288.9
9291.4
9293.1
9295.0
9297.7
9300.3
9301.7
9304.6
9308.8
9309.6
9311.7
9316.5
9319.1
9323.1
9324.2
9325.3
9327.8
9331.5
9333.6
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9336.0
9339.4
9342.5
9345.5
9350.5
9353.0
9357.5
9358.9

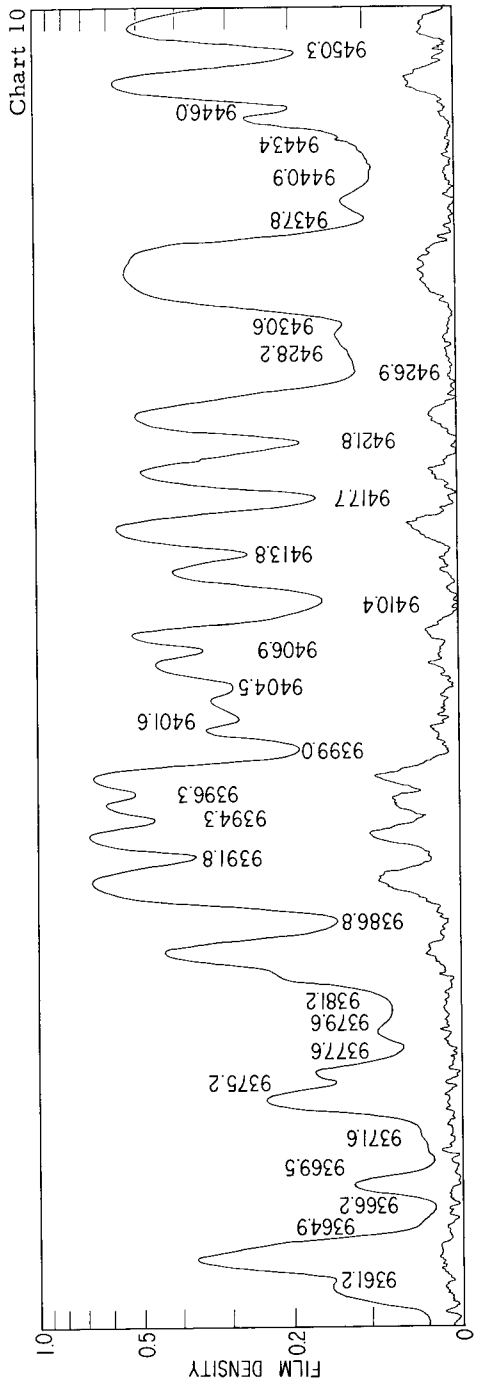
Chart 10
FILM DENSITY
1.0
0.5
0.2
0
9361.2
9364.9
9366.2
9369.5
9371.6
9375.2
9377.6
9379.6
9381.2
9386.8
9391.8
9394.3
9396.3
9399.0
9401.6
9404.5
9406.9
9410.4
9413.8
9417.7
9421.8
9426.9
9428.2
9430.6
9437.8
9440.9
9443.4
9446.0
9450.3

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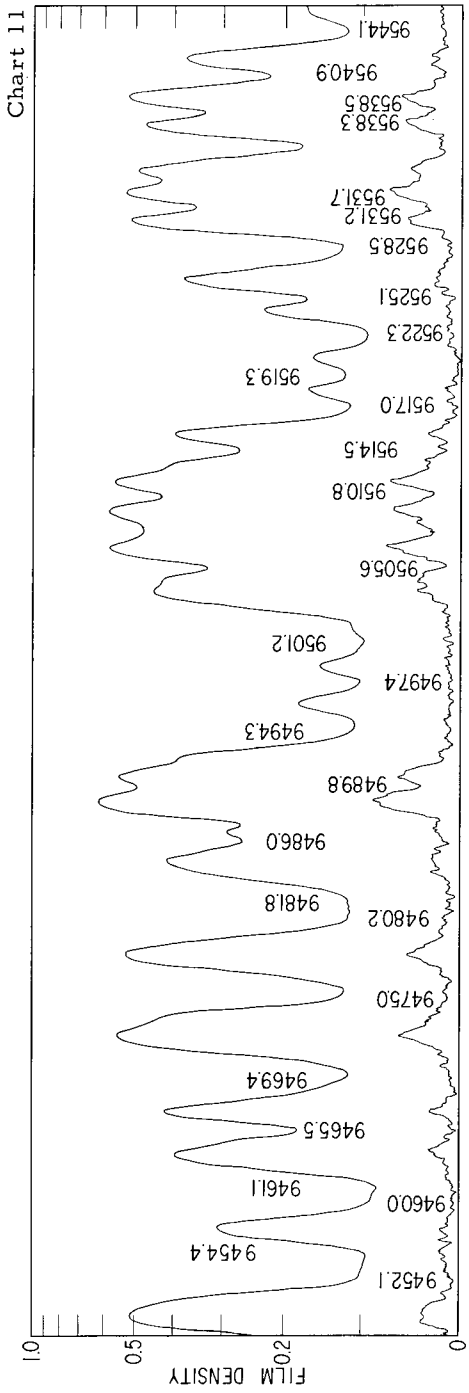

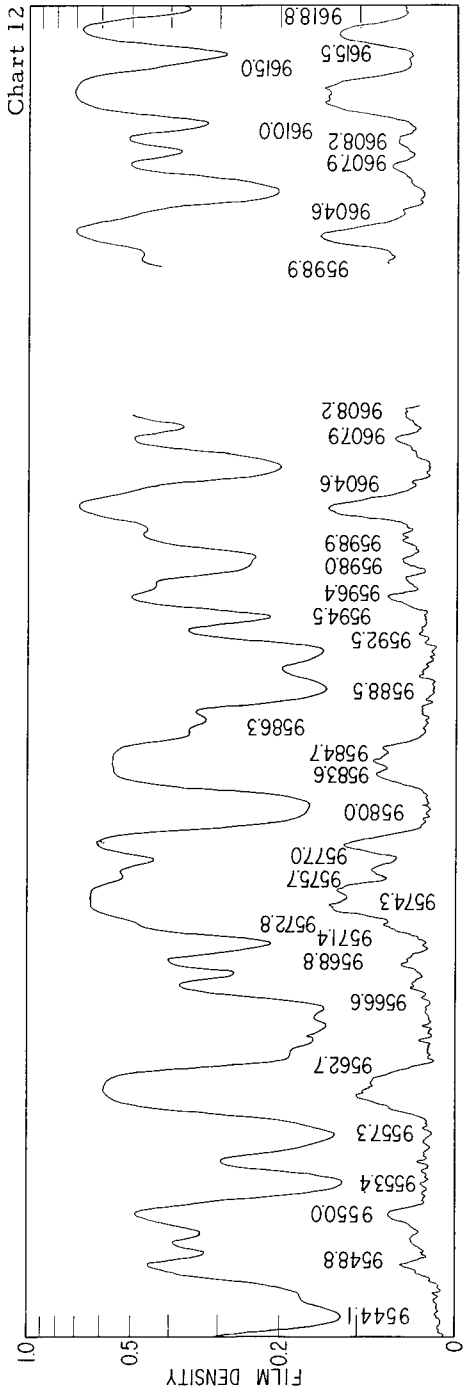

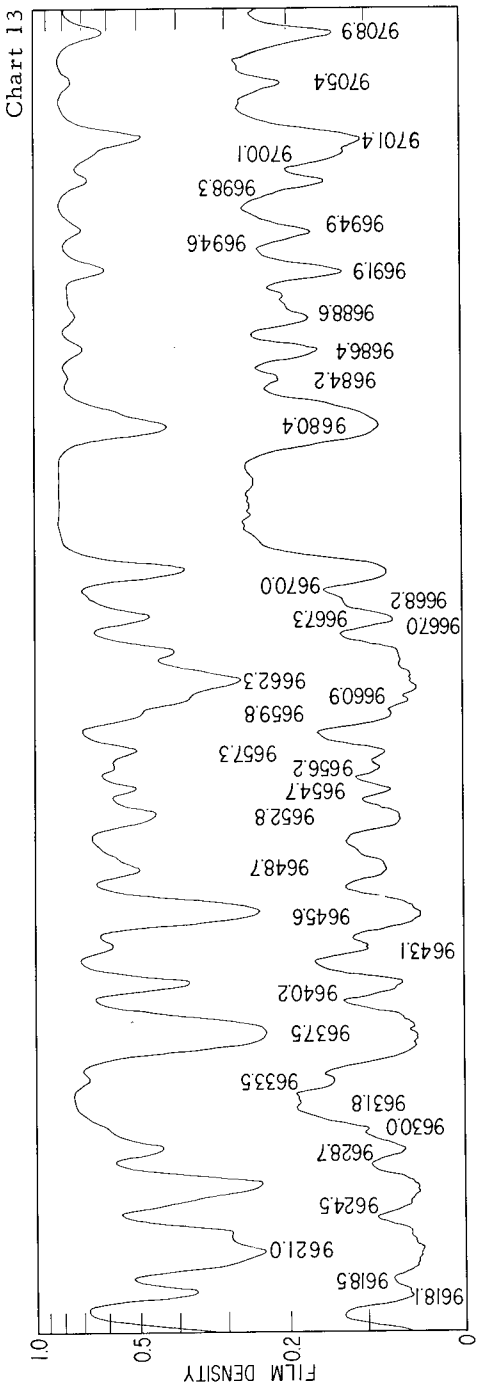
Chart 13
FILM DENSITY
1.0
0.5
0.2
0
9618.1
9618.5
9621.0
9624.5
9628.7
9630.0
9631.8
9633.5
9637.5
9640.2
9643.1
9645.6
9648.7
9652.8
9654.7
9656.2
9657.3
9659.8
9660.9
9662.3
9667.0
9667.3
9668.2
9670.0
9680.4
9684.2
9686.4
9688.6
9691.9
9694.6
9694.9
9698.3
9700.1
9701.4
9705.4
9708.9

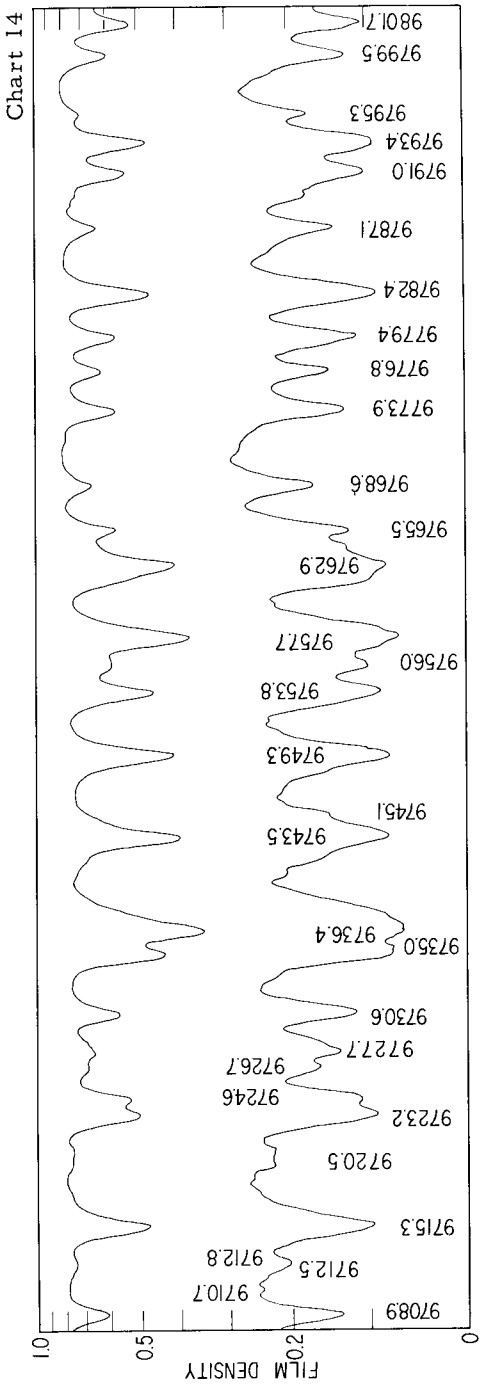
Chart 14
FILM DENSITY
1.0
0.5
0.2
0
9708.9
9710.7
9712.5
9712.8
9715.3
9720.5
9723.2
9724.6
9726.7
9727.7
9730.6
9735.0
9736.4
9743.5
9745.1
9749.3
9753.8
9756.0
9757.7
9762.9
9765.5
9768.6
9773.9
9776.8
9779.4
9782.4
9787.1
9791.0
9793.4
9795.3
9799.5
9801.7

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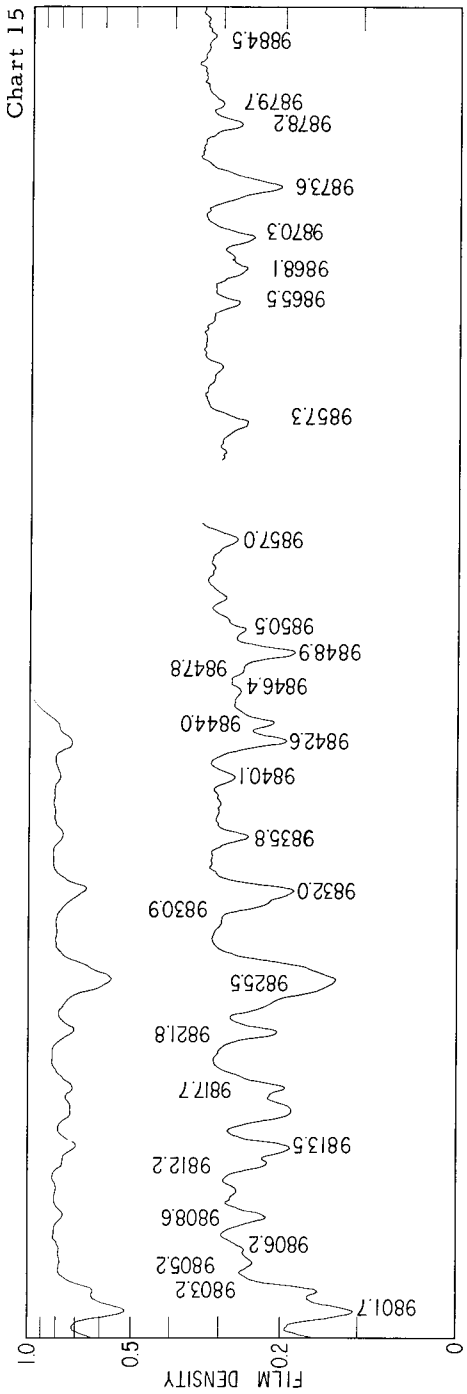

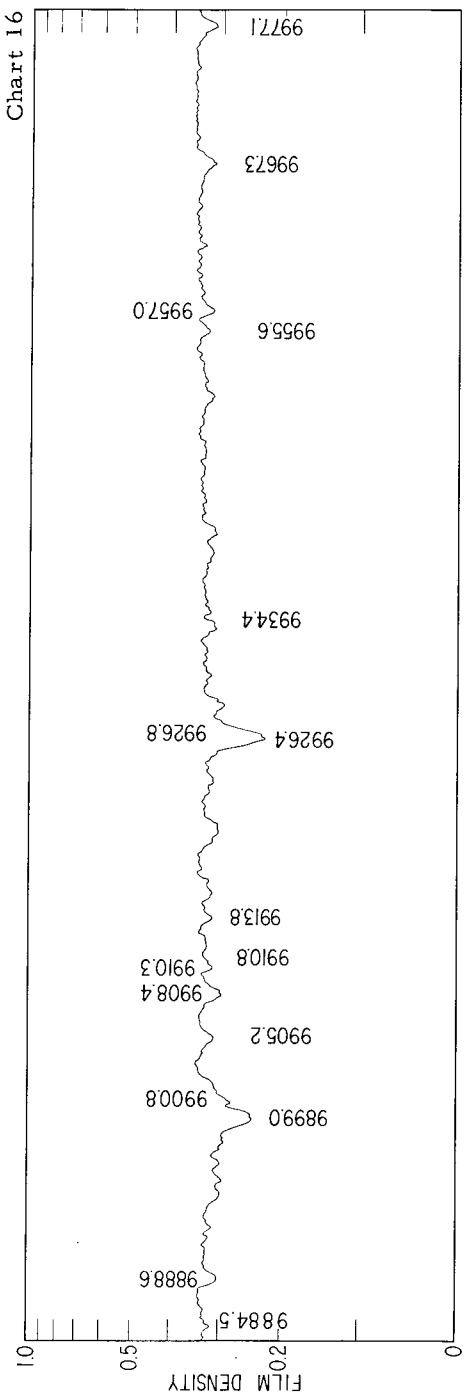

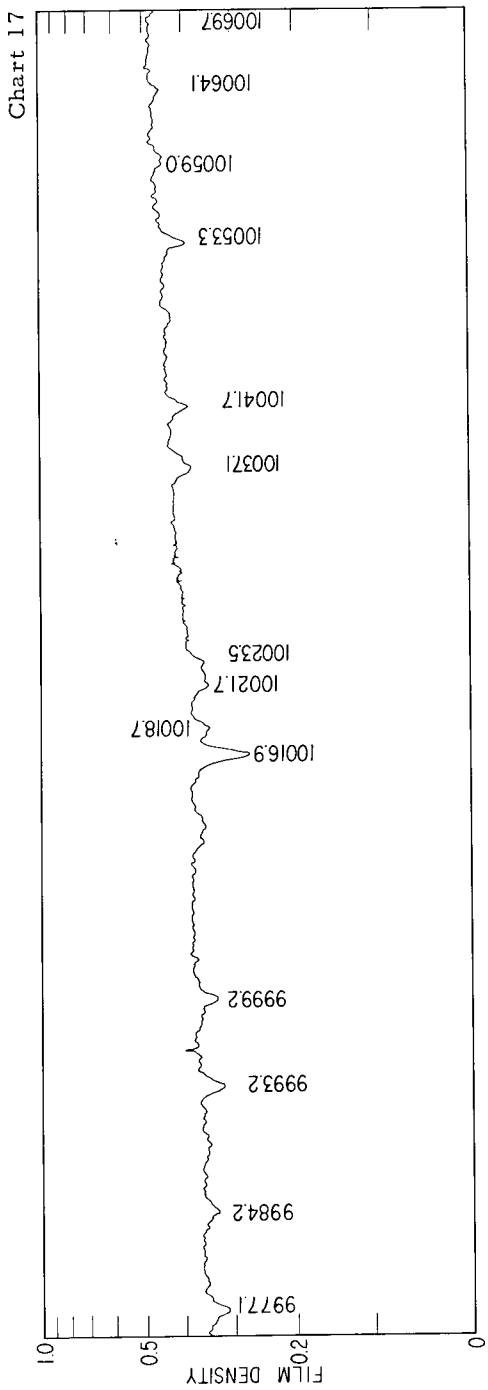
Chart 17
1.0
0.5
0.2
0
FILM DENSITY
100697
100641
100590
100533
100417
100371
100235
100217
100187
100169
99992
99932
99842
99771

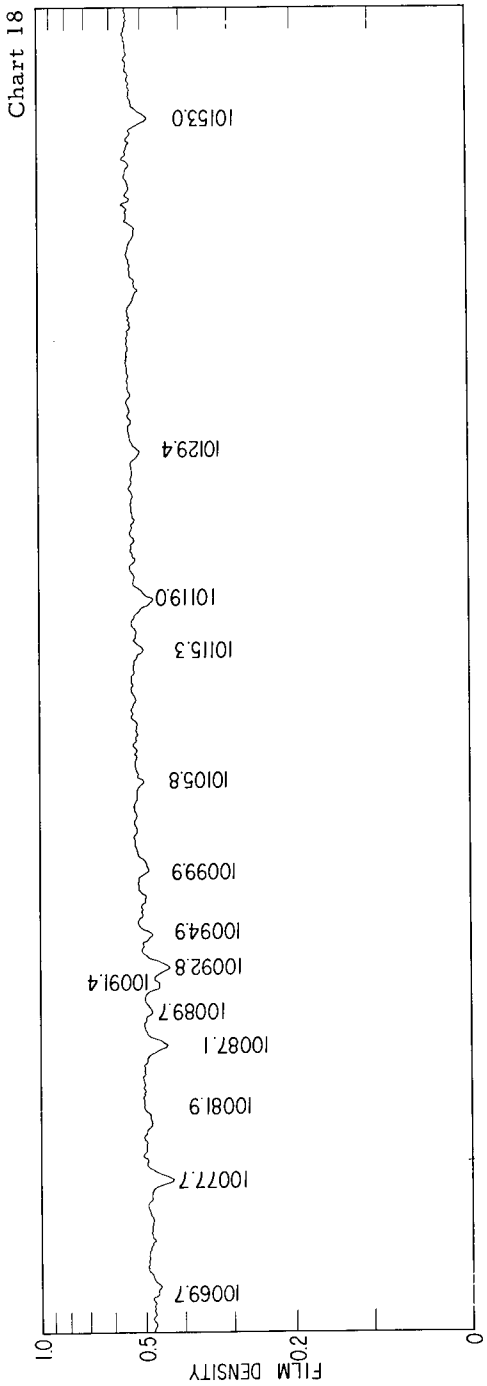
Chart 18
1.0
0.5
0.2
0
FILM DENSITY
101530
101294
101190
101153
101058
100999
100949
100928
100914
100897
100871
100819
100777
100697

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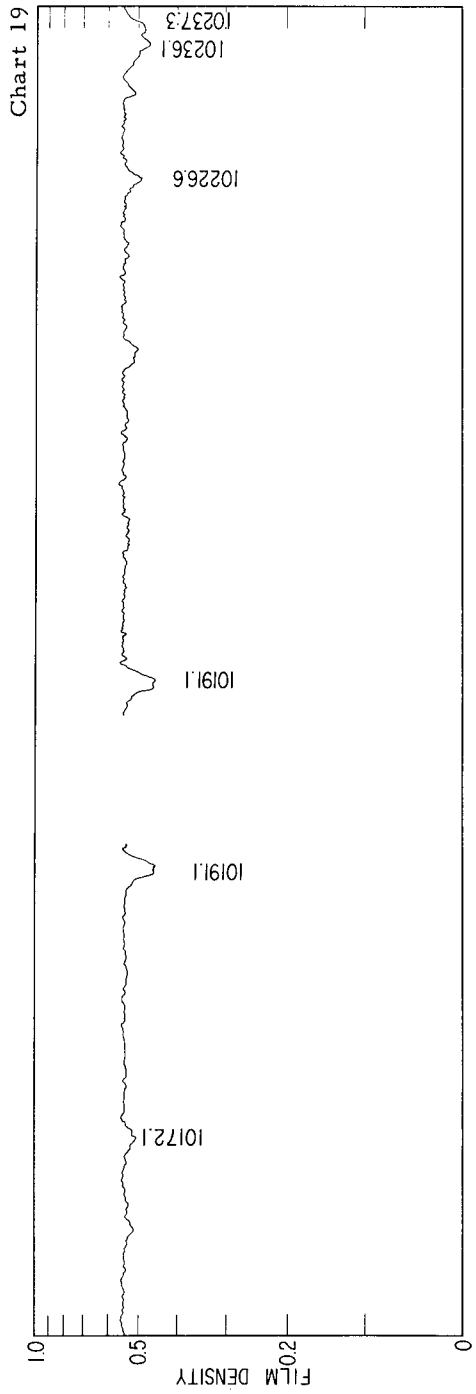

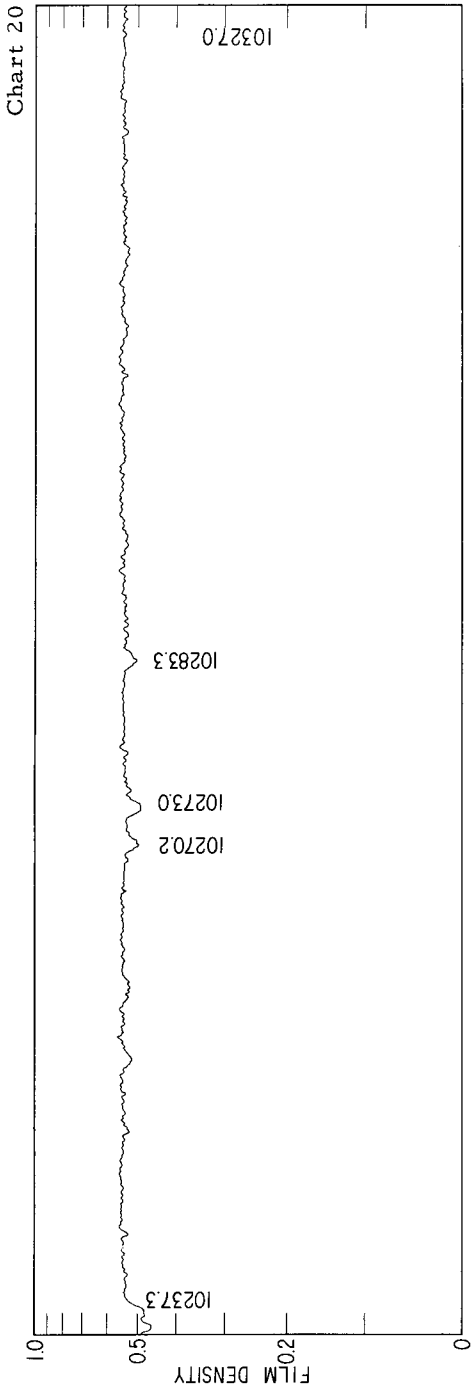

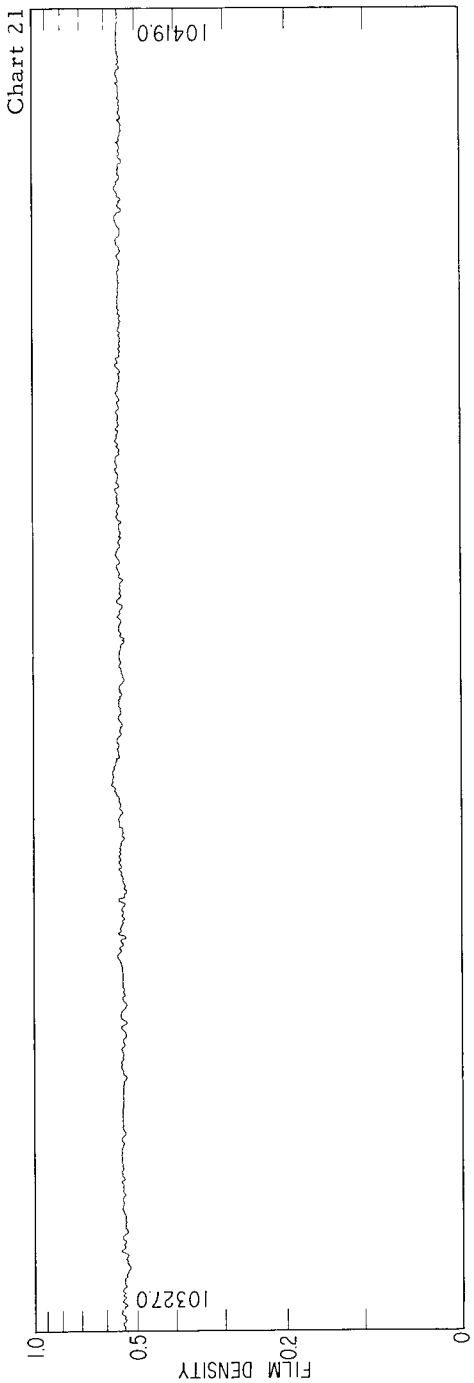
Chart 21
104190
103270
1.0
0.5
0.2
0
FILM DENSITY

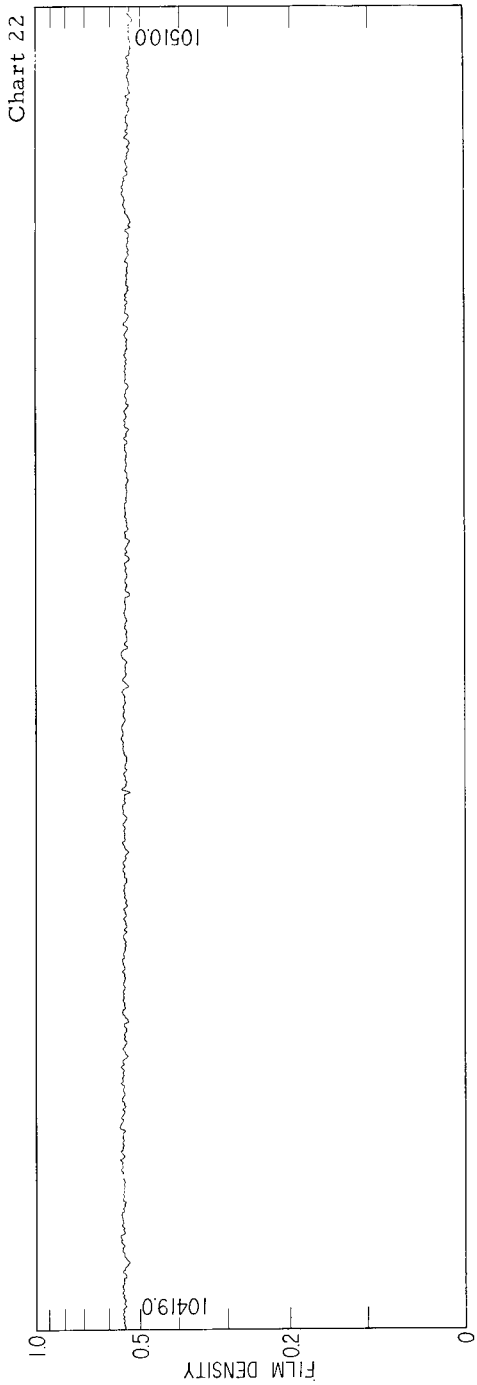
Chart 22
105100
104190
1.0
0.5
0.2
0
FILM DENSITY

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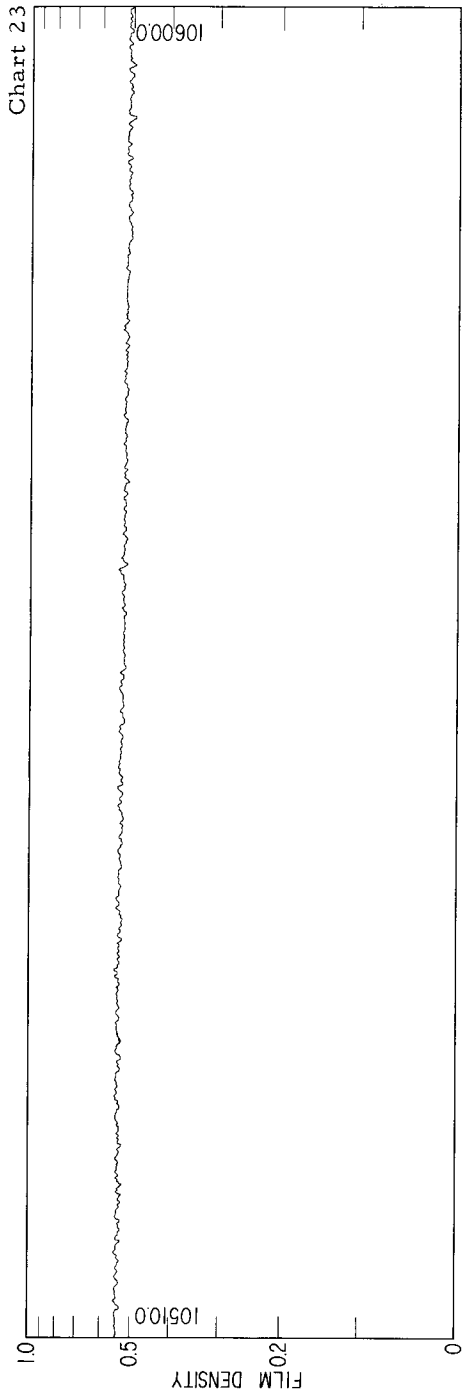

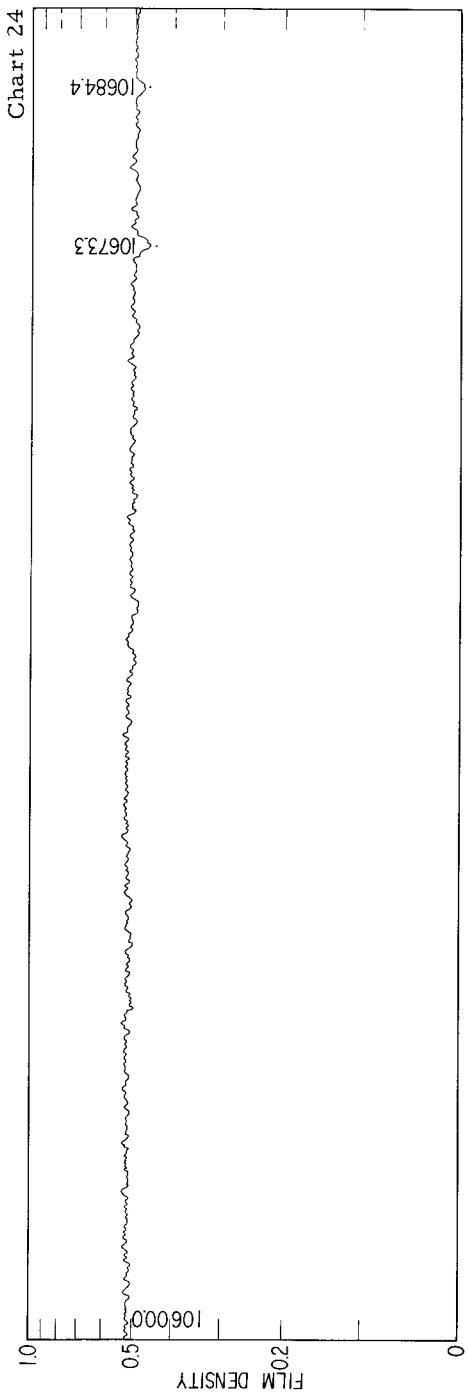

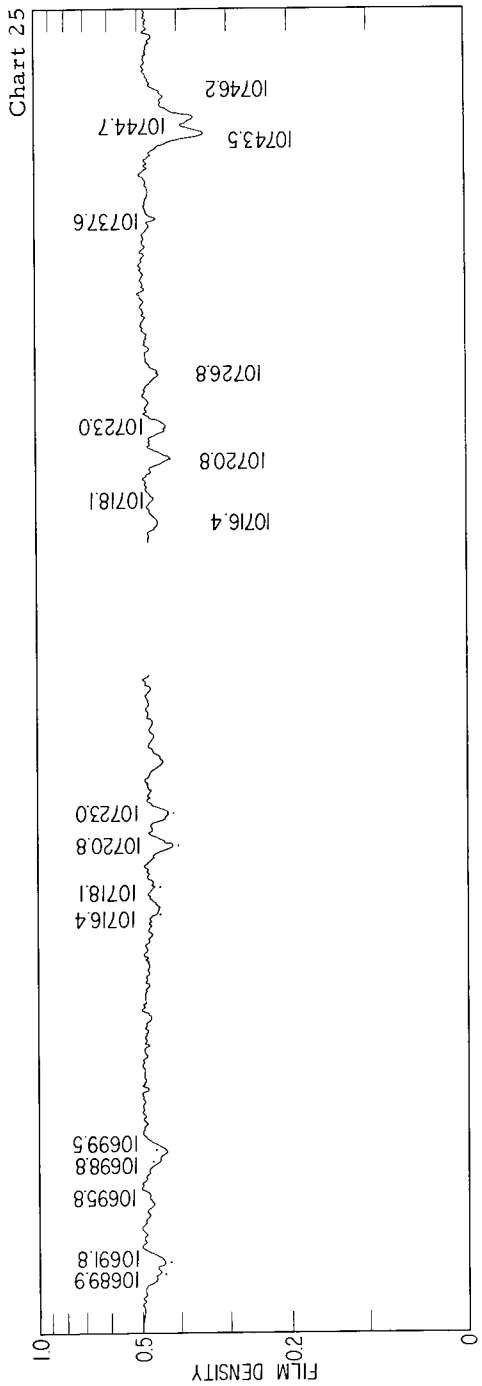
Chart 25
FILM DENSITY
1.0
0.5
0.2
0
10689.9
10691.8
10695.8
10698.8
10699.5
10716.4
10718.1
10720.8
10723.0
10723.0
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10743.5
10744.7
10746.2

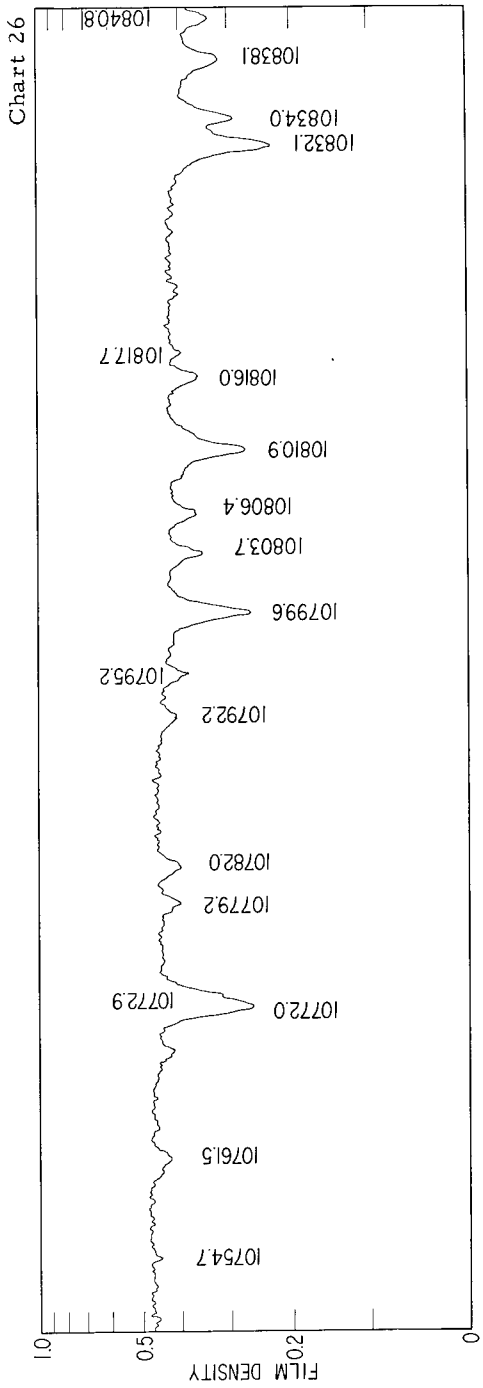
Chart 26
FILM DENSITY
1.0
0.5
0.2
0
10754.7
10761.5
10772.0
10772.9
10779.2
10782.0
10792.2
10795.2
10799.6
10803.7
10806.4
10810.9
10816.0
10817.7
10832.1
10834.0
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10840.8

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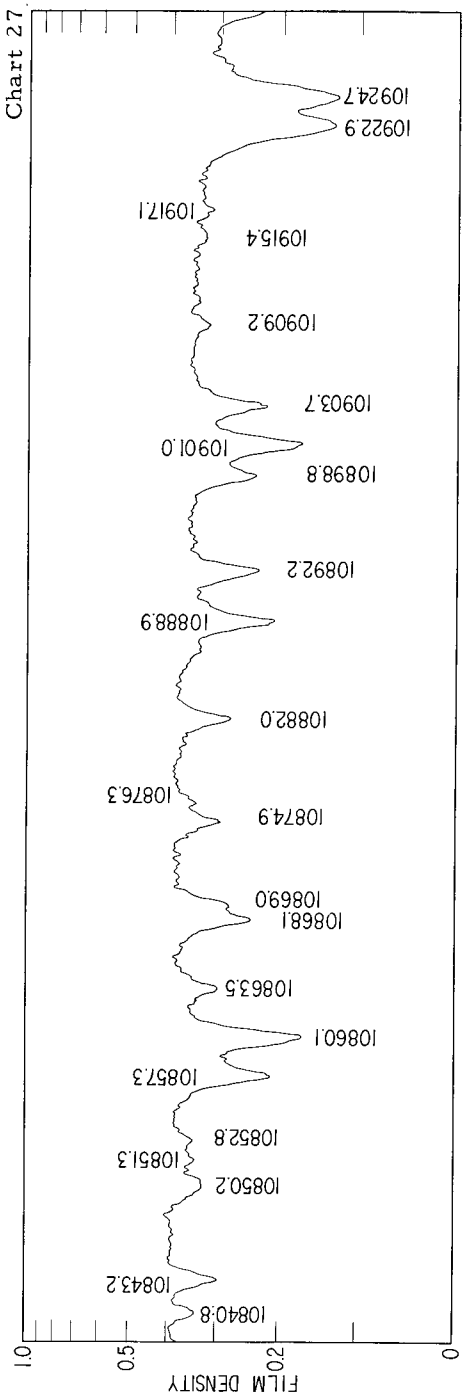

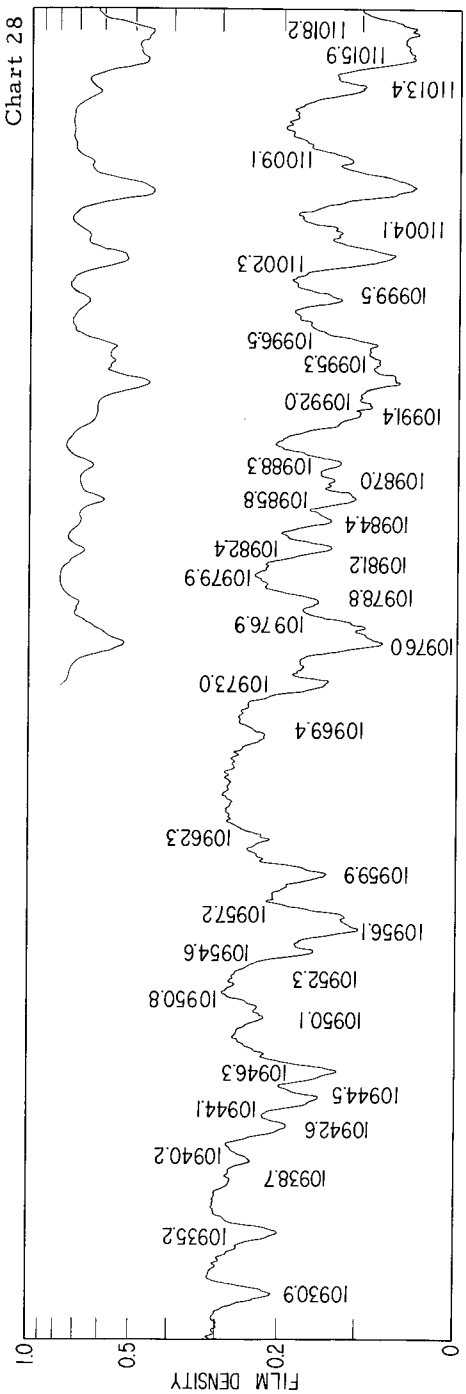

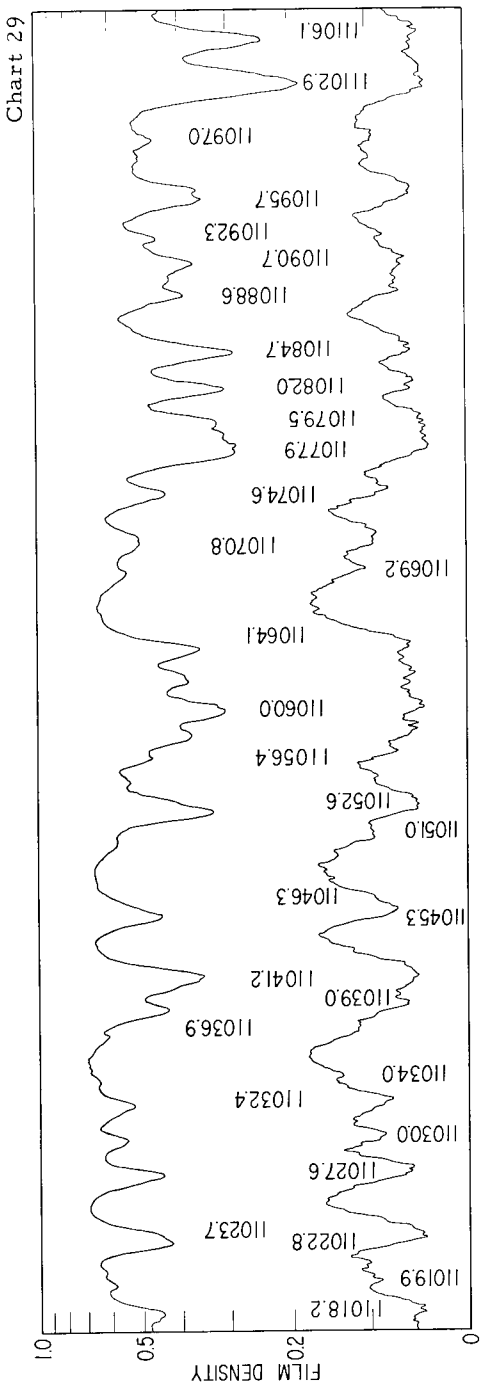
Chart 29
FILM DENSITY
1.0
0.5
0.2
0
1018.2
1019.9
1022.8
1023.7
1027.6
1030.0
1032.4
1034.0
1036.9
1039.0
1041.2
1045.3
1046.3
1051.0
1052.6
1056.4
1060.0
1064.1
1069.2
1070.8
1074.6
1077.9
1079.5
1082.0
1084.7
1088.6
1090.7
1092.3
1095.7
1097.0
1102.9
1106.1

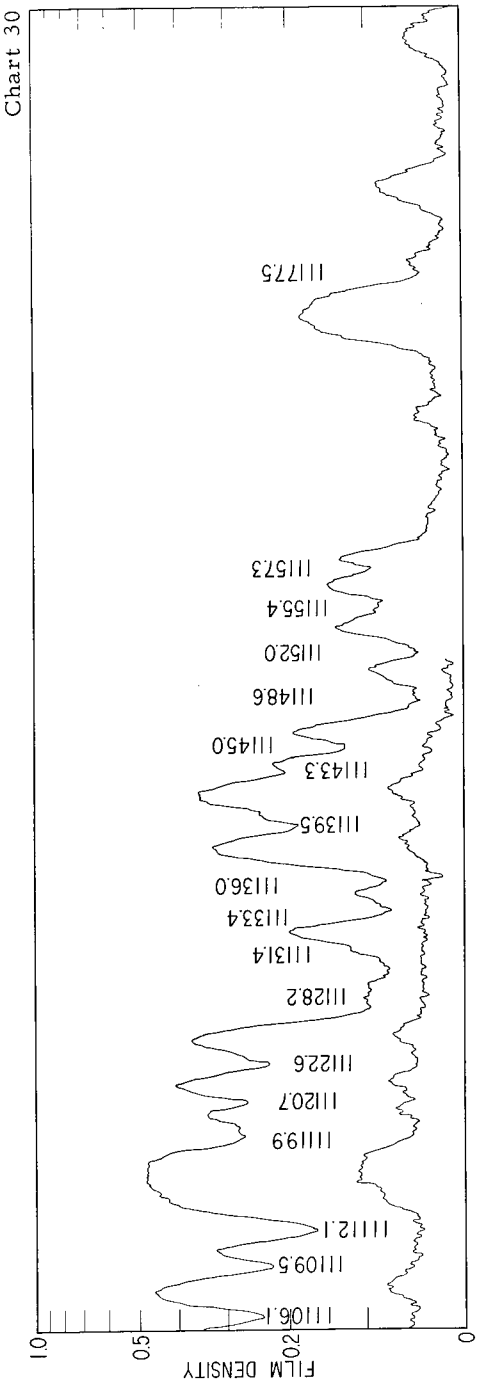
Chart 30
FILM DENSITY
1.0
0.5
0.2
0
1106.1
1109.5
1112.1
1119.9
1120.7
1122.6
1128.2
1131.4
1133.4
1136.0
1139.5
1143.3
1145.0
1148.6
1152.0
1155.4
1157.3
1177.5

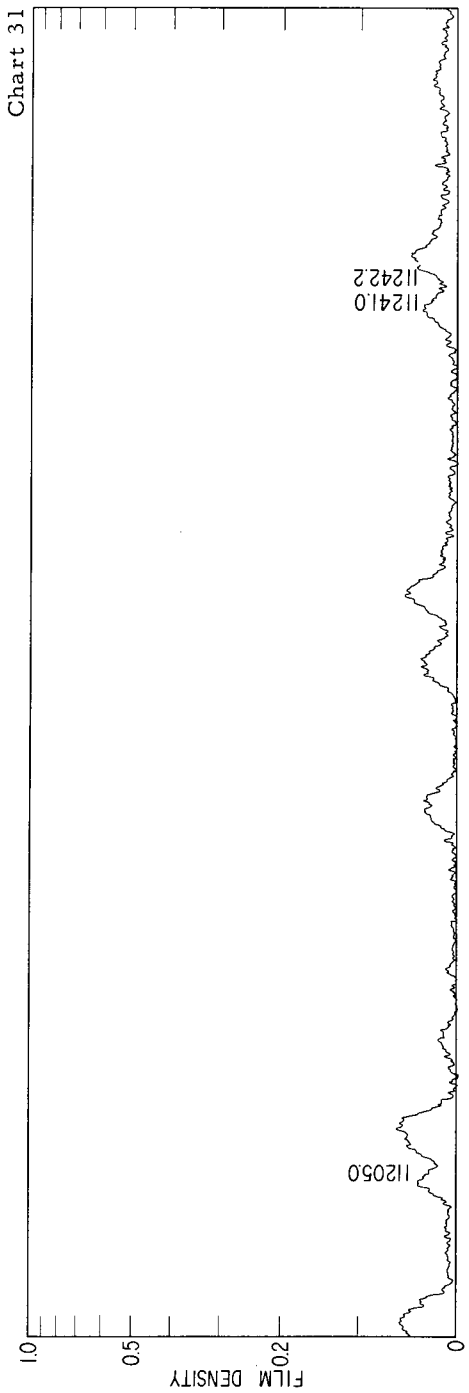
Chart 31
FILM DENSITY
1.0
0.5
0.2
0
11205.0
11241.0
11242.2

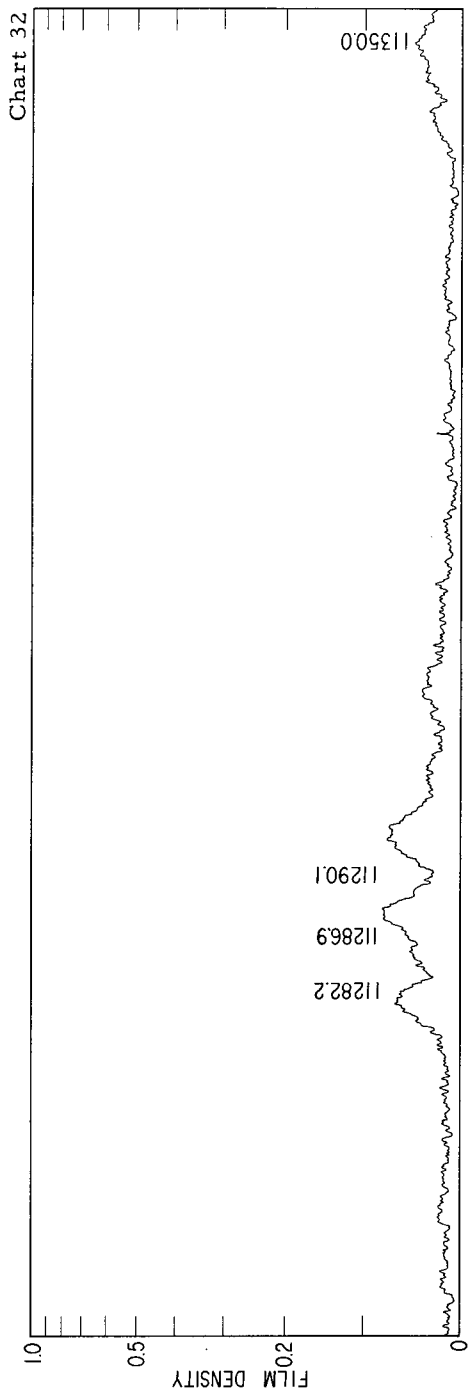
Chart 32
FILM DENSITY
1.0
0.5
0.2
0
11282.2
11286.9
11290.1
11350.0

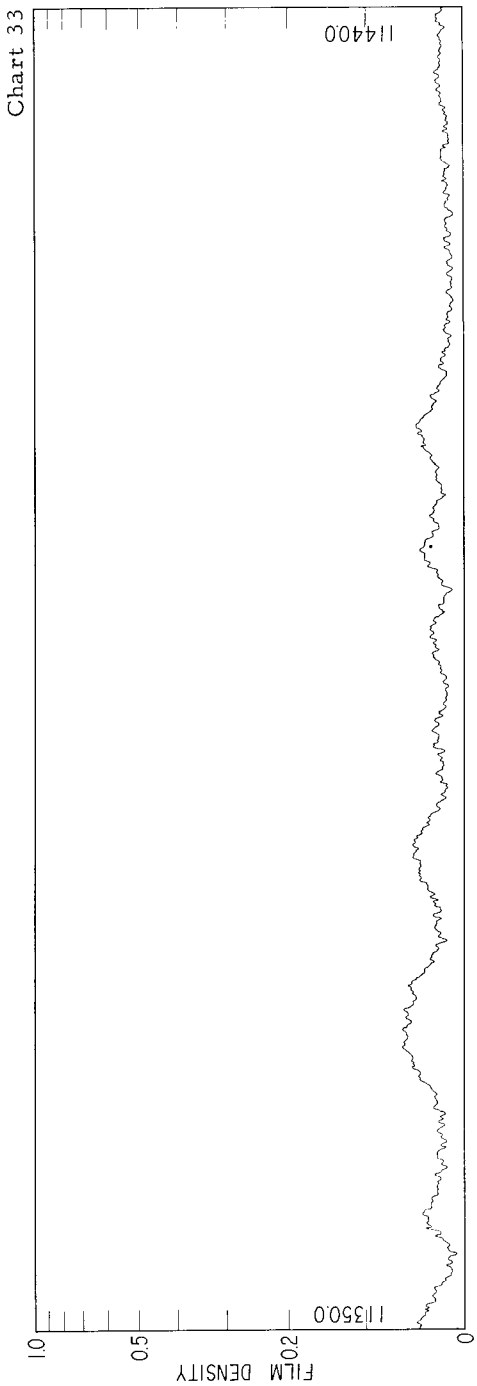
Chart 33
11400
11350
FILM DENSITY
1.0
0.5
0.2
0

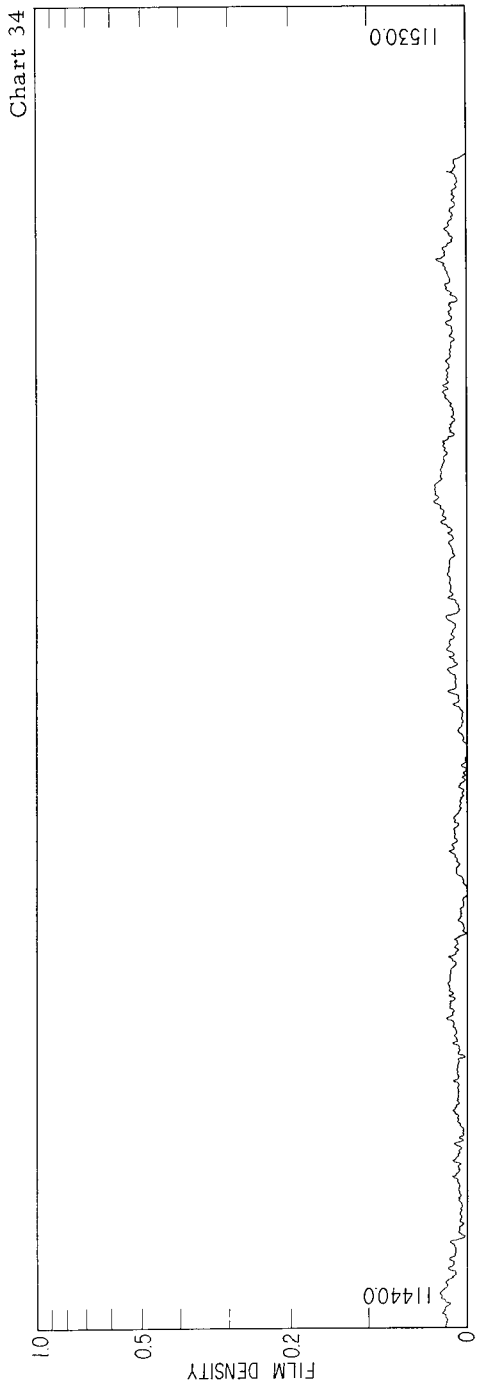
Chart 34
11530
11400
FILM DENSITY
1.0
0.5
0.2
0

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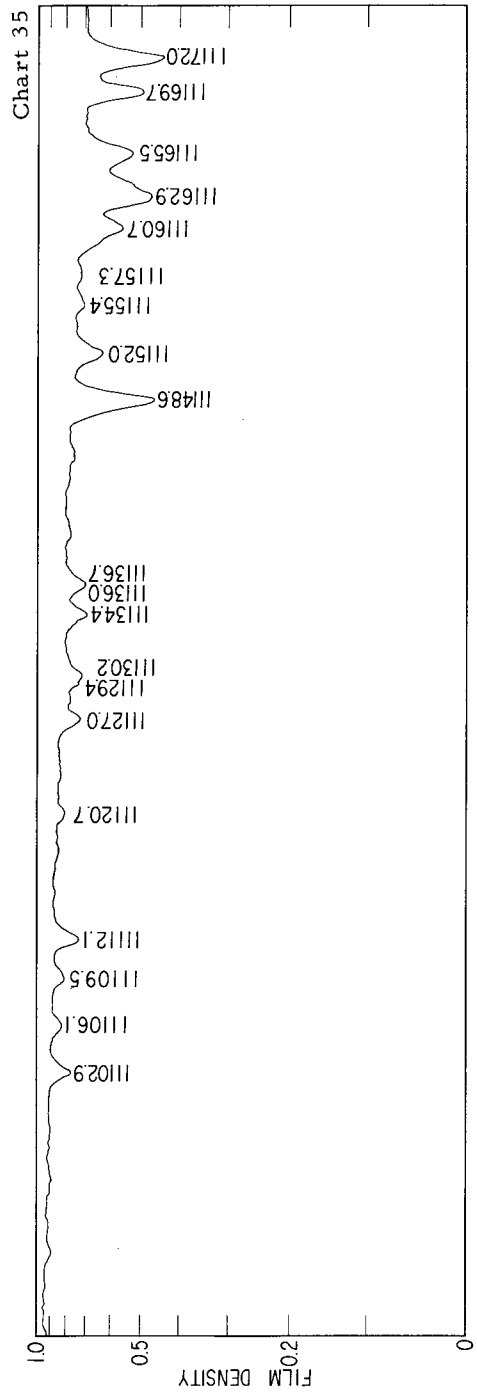

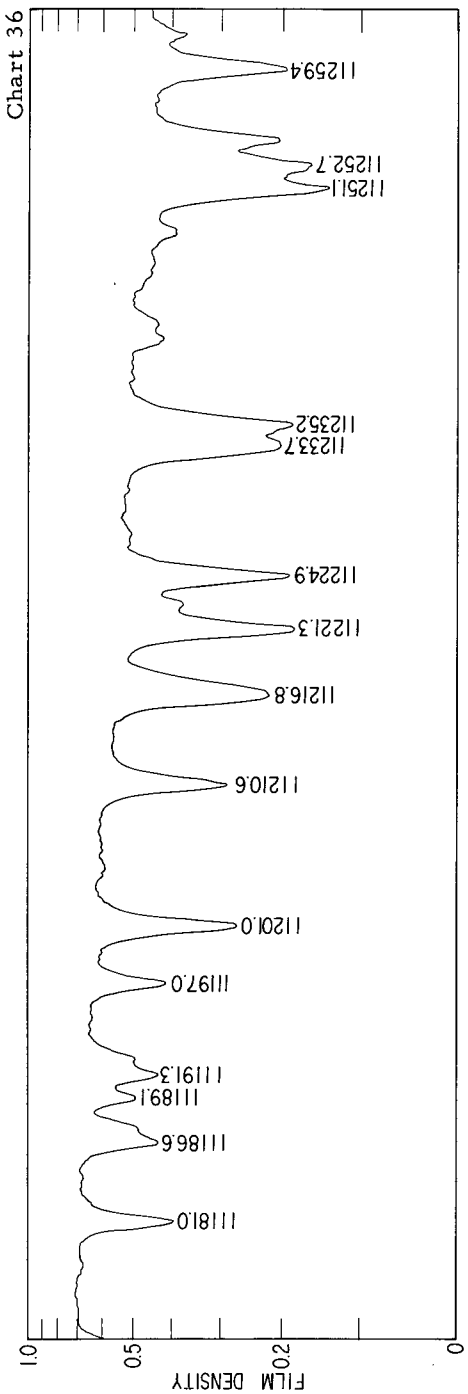

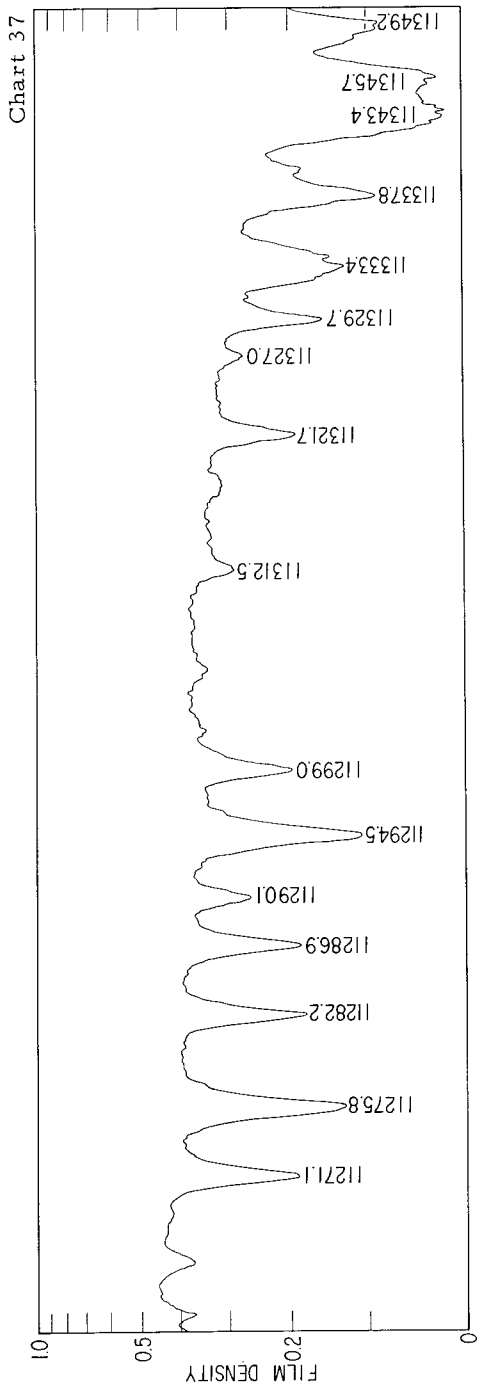
Chart 37
FILM DENSITY
1.0
0.5
0.2
0
11271.1
11275.8
11282.2
11286.9
11290.1
11294.5
11299.0
11312.5
11321.7
11327.0
11329.7
11334
11337.8
11343.4
11345.7
11349.2

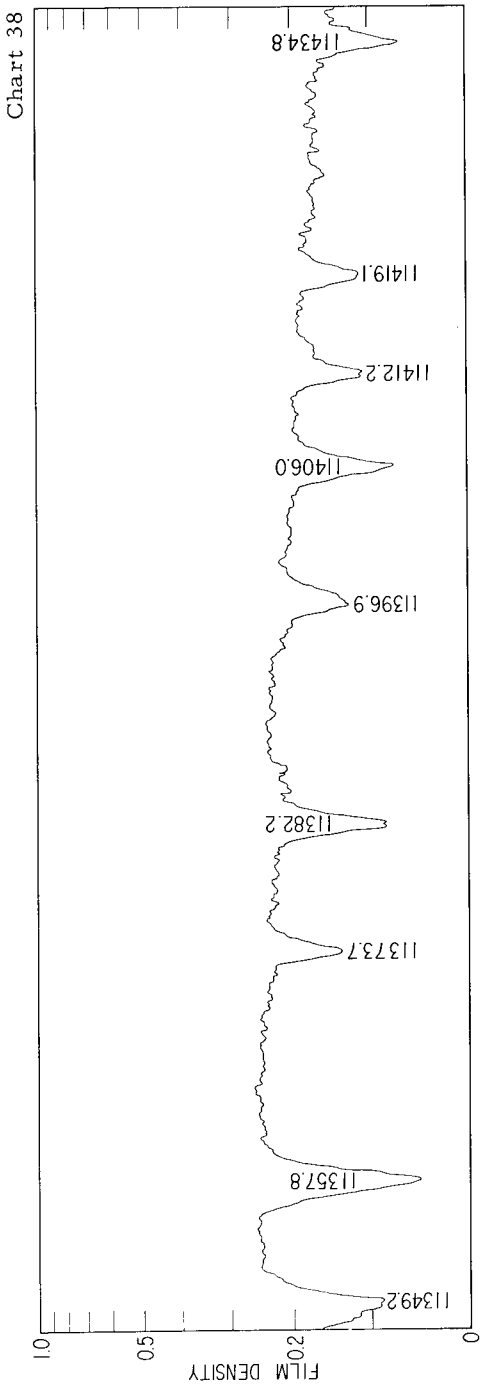
Chart 38
FILM DENSITY
1.0
0.5
0.2
0
11349.2
11357.8
11373.7
11382.2
11396.9
11406.0
11412.2
11419.1
11434.8

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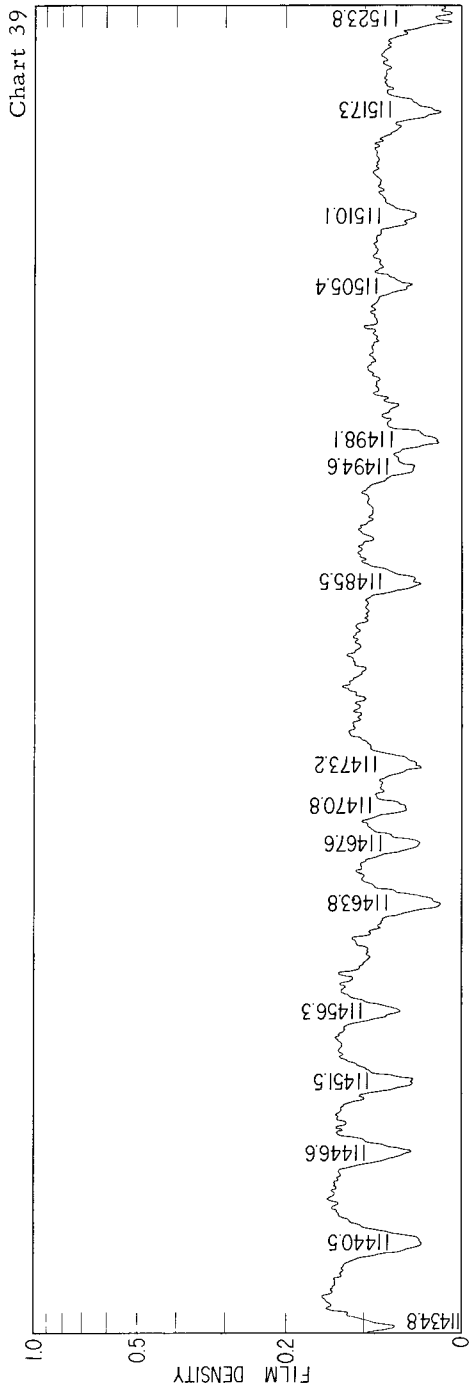

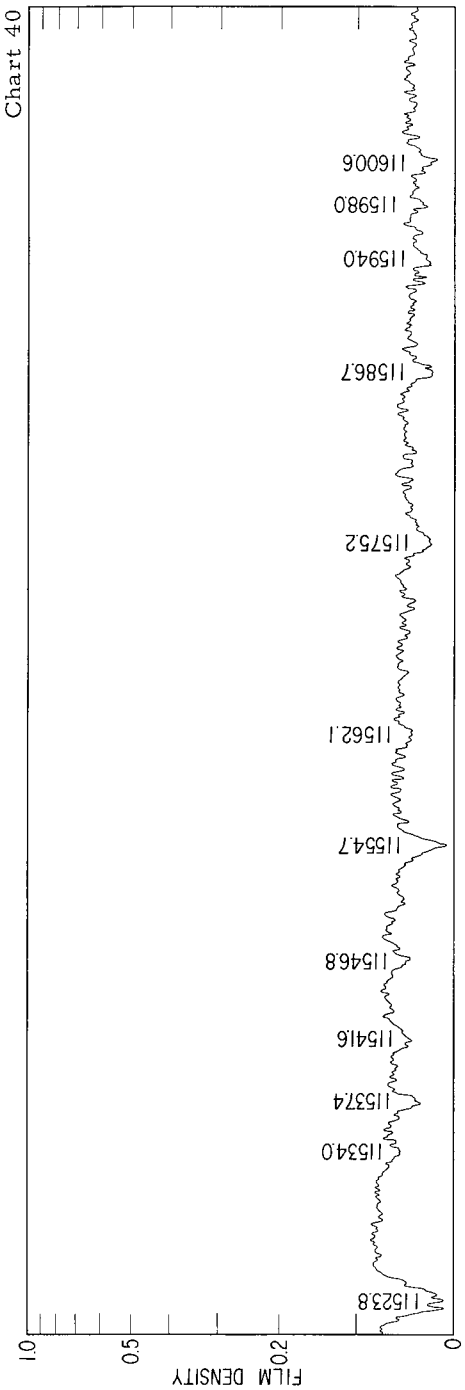

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DOCUMENT CONTROL DATA - R&D

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2b. GROUP

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11. SUPPLEMENTARY NOTES

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13. ABSTRACT

This report presents an atlas of the atmospheric spectral absorption structure of a 10.1-mile sea level path when the atmosphere contained 4.5 cm of precipitable water and when the atmosphere contained 12 cm of precipitable water. A neodymium glass laser spectrum is also included and shown to emit in a spectral region which is particularly free of atmospheric absorption.

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Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Neodymium laser						
Absorption spectrum						
Neodymium laser spectrum						
Atmosphere absorption spectrum						

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