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FINAL REPORT

INFRARED REFLECTANCE SPECTRA FOR  
SELECTED PAINT PIGMENTS

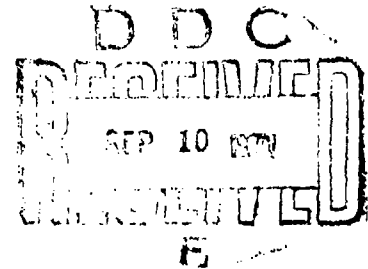
BY

MERRILL COHEN

AND

JOHN P. DONER

JULY 1971



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## ABSTRACT

This report presents data on the near infrared reflectance spectra, 0.6-2.0 micron region, for 89 pigments in a wide range of colors. Pigments, both organic and inorganic, were selected for low infrared absorption and possible use in the design of military coatings with controlled infrared reflectance. The data obtained provides a basis for characterization of the pigments examined based on reflectance properties.

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## I. INTRODUCTION

Recent investigations on the development of dark colored Solar Heat Reflecting Coatings for military applications have demonstrated the inadequacy of fundamental data on the near infrared reflectance characteristics of paint pigments. While many publications report visible reflectance spectra, rarely is infrared data included.

The growing demand for the design of military coatings to provide visual camouflage for tactical situations as well as other special reflectance characteristics is a result of added functional requirements. Coatings are now being considered for their ability to reduce solar heat absorption, thereby providing increased operational reliability to electronic equipment exposed to solar heatings as well as personnel comfort. Coatings capable of defeating new detection devices are also being investigated and paints with special spectral characteristics have found recent use.

Initial work conducted in this area at the Coating & Chemical Laboratory began with the development of a solar heat reflecting olive drab paint. This first work was accomplished using a photocell reflectometer equipped with Wratten 87 and 89 filters.

While this early work provided a paint which was responsive to the then current requirements, the narrow spectral region in which the filter-photocell combination was sensitive, limited the development of optimum systems to meet current and future requirements. Therefore a program was initiated to measure spectral reflectance of coatings from 0.2-2.2 microns to provide the required data.

## II. DETAILS OF TEST

### A. Basic Formulations.

Reflectance data on pigments is generally reported based on the dry pigment pressed into a tablet. This method can result in high reflectance readings for pigments that, in fact, show considerable transparency when used in concentrations normally employed in paints. For this reason the pigments were studied at concentration levels representative of those used in coatings. The pigments were dispersed in a resin binder as shown in the basic formulations in Table I. The styrenated alkyd resin was chosen based on previous studies that showed it to have excellent transparency in the near infrared spectral region. The pigments investigated, Table II, included both inorganic and organic types.

The inorganic pigments were representative of those generally used in Army paints. They were made into Type I and II coatings of Table I depending on the oil absorption of the pigment with the higher oil absorption ones being made at the lower pigment concentration and vice versa. The two concentrations were required because the viscosity

increase which generally occurs in a coating as the oil absorption of the pigment increases can interfere with proper pigment dispersion. The organic pigments being still higher in oil absorption were made at the even lower pigment concentration of the Type III coating. All the paints were prepared by dispersing the pigment and vehicle in a porcelain ball mill for 18 hours using a 2:1 ratio of pebbles to paint.

#### B. Preparation of Test Specimens.

Test panels of 2024 Aluminum alloy (3 x 6 inches), were vapor degreased and solvent cleaned in accordance with Federal Test Method Standard No. 141, Method 2011. Black and white lustreless enamels conforming to Federal Specification TT-E-516 were then spray applied to a dry film thickness of 0.9-1.1 mils to provide highly reflective and absorptive substrates for determining the degree of transparency of the pigment over the spectral range investigated. The test paints were then spray applied using a automatic spray apparatus over the black and white substrates to a dry film thickness of 0.9-1.1 mils and air dried 18 hours. A sample disc 1-11/16 inches was then stamped from each test panel and reflectance spectra determined from 0.6-2.0 microns.

#### C. Determination of Reflectance Spectra.

Reflectance spectra from 0.6 to 2.0 microns were determined using a Cary 14 Recording Spectrophotometer equipped with a 9 inch (26 Centimeter) integrating sphere reflectance attachment. Sample illumination was monochromatic at an angle of about 8° to the normal. Magnesium oxide was used as the reference standard.

#### D. Pigment Classification.

The spectrum for each pigment was examined over black and white substrates and classified according to optical type and reflectance as follows:

1. Optical type - Difference in percent reflectance over white and over black.

- |                 |         |
|-----------------|---------|
| a. Opaque       | 15      |
| b. Transitional | 15 - 30 |
| c. Transparent  | 30      |



2. Reflectance Level - Average percent reflectance over black and white substrates.

- a. High                    55
- b. Medium                31 - 55
- c. Low                    16 - 30
- d. Absorbing            15

### III. SUMMARY

This study provides data necessary for the proper selection of pigments to provide primary military colors with controlled IR reflectance. It will enable the formulation of coatings with color permanence in the visible range yet possessing special spectral properties for solar heat rejection or nonvisible spectral properties for other applications.

APPENDIX A

**Preceding page blank**

TABLE I - FORMULATIONS

	Parts by Weight		
	Types		
	I	II	III
Inorganic Pigment	354.6	254.2	---
Organic Pigment	--	---	110.8
Styrenated Alkyd, 50% N.V.	490.8	491.5	443.2
Xylene	151.1	251.0	443.1
Diethylamine	0.7	0.7	0.7
6% Cobalt Naphthenate	1.4	1.3	1.1
Antioxidant	1.4	1.3	1.1
Total Weight	1000.0	1000.0	1000.0
Total solids, %	60.0	50.0	33.3
Pigment on the total paint, %	35.5	25.4	11.1
Vehicle solids on total paint, %	24.5	24.6	22.2
Fineness of grind	7	7	7

TABLE II - Pigment Identification

Chemical Class	Spectra Figure No.	Average Reflectance Over		Diff.	Classification/	Formula Type2/	Code4/	Manufacturer Identification
		Black	White					
<u>Inorganics</u>								
Titanium dioxide	1 and 2	N/A	81	N/A	HO	I	A	Tipure R610
Carbon black3/	1	6	N/A	N/A	AO	III	C	Superba carbon black
Iron oxide	3	7	45	38	AMT	II	B	Indian red R-809R
Iron oxide	4	12	13	1	AAO	II	C	Mapico brown 420
Cadmium sulfo selenide	5	21	43	22	LMTR	I	D	Calco cadmium red L 74-5360
Cadmium sulfide	6	11	69	58	AHT	I	D	Cadmium orange 47-4700
Lead chromate	7	40	73	33	MHT	I	E	Chrome orange X-819 CP light
Molybdate orange	8	53	74	21	MHTR	I	A	Molybdate orange YE698D
Cadmium sulfide	9	22	71	49	LHT	I	D	Cadmium yellow lemon 47-4200
Lead chromate	10	42	75	33	MHT	I	A	Medium chrome yellow Y469D
Iron oxide	11	36	58	22	MHTR	II	C	Mapico yellow OK orange
Lead chromate plus	12	13	44	31	LMT	II	A	Chrome green med Lt G-562-D
Chromium oxide	13	41	50	11	MMO	II	E	Chromium oxide green X-1134
Aluminum sulfo-silicate	14	6	45	39	AMT	II	F	Wera blue 8290
Ferric ferrocyanide	15	7	37	30	AMTR	III	E	Chinese blue A-1835 CP
Inorganic pigment	16	8	50	42	AMT	II	F	Aurora violet X-2262
<u>Organics</u>								
<u>Reds</u>								
Monoazo	17	6	18	8	AAO	III	G	Hostaperm brown FG 17-3000
Monoazo	18	11	73	62	AHT	III	G	Hostaperm red FGG 13-3350
Monoazo	19	17	71	54	LHT	III	H	Cromophthal scarlet A2G'
Monoazo	20	7	68	61	AHT	III	H	Cromophthal red 3 E
Monoazo	21	6	71	65	AHT	III	F	Barium lithol toner medium RT-2504
Monoazo	22	5	47	42	AMT	III	I	Per carmino red FF toner 35-5001

See Page 11 for footnotes.

TABLE II - Continued

Chemical Class	Spectra Figure No.	Average Reflectance Over		Diff.	Classification	Formula Type	Code	Manufacturer Identification
		Black	White					
Monoazo	23	27	46	19	LMTR	III	A	Toluidine toner RT-386-4
Monoazo	24	25	45	20	LMTR	III	A	Toluidine toner RT-606-D
Monoazo	25	24	45	21	LMTR	III	A	Toluidine toner RT-232-D
Diazo	26	9	71	62	AHT	III	H	Cromophthal red GR
Diazo	27	7	75	68	AHT	III	F	Michigan red toner RT 1382
Diazo	28	15	68	53	AHT	III	I	Permanent red toner R-39-4001
Indigo	29	7	43	36	AMT	III	A	Thioindigoid maroon RT-552-D
Indigo	30	8	45	37	AMT	III	I	Anthragen red violet RHP 49-4001
Isoindoline	31	11	49	38	AMT	III	J	Irgazine red 23LT
Oxynaphthanoic acid	32	7	47	40	AMT	III	F	Molara red 52
Oxynaphthanoic acid	33	21	72	51	LHT	III	G	Hostaperm vat red TG 13-4200
Perylene	34	17	70	53	LHT	III	K	Paliogen red G6
Perylene	35	13	64	51	AHT	III	K	Paliogen maroon G
Pyrazolone	36	25	78	53	LHT	III	L	Electra red pigment 14
Quinacridone	37	10	72	62	AHT	III	A	Monastral red RT-759-D
Quinacridone	38	6	79	73	AHT	III	A	Monastral red RT-742-D
Quinacridone	39	7	75	68	AHT	III	D	Cyanadur red 2C-8005
Organic red	40	18	71	53	LHT	III	F	Guyandot red toner cark RT-5R40
Organic red	41	18	74	56	LHT	III	F	Duratone red toner red light RT-5928
Organic red	42	34	83	49	MHT	III	F	Dixie red medium RT-5340
<u>Oranges</u>								
Monoazo	43	19	65	46	LHT	III	L	Fanchon orange VH-5
Diazo	44	14	72	58	AHT	III	L	Diane orange Y-25
Isoindoline	45	14	75	61	AHT	III	J	Irgazin orange R LT
Naphthalene tetra-carboxylic acid	46	13	68	55	AHT	III	G	Hostaperm orange GR 2-4002
Dinitroaniline	47	16	73	57	LHT	III	A	Orange toner YT-419-t

See Page 11 for footnotes.

TABLE 11 - Continued

Chemical Class	Spectra Figure No.	Average Reflectance Over		Diff.	Classification	Formula Type <sup>2/</sup>	Code <sup>4/</sup>	Manufacturer Identification
		Black	White					
<u>Yellows</u>								
Monoazo	48	22	70	48	LHT	III	A	Toluidine yellow R YT-729-D
Monoazo	49	12	72	60	AHT	III	A	Toluidine yellow G YT-445-D
Monoazo	50	10	76	66	AHT	III	G	Hostaperm yellow IGL 11-3010
Diazo	51	9	74	65	AHT	III	H	Cromophthal yellow GR
Diazo	52	12	70	58	AHT	III	L	Fanchon yellow G YH-1
Benzidine	53	18	75	57	LHT	III	E	Sacandaga yellow Y-2476
Benzidine	54	7	77	70	AHT	III	F	Orinle yellow 17
Anthrapyrimidine	55	13	71	58	AHT	III	K	Phlogon yellow RT
Anthrapyrimidine	56	7	46	39	AMT	III	L	Indofast yellow Y-5783
Anthraquinone	57	11	43	32	AMT	III	L	Lamino yellow Y-5776
Isoindolone	58	14	72	58	AHT	III	J	Irgazin yellow 2 GLT
Quinacridone	59	6	40	34	AMT	III	A	Newport gold YT-789-I
<u>Greens</u>								
Monoazo	60	8	63	55	AHT	III	K	Lithofast green yellow G
Nickel azo	61	9	42	33	AMT	III	A	Green gold YT-562-D
Nitroso-naphthol	62	6	52	46	AMT	III	E	Chippewa green X-1291
Phosphomolybdic acid	63	7	62	55	AHT	III	I	Solar green BMN 67-3012
Phospho tungstic acid	64	8	71	63	AHT	III	E	Avori green A-4379
Phospho tungstic acid	65	12	68	56	AHT	III	E	Elgin green A-4381
Phthalocyanine	66	8	66	58	AHT	III	E	Monarch green toner A-4433
Phthalocyanine	67	8	60	22	AHT	III	E	Monarch green VY X-3156
Phthalocyanine	68	10	62	52	AHT	III	A	Ranapo green GP-755-D
Phthalocyanine	69	8	64	56	AHT	III	K	Heliogen green R6A
Phthalocyanine	70	9	61	52	AHT	III	K	Green 66

See Page 11 for footnotes.

TABLE 11 - Continued

Chemical Class	Spectra Figure No.	Average Reflectance Over		Diff.	Classification	Formula Type	Manufacturer Identification	
		Black	White				Code	Identification
<u>Blues</u>								
Anthraquinone	71	9	62	53	AHT	III	E	Special blue X-2137
Diazo	72	8	45	37	AHT	III	L	Diane blue B-34
Indanthrone	73	10	64	54	AHT	III	H	Cromophthal blue A4R
Triphenylmethane	74	8	63	55	AHT	III	F	Alkali blue BT-7150
Quinone	75	7	60	53	AHT	III	L	Foil blue BT-9
Phosphotungstic acid	76	10	68	58	AHT	III	E	Marine blue toner X-2759
Phthalocyanine	77	11	45	34	AHT	III	A	Ramapo blue BP-173-D
Phthalocyanine	78	10	62	52	AHT	III	M	Zulu blue R-MC 4851
Phthalocyanine	79	10	64	54	AHT	III	E	Monarch blue MCF X-2371
Phthalocyanine	80	10	60	50	AHT	III	D	Cyan blue BNF 55-3750
<u>Violets</u>								
Anthraquinone	81	8	66	58	AHT	III	A	Platinum violet BP-273-D
Dioxazine	82	10	68	58	AHT	III	L	Indofast violet lake B-4000
Dioxazine	83	9	63	54	AHT	III	I	Perm violet M toner 47-3001
Dioxazine	84	9	67	58	AHT	III	D	Cyanadur violet 55-8500
Indigo	85	11	66	55	AHT	III	I	Anthragen red violet RHP 49-4001
Methyl violet	86	7	60	53	AHT	III	E	Methyl violet toner A-8027
Phosphomolybdic acid	87	9	68	59	AHT	III	I	Solar violet RMH 47-3612
Phosphomolybdic acid	88	8	67	59	AHT	III	I	Solar violet RTM 48-3612
Organic violet	89	6	70	64	AHT	III	L	Fast bordeaux violet B-11

See Page 11 for footnotes.

TABLE II - Continued

<sup>1/</sup> Classification - Letter designation denotes reflectance over black; over white; and optical type. Example: AHT = Absorbing over black; high reflecting over white; and transparent optical type.

<u>Reflectance Level</u>		<u>Optical Types</u>	
A = Absorbing	0-15	O = Opaque	0-15
L = Low	16-30	TR = Transitional	16-30
M = Medium	31-55	T = Transparent	30
H = High	55		

<sup>2/</sup> See Table I

<sup>3/</sup> Included with inorganics as the black substrate.

<sup>4/</sup> Pigment manufacturers.

<u>Code</u>	<u>Manufacturer</u>
A	E. I. duPont
B	Chas Pfizer
C	Columbian Carbon Company
D	American Cyanamid
E	Imperial Color and Chemical
F	Holland - Suco
G	American Hoechst
H	Ciba Corp.
I	General Aniline and Film
J	Geigy Chemical Corp.
K	BASF Corp.
L	Harmon Colors
M	Harshaw Chemical Co.



APPENDIX B

FIGURE 1  
BLACK & WHITE SUBSTRATES

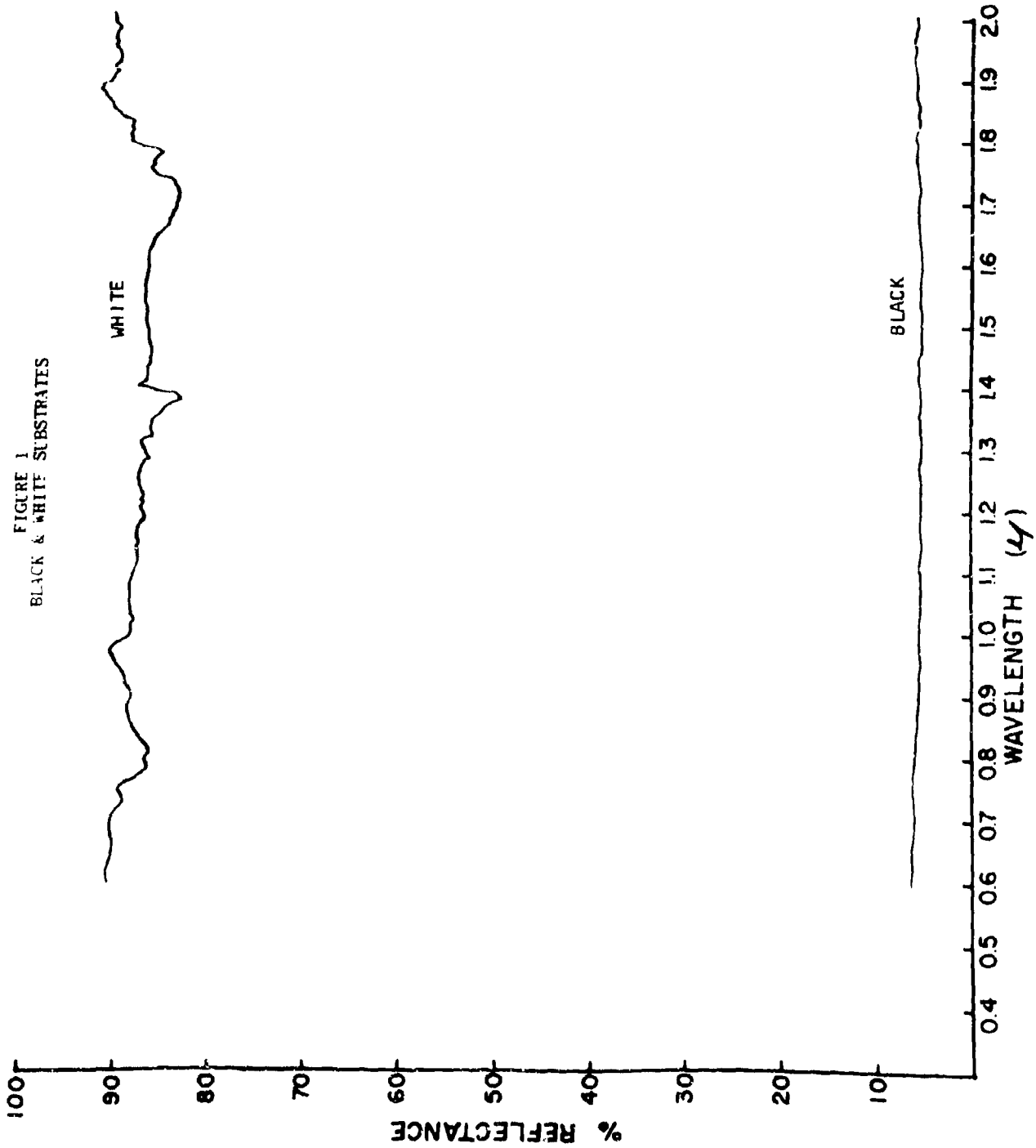


FIGURE 2  
TITANIUM DIOXIDE WHITE

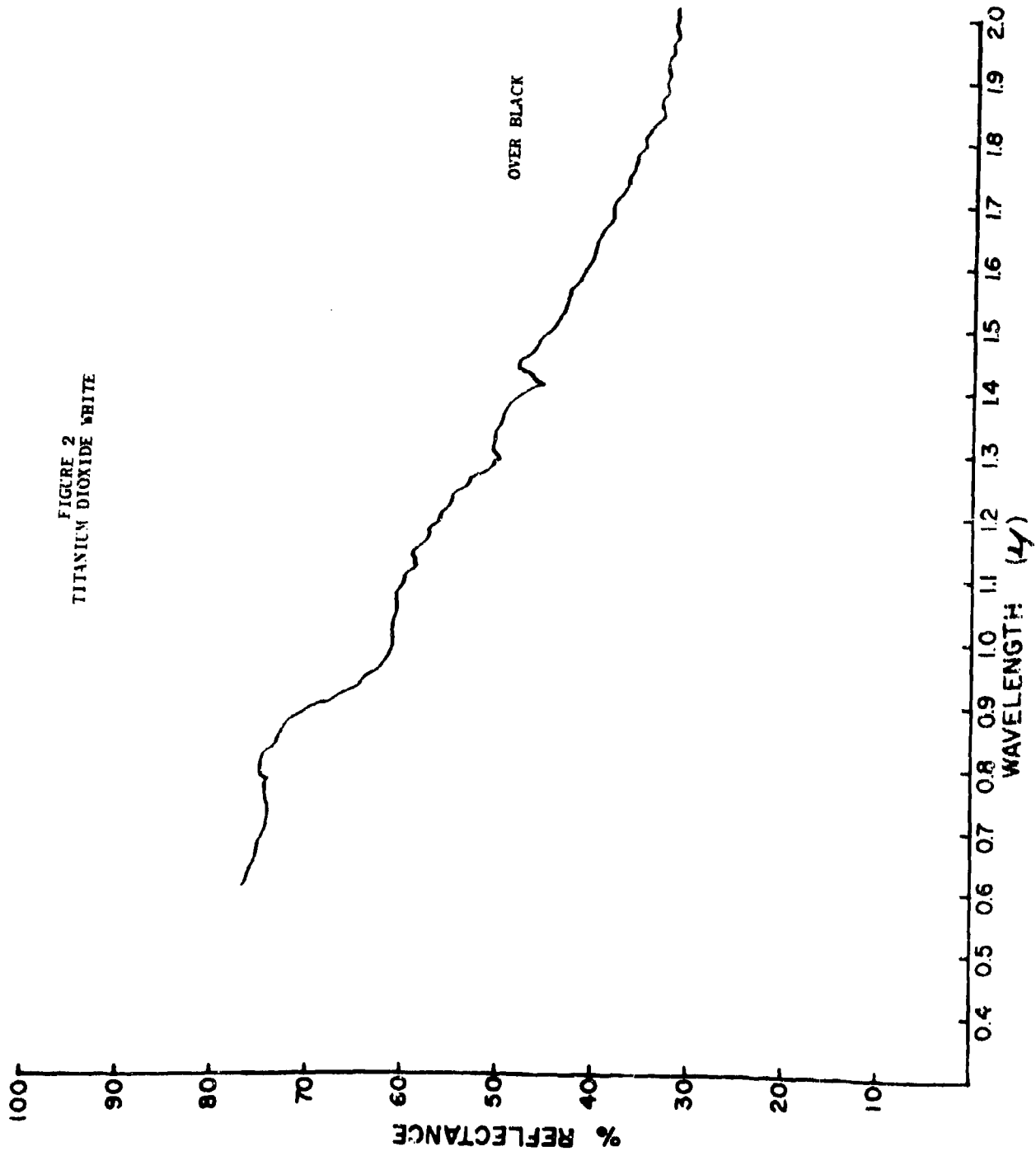


FIGURE 3  
IRON OXIDE PIG.

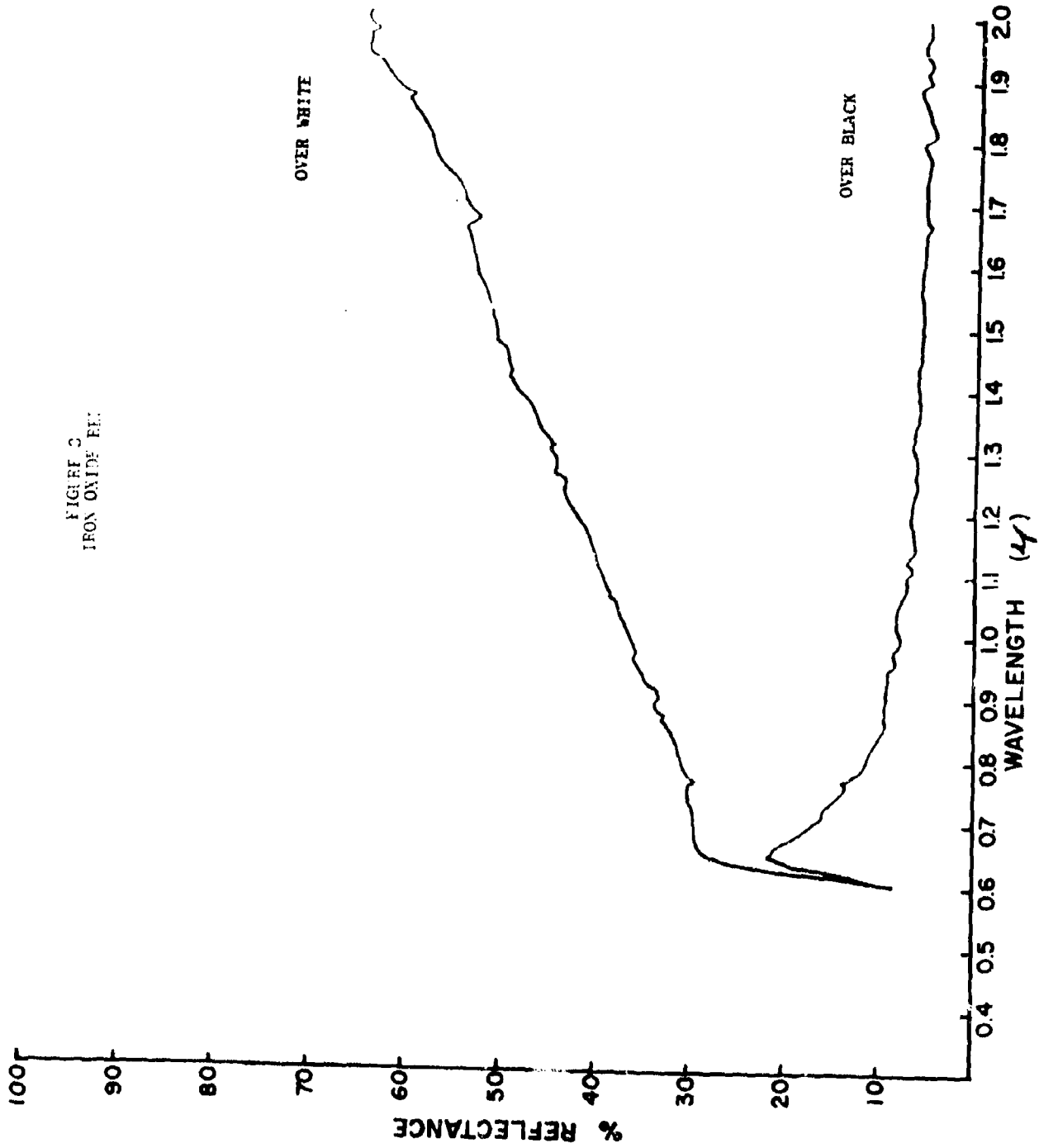


FIGURE 4  
IRON OXIDE BROWN

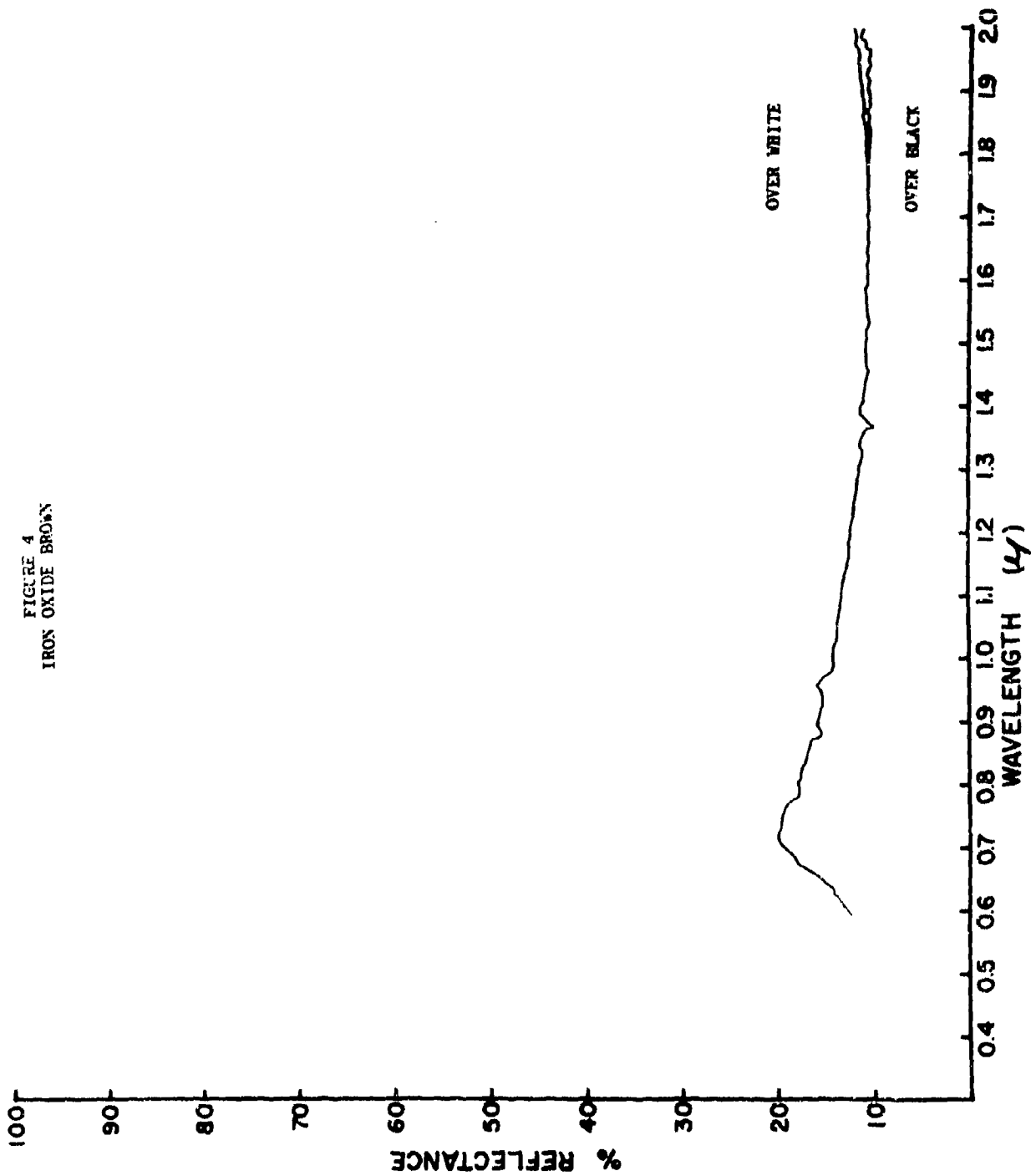


FIGURE 5  
CAMPBELL SULFO SELENIDE RED

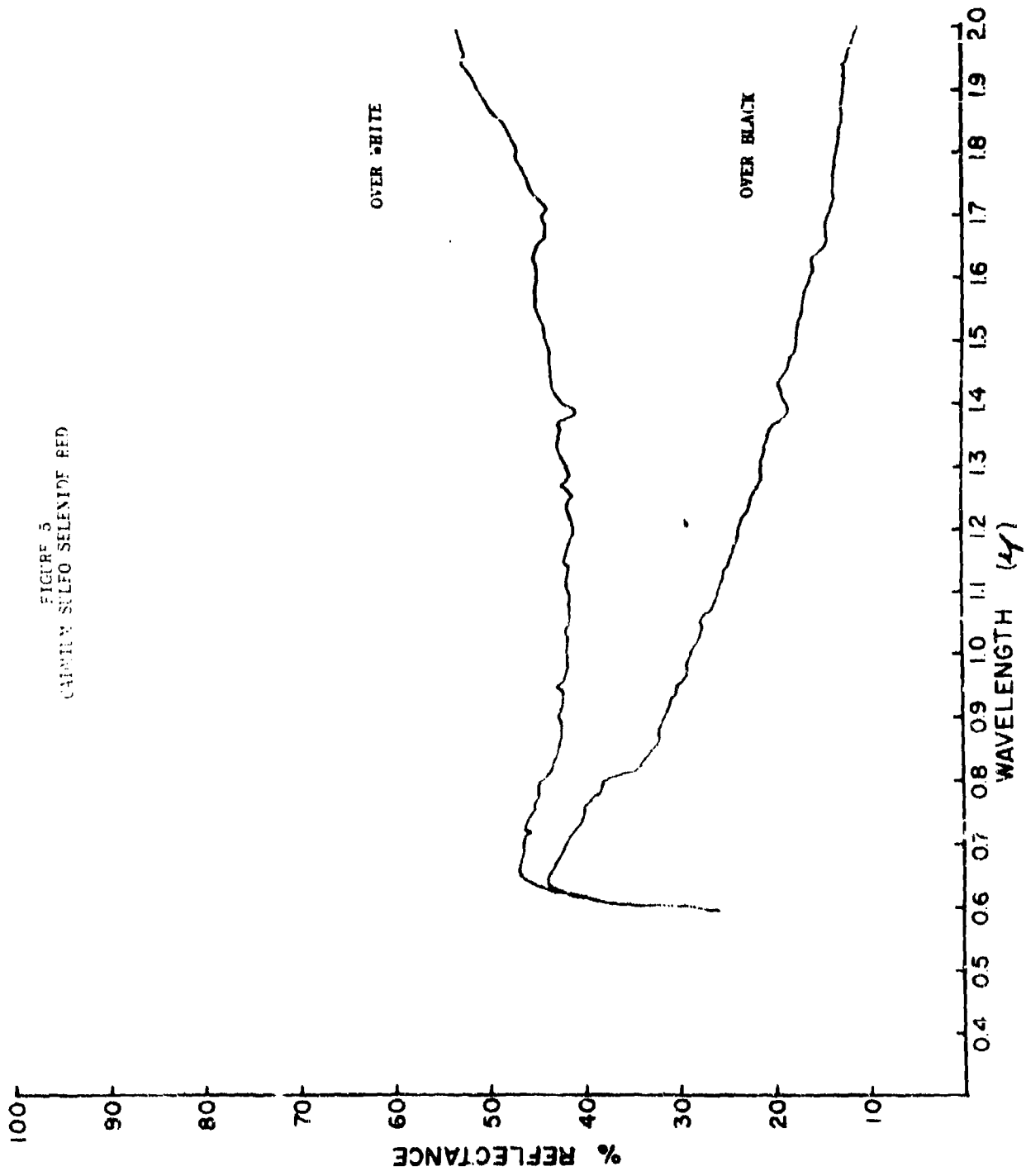


FIGURE 6  
CADMIUM SULFIDE OPAL

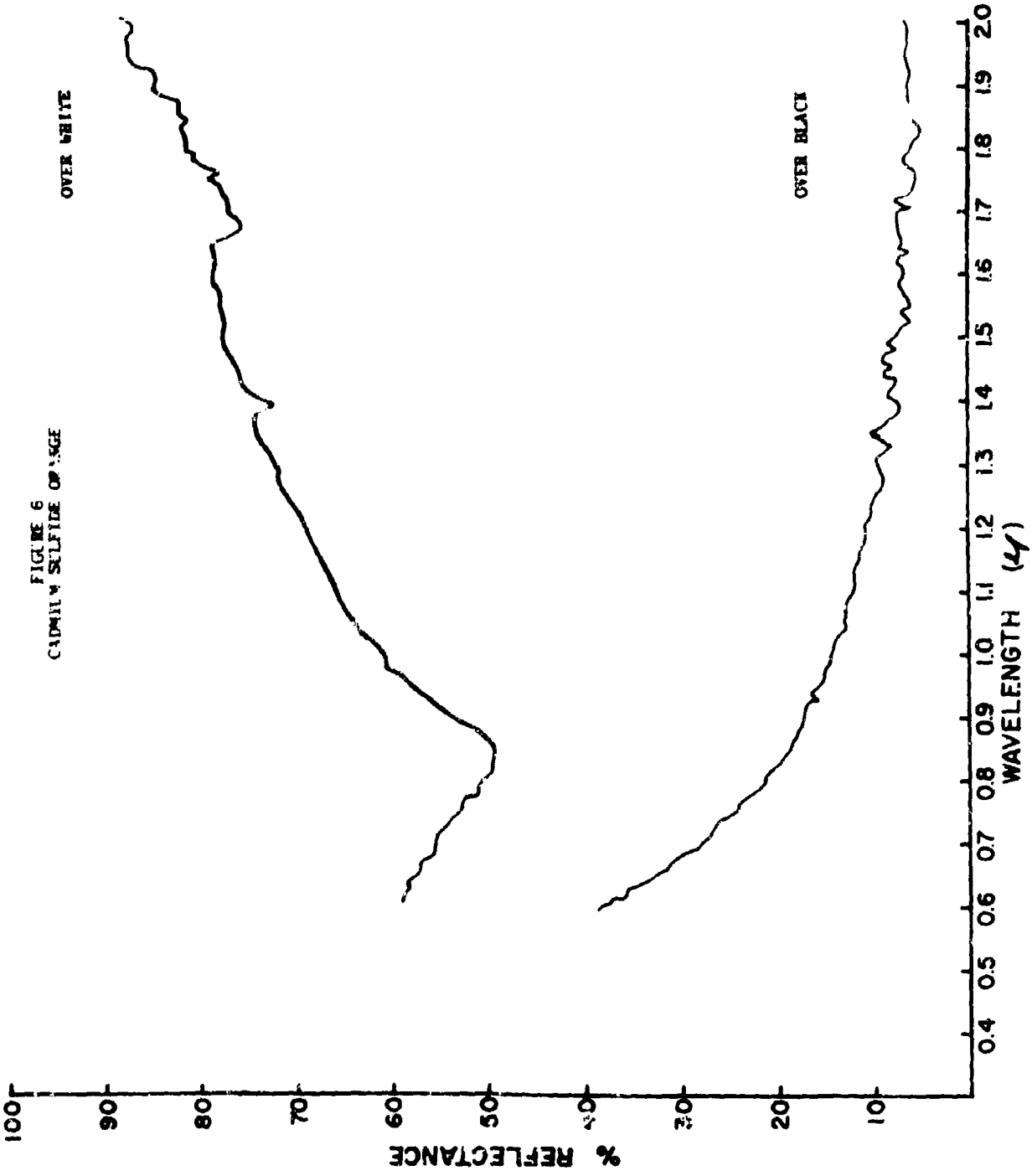


FIGURE 7  
LEAD CHROMATE ORANGE

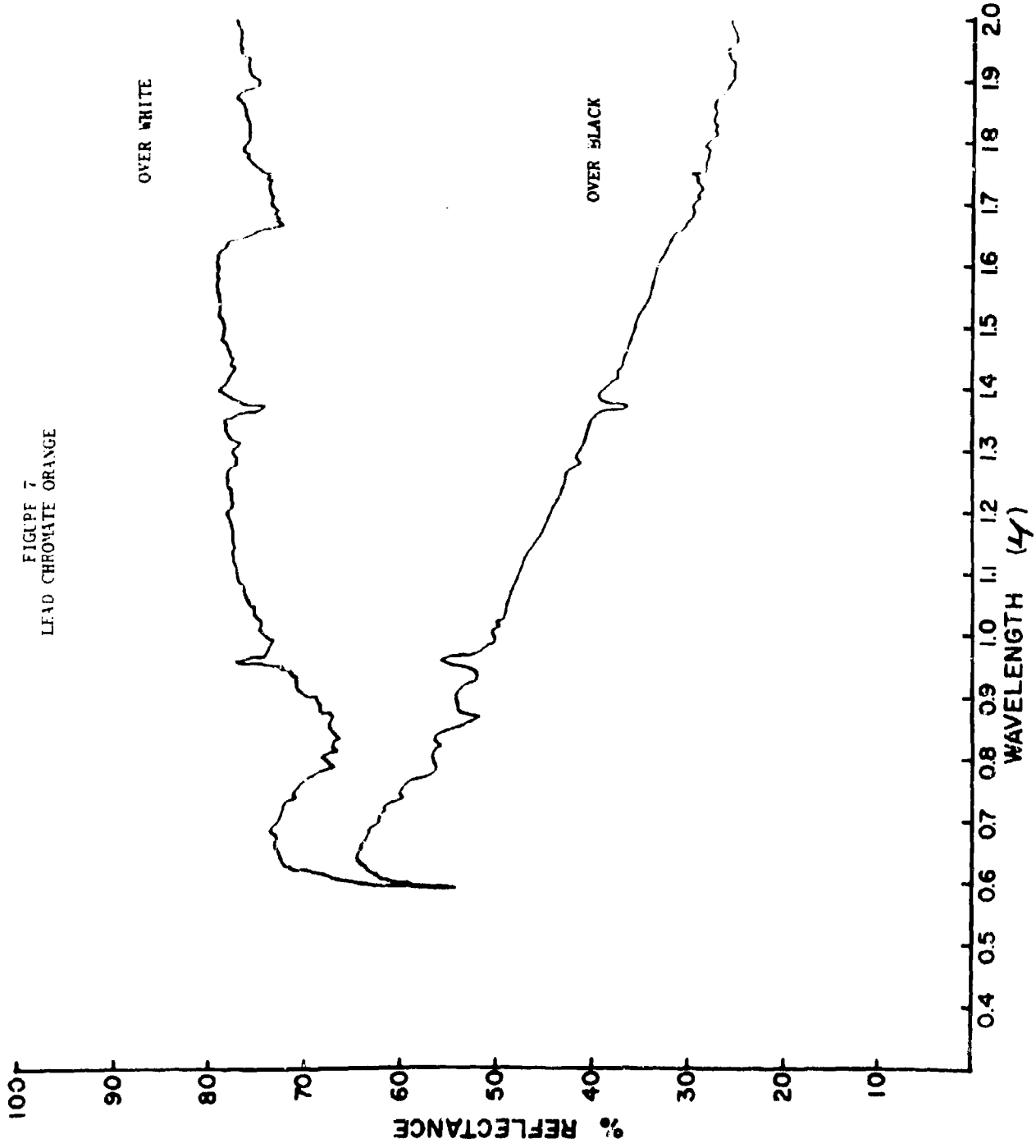




FIGURE 8  
MOLYBDATE ORANGE

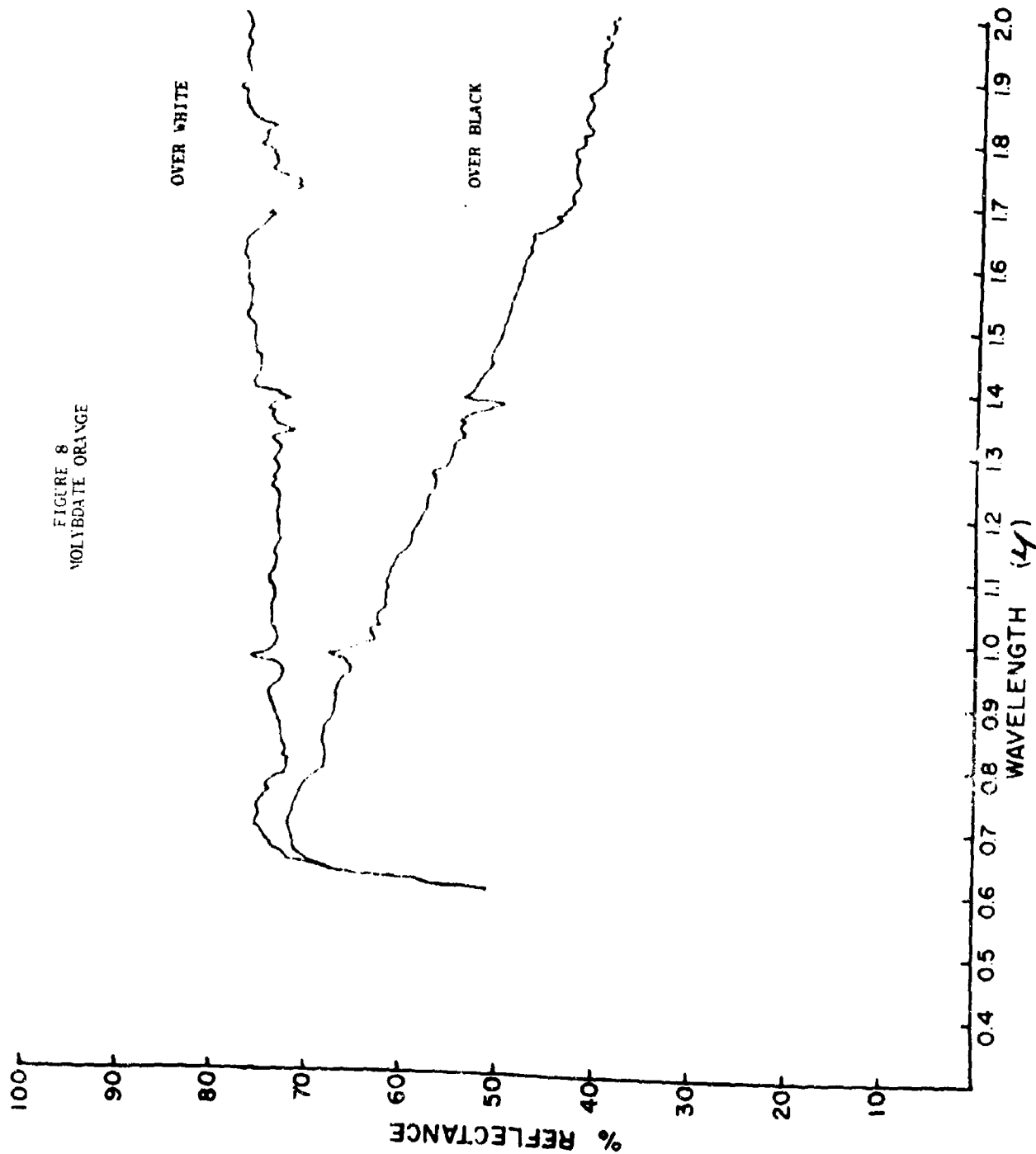


FIGURE 9  
CADMIUM SULFIDE YELLOW\*

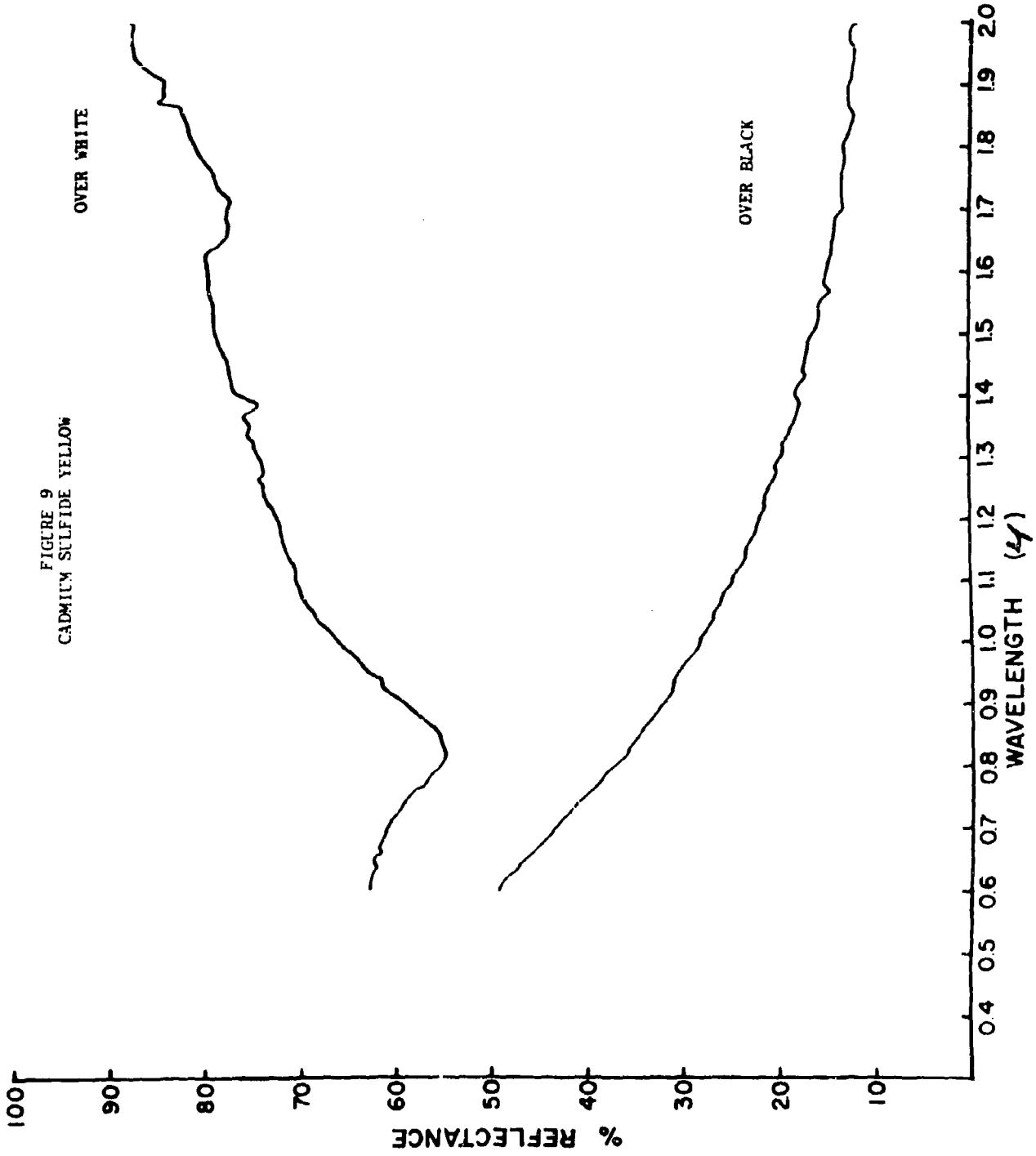


FIGURE 10  
LEAD CHROMATE YELLOW

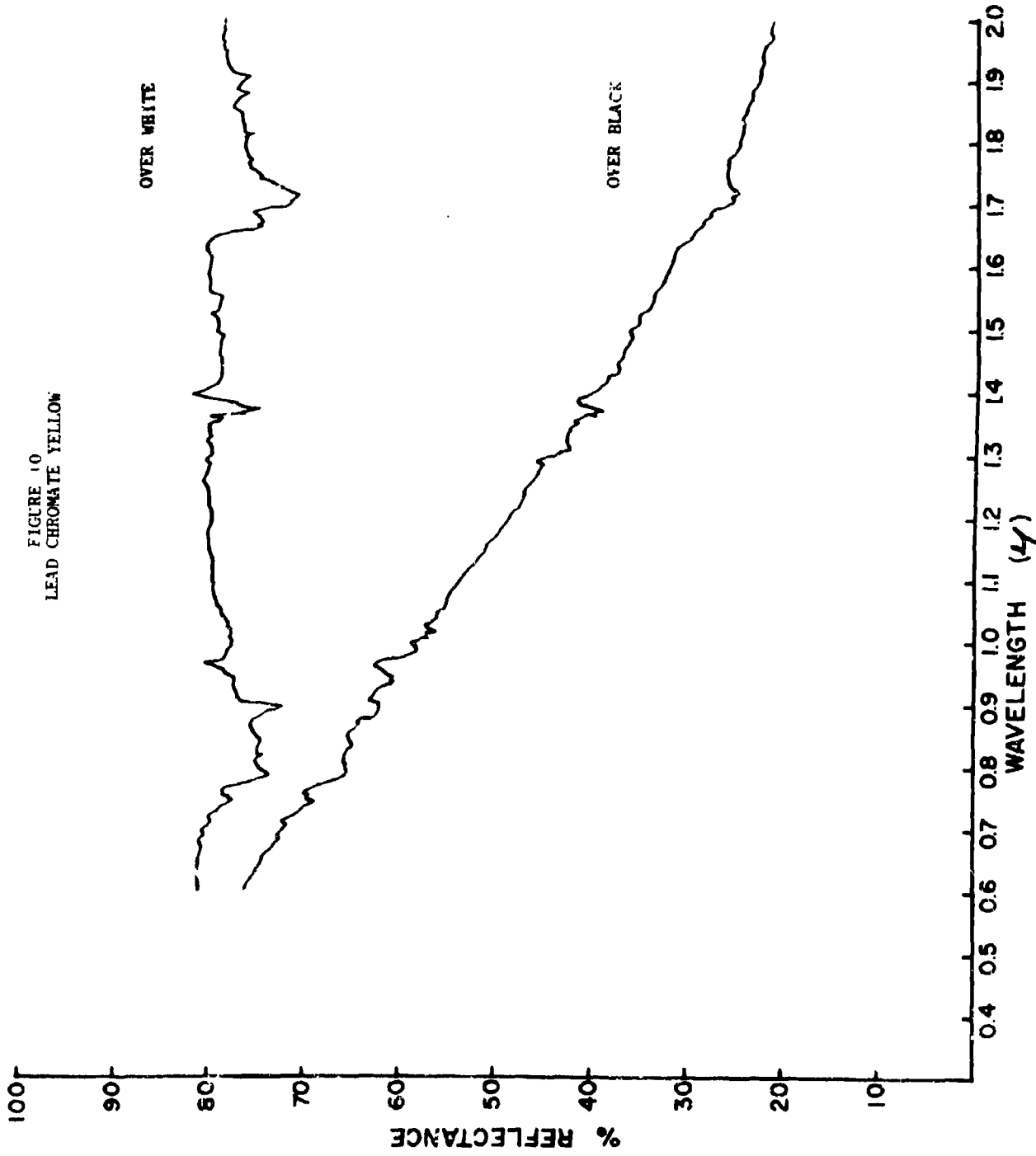


FIGURE 11  
IRON OXIDE YELLOW

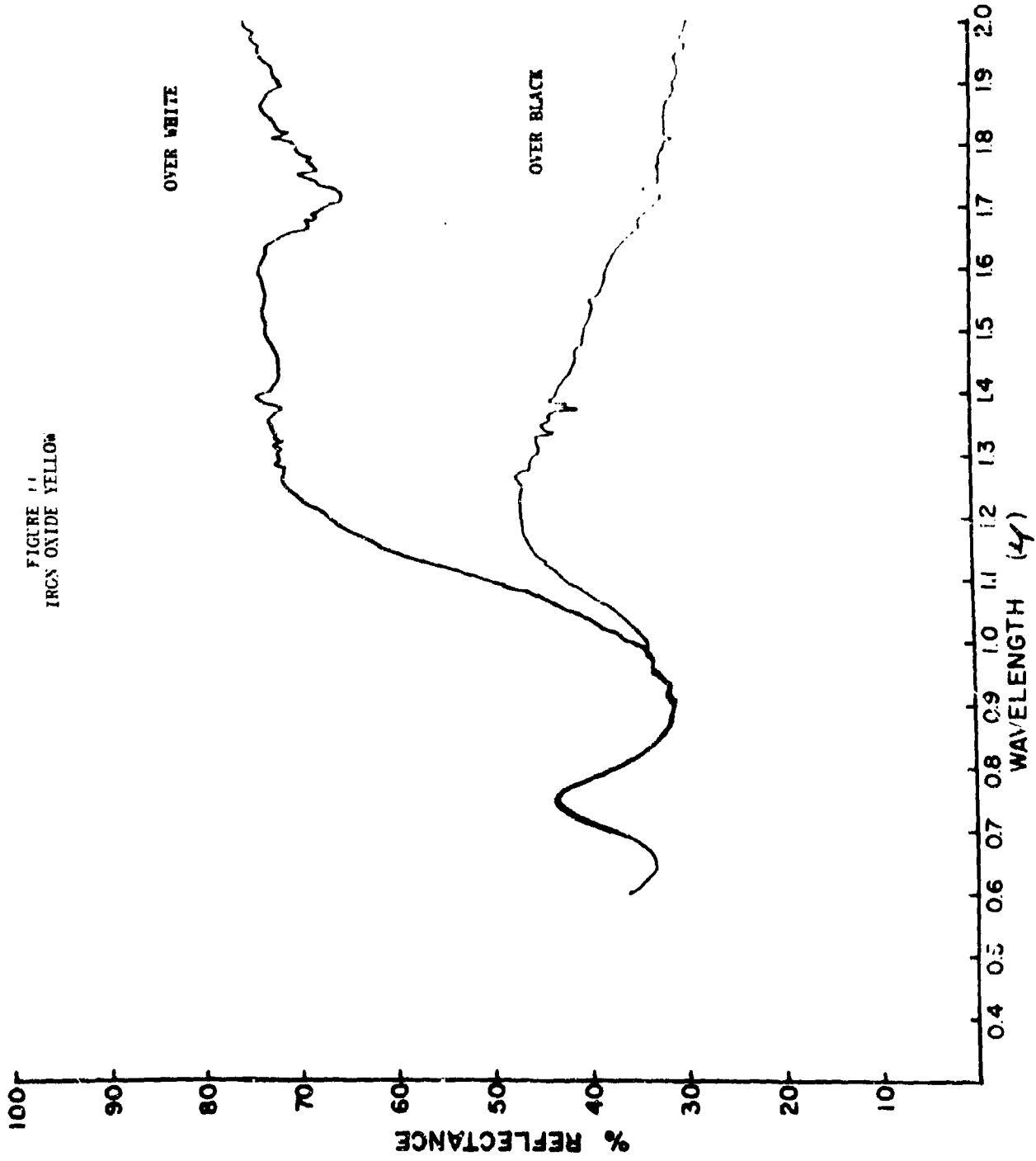


FIGURE 12  
LEAD CHROMATE - FERRIC FERRO  
CYANIDE GREEN

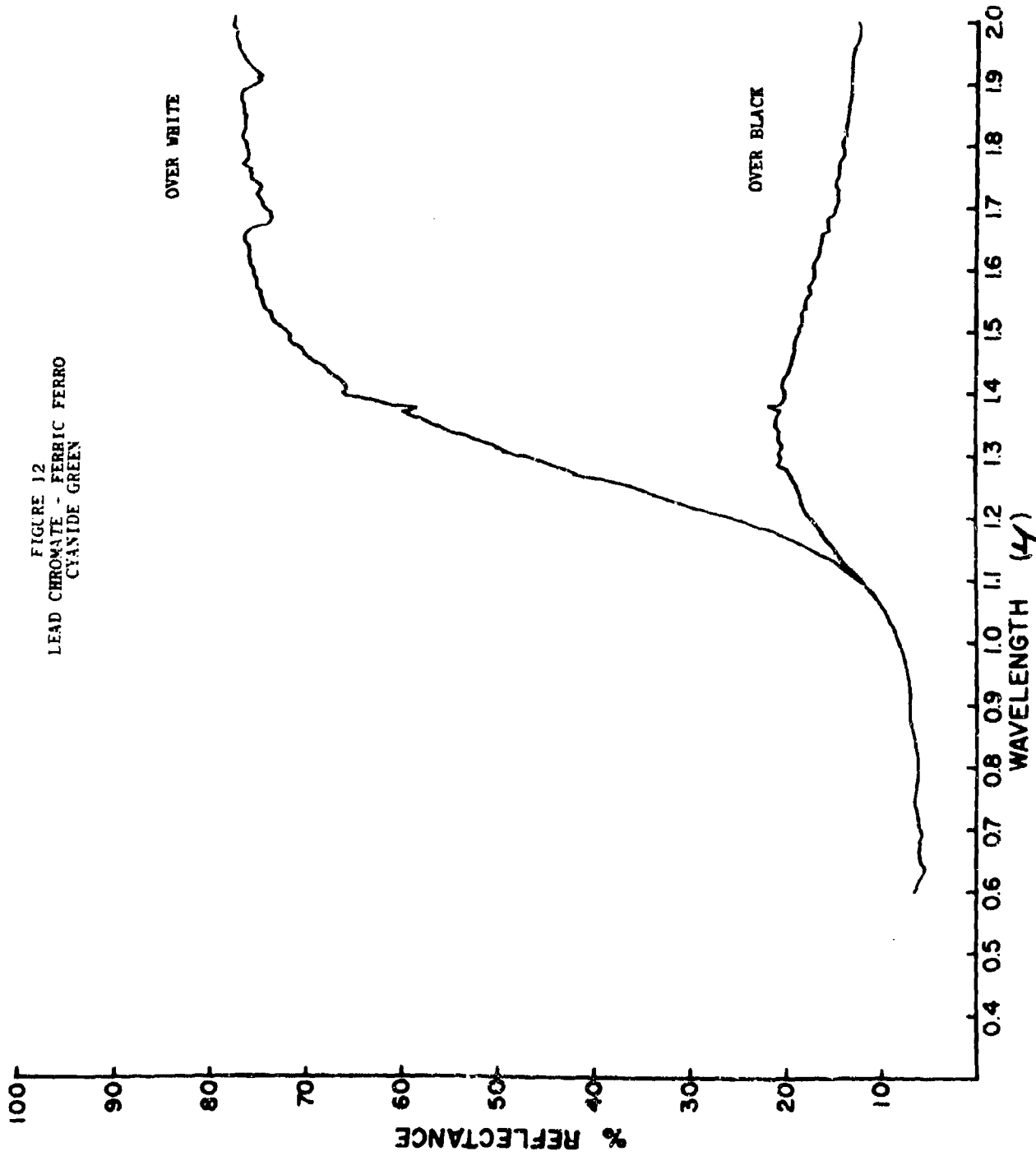


FIGURE 13  
CHROMIUM OXIDE GREEN

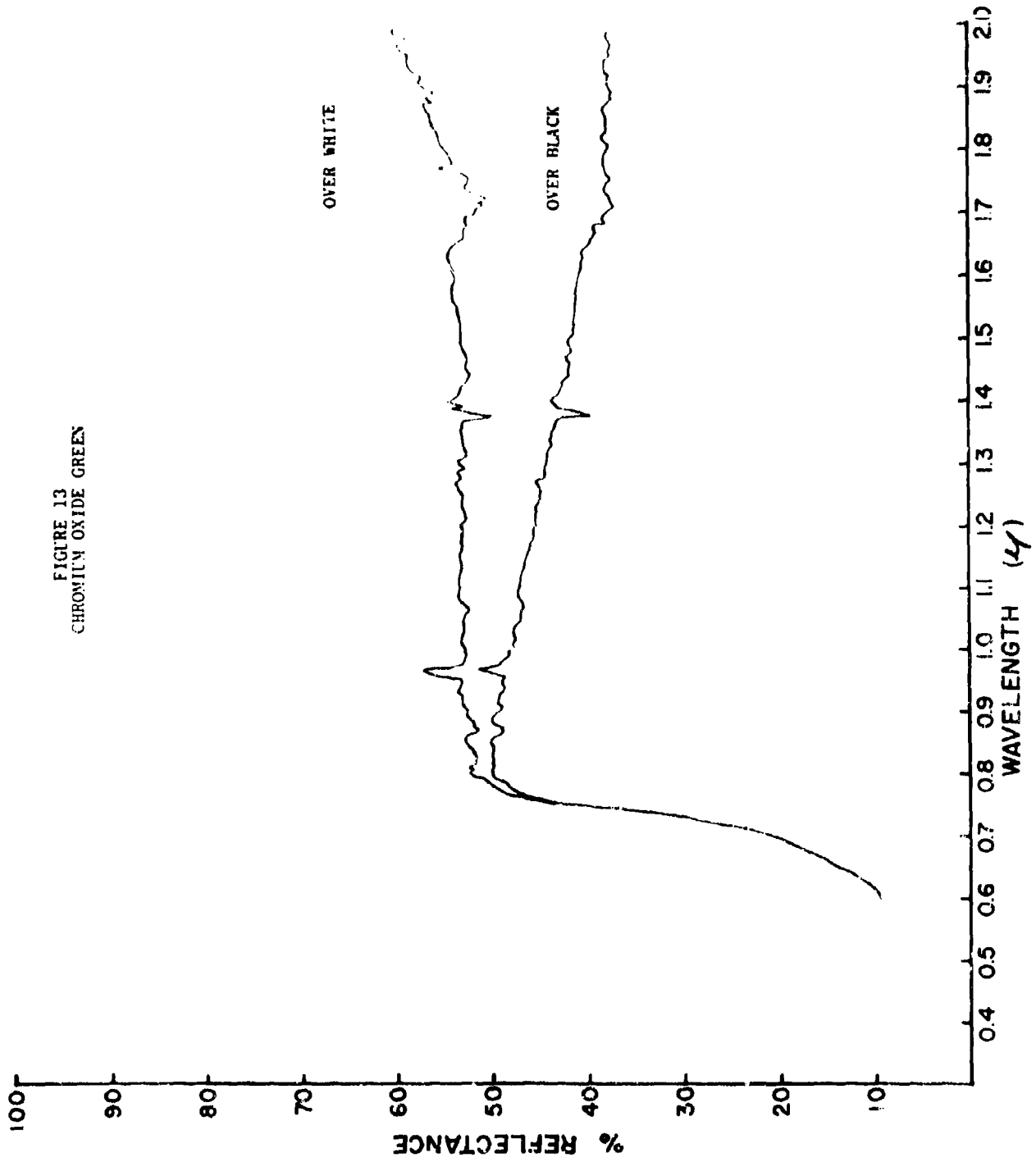
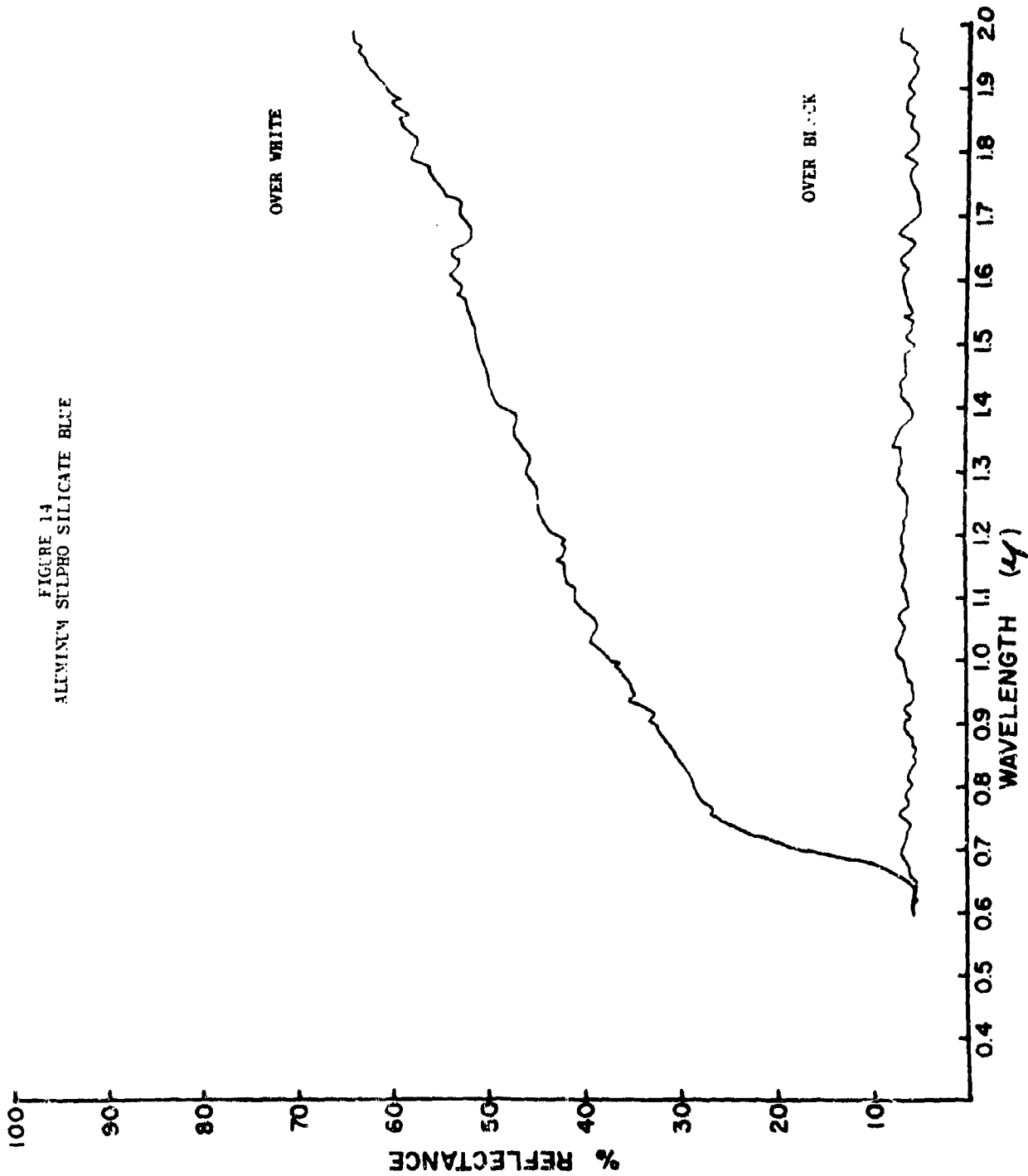


FIGURE 14  
ALUMINUM SULPHO SILICATE BLUE



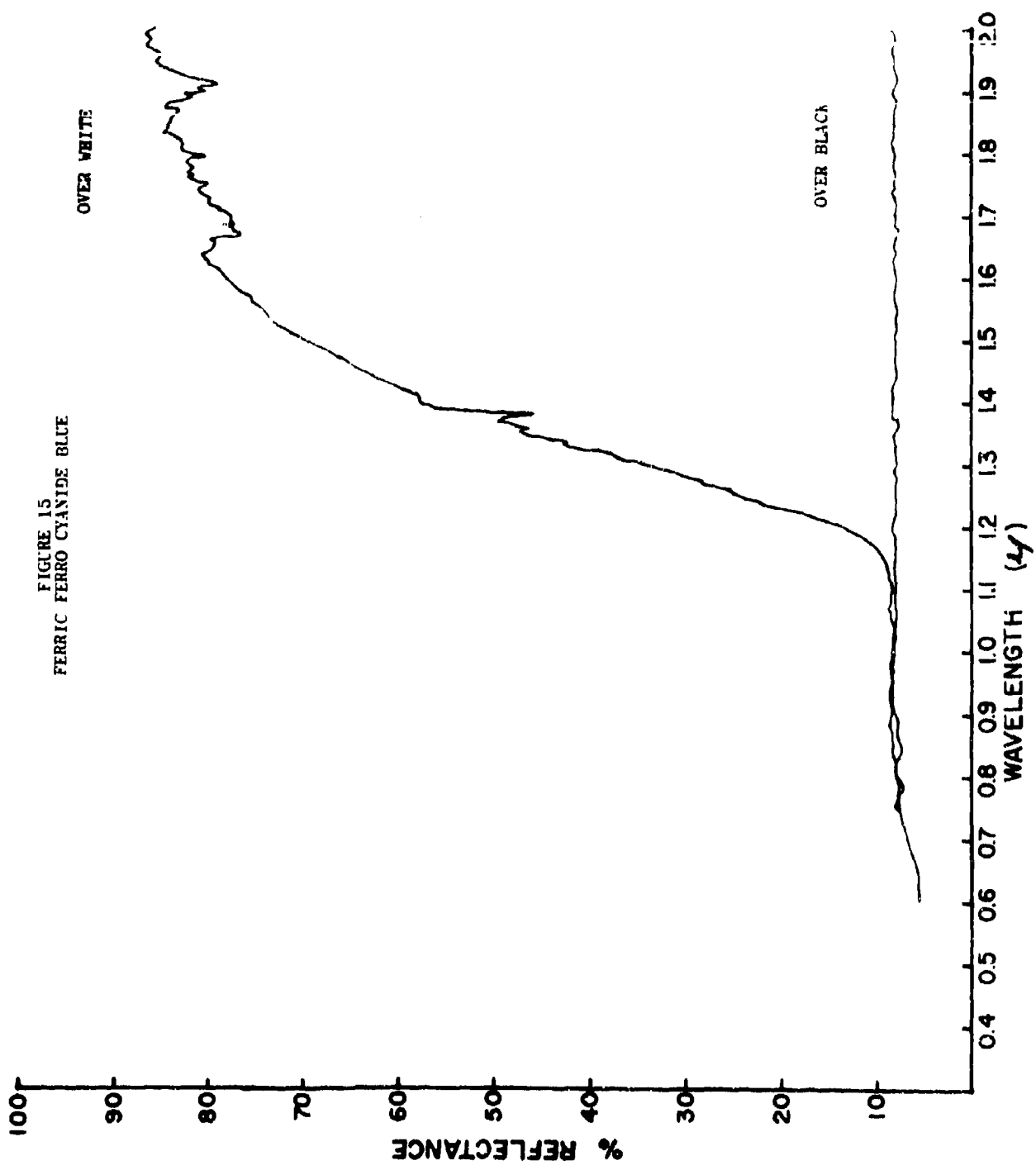
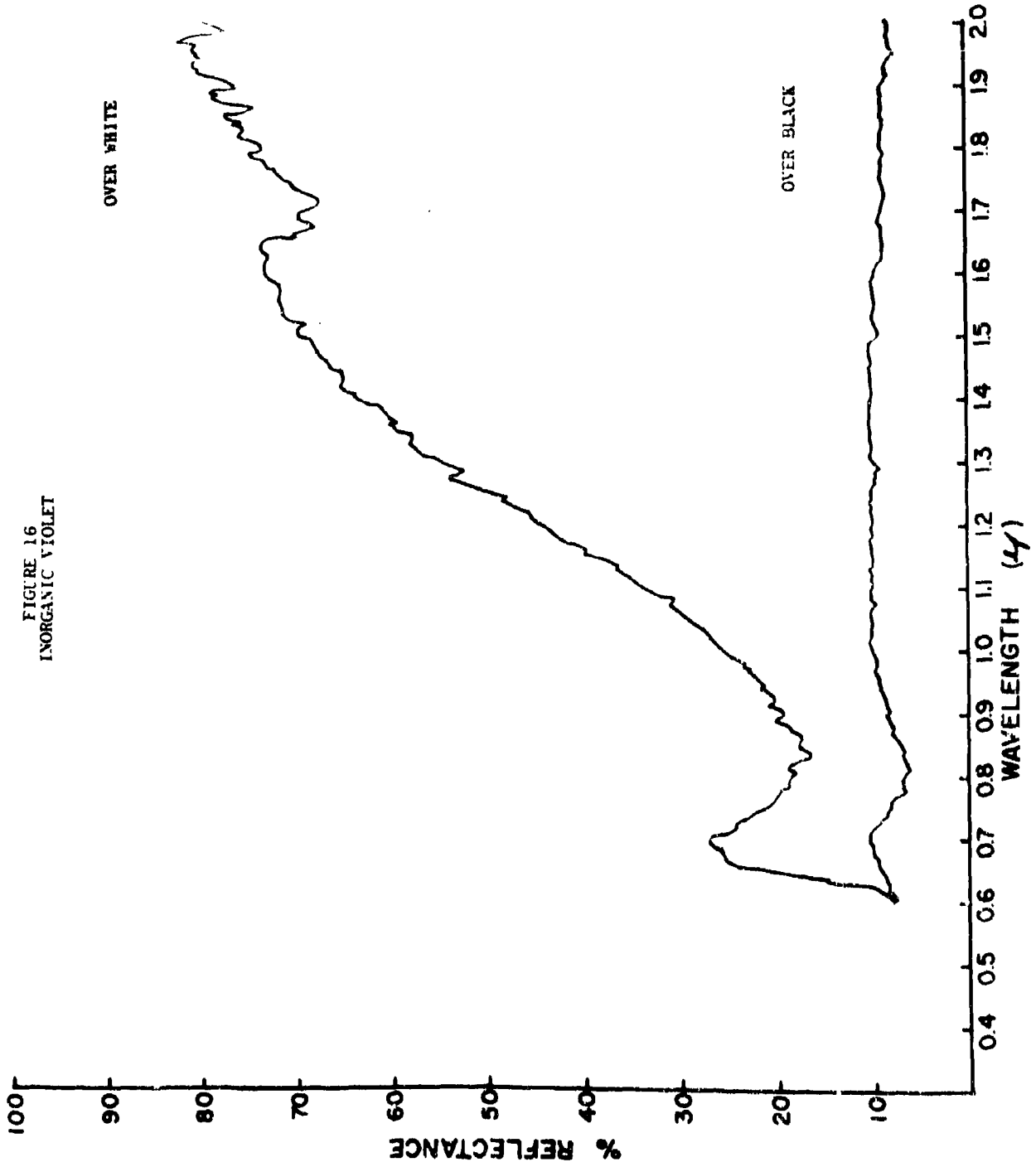




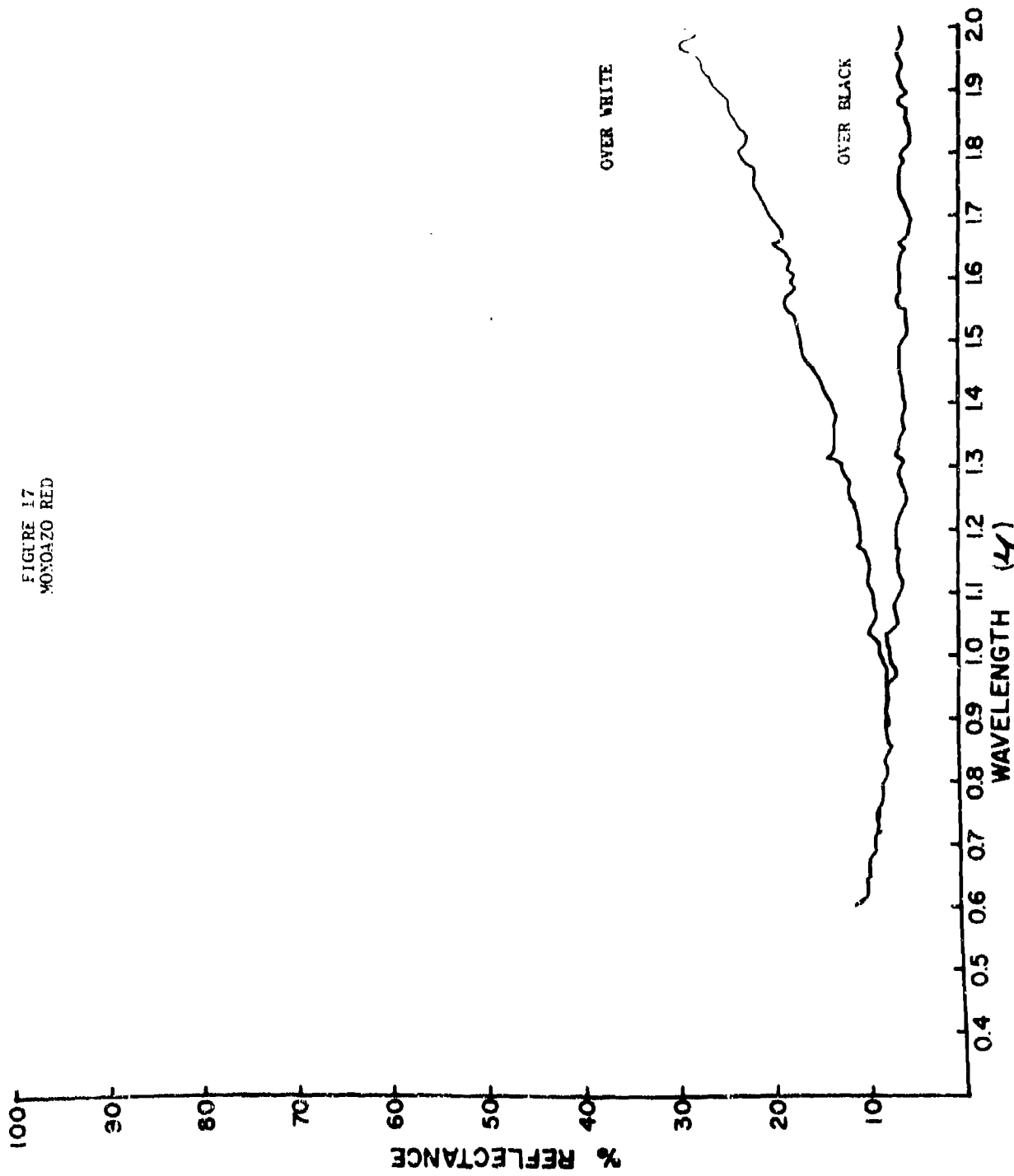
FIGURE 16  
INORGANIC VIOLET



OVER WHITE

OVER BLACK

FIGURE 17  
MONOAZO RED



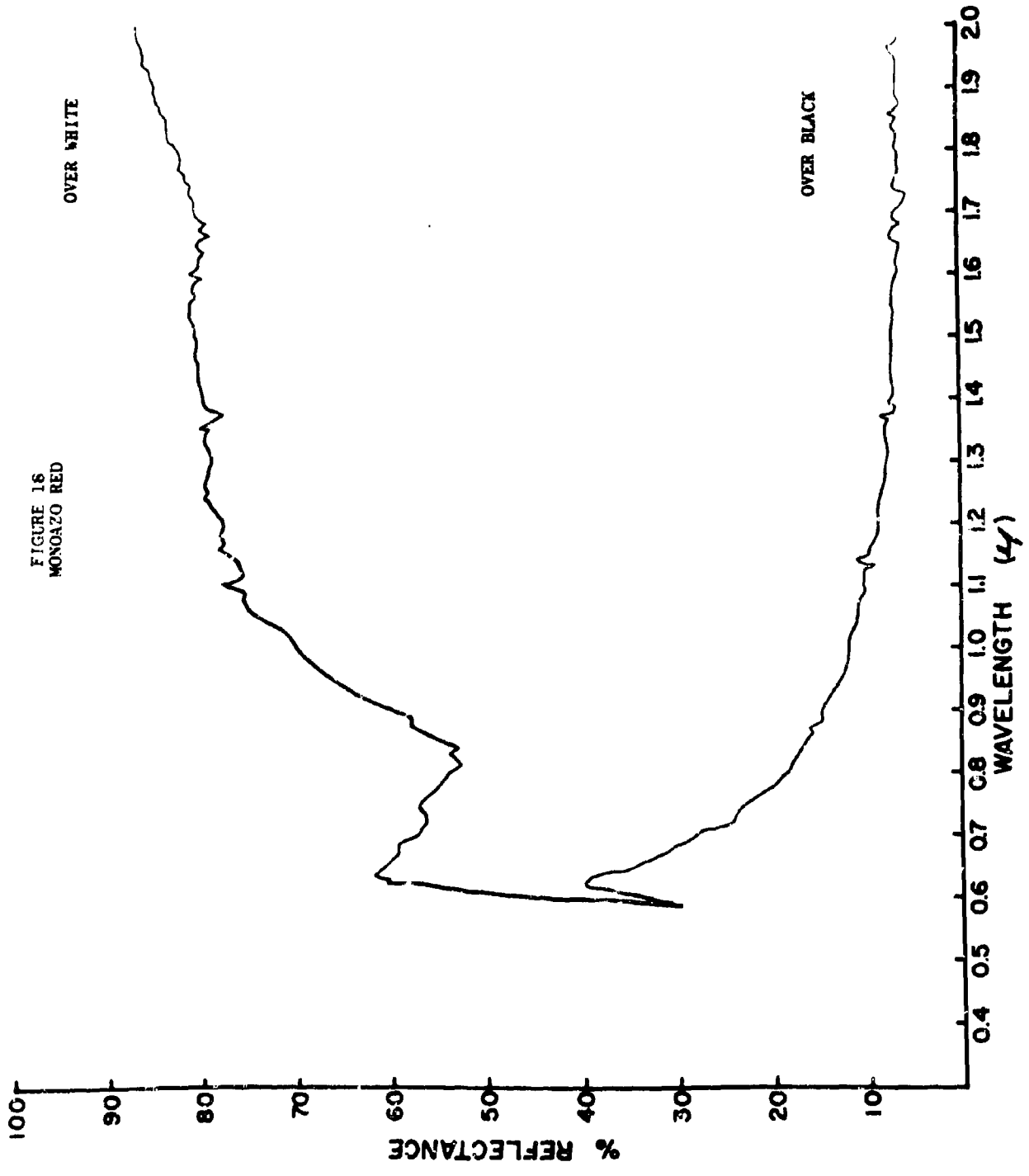
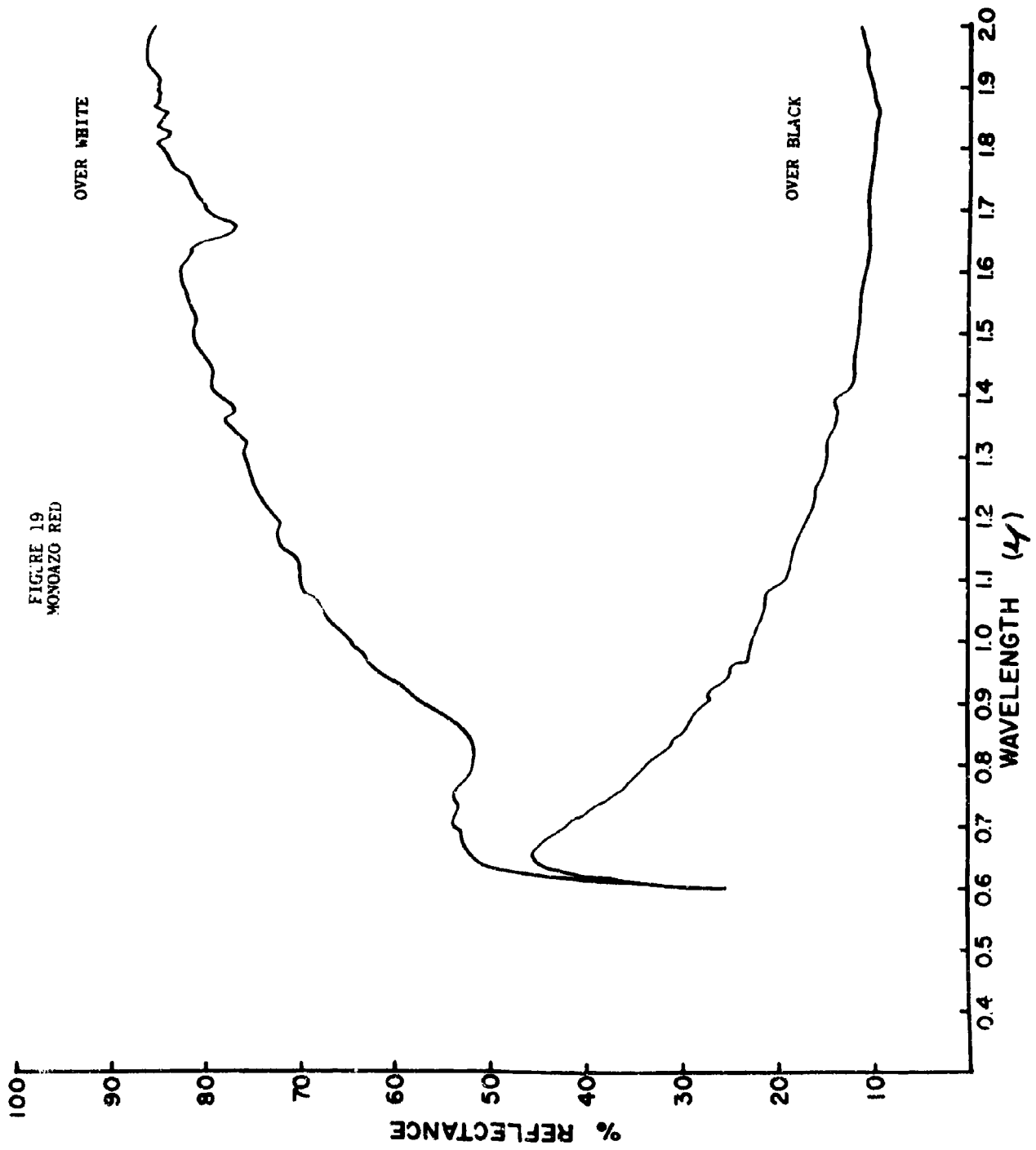


FIGURE 16  
MONAZO RED

OVER WHITE

OVER BLACK

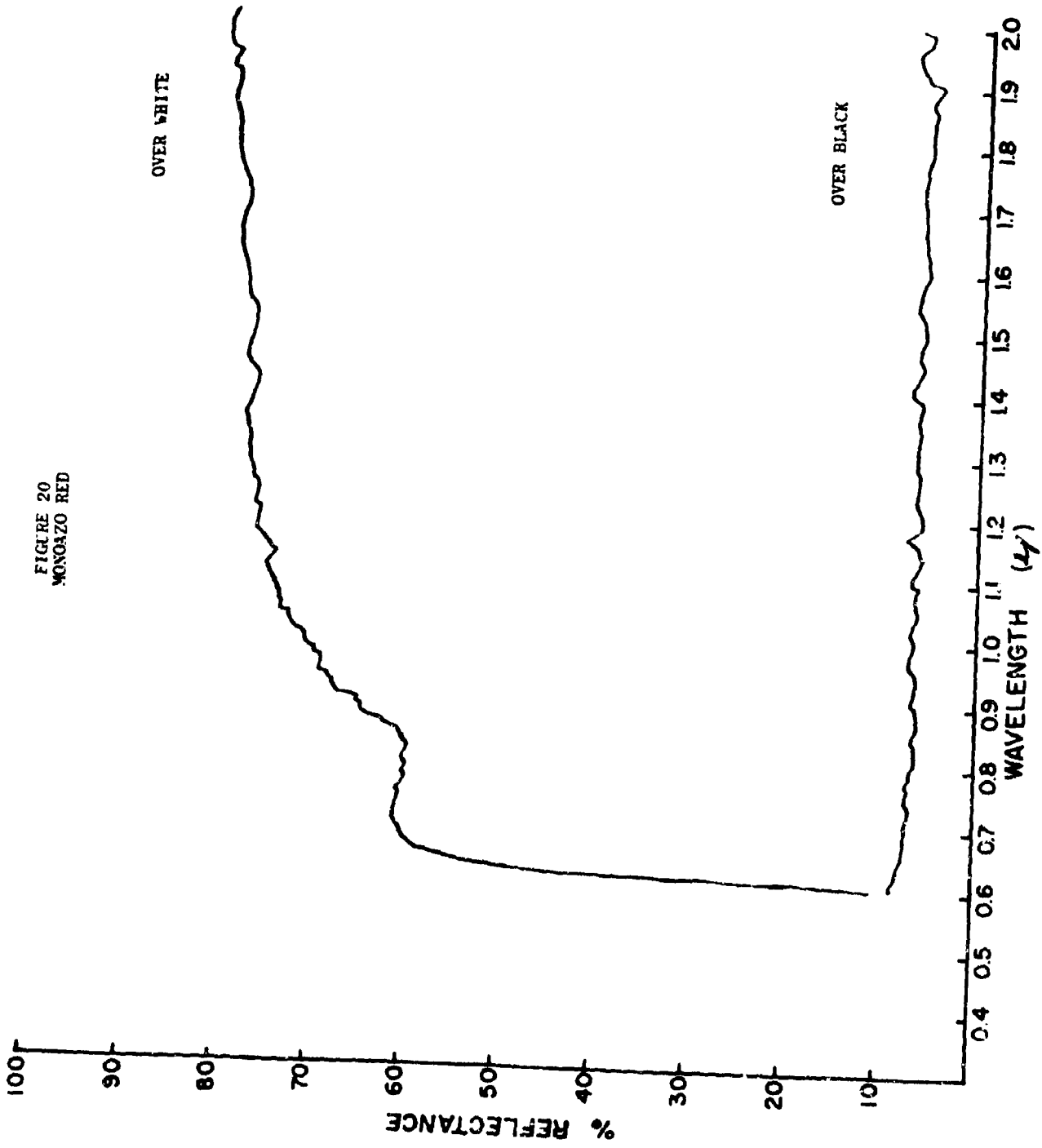
FIGURE 19  
MONOAZO RED



OVER WHITE

OVER BLACK

FIGURE 20  
MONOZO RED



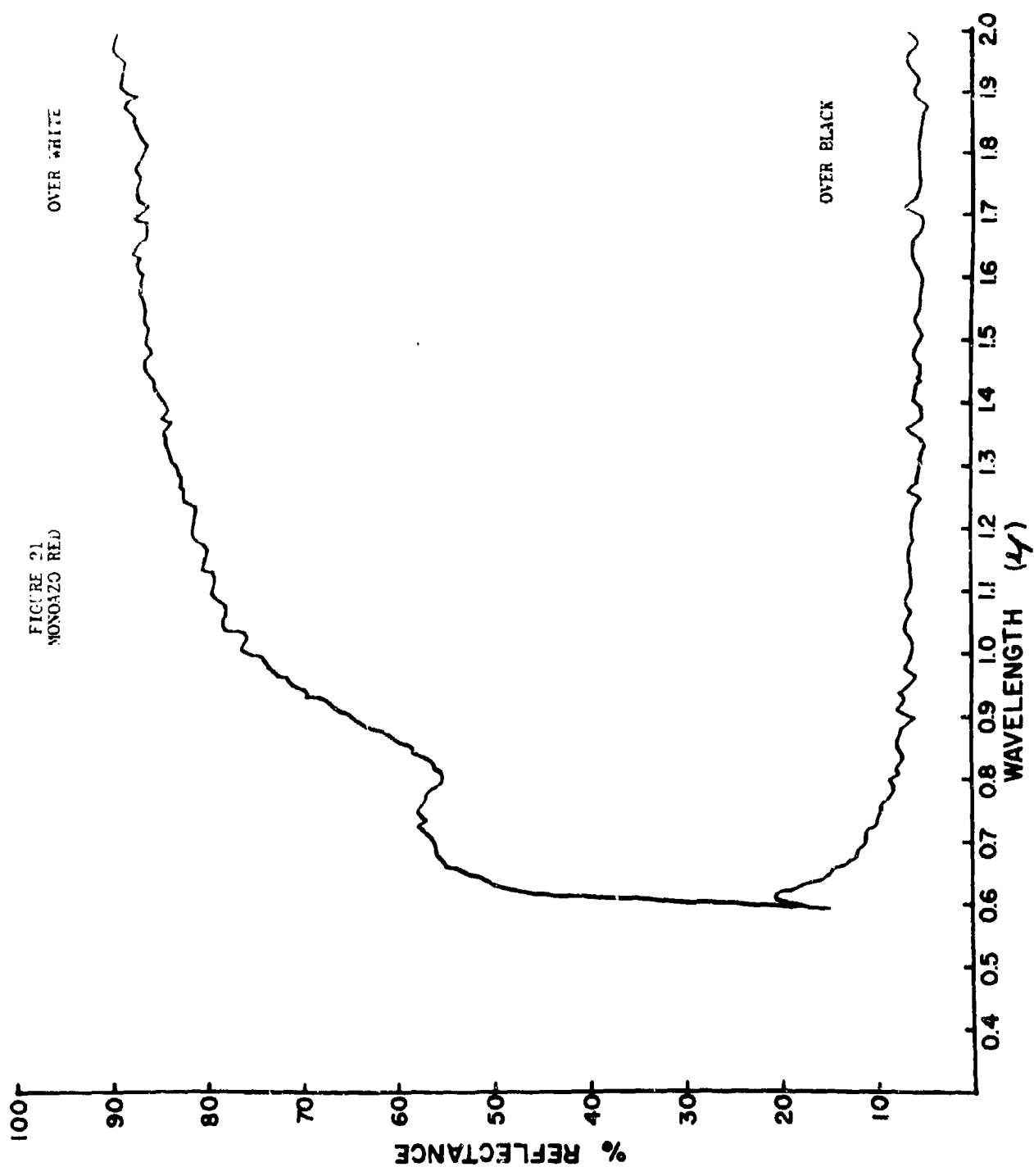


FIGURE 21  
MONAZO RED

OVER WHITE

OVER BLACK

WAVELENGTH (μ)

FIGURE 22  
MONOAZO RED

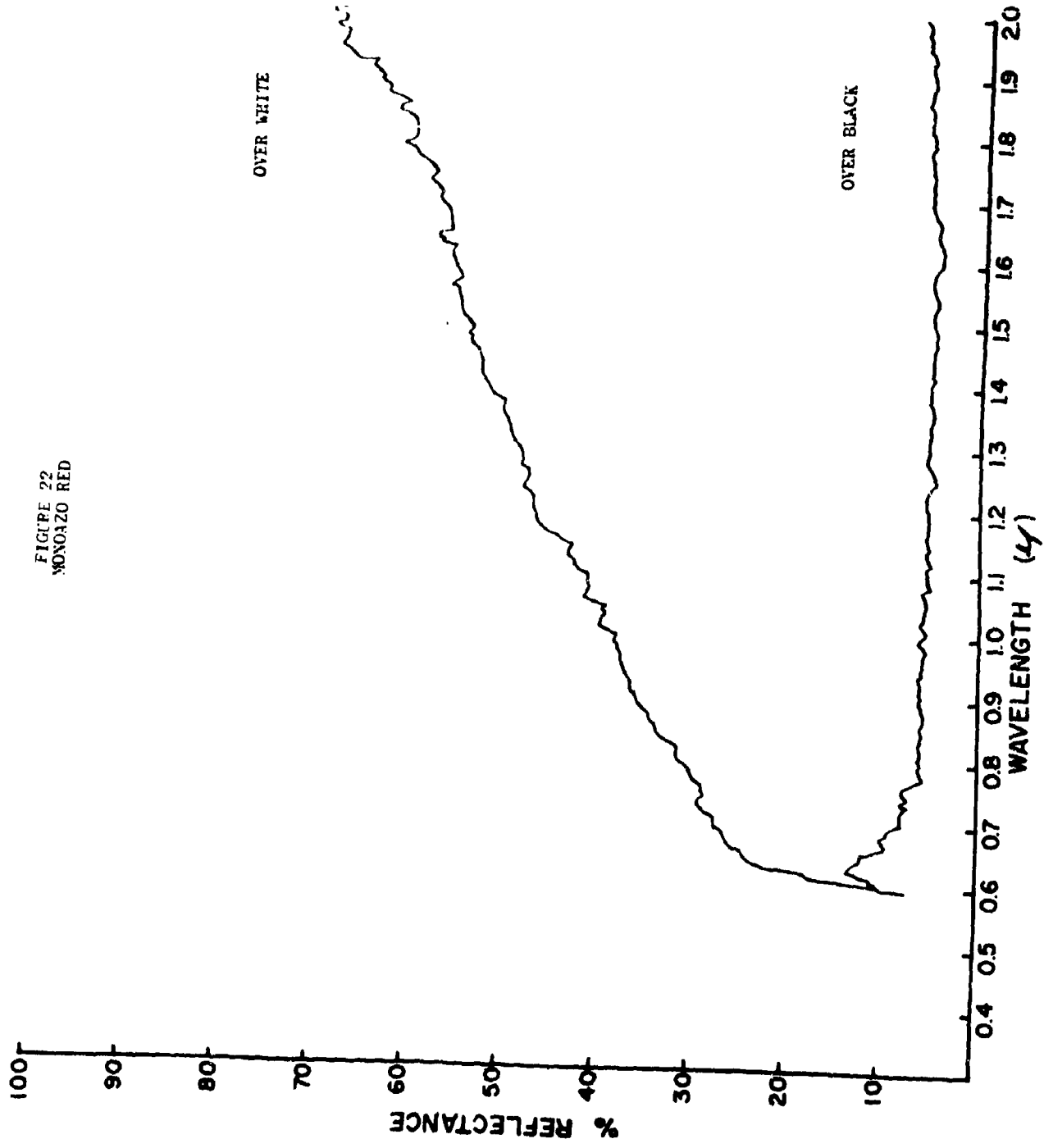


FIGURE 23  
MONOAZO RED

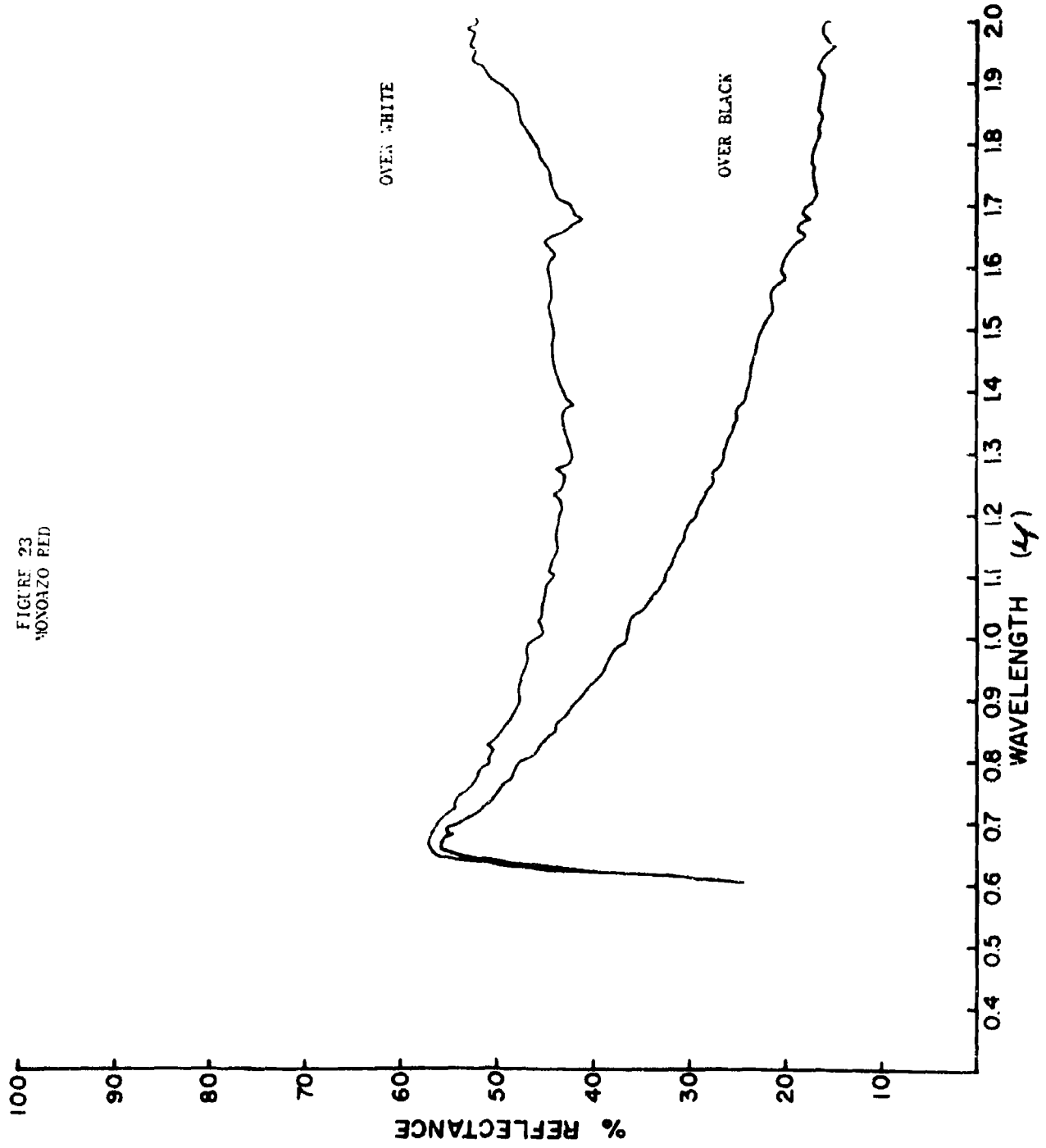




FIGURE 24  
MONOAZO RED

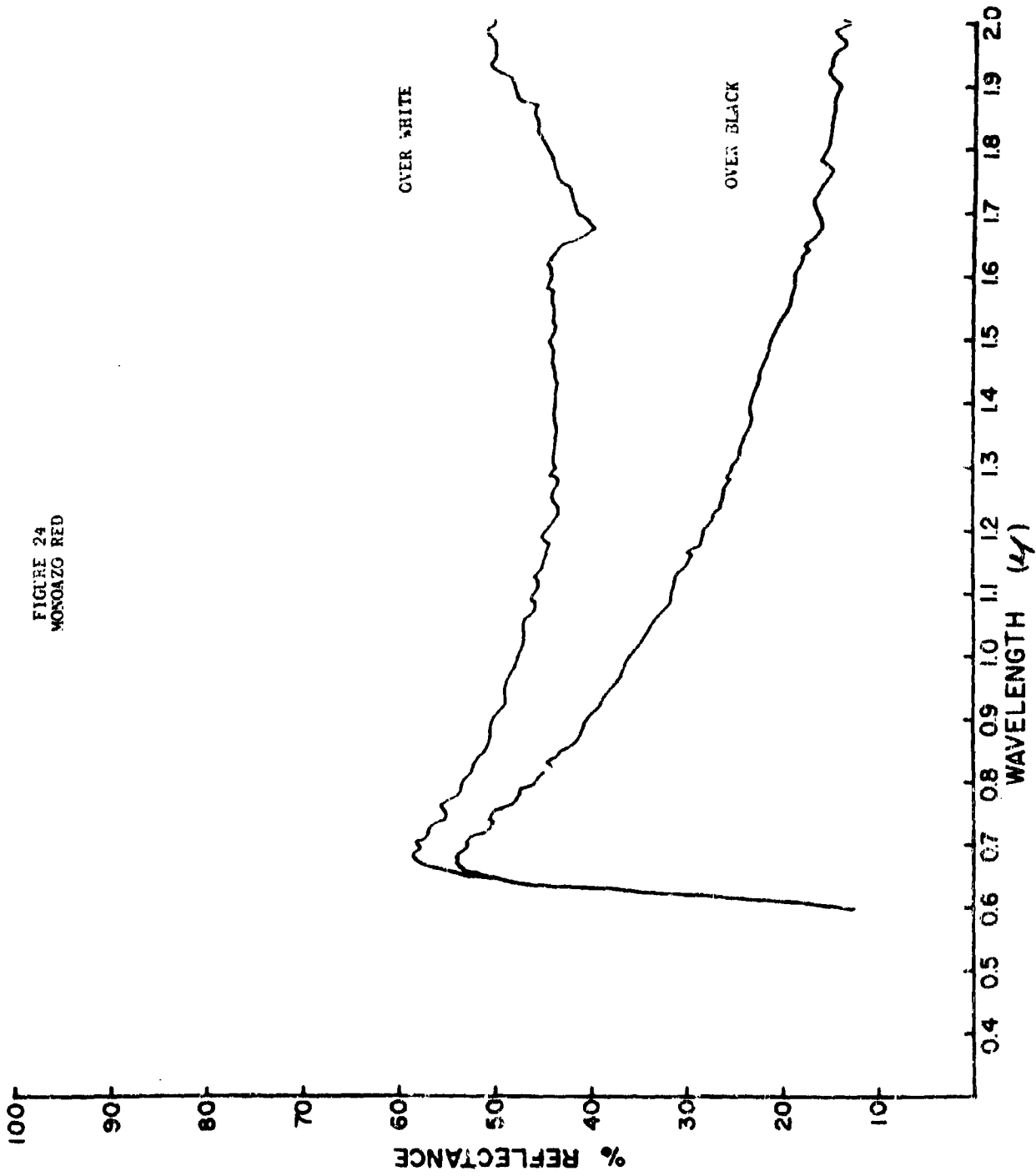


FIGURE 25  
MONOAZO RED

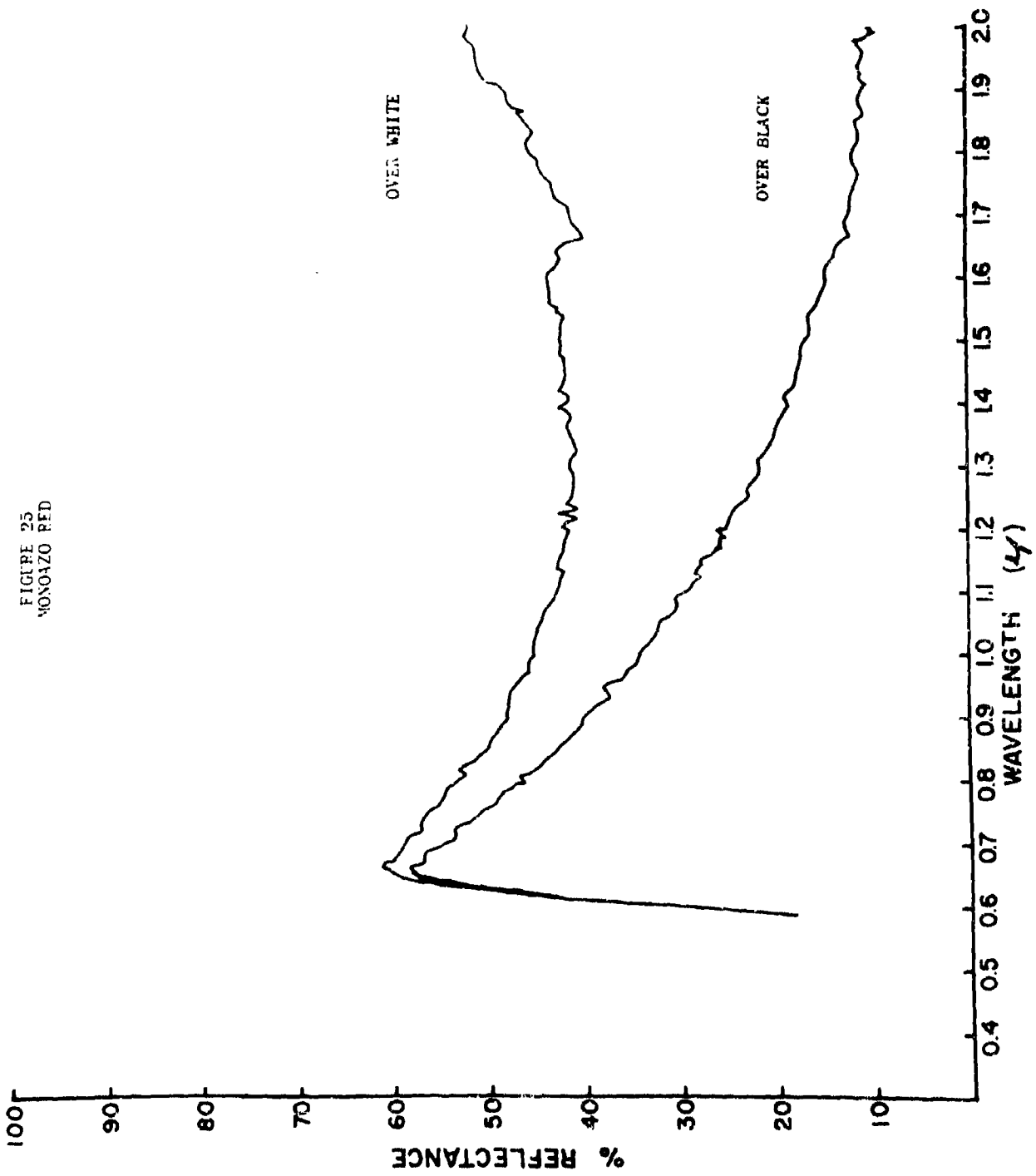
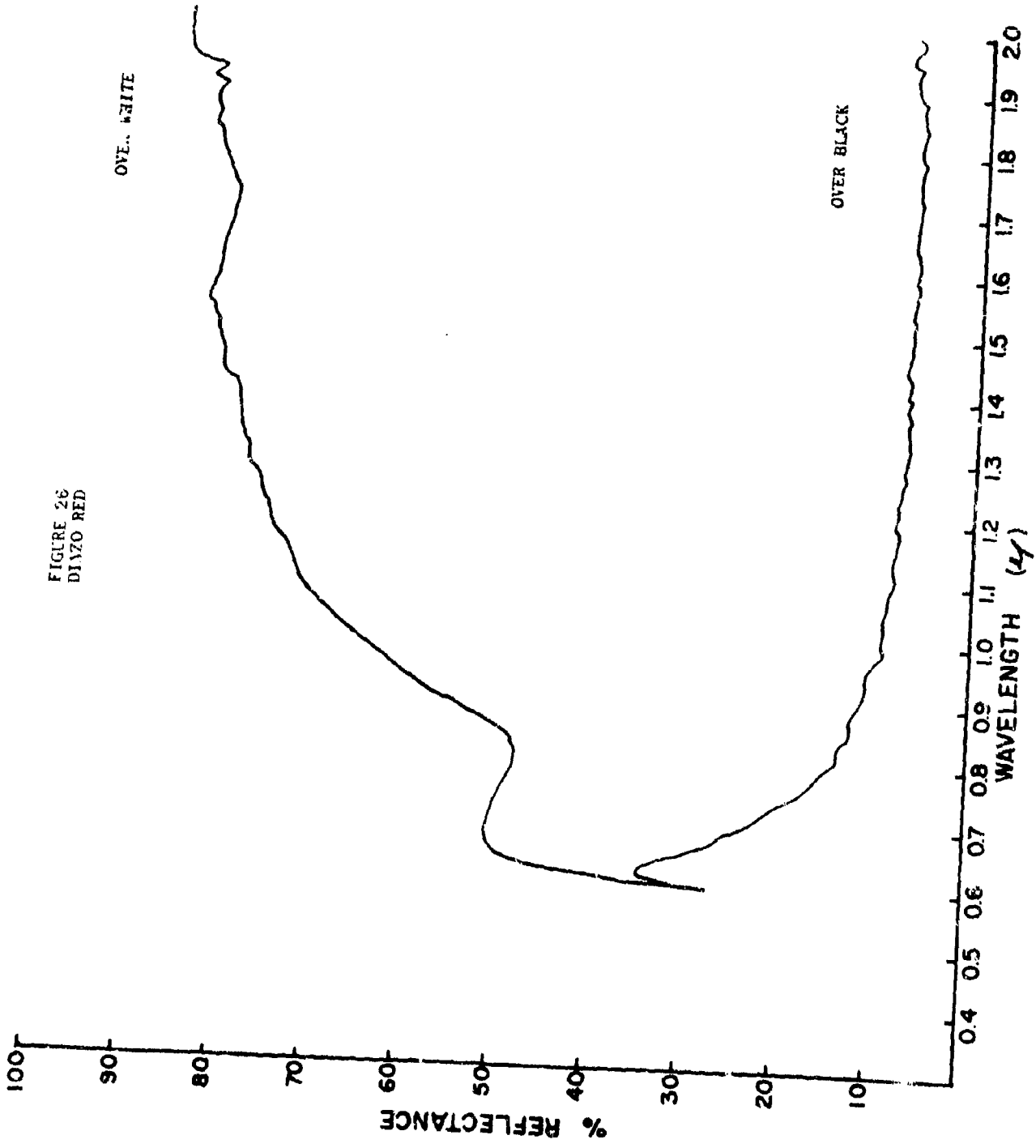


FIGURE 26  
DIAZO RED



OVER WHITE

OVER BLACK

FIGURE 27  
DIAZO RED

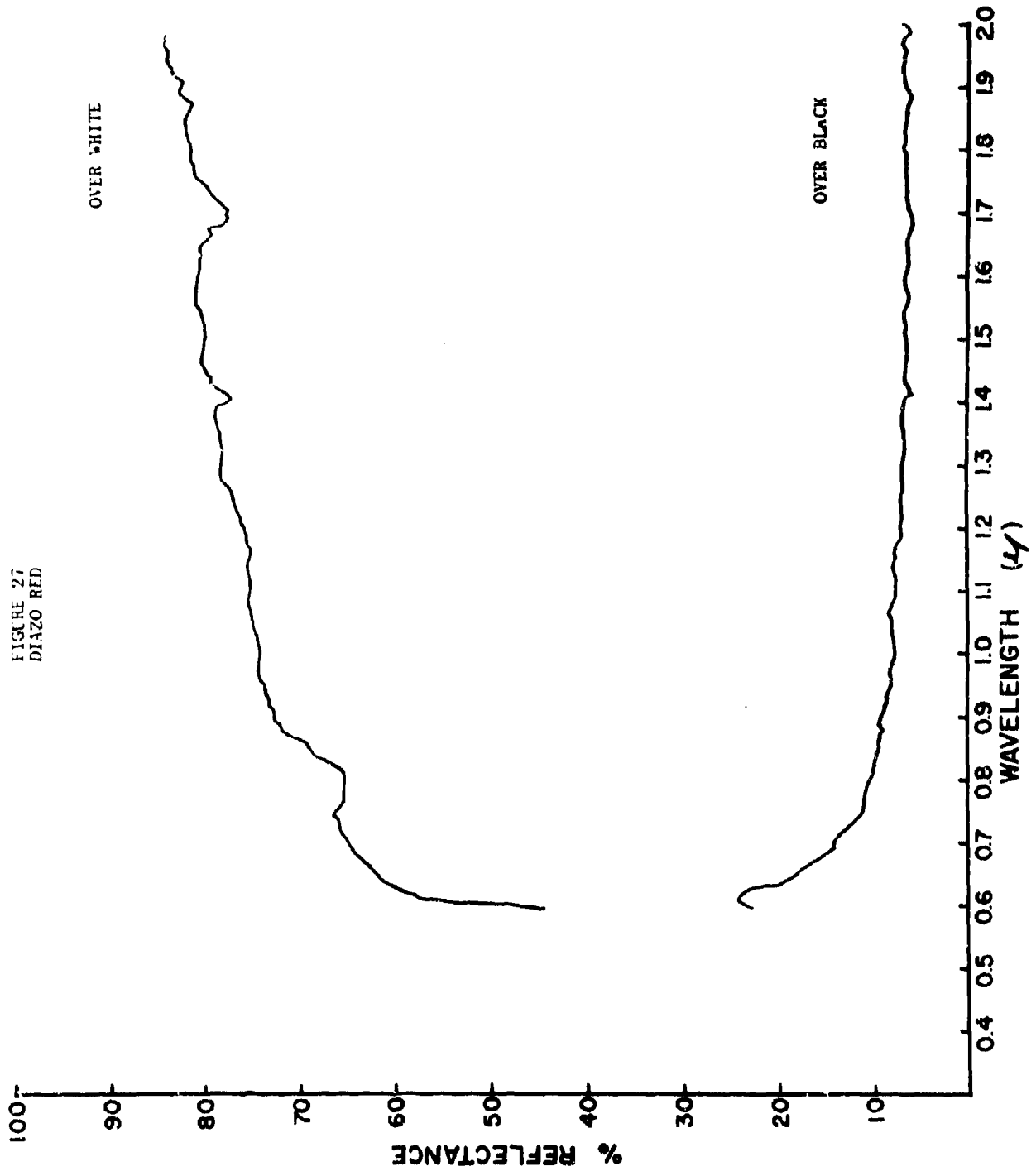


FIGURE 28  
DIAZO RED

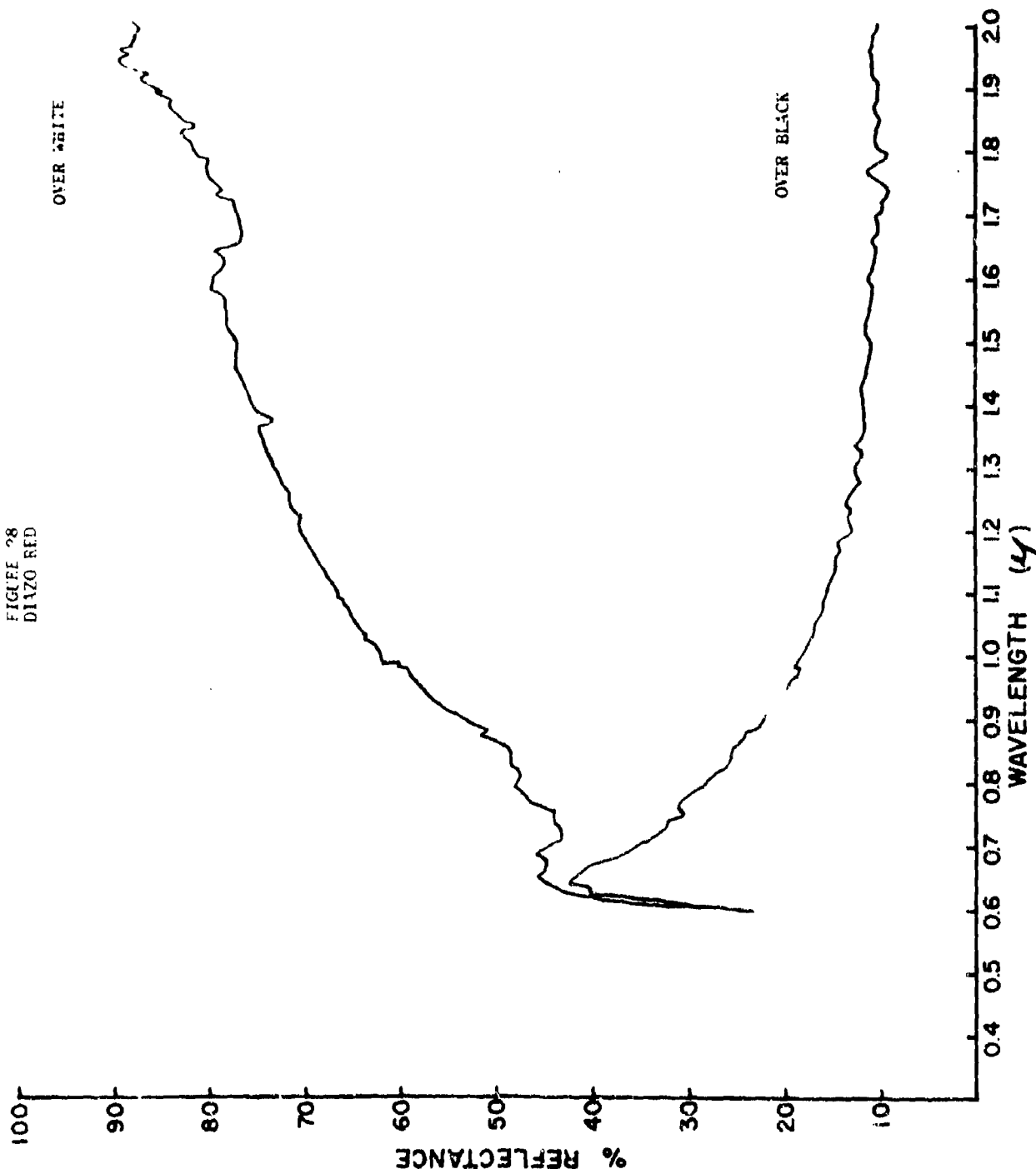


FIGURE 29  
INDIGO RED

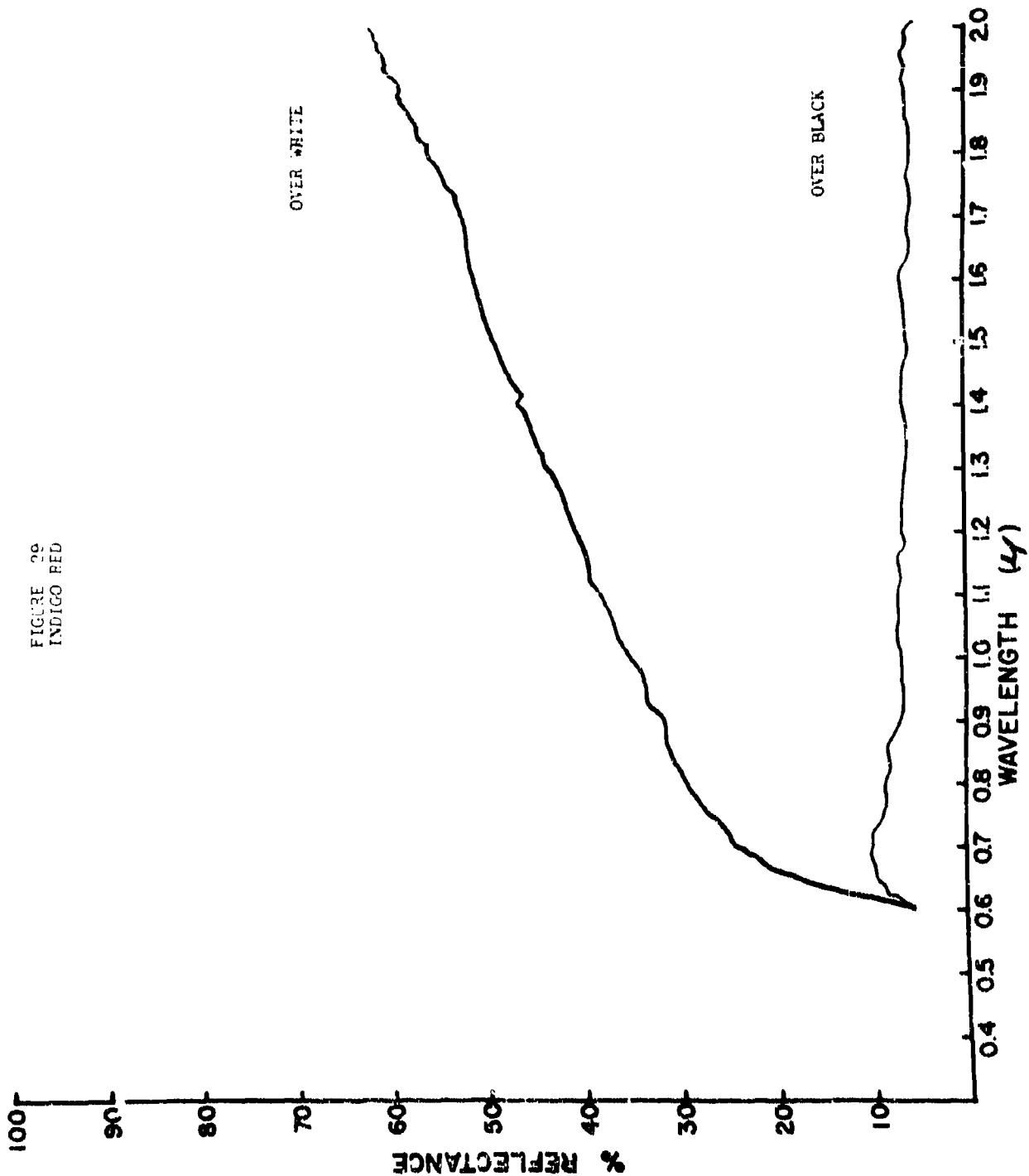


FIGURE 37  
INDIGO REF.

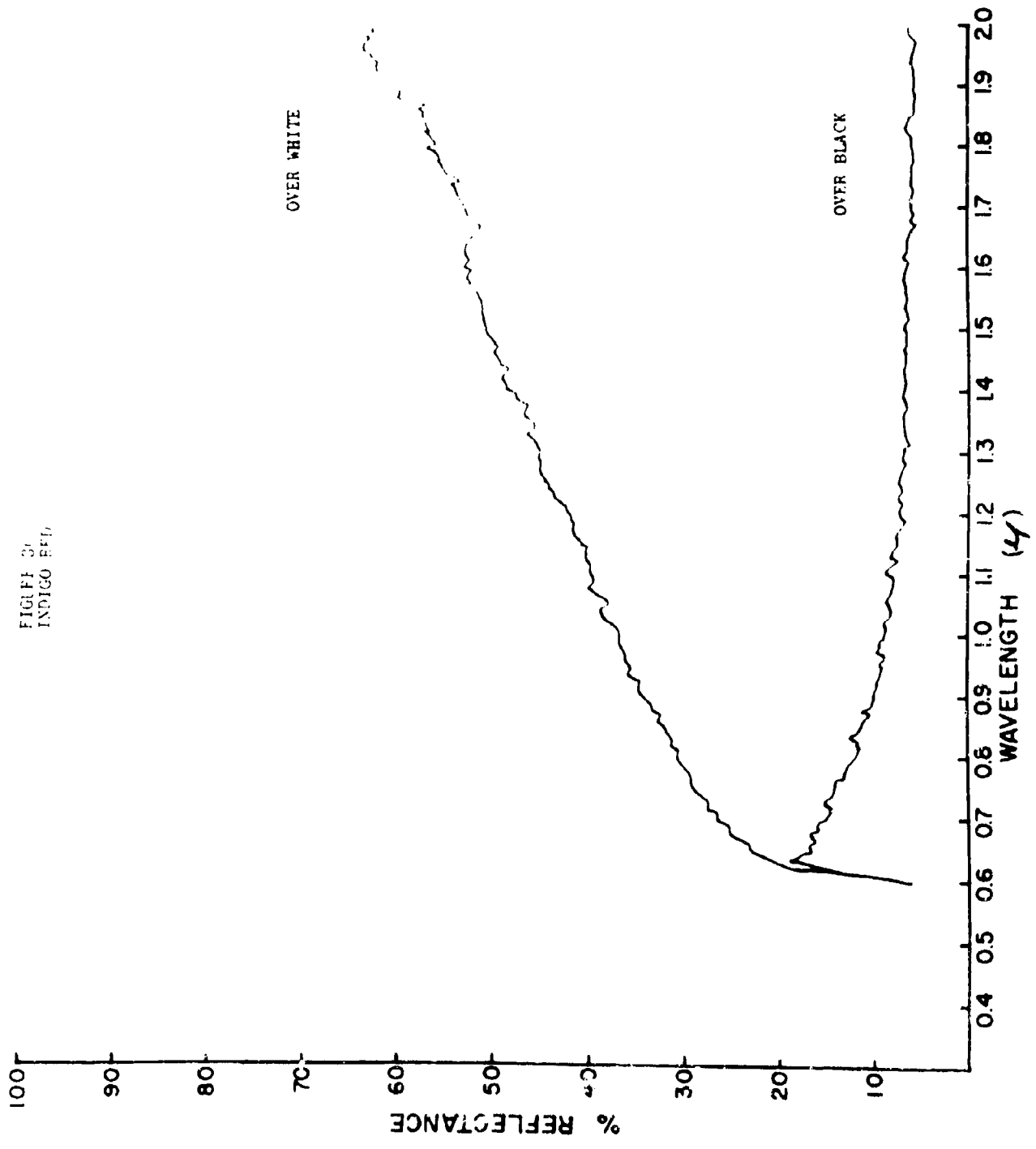


FIGURE 31  
ISOINDOLINE RED

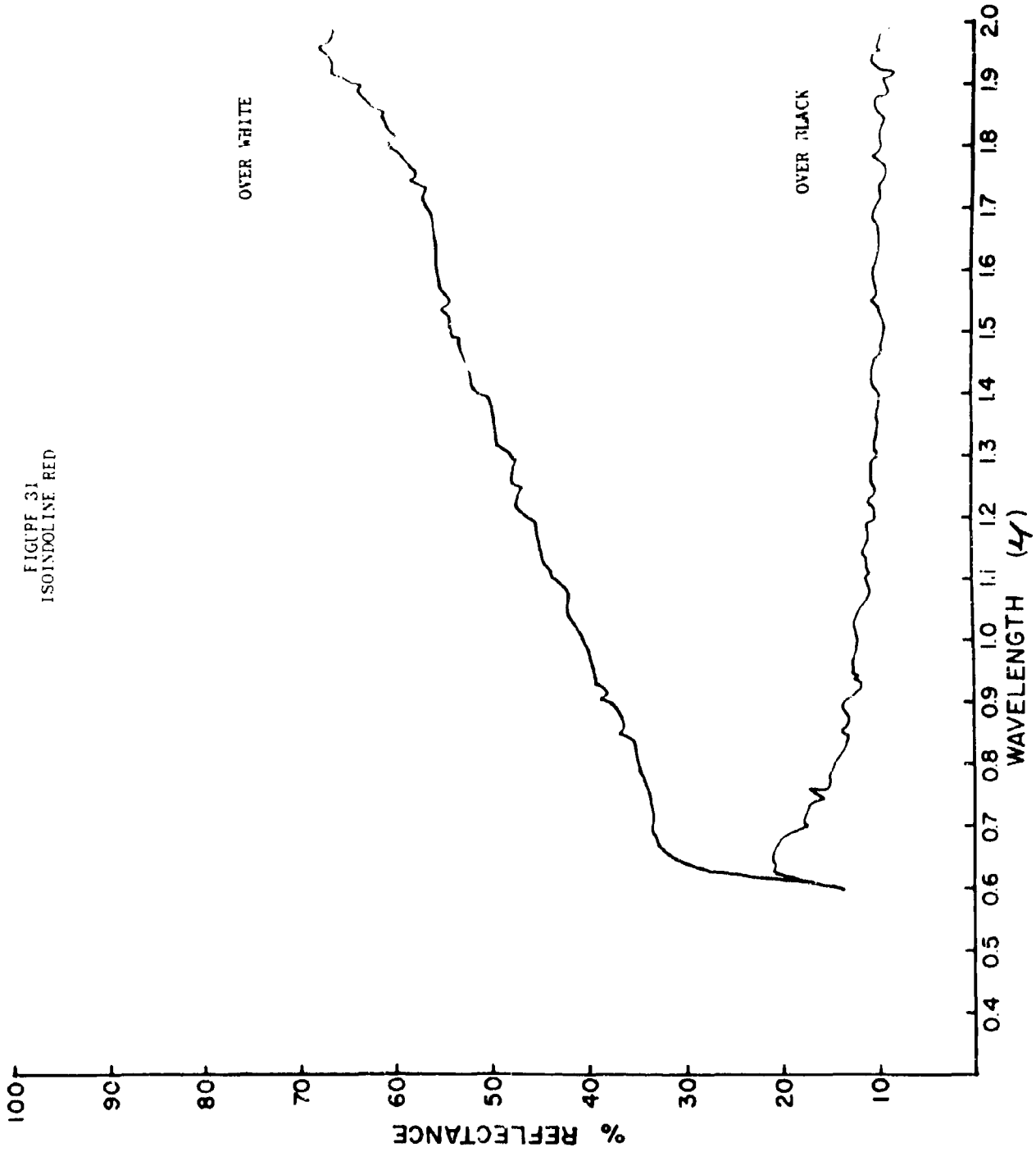




FIGURE 32  
OXYPHANTHANOIC ACID  
RED

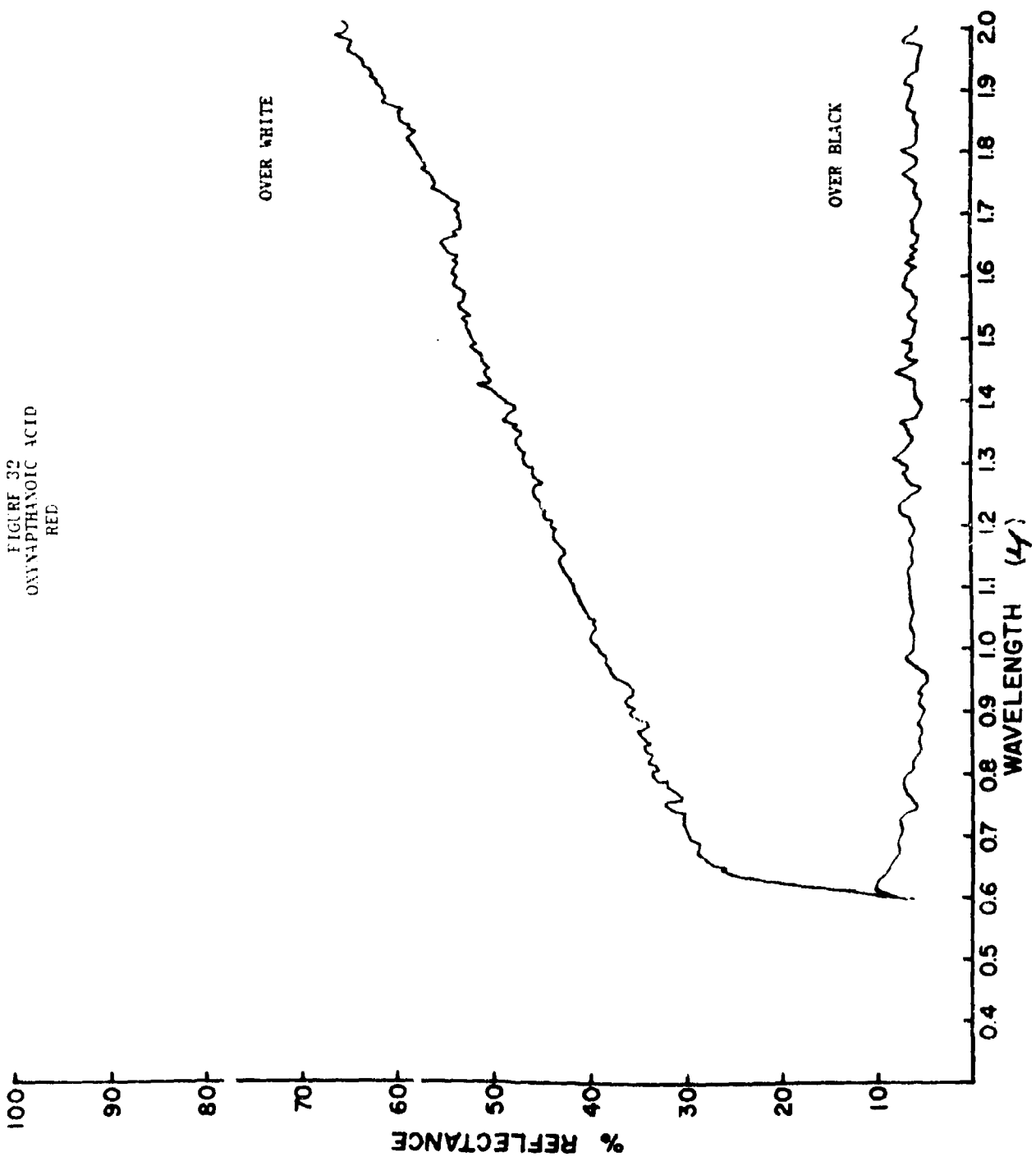


FIGURE 33  
ONYNAPHTHANOIC ACID RED

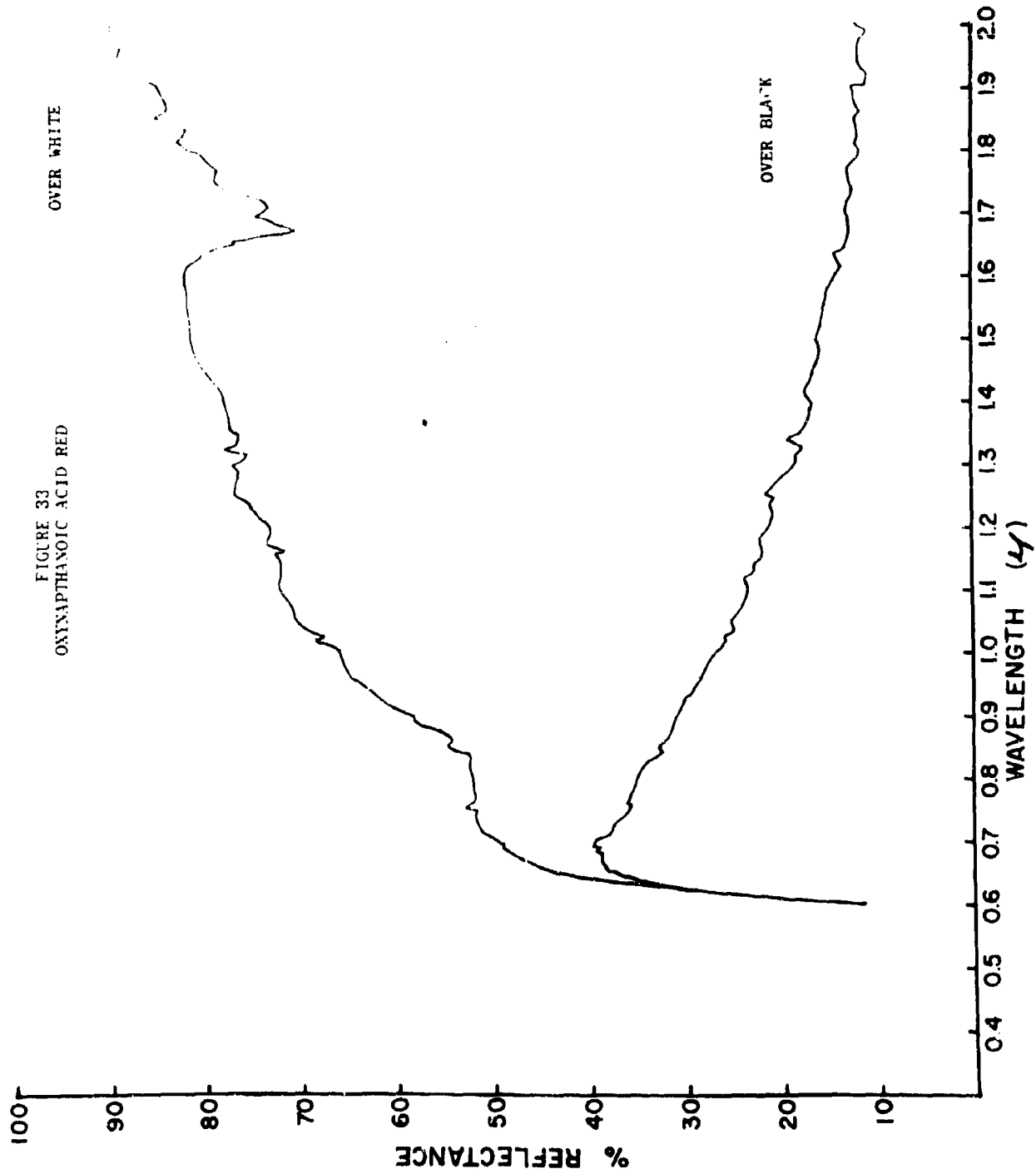


FIGURE 34  
PERYLENE RFD

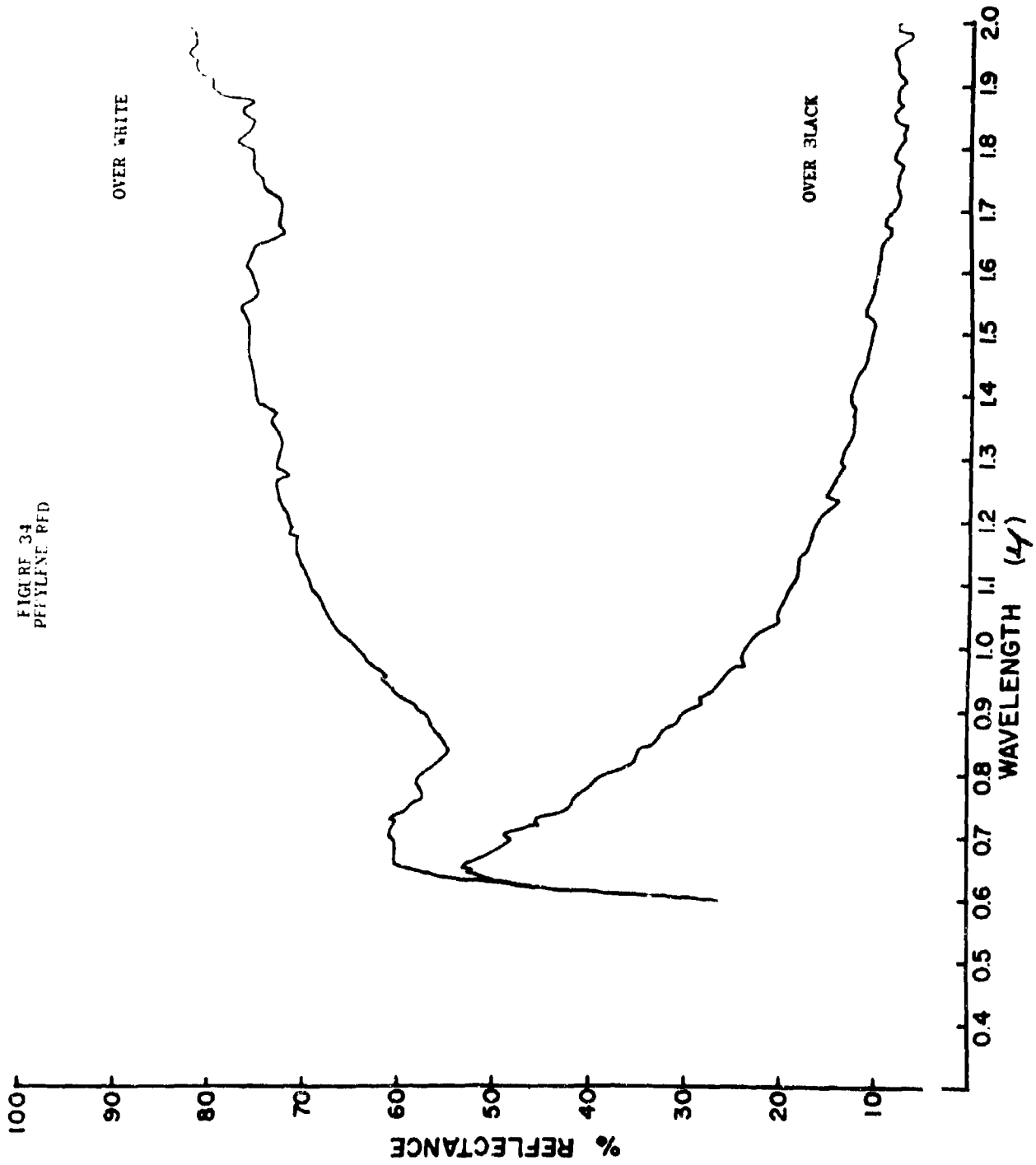


FIGURE 35  
PERYLONE RED

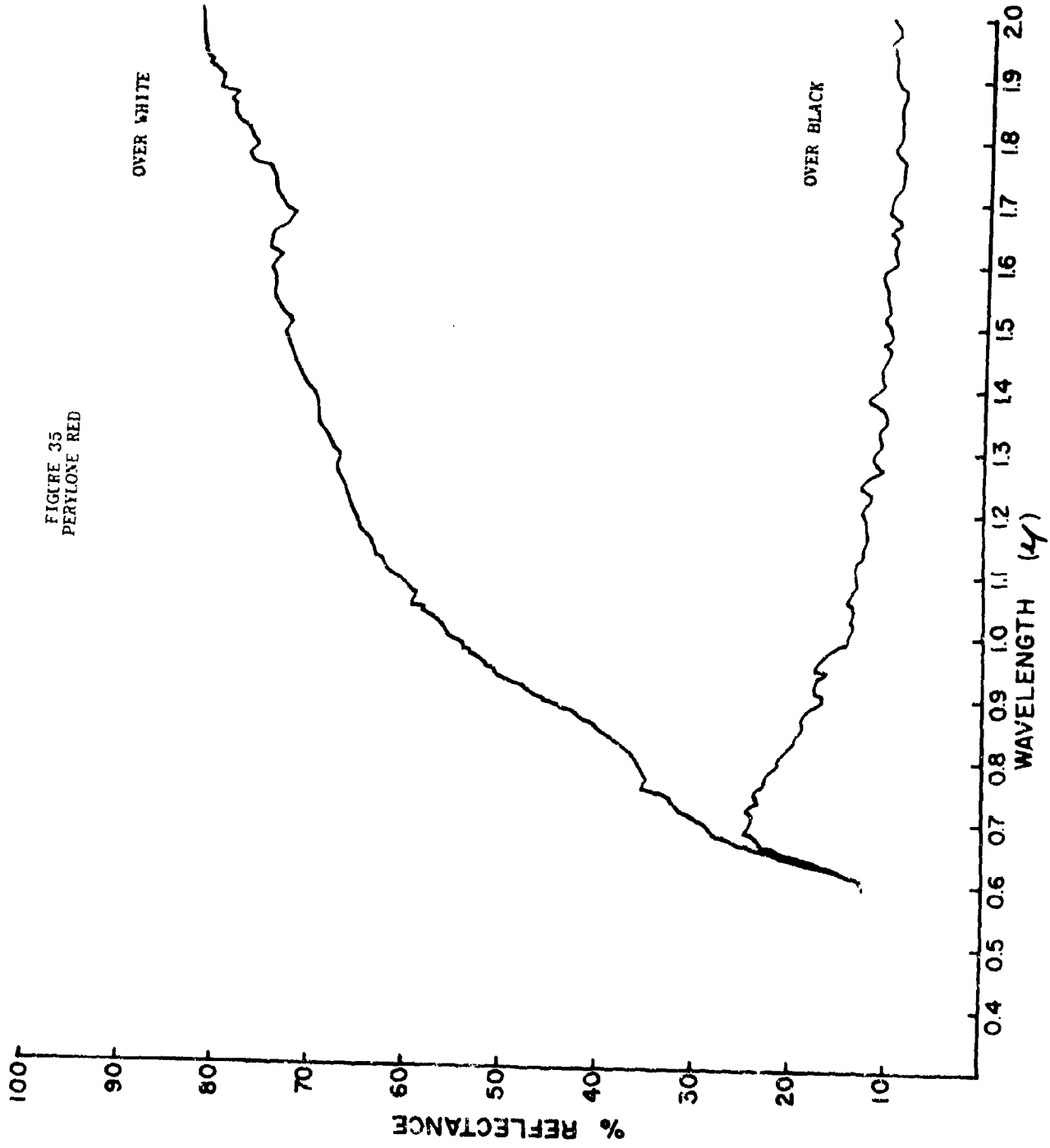


FIGURE 23  
PYFAZOLONE REF

OVER WHITE

OVER BLACK

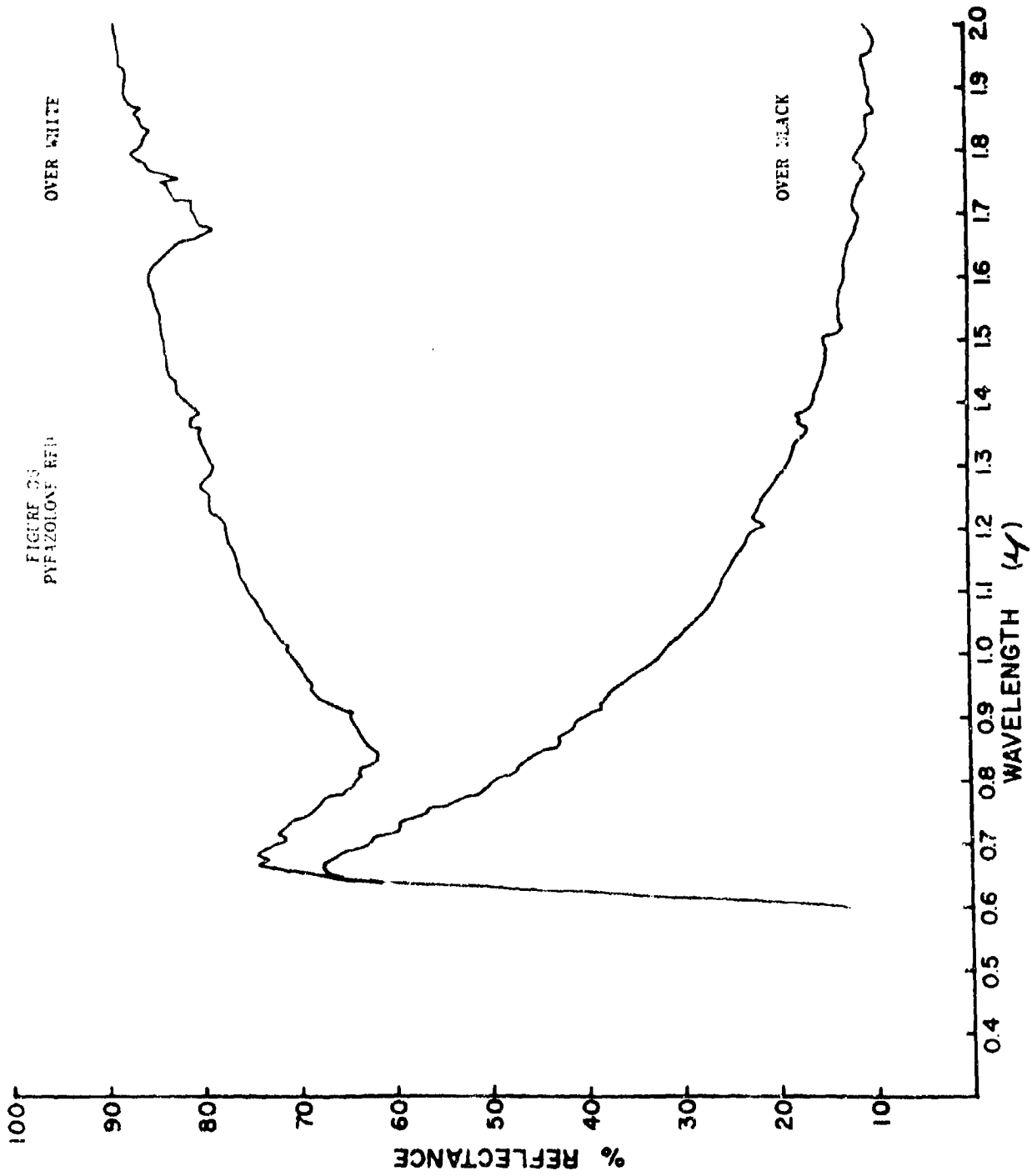


FIGURE 37  
QUINACRIDONE RED

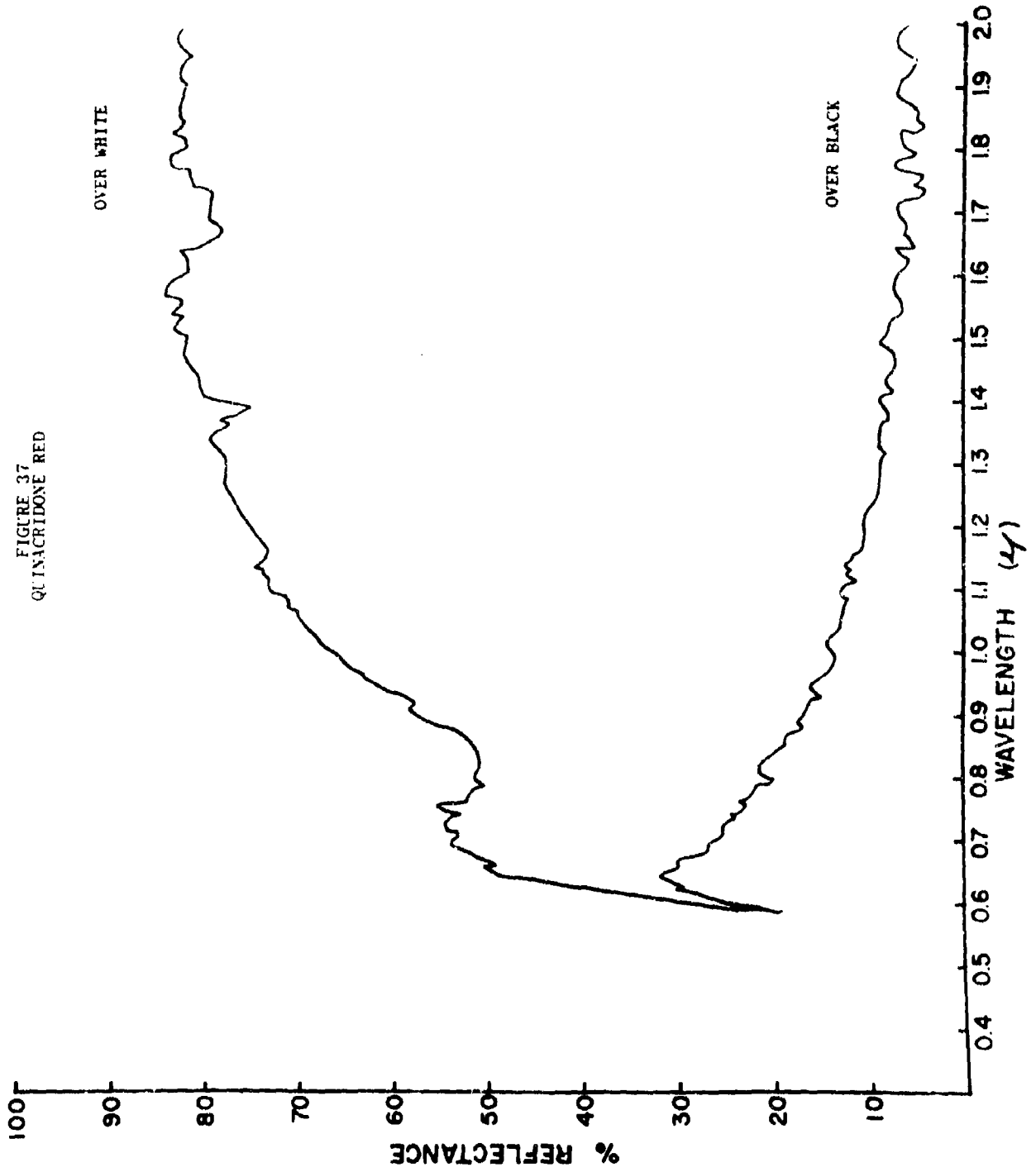


FIGURE 38  
QUINACRIDONE RED

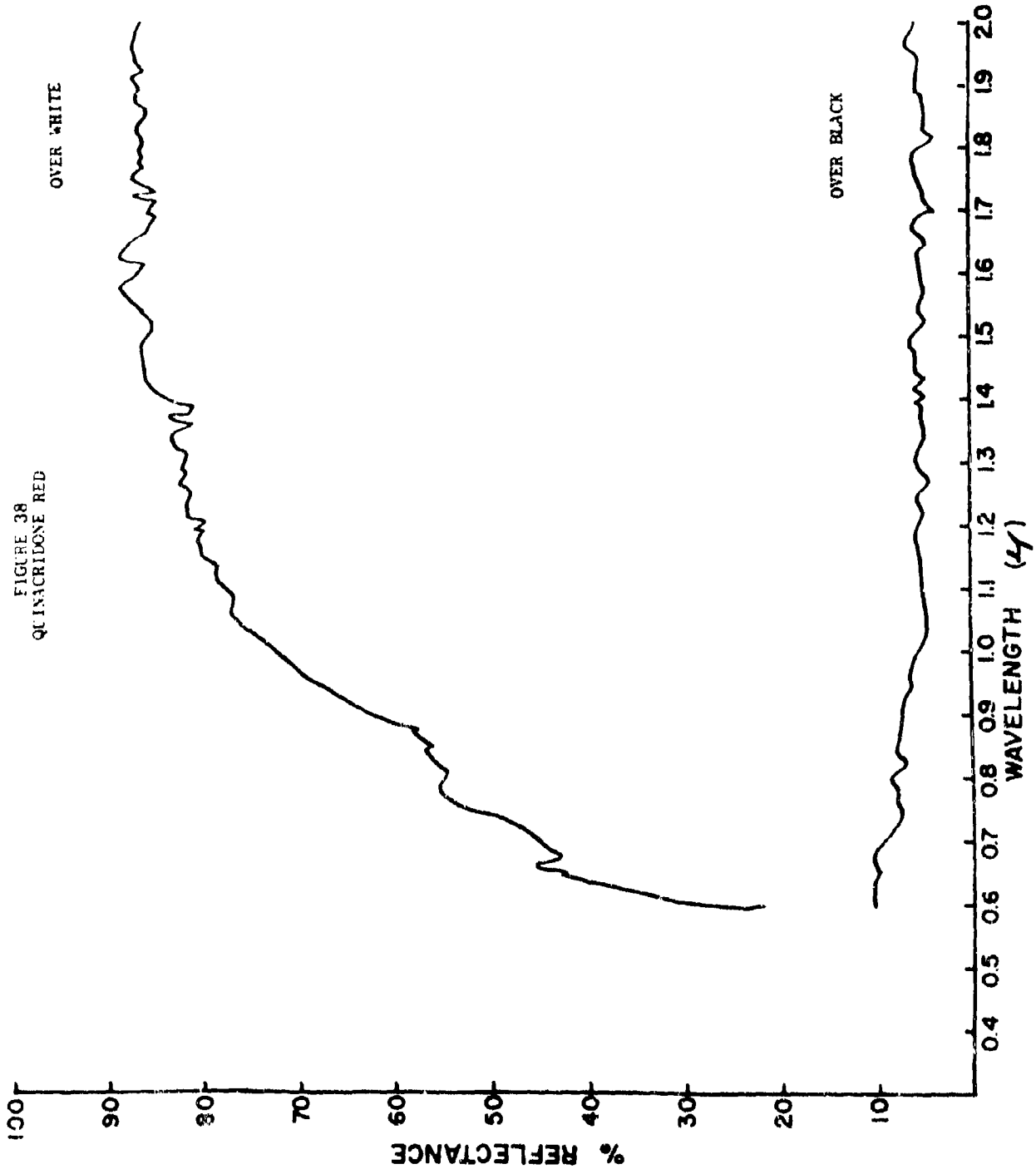


FIGURE 39  
QUINACRIDONE RED

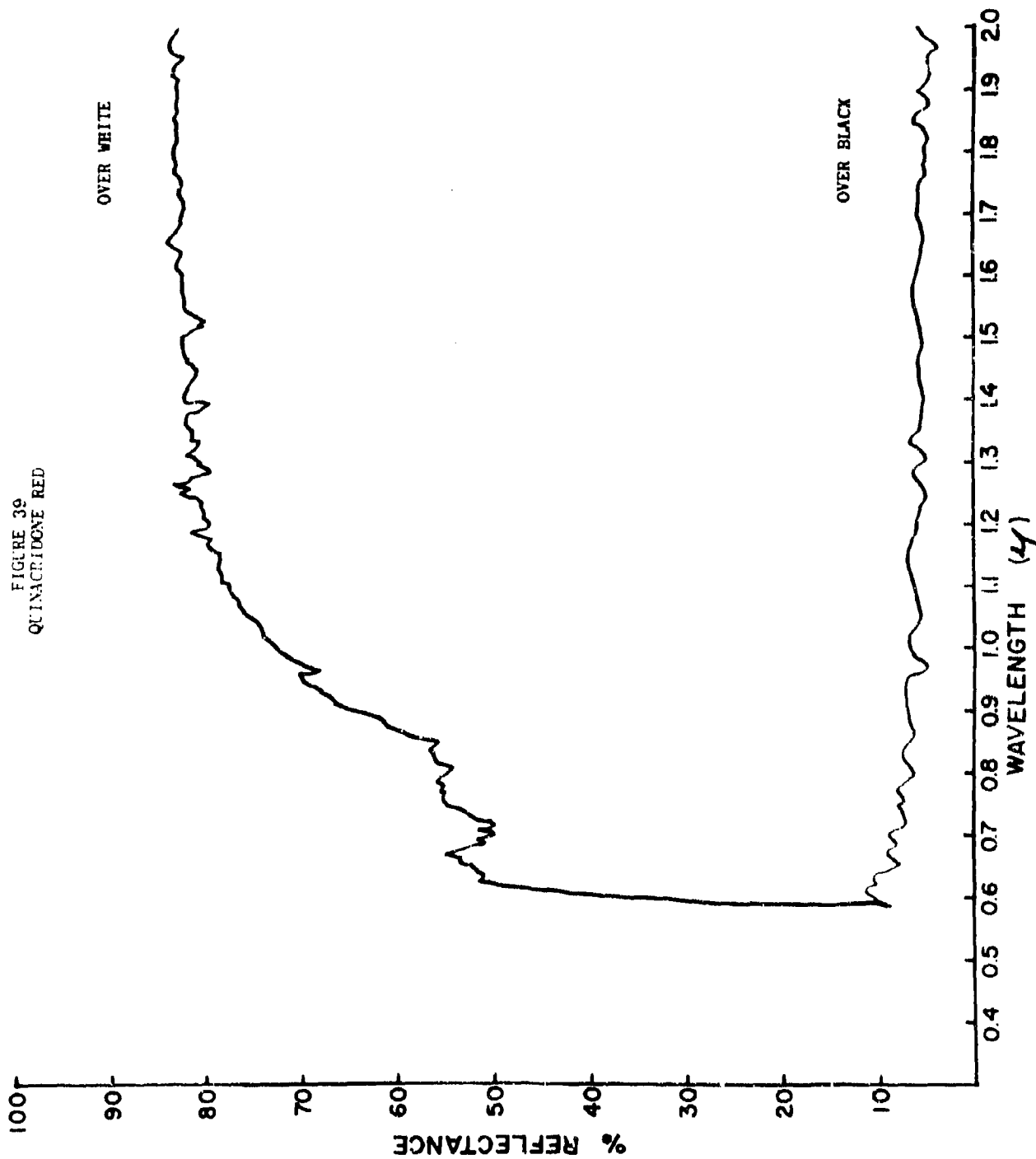




FIGURE 41  
ORGANIC REF.

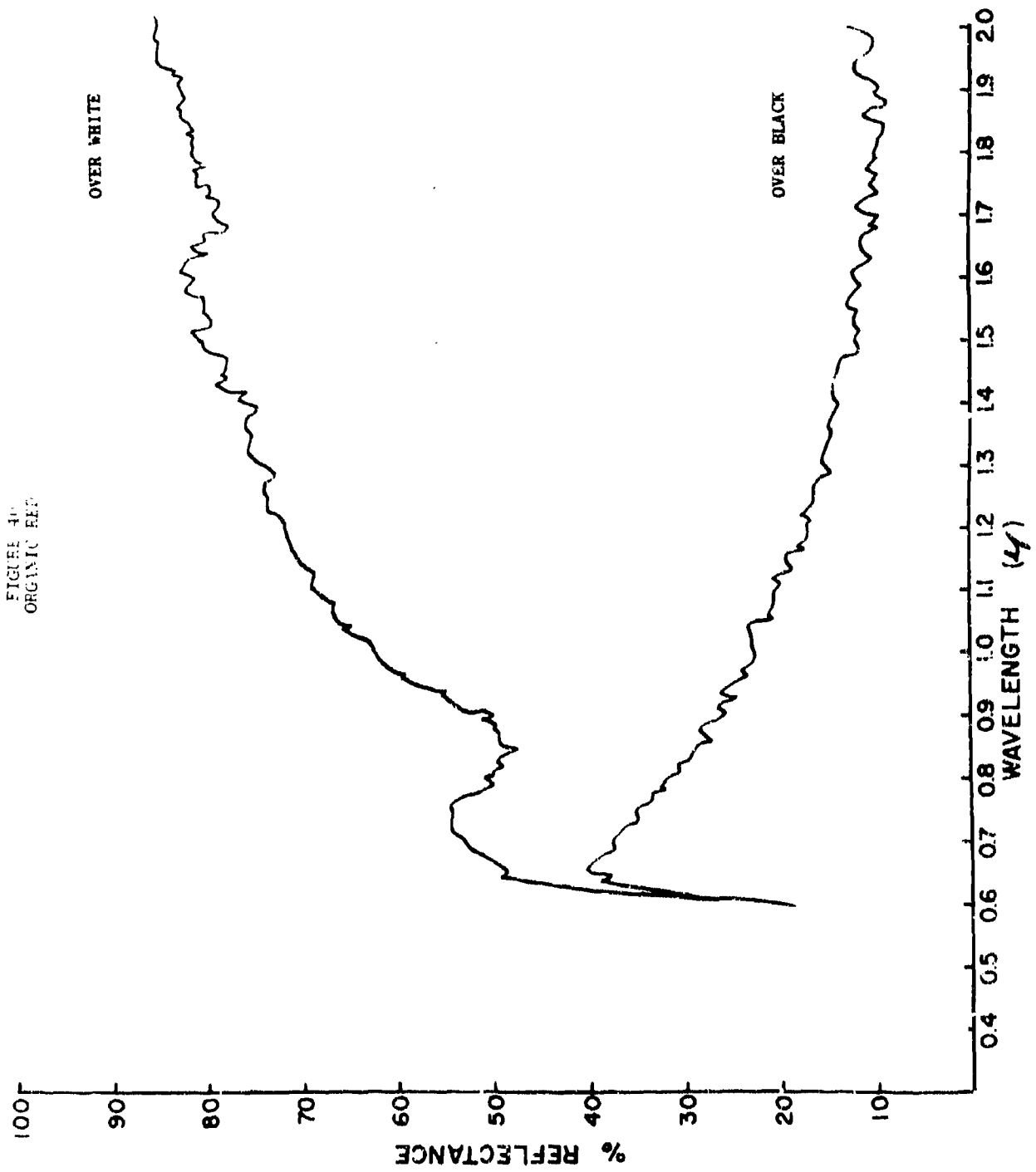


FIGURE 41  
ORGANIC RED

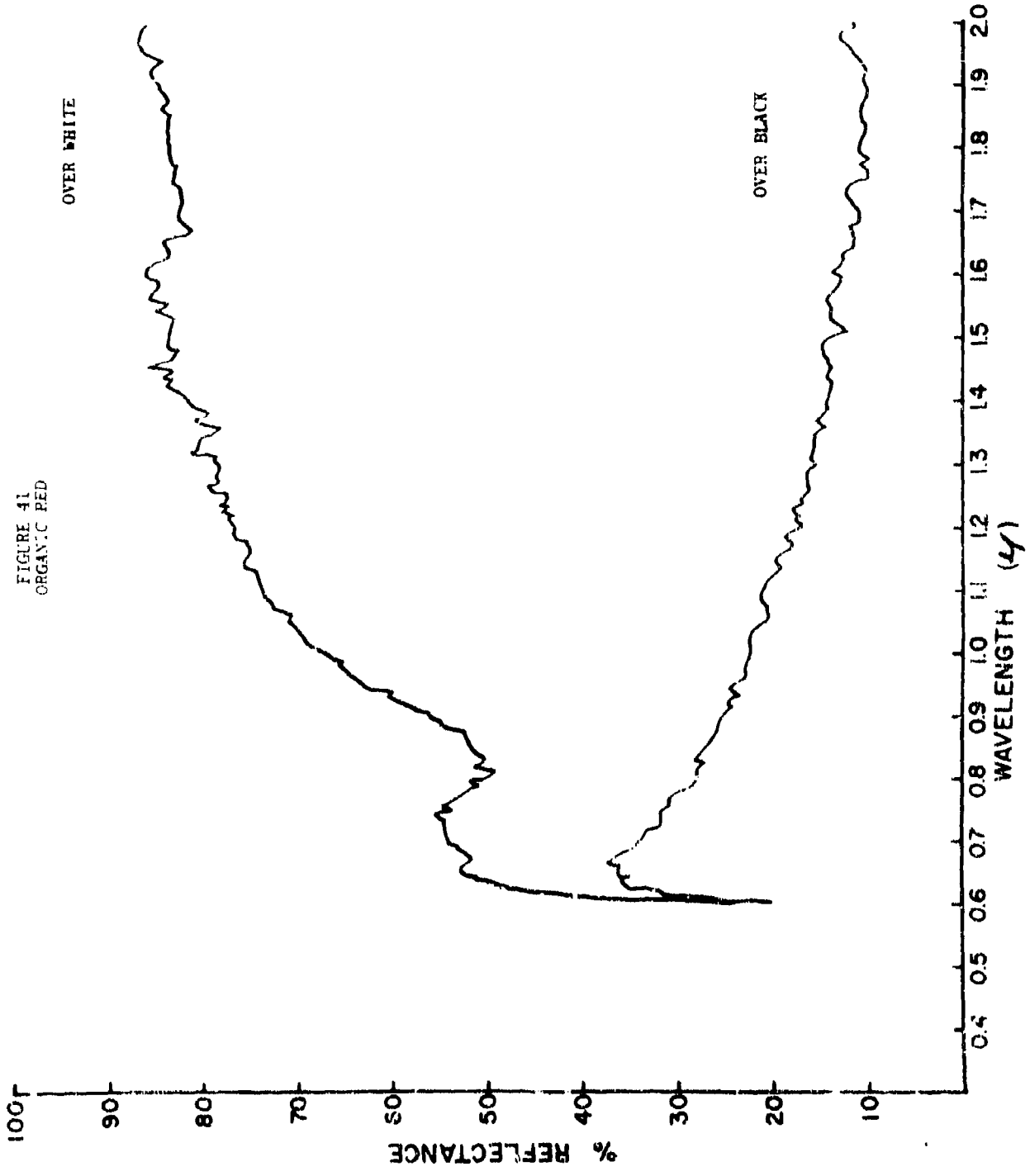
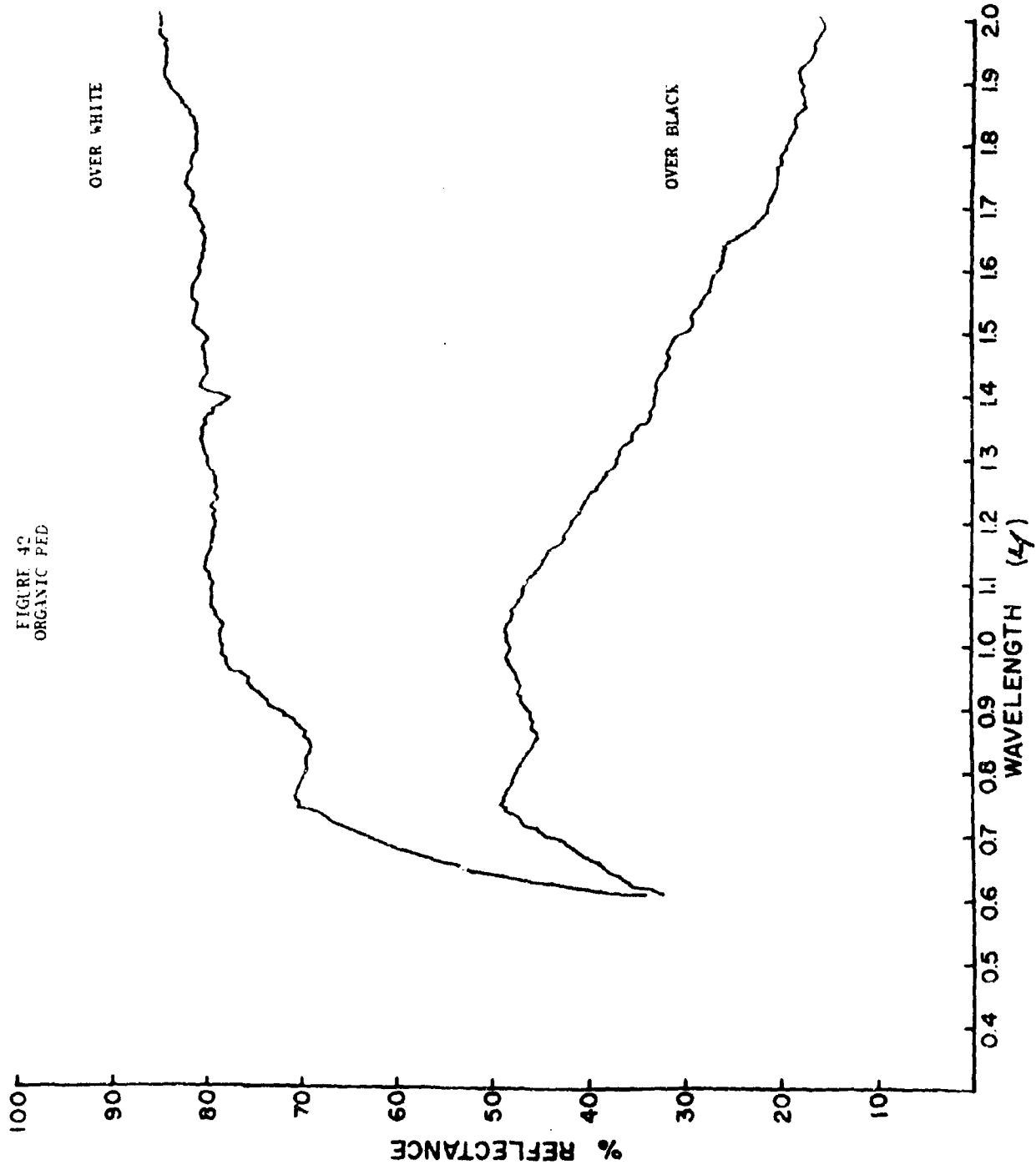


FIGURE 42  
ORGANIC PFD



FLORID  
MONGAZO ORANGE

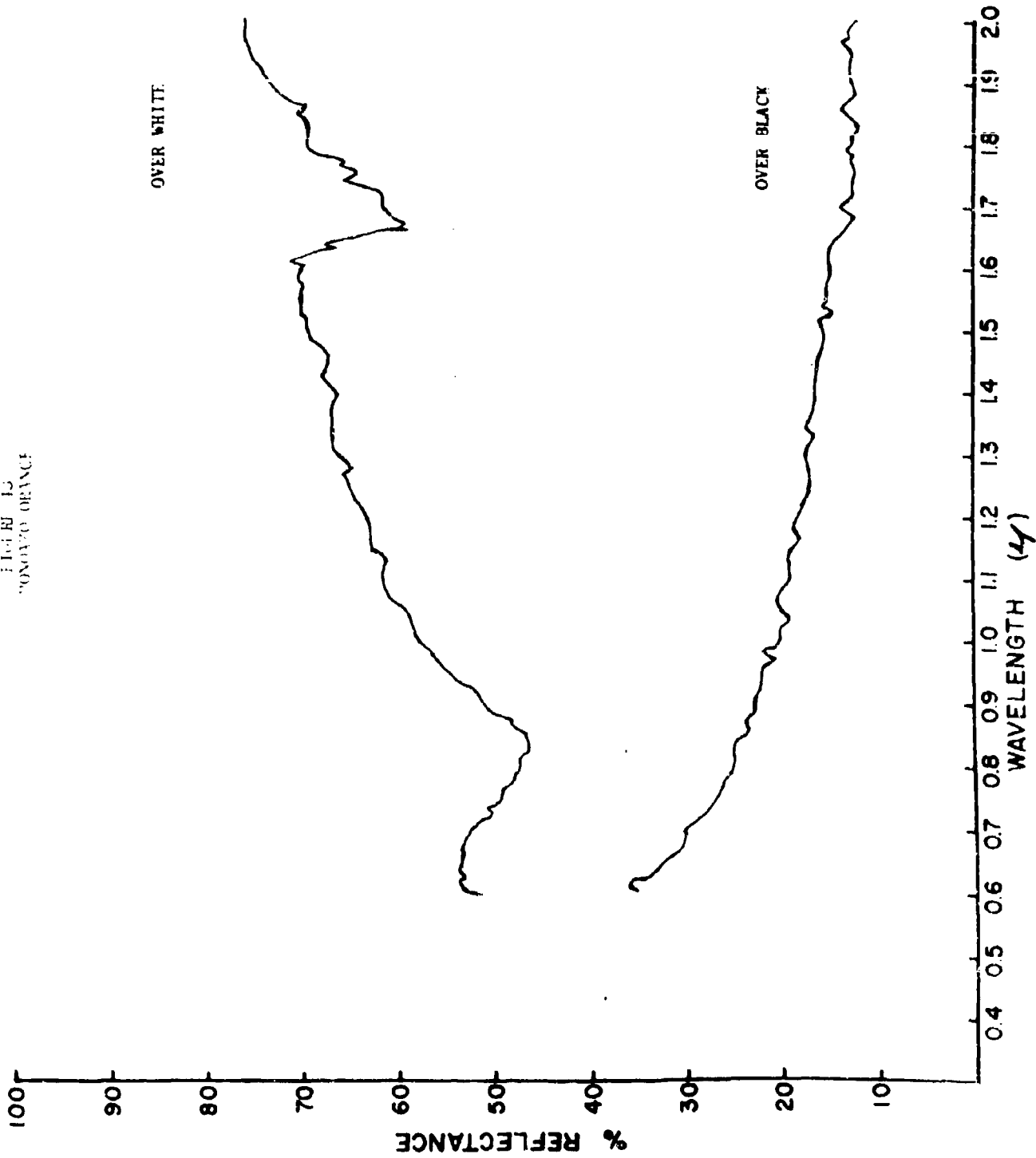


FIGURE 44  
DIAZO ORANGE

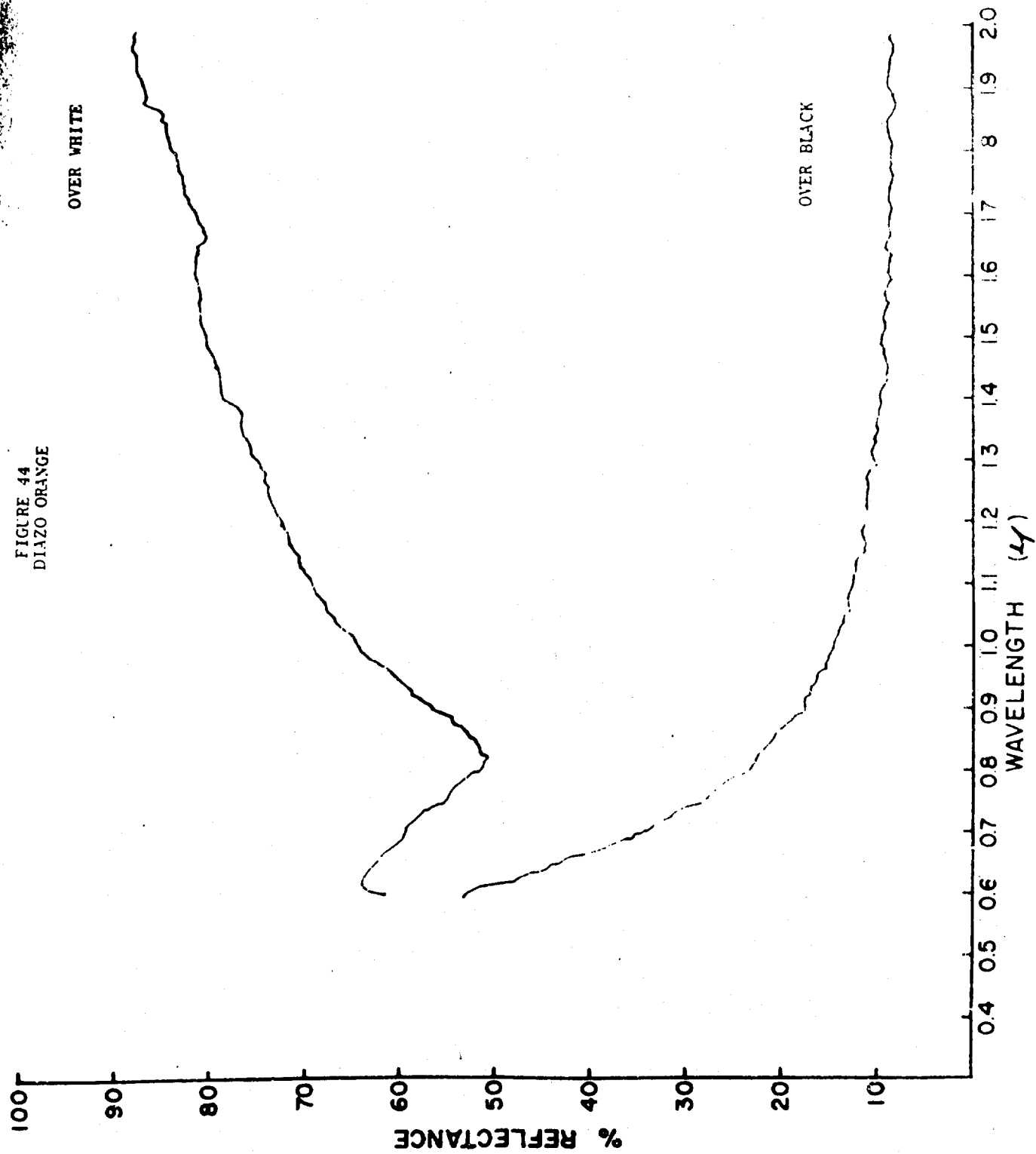


FIGURE 45  
ISOINDOLINE ORANGE

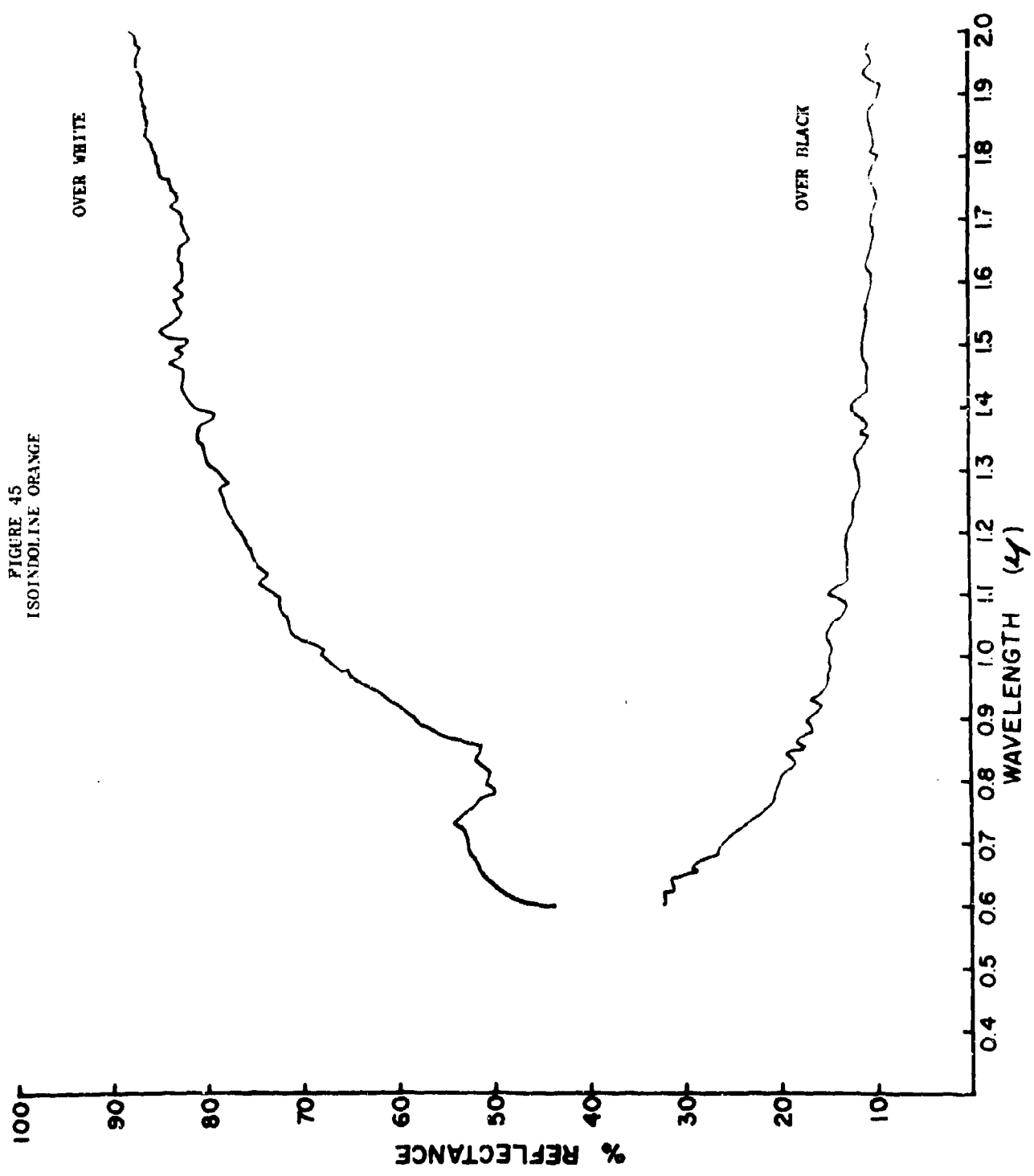


FIGURE 16  
NAPHTHALENE TETRA-  
CARBOXYLIC ACID ORANGE

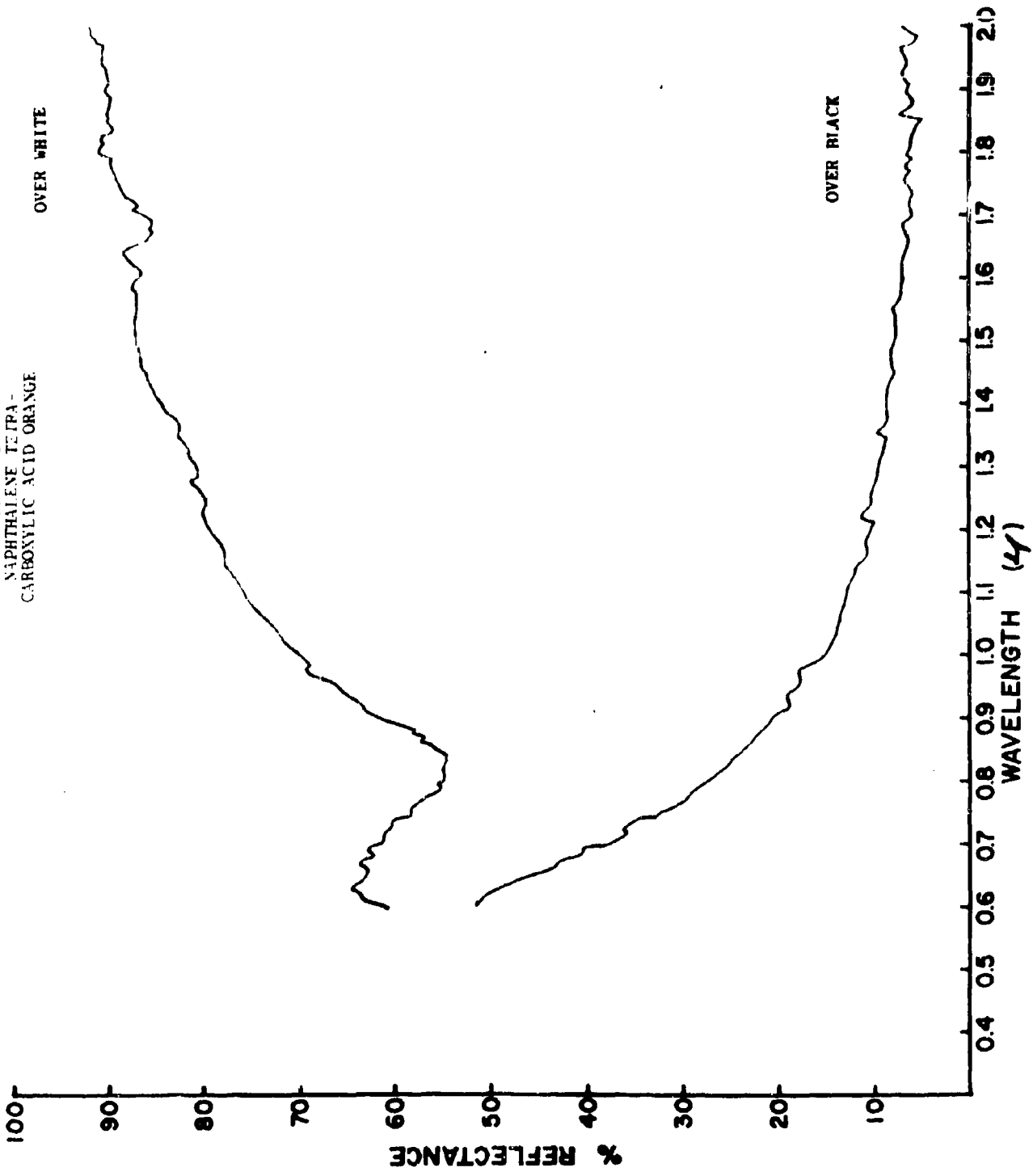


FIGURE 47  
NITRO-ORANGE

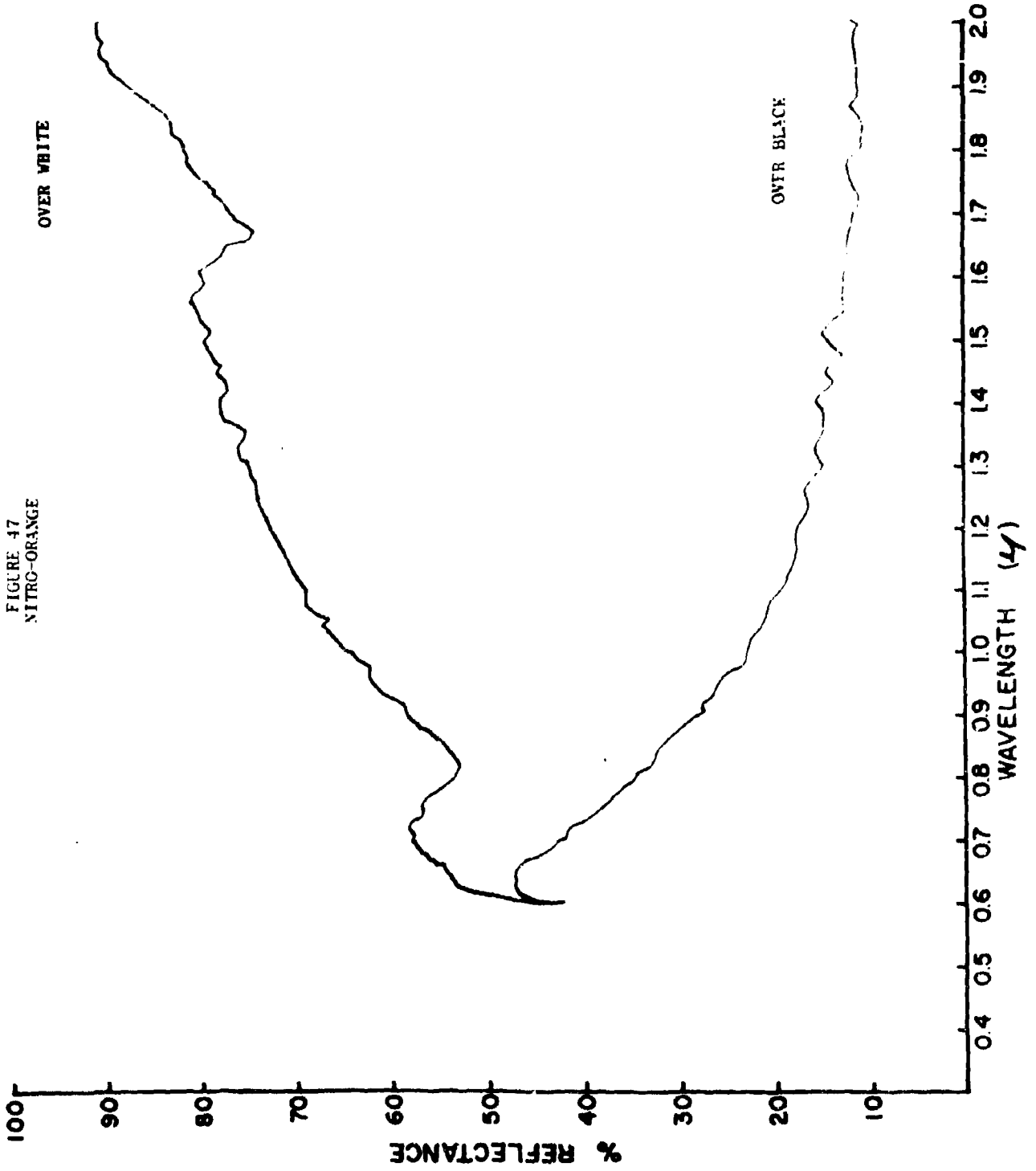




FIGURE 48  
MONOAZO YELLOW

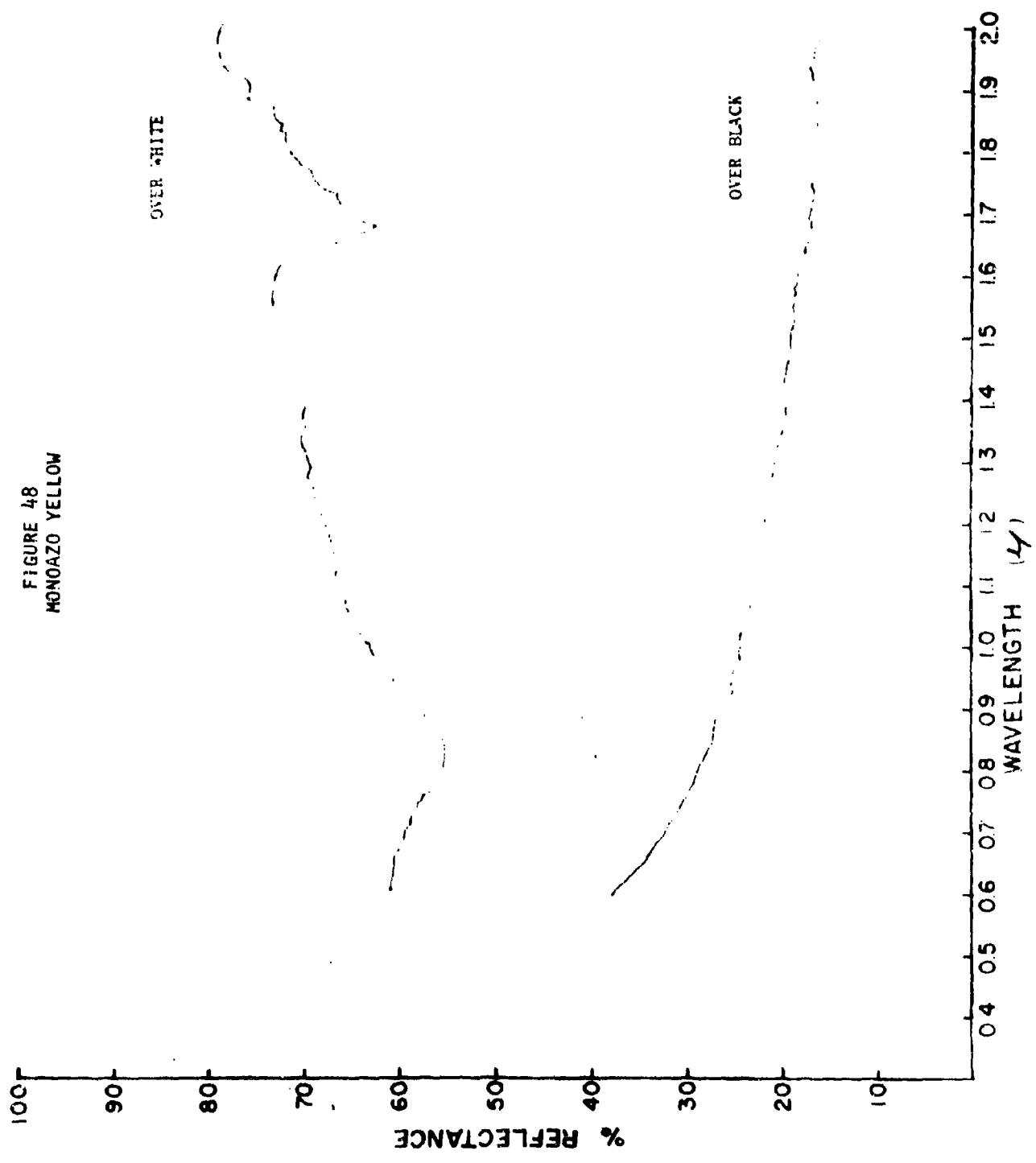


FIGURE 49  
MONOAZO YELLOW

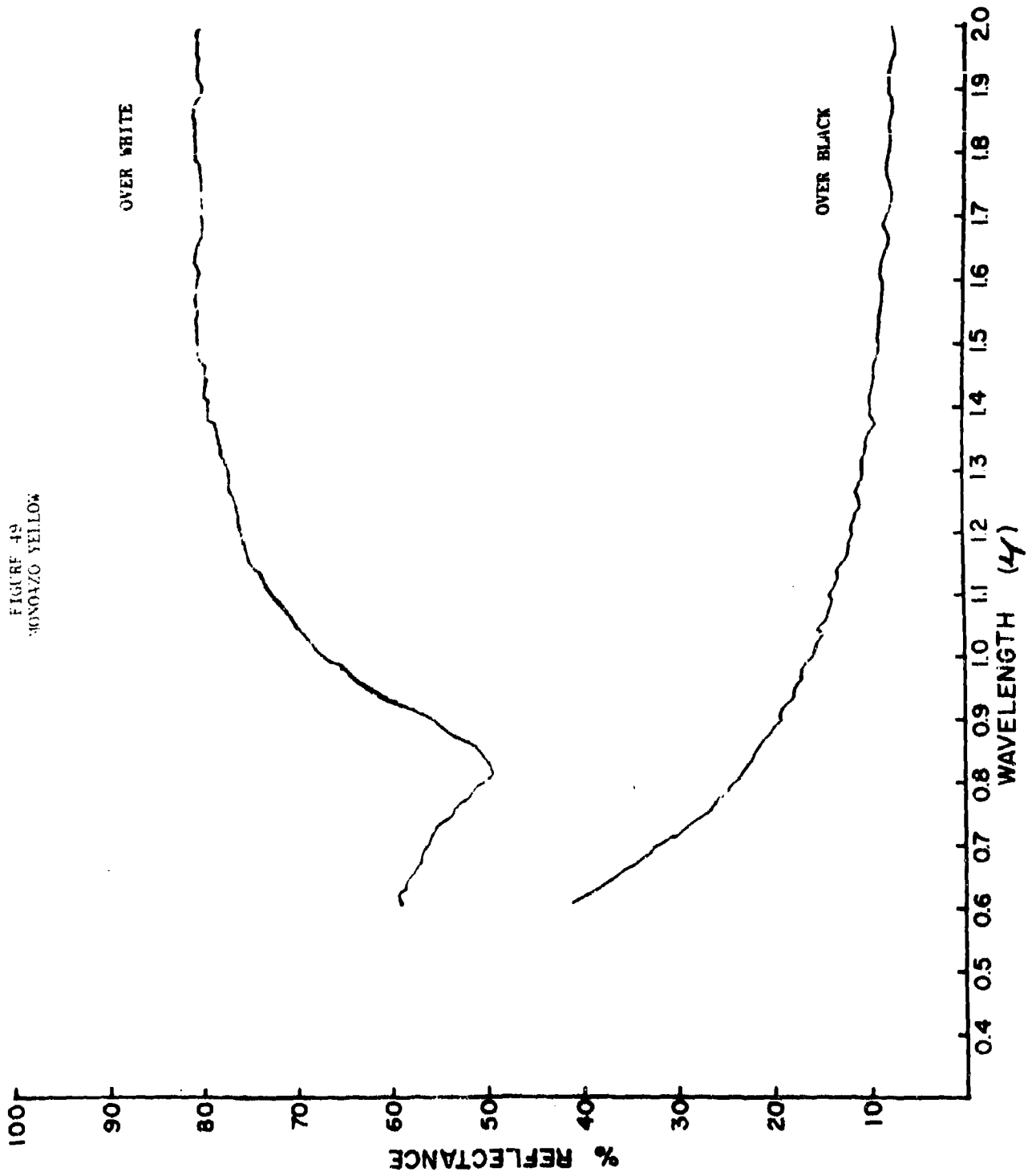


FIGURE 50  
MONOZO YELLOW

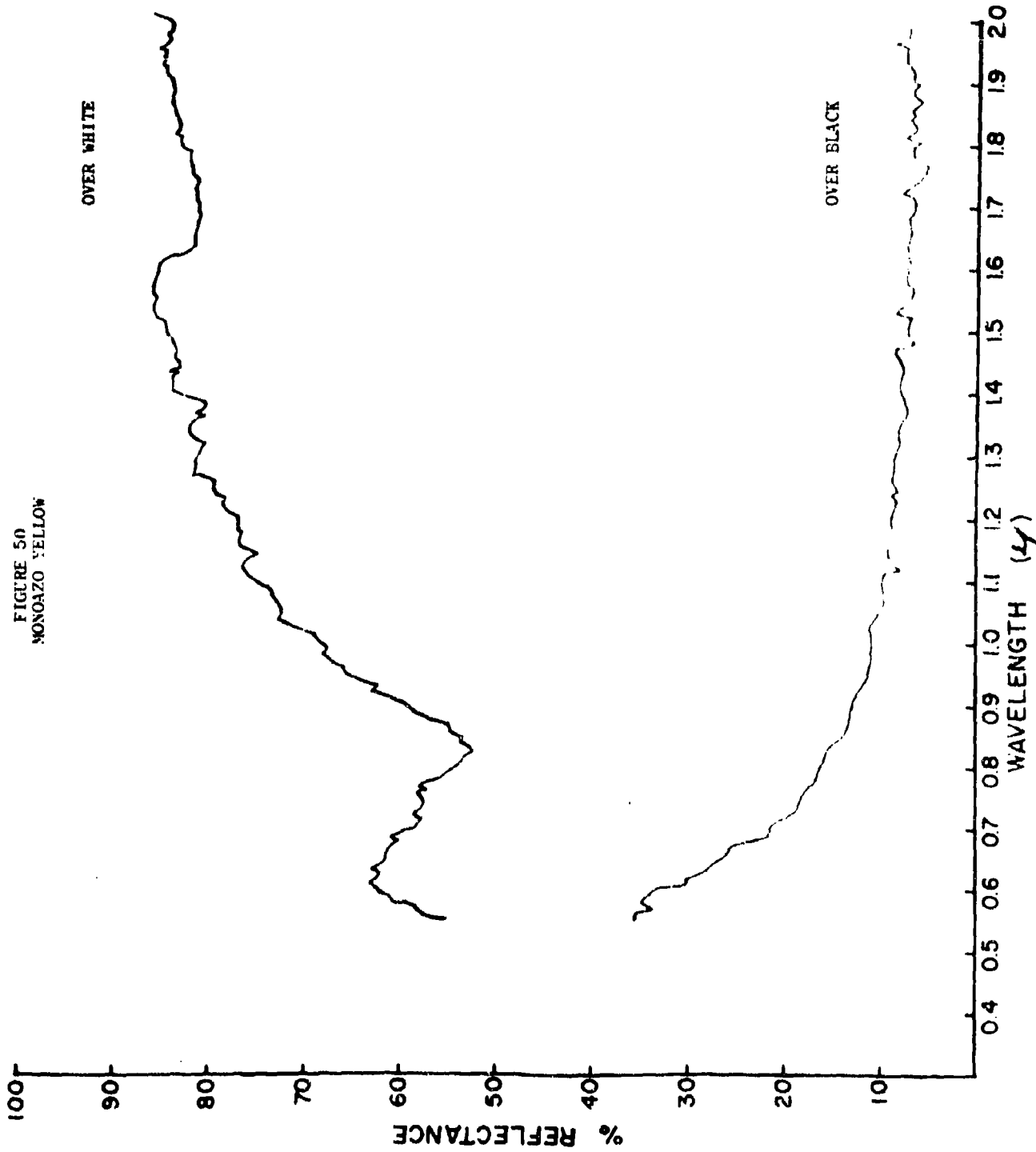


FIGURE 51  
CINNO YELLOW

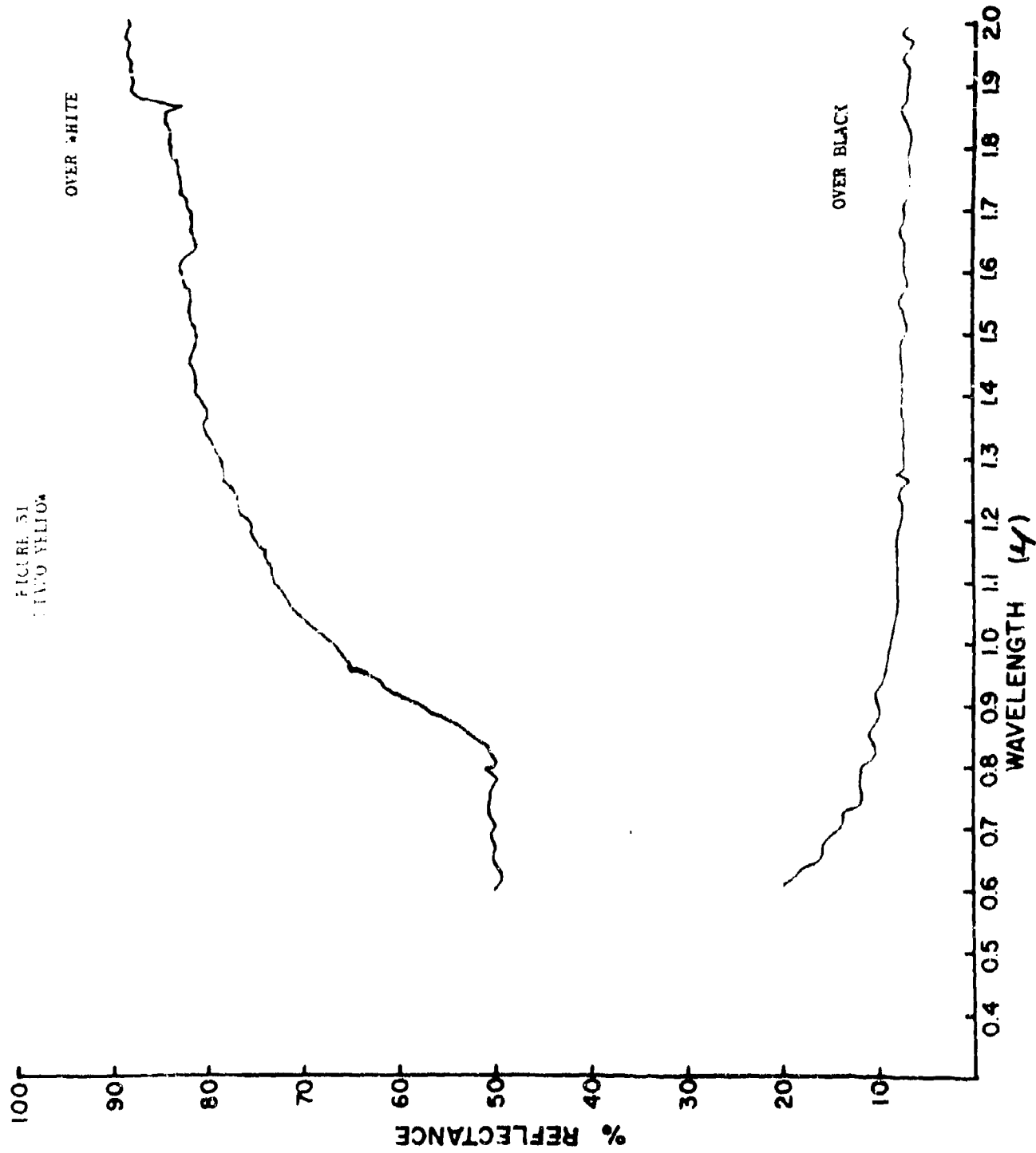


FIGURE 52  
DIAZO YELLOW

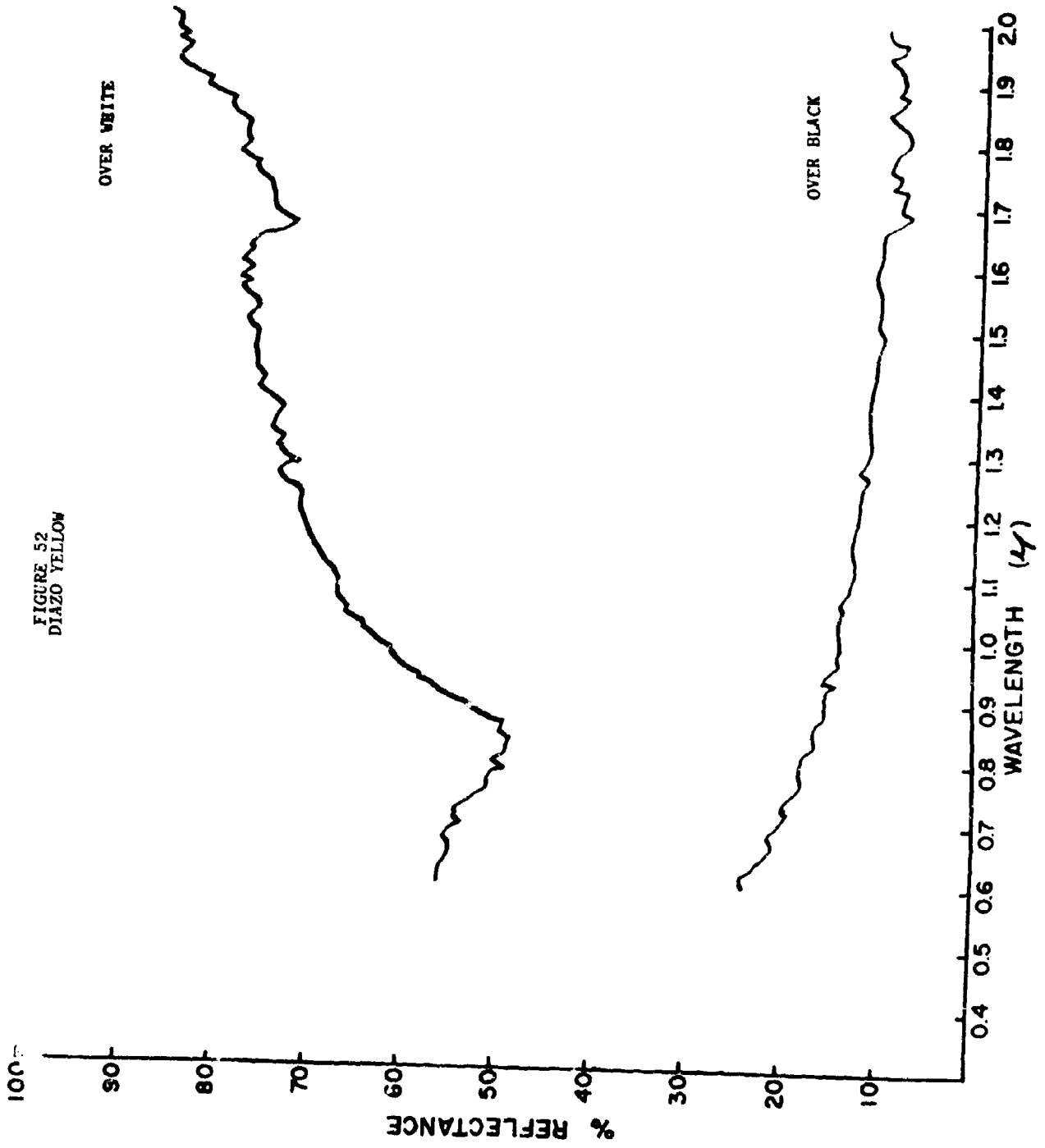


FIGURE 53  
ACETOACETIC ARYLIDE YELLOW

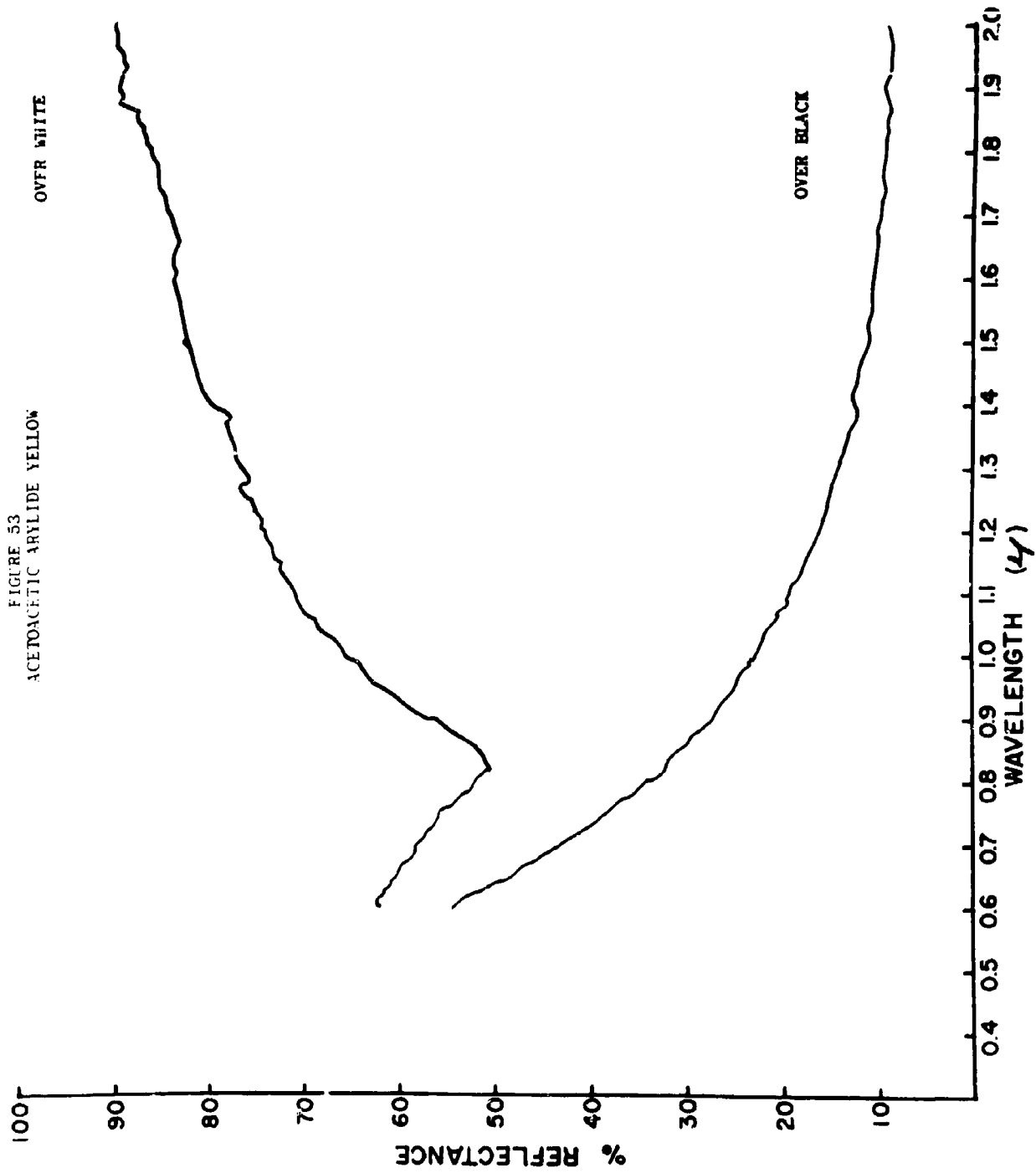


FIGURE 54  
ACETOACETIC ARYLIDE YELLOW

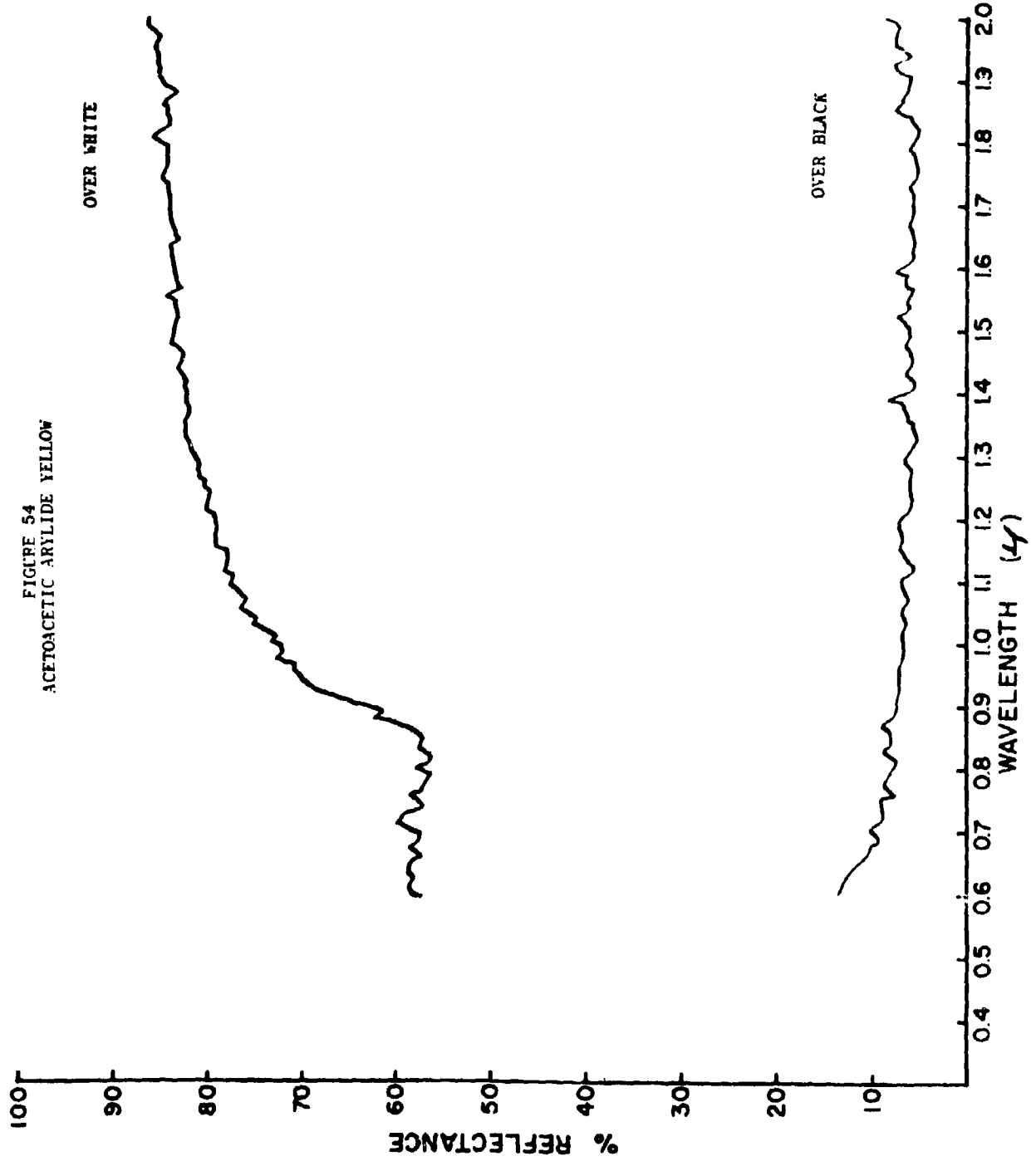


FIGURE 55  
ANTHRAPYRIMIDINE YELLOW

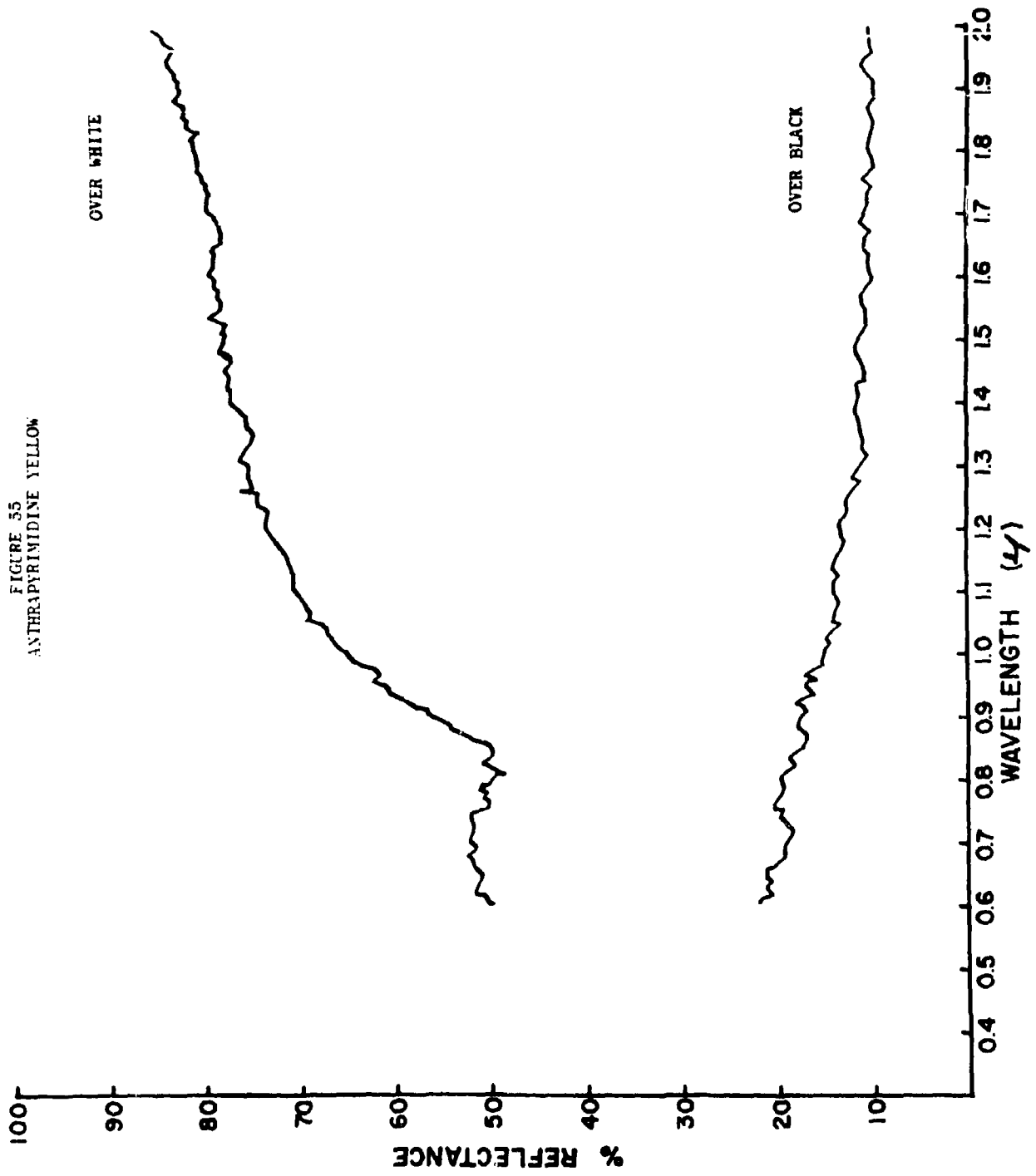




FIGURE 56  
ANTHRAPYRIMIDINE YELLOW

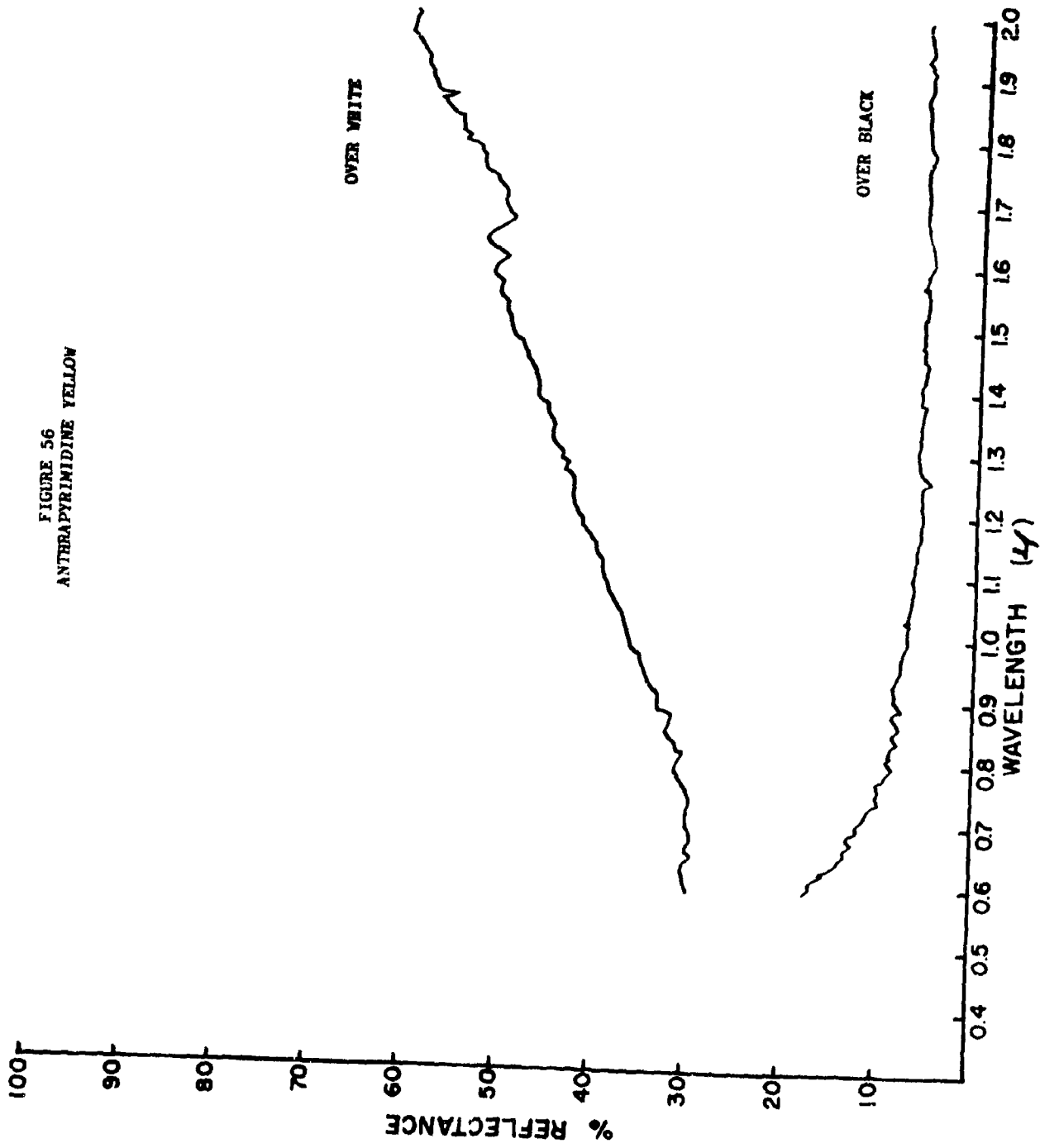


FIGURE 57  
ANTHRAQUINONE YELLOW

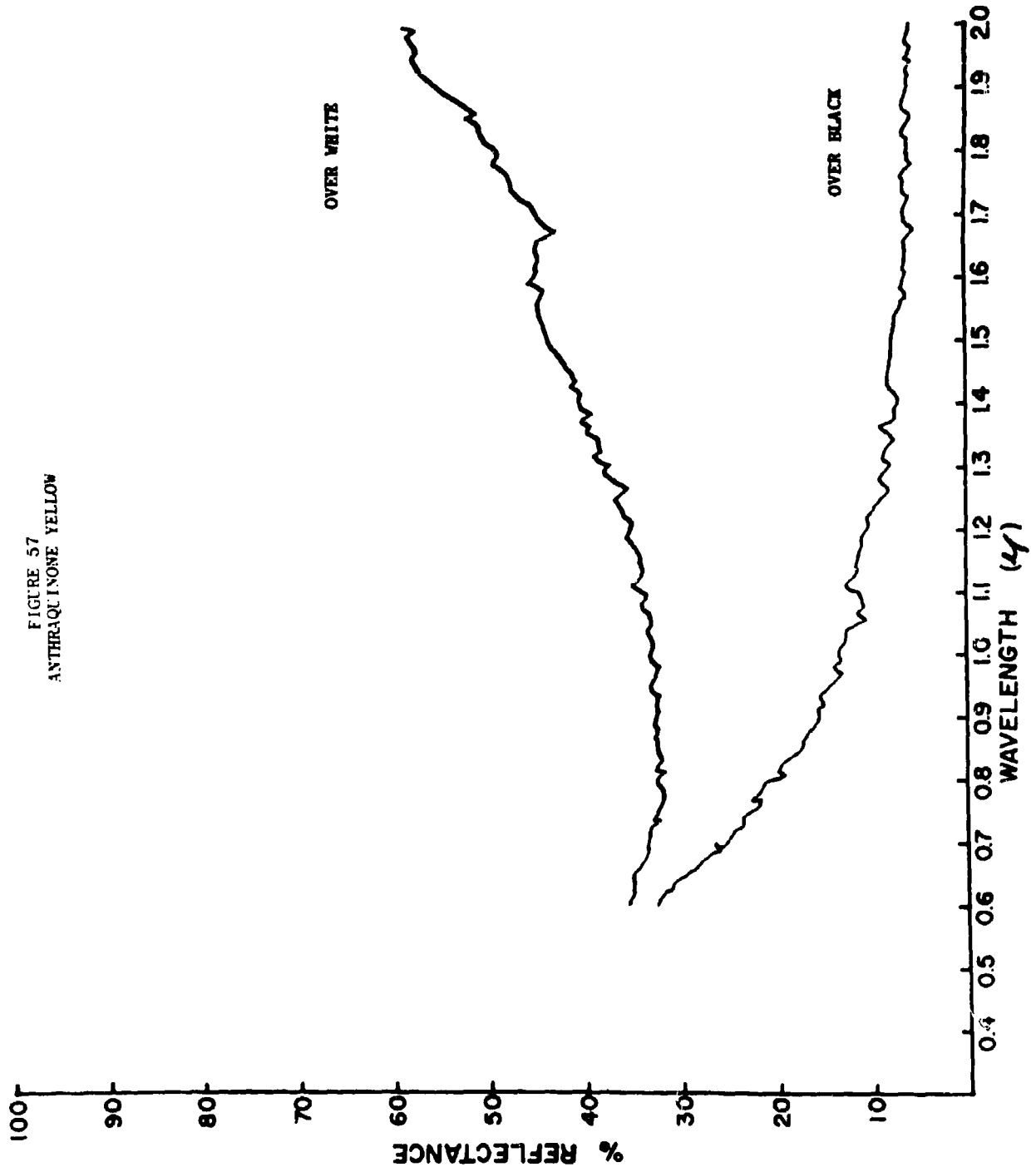


FIGURE 58  
ISOINDOLONE YELLOW

OVER WHITE

OVER BLACK

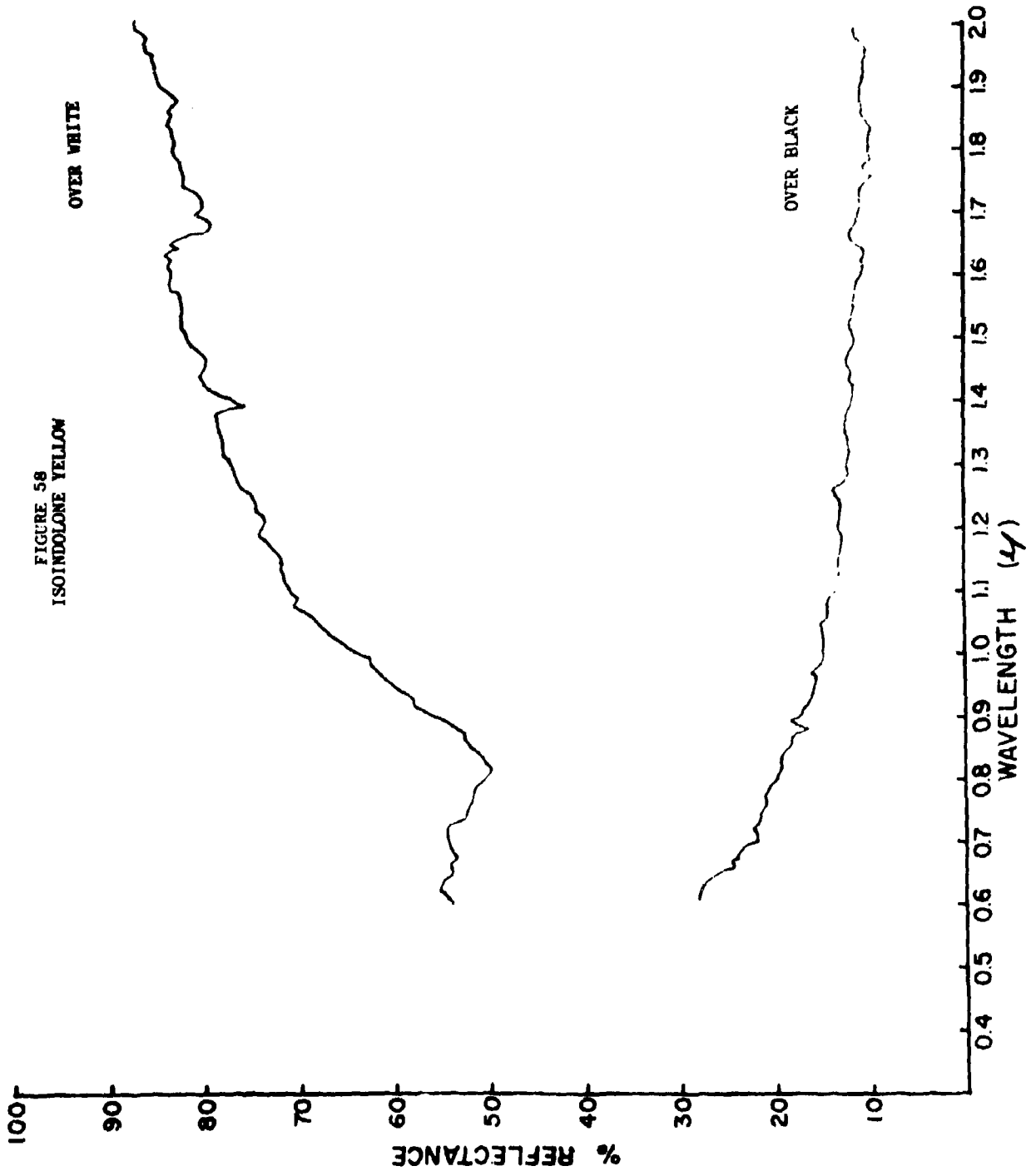


FIGURE 59  
QUINACRIDONE YELLOW

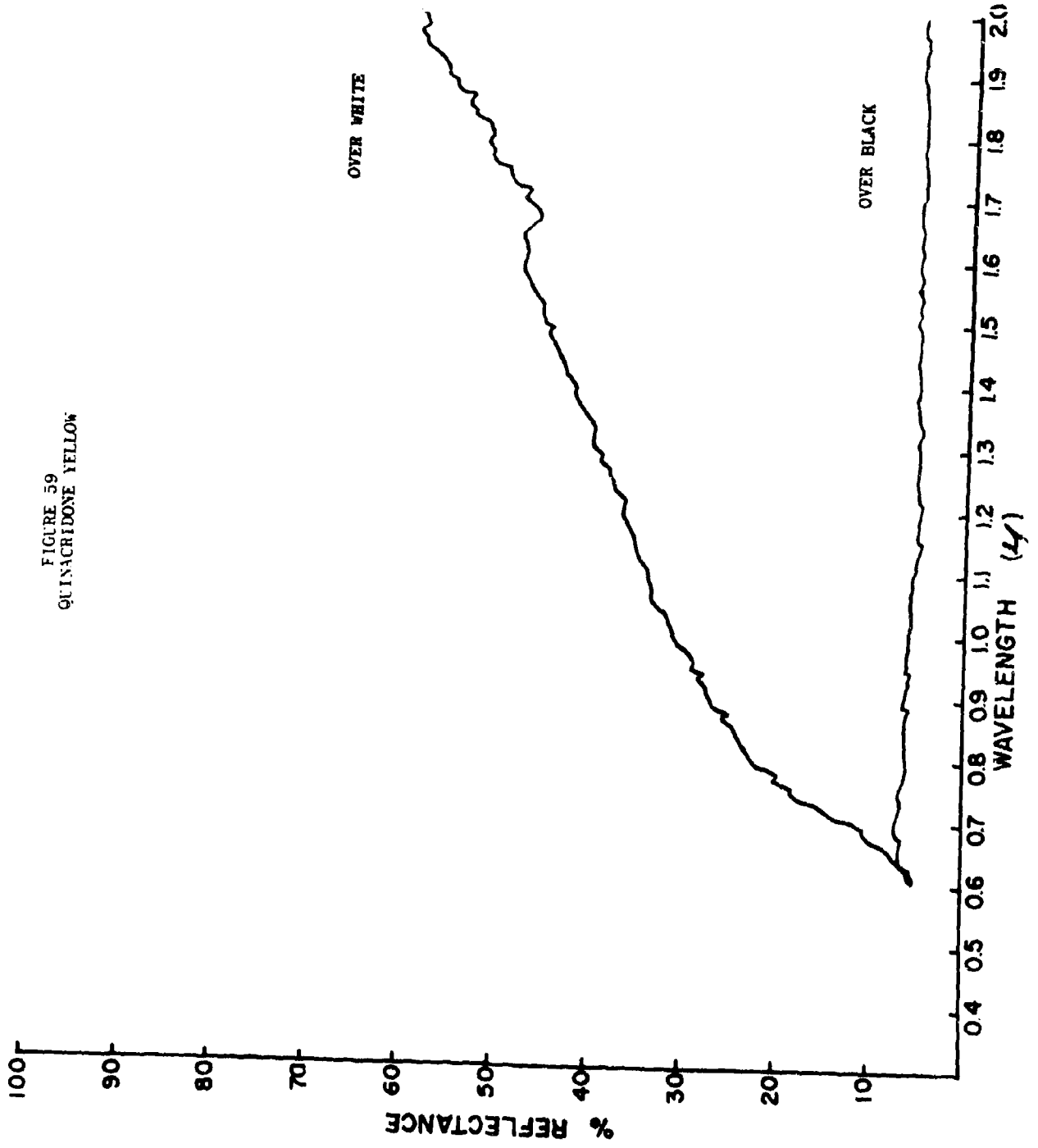


FIGURE 60  
MONOZO GREEN

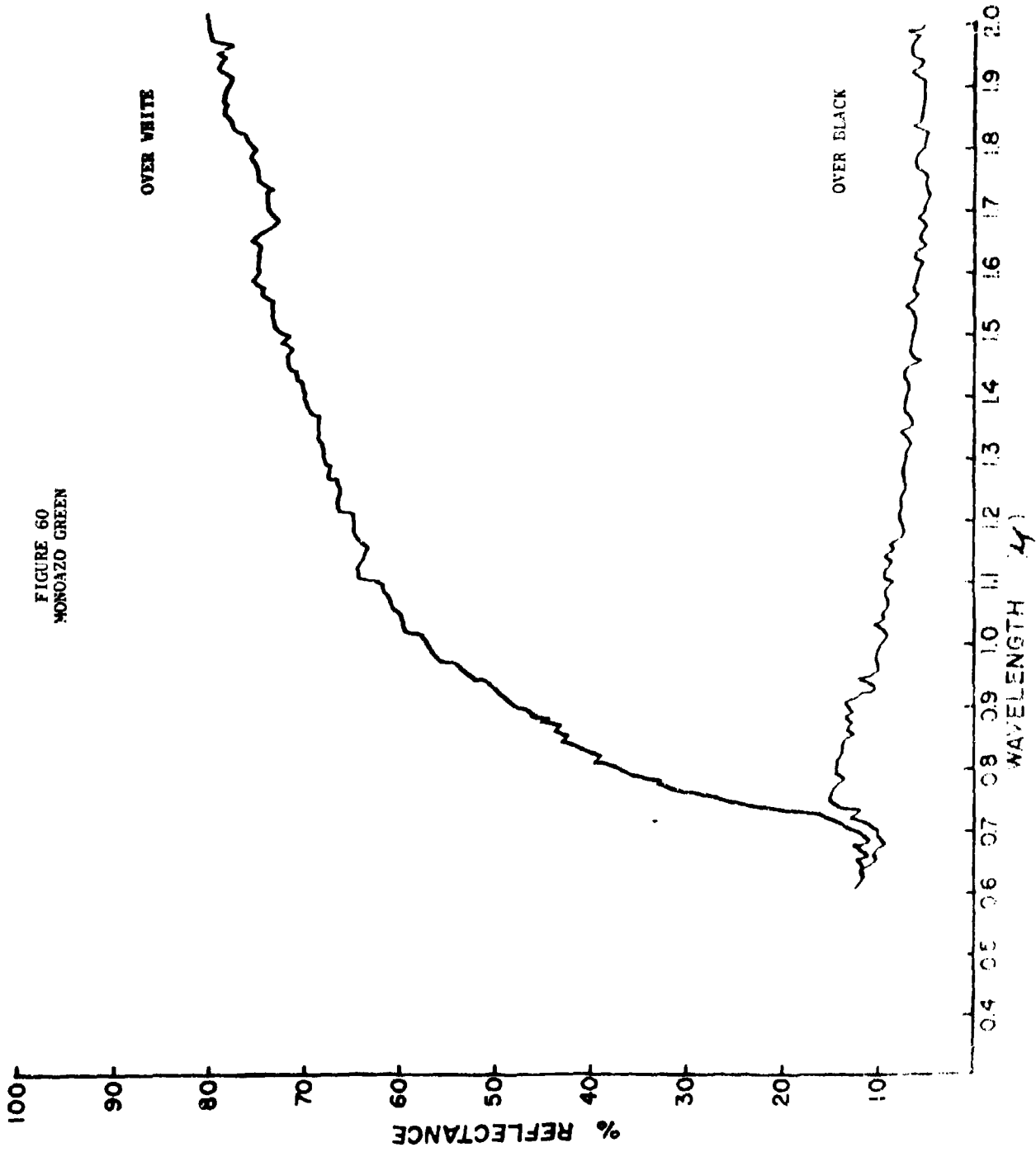


FIGURE 61  
NICKEL AZO GREEN

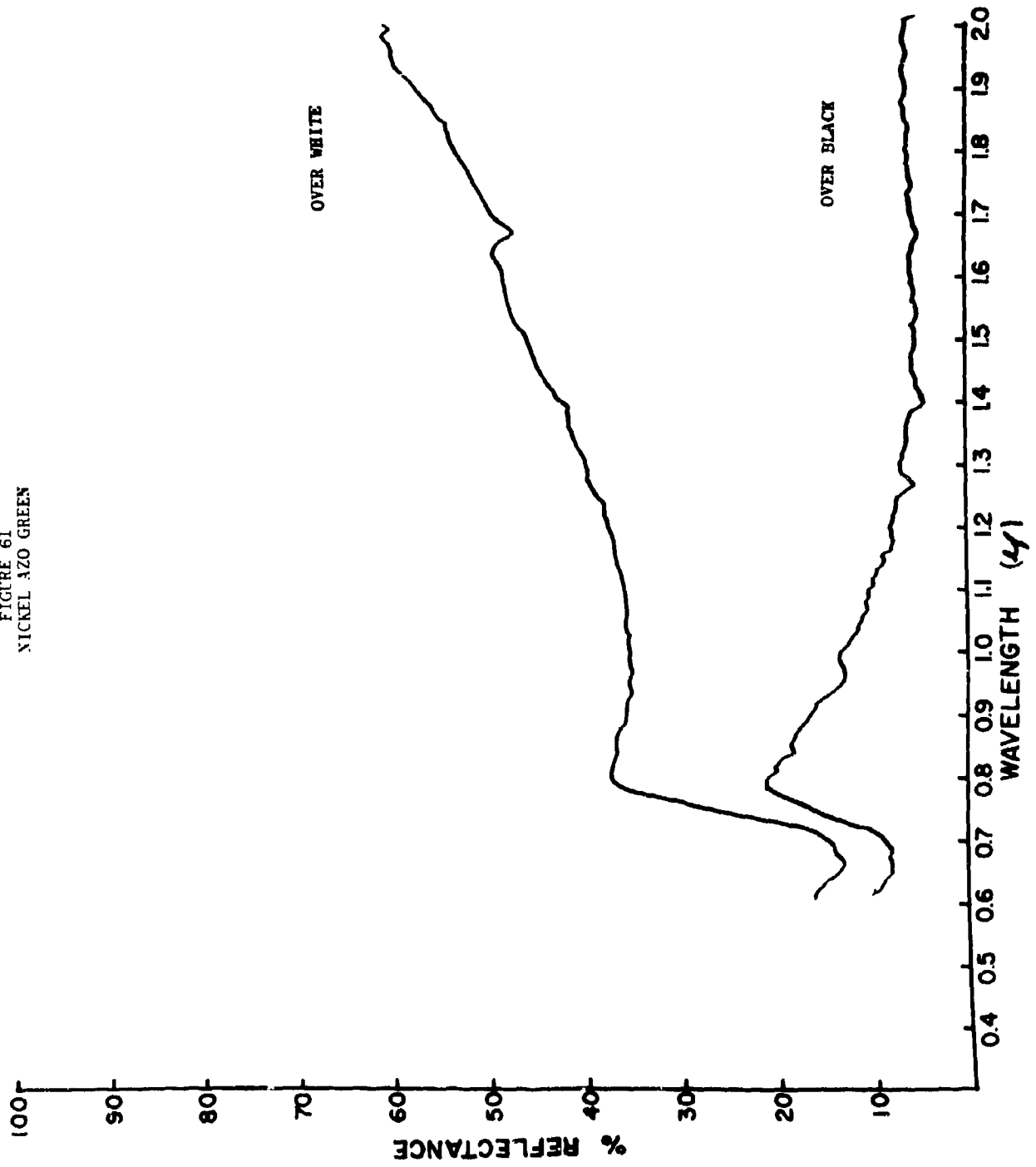


FIGURE 62  
NITROSO BETA NAPHTHOL  
GREEN

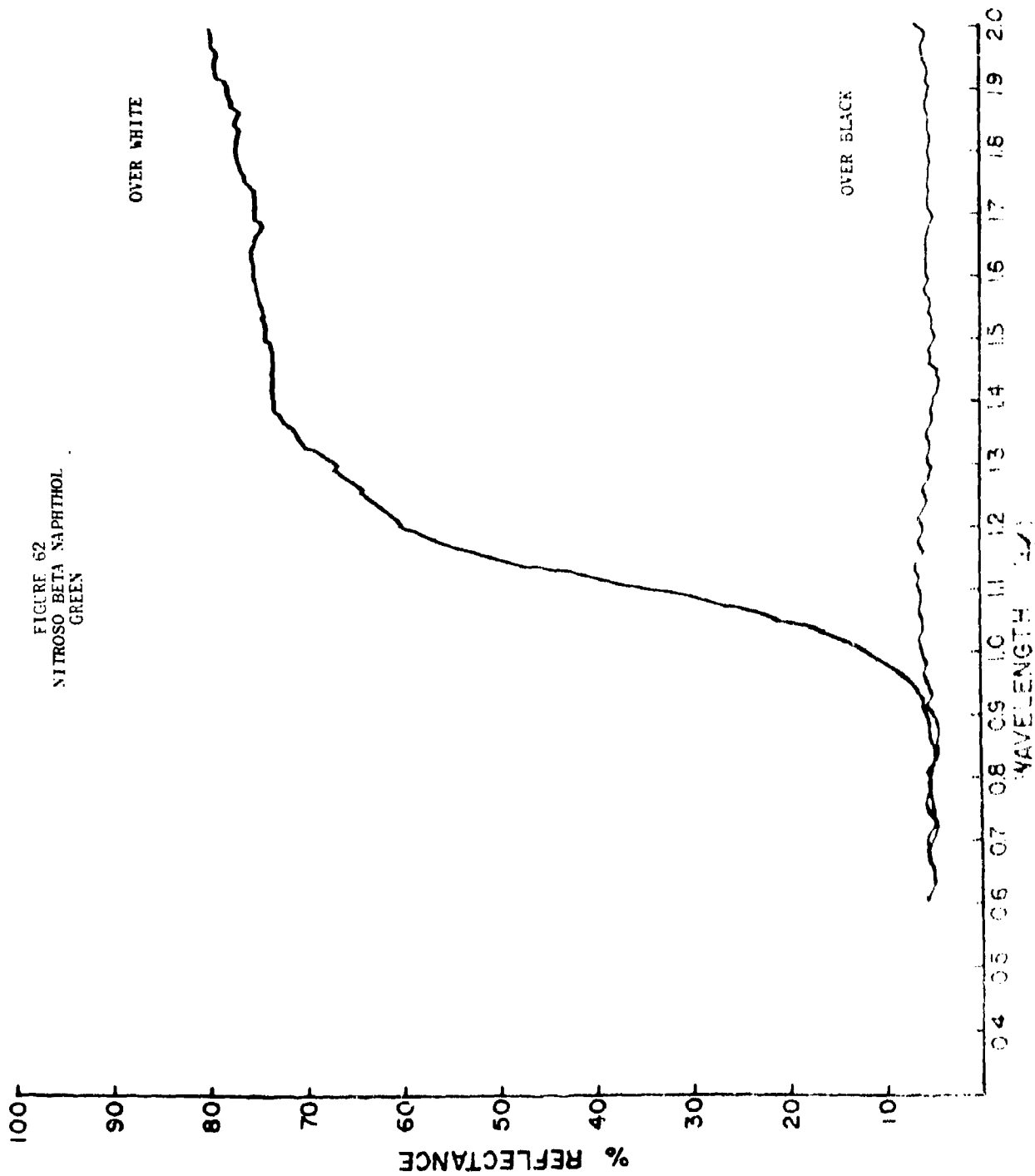


FIGURE 63  
PHOSPHO MOLYBDIC ACID  
GREEN

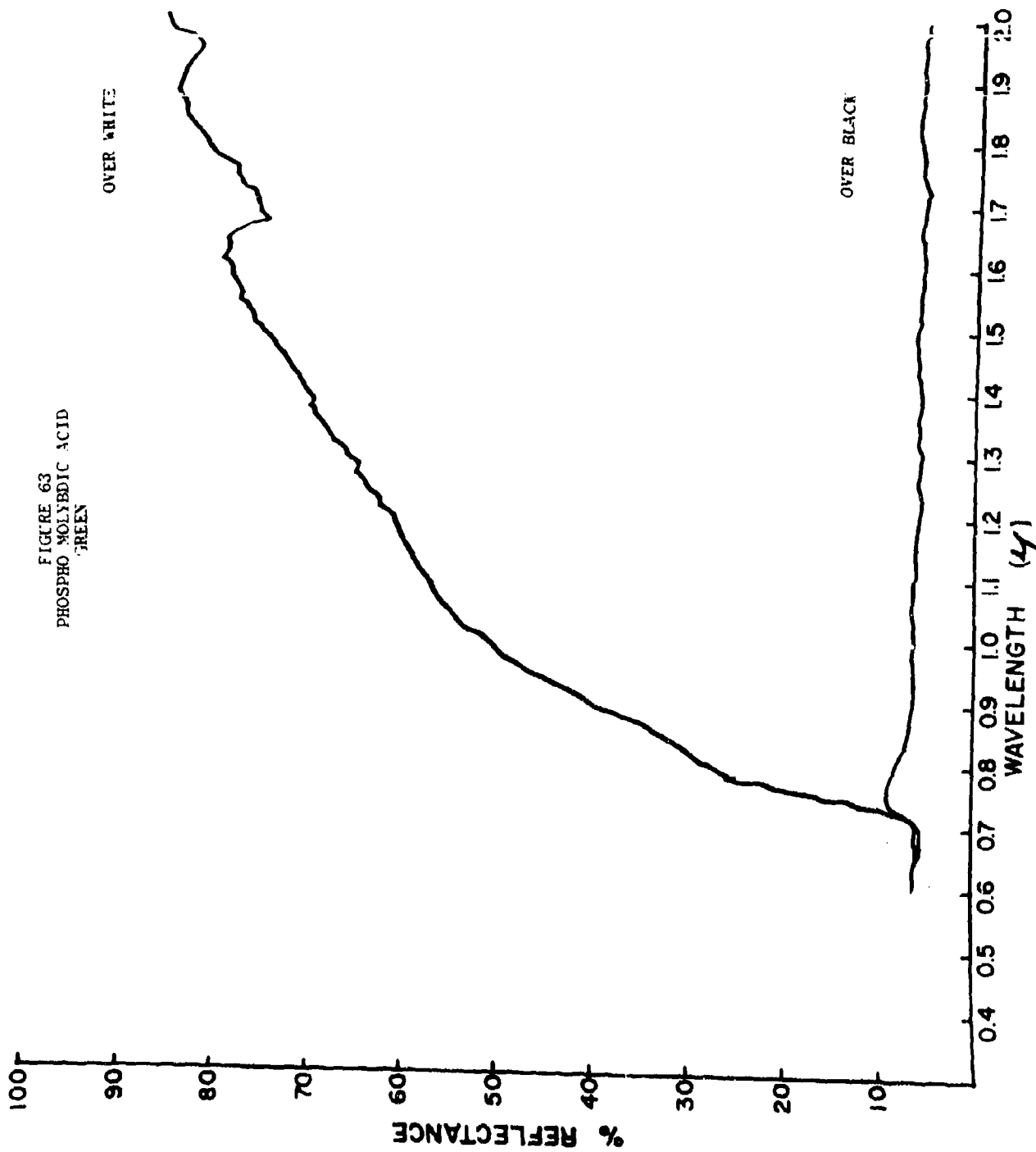




FIG. RE 64  
PHOSPHO TUNGSTIC ACID  
GREEN

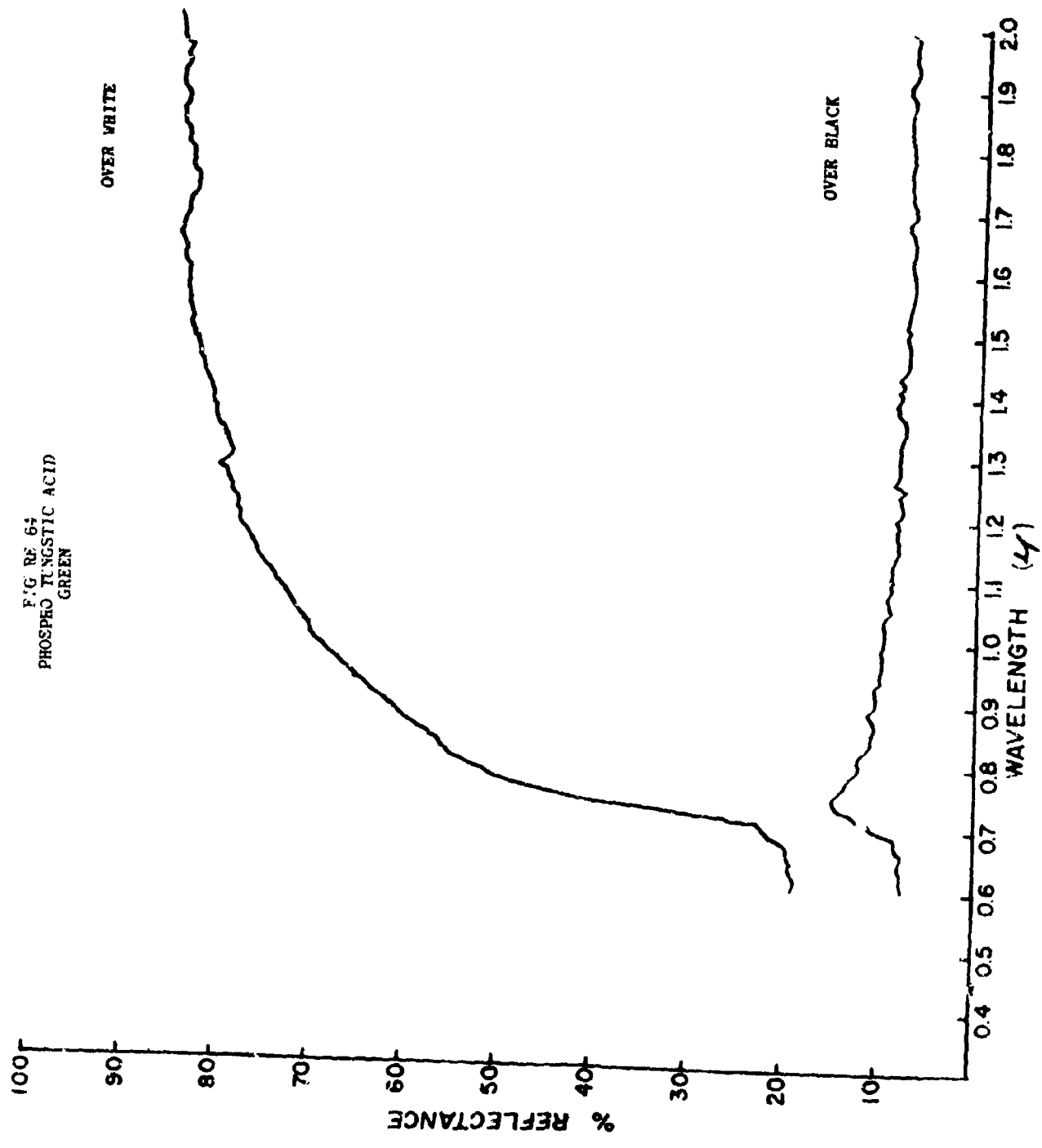


FIGURE 65  
PROSPHO TUNGSTIC ACID  
GREEN

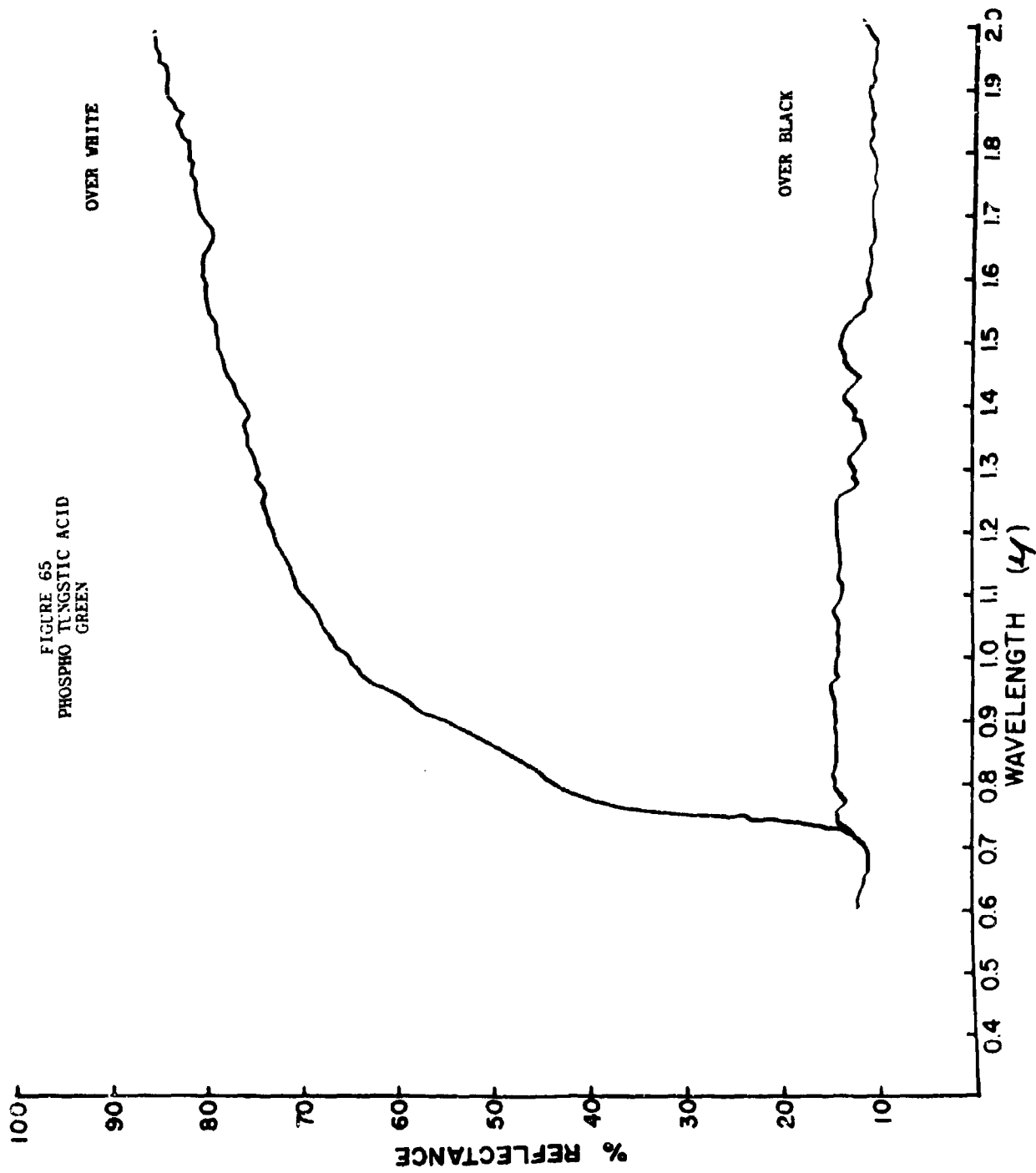


FIGURE 66  
CHLORINATED PHTHALOCYANINE  
GREEN

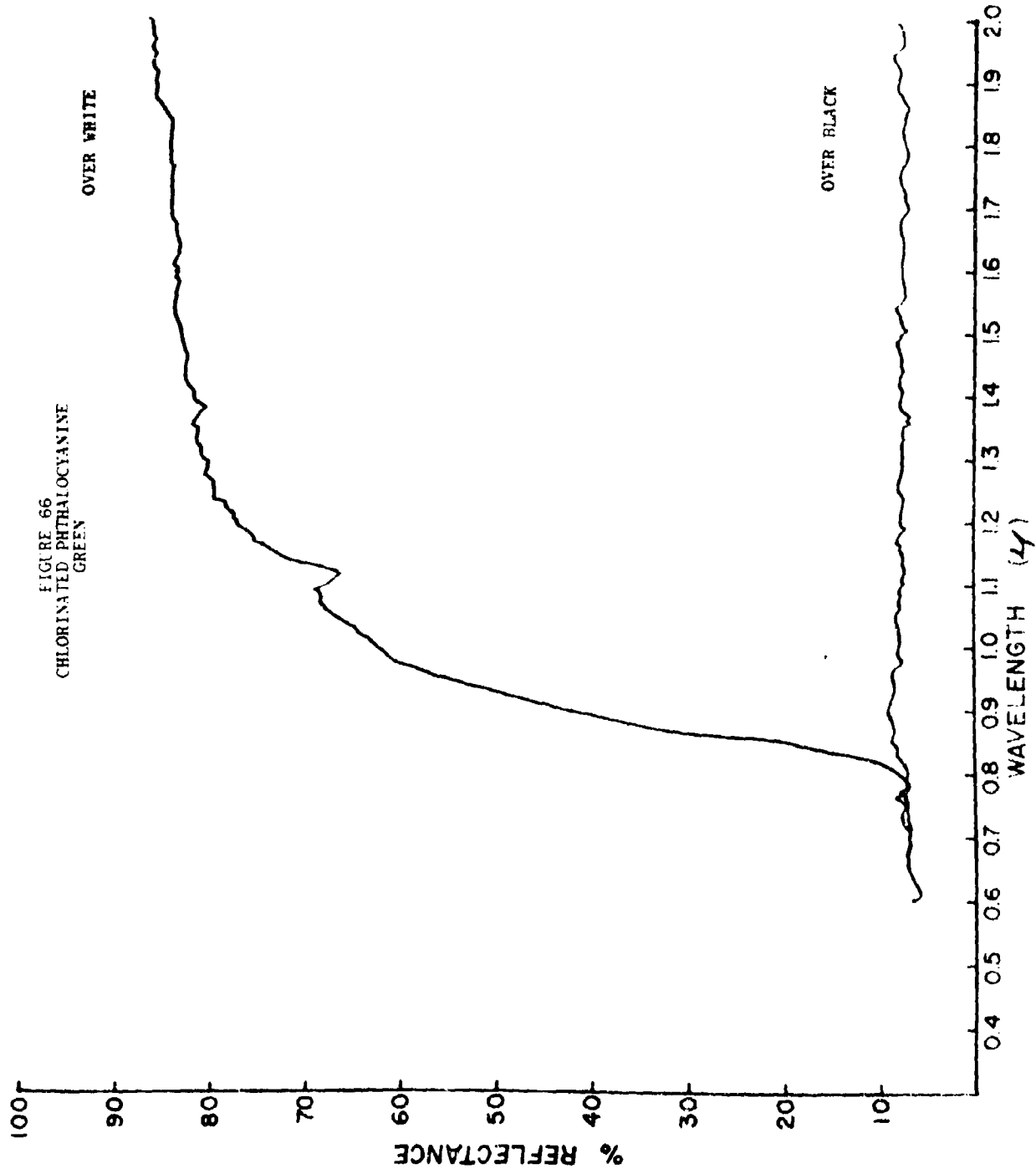


FIGURE 67  
CHLORINATED PHTHALOCYANINE  
GREEN

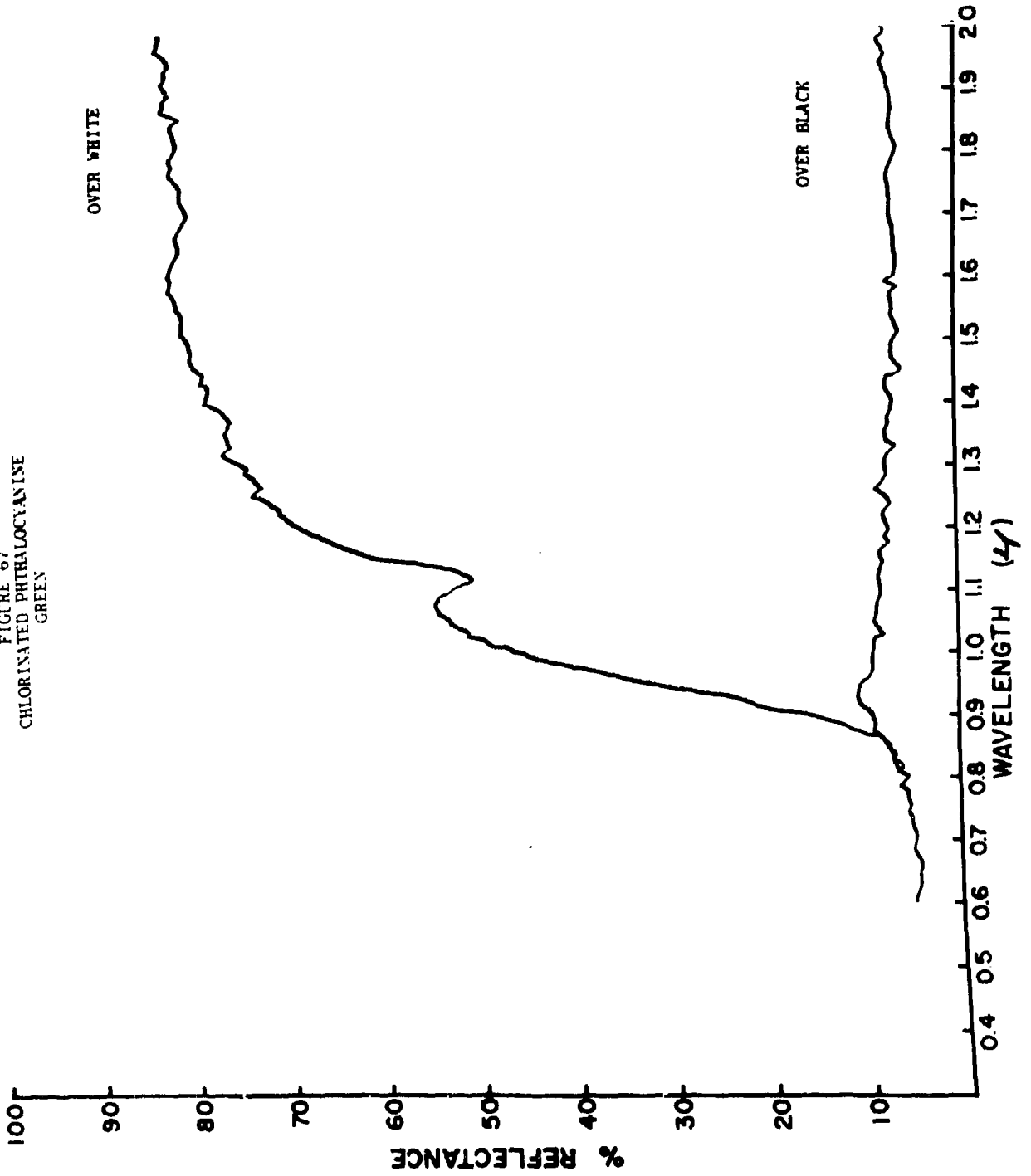
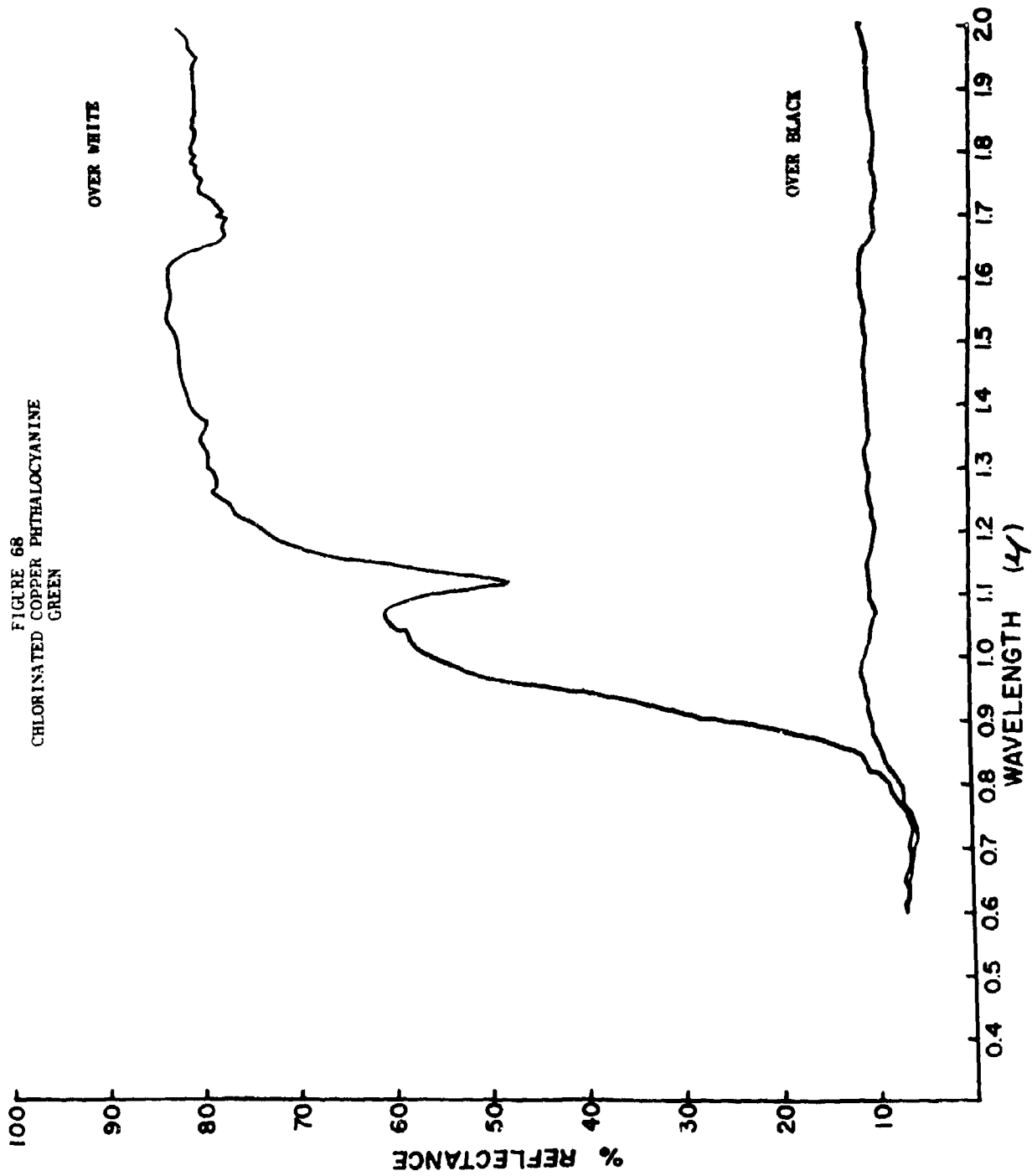


FIGURE 68  
CHLORINATED COPPER PHTHALOCYANINE  
GREEN



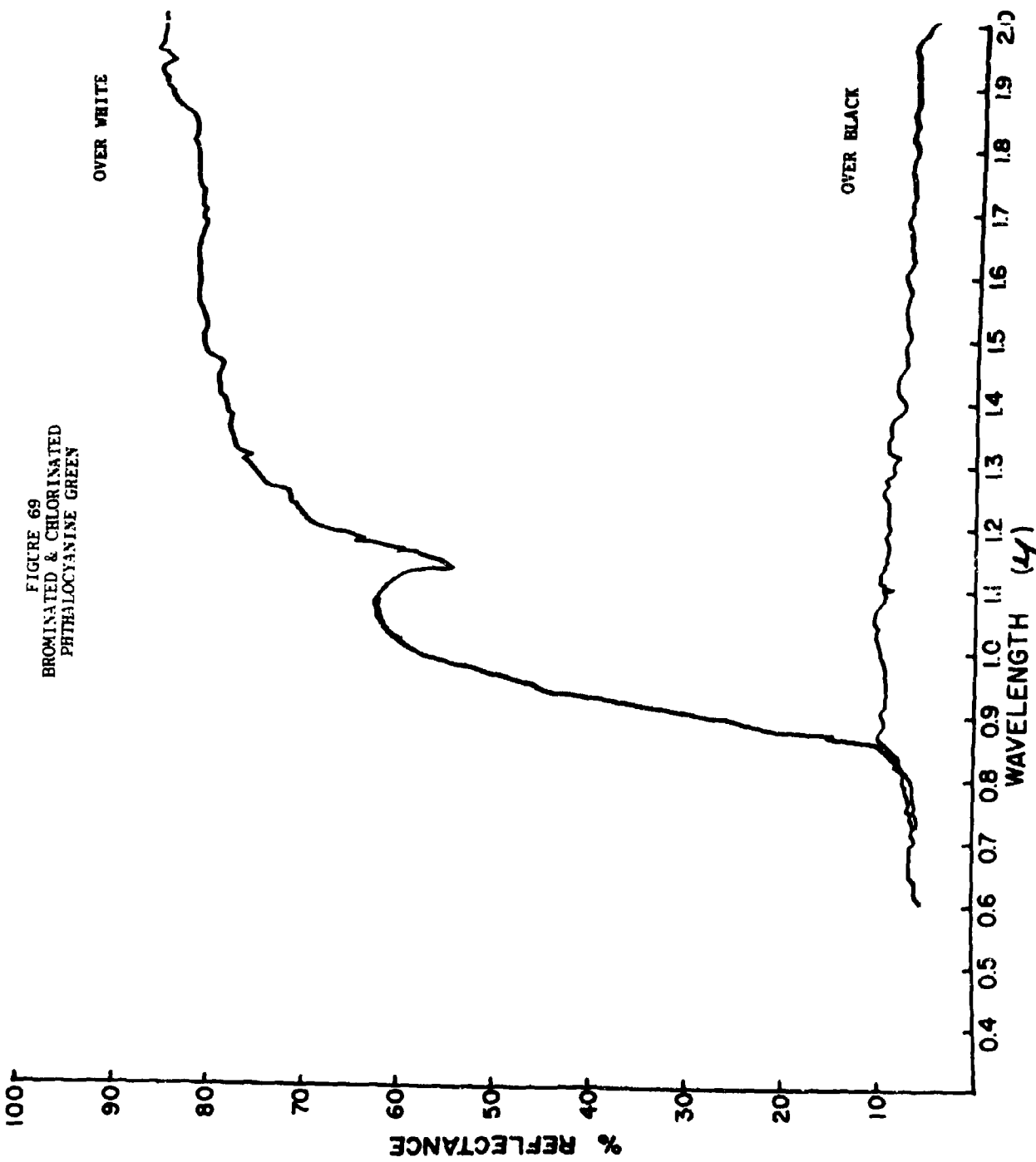


FIGURE 69  
BROMINATED & CHLORINATED  
PHthalOCYANINE GREEN

FIGURE 70  
BROMINATED & CHLORINATED  
PHTHALOCYANINE GREEN

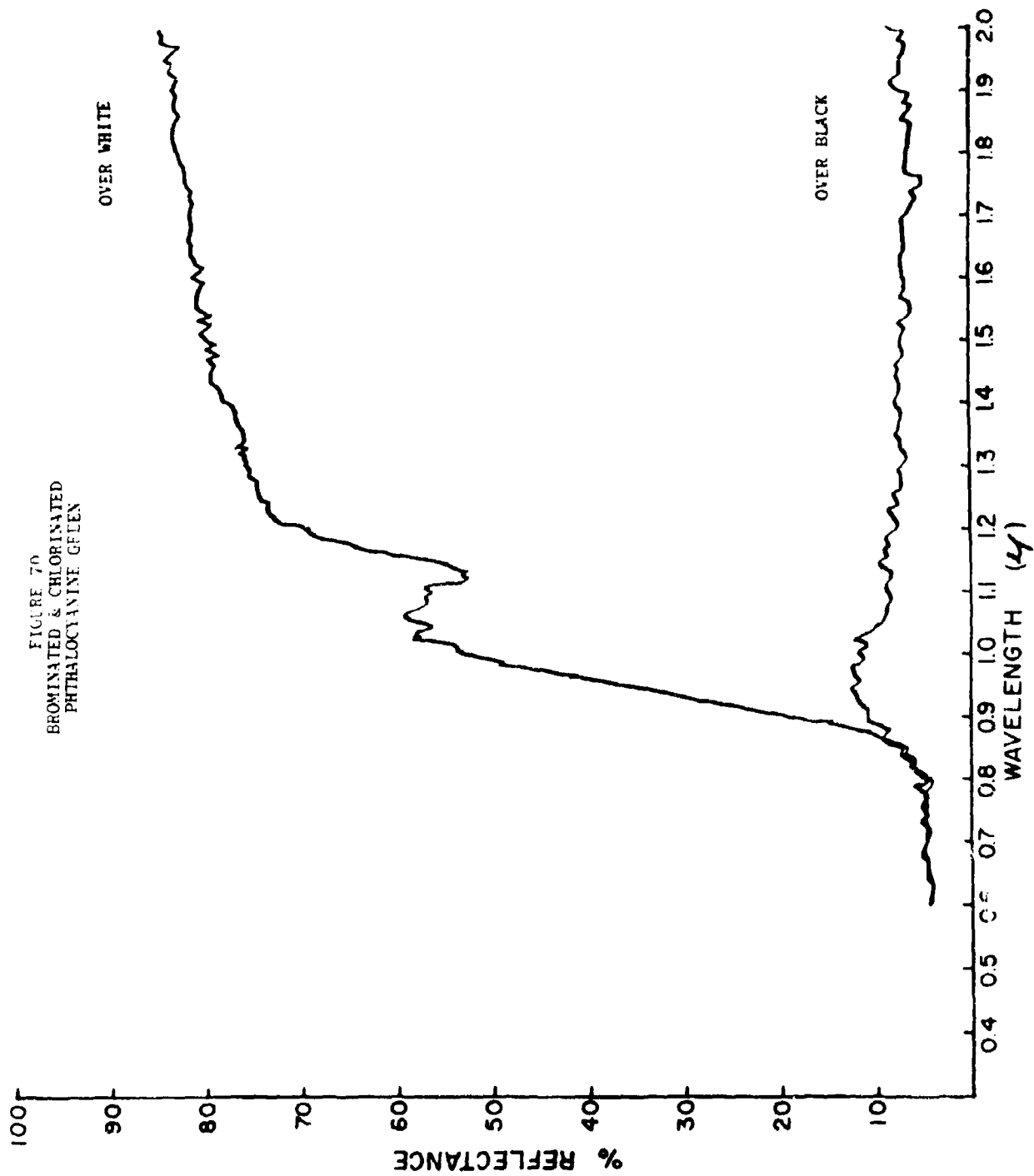


FIGURE 71  
ANTHRAQUINONE BLUE

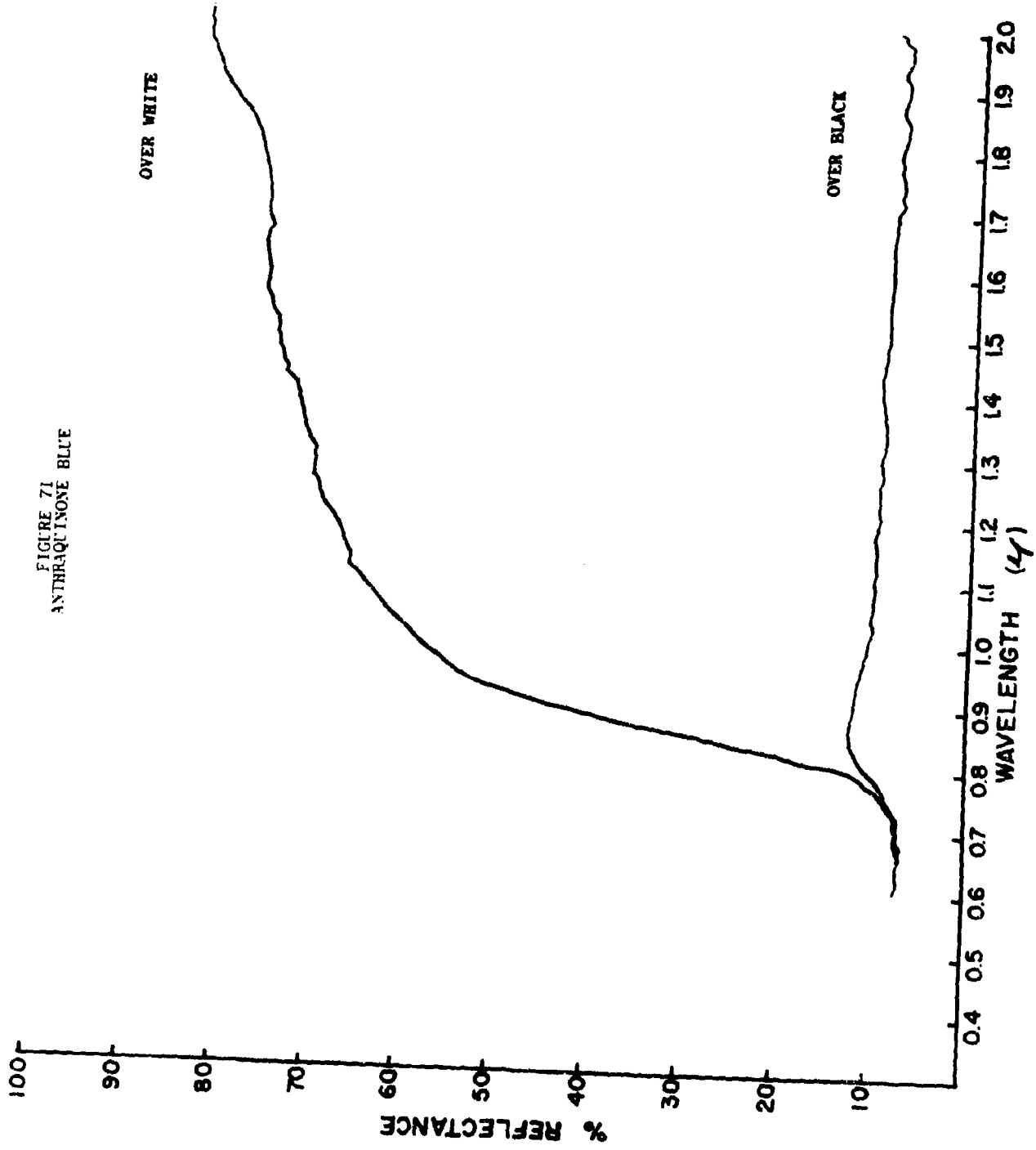




FIGURE 72  
DIAZO BLUE

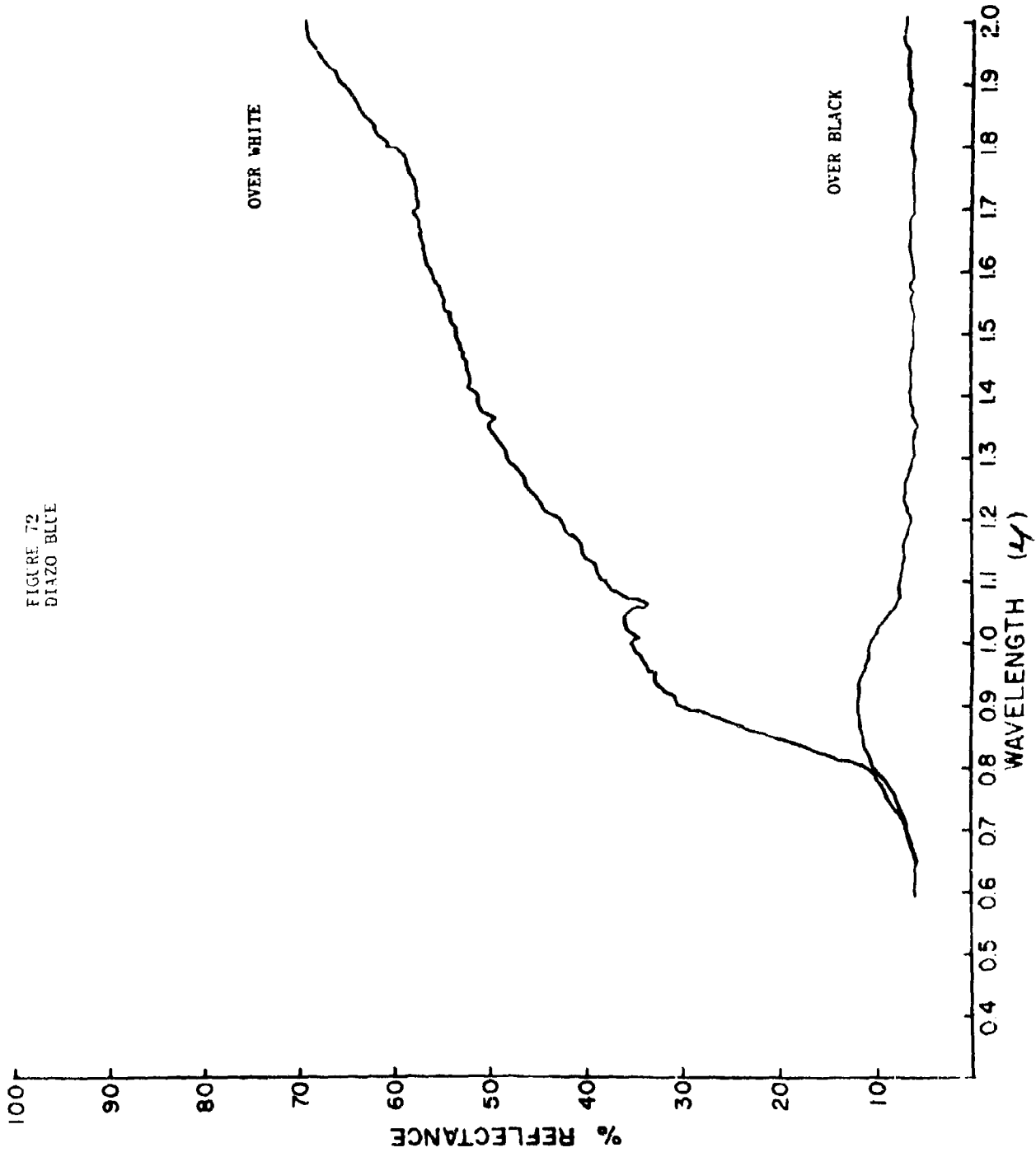


FIGURE 73  
INDANTHROSE BLUE

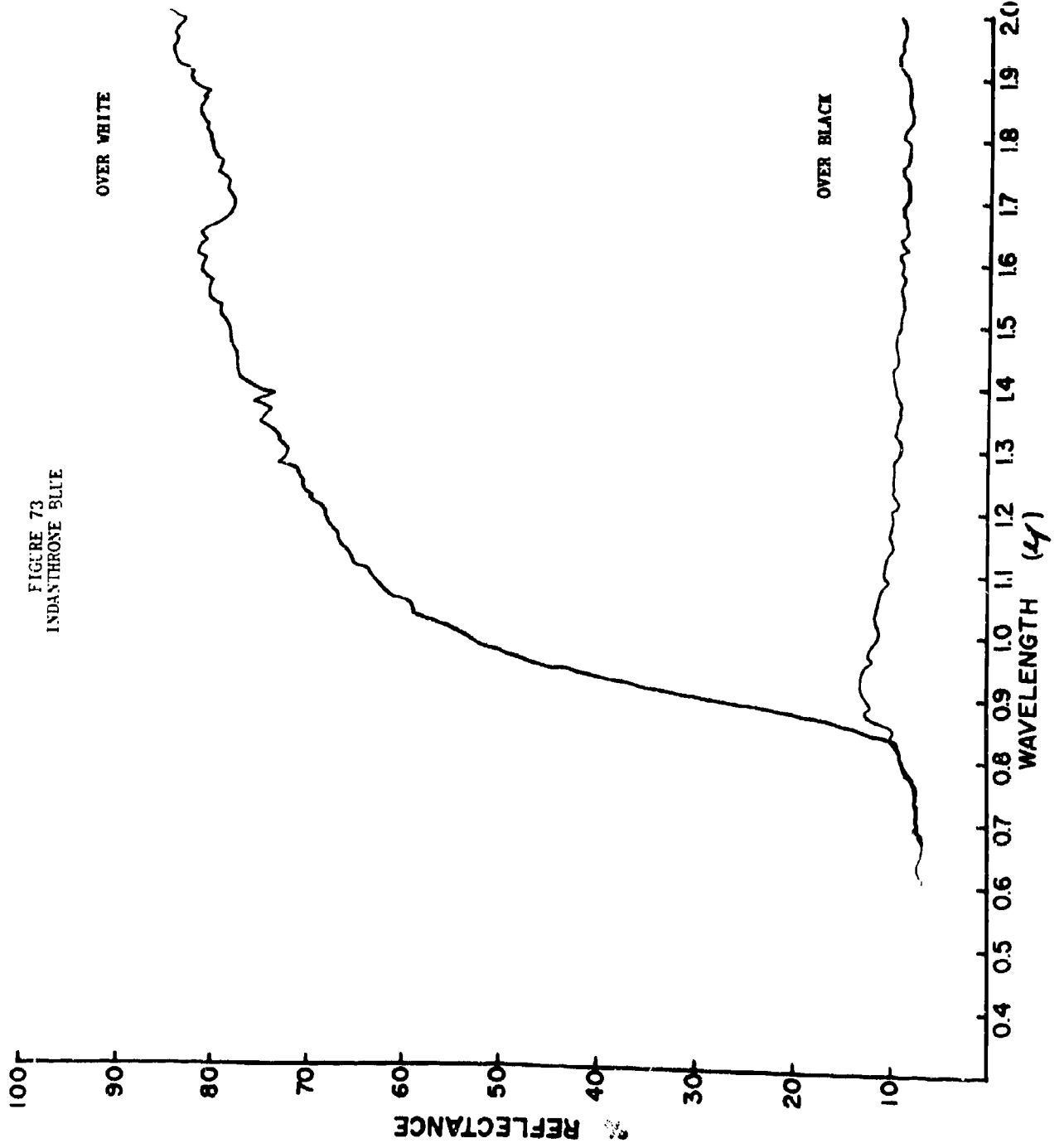
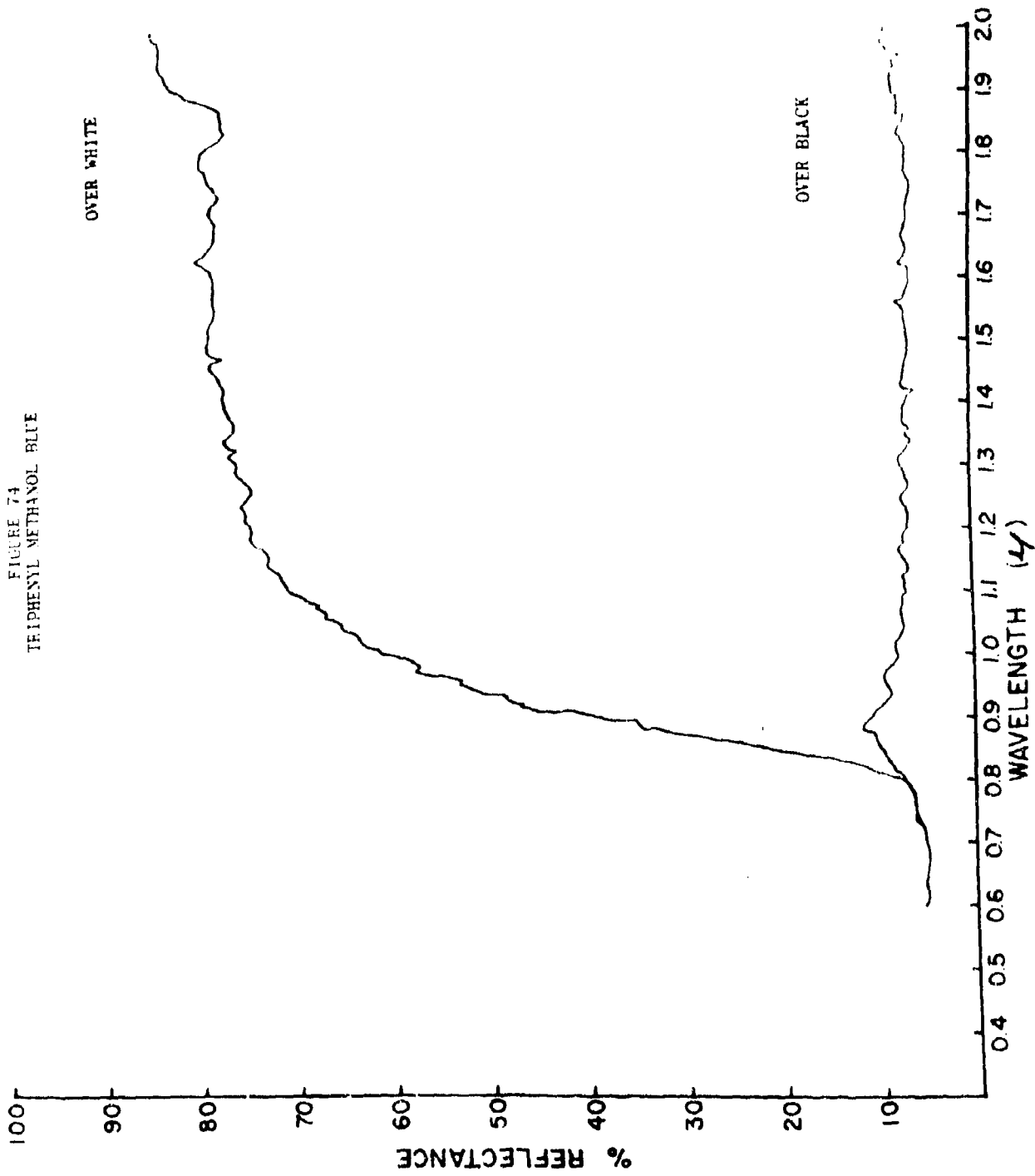


FIGURE 74  
TRIPHENYL METHANOL BLUE



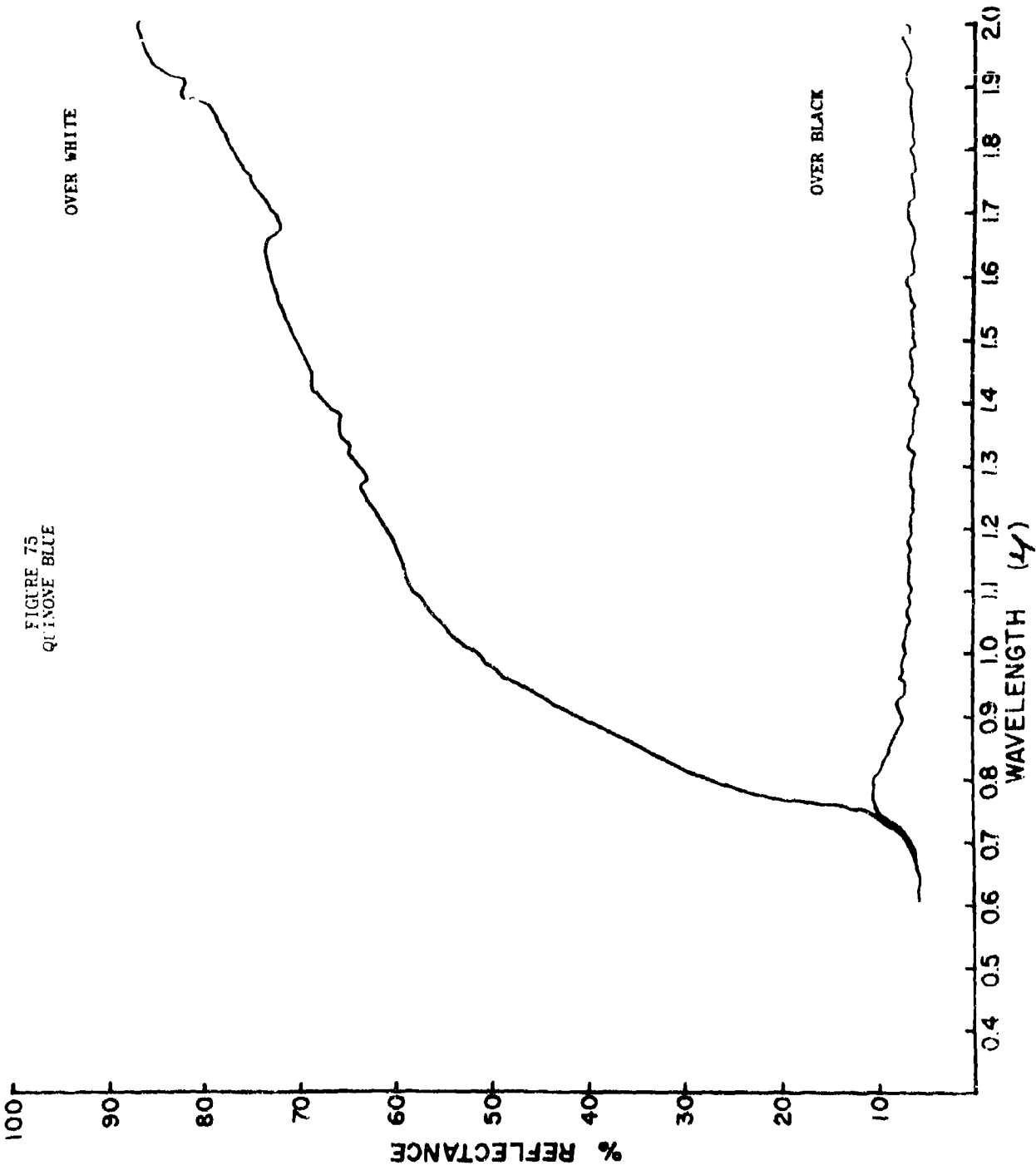


FIGURE 75  
QUINONE BLUE

OVER WHITE

OVER BLACK

FIGURE 76  
PHOSPHO TUNGSTIC ACID BLUE

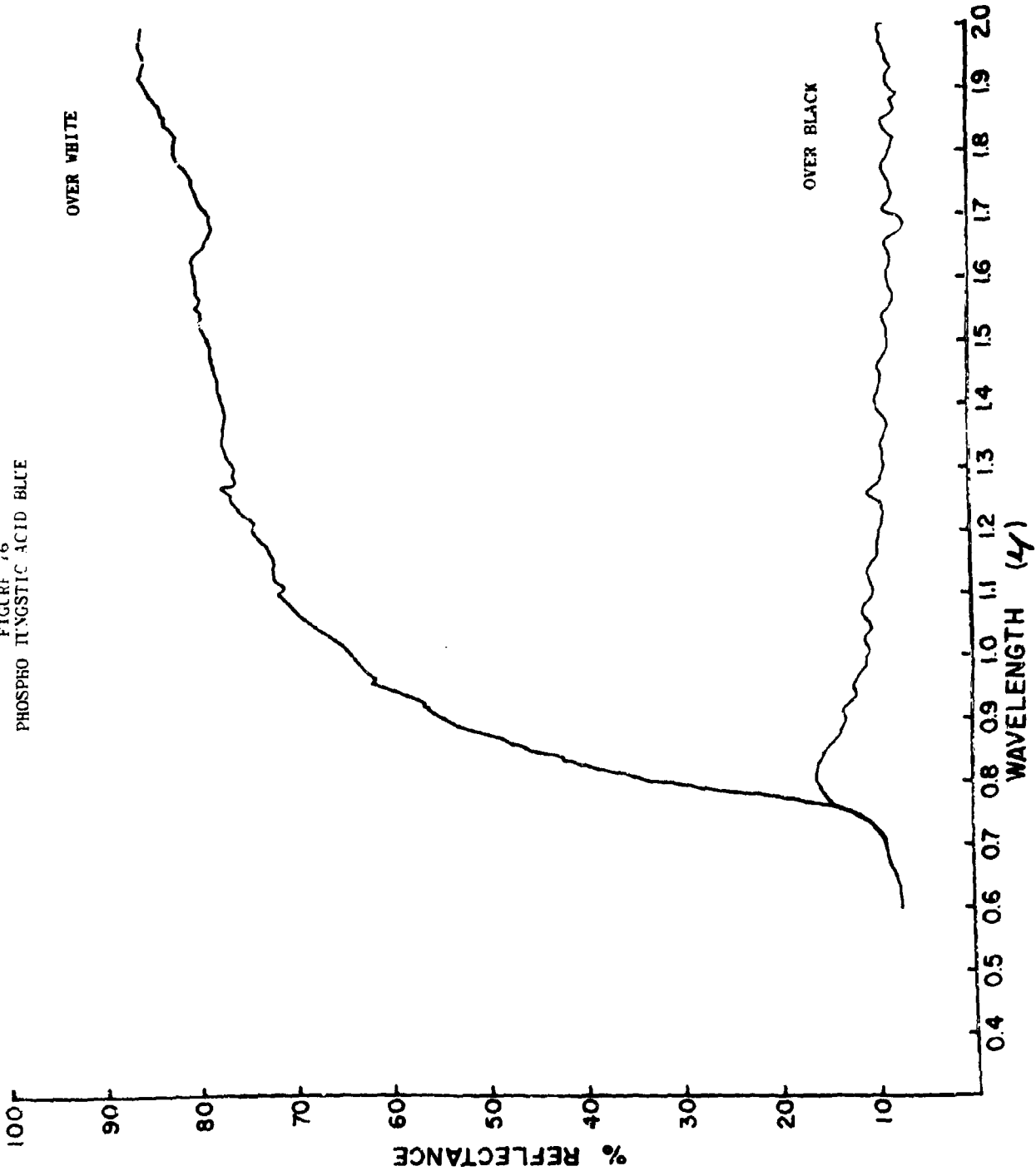


FIGURE 77  
METAL FREE PHTHALOCYANINE  
BLUE

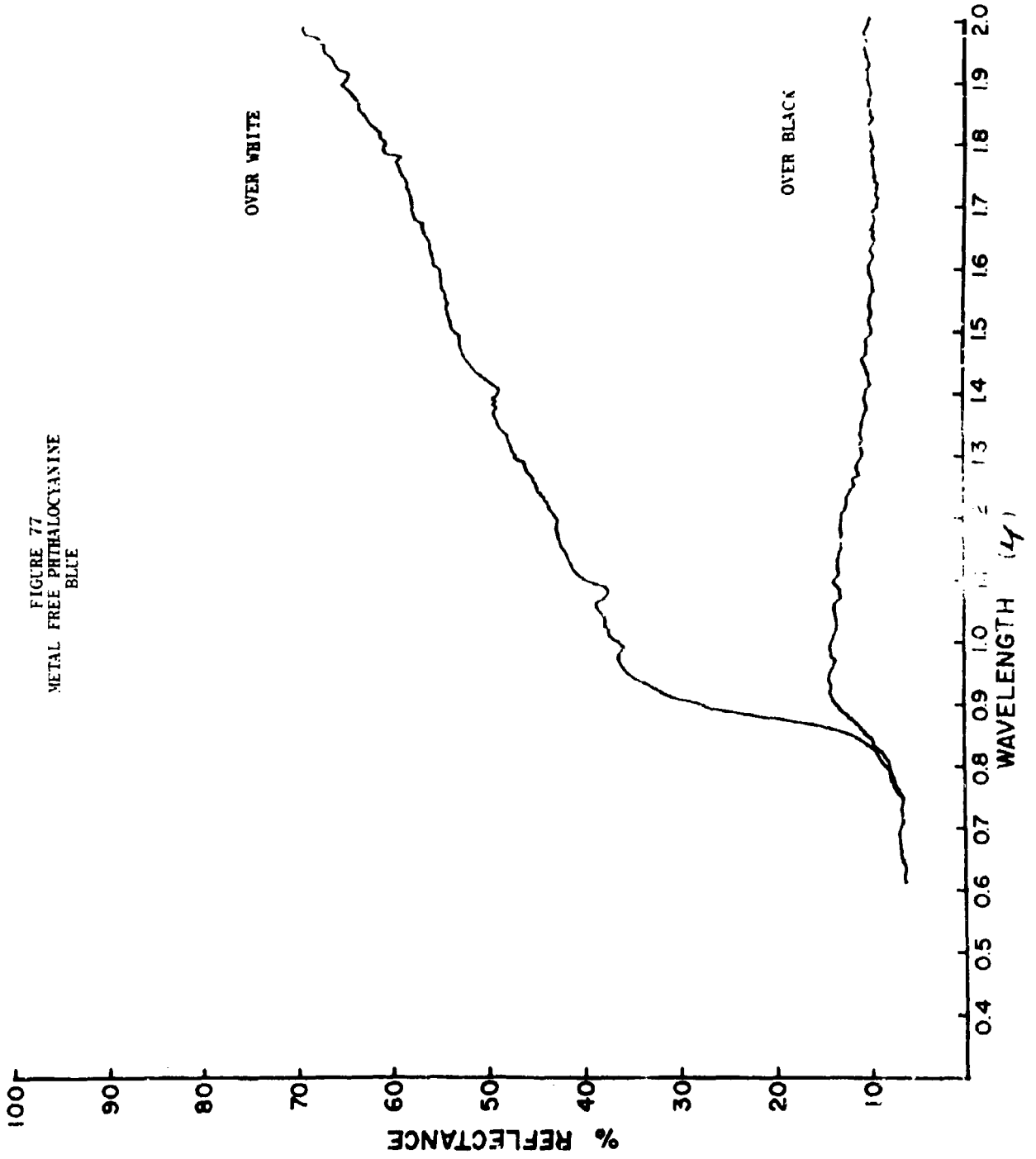


FIGURE 78  
COPPER PHTHALOCYANINE  
BLUE

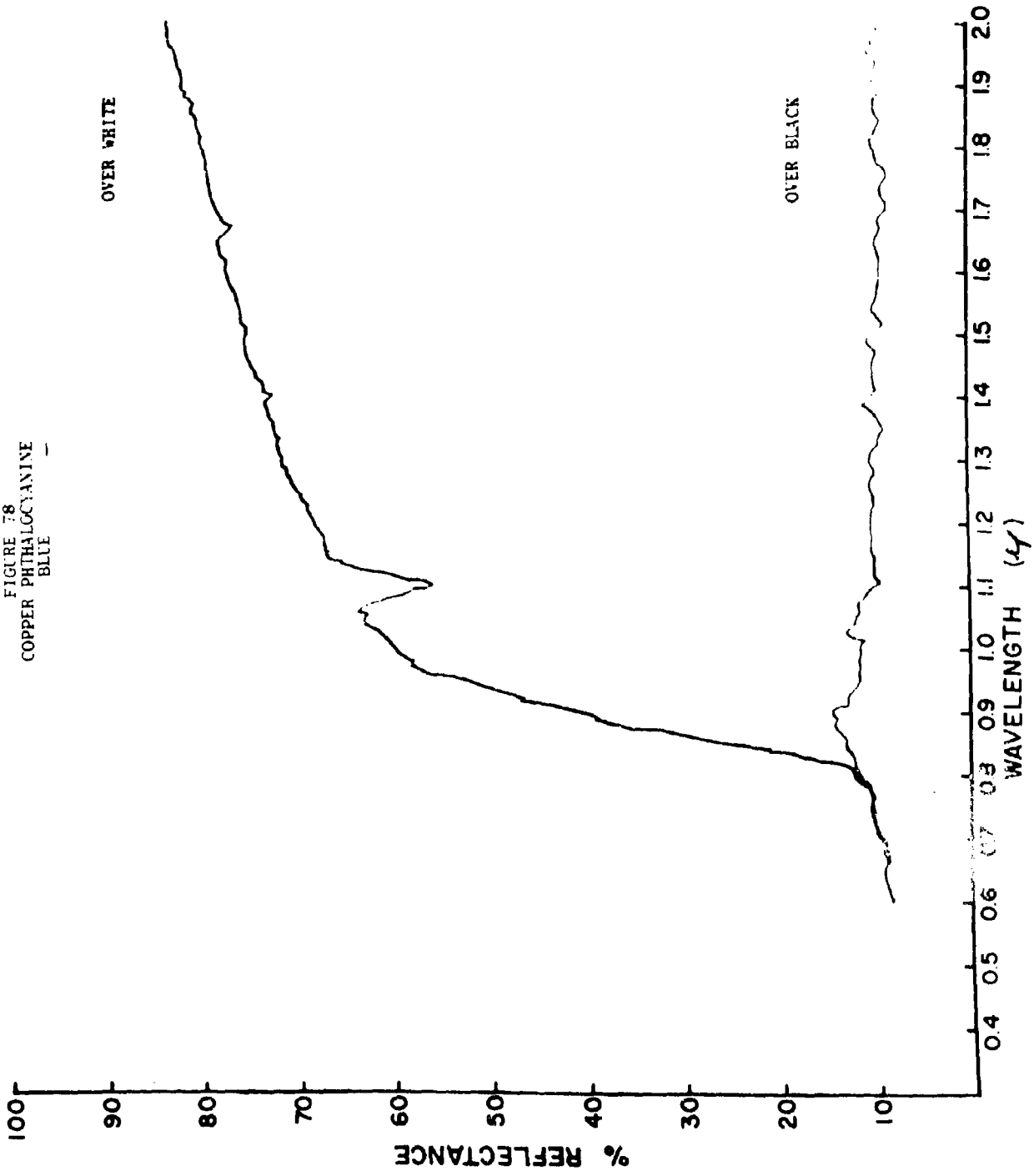


FIGURE 79  
COPPER PHTHALOCYANINE  
BLUE

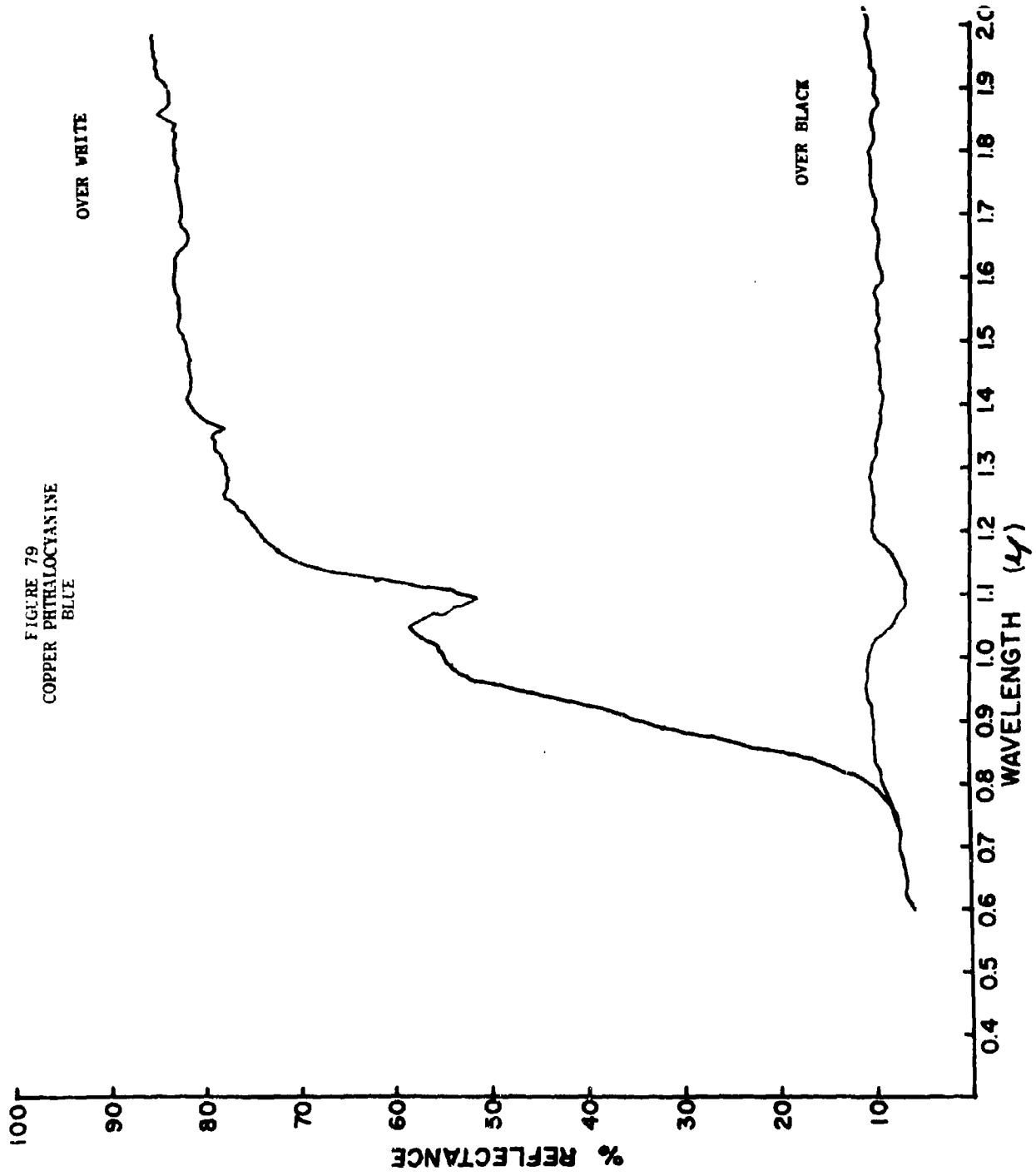




FIGURE 80  
COPPER PHTHALOCYANINE  
BLUE

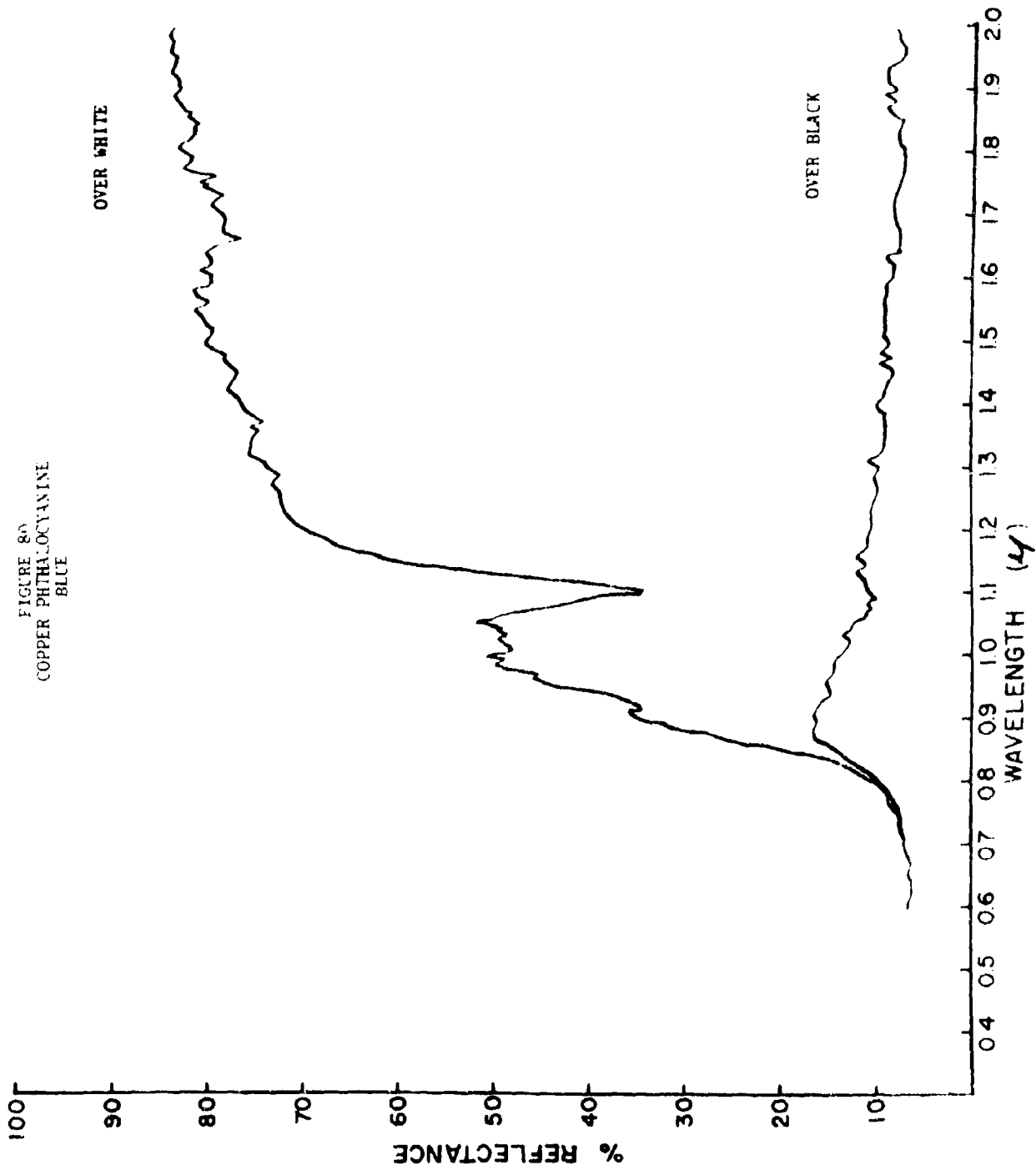
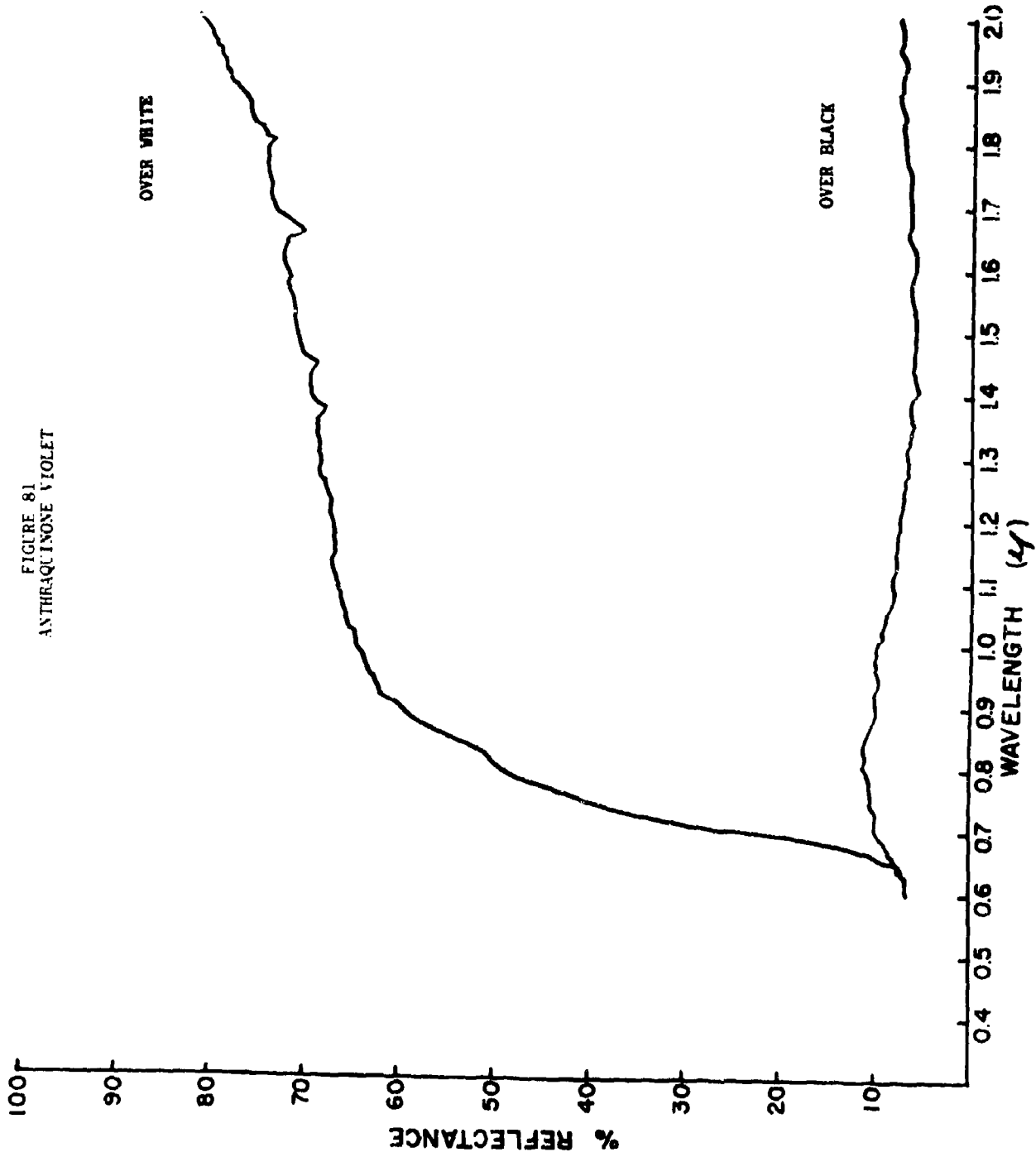


FIGURE 81  
ANTHRAQUINONE VIOLET



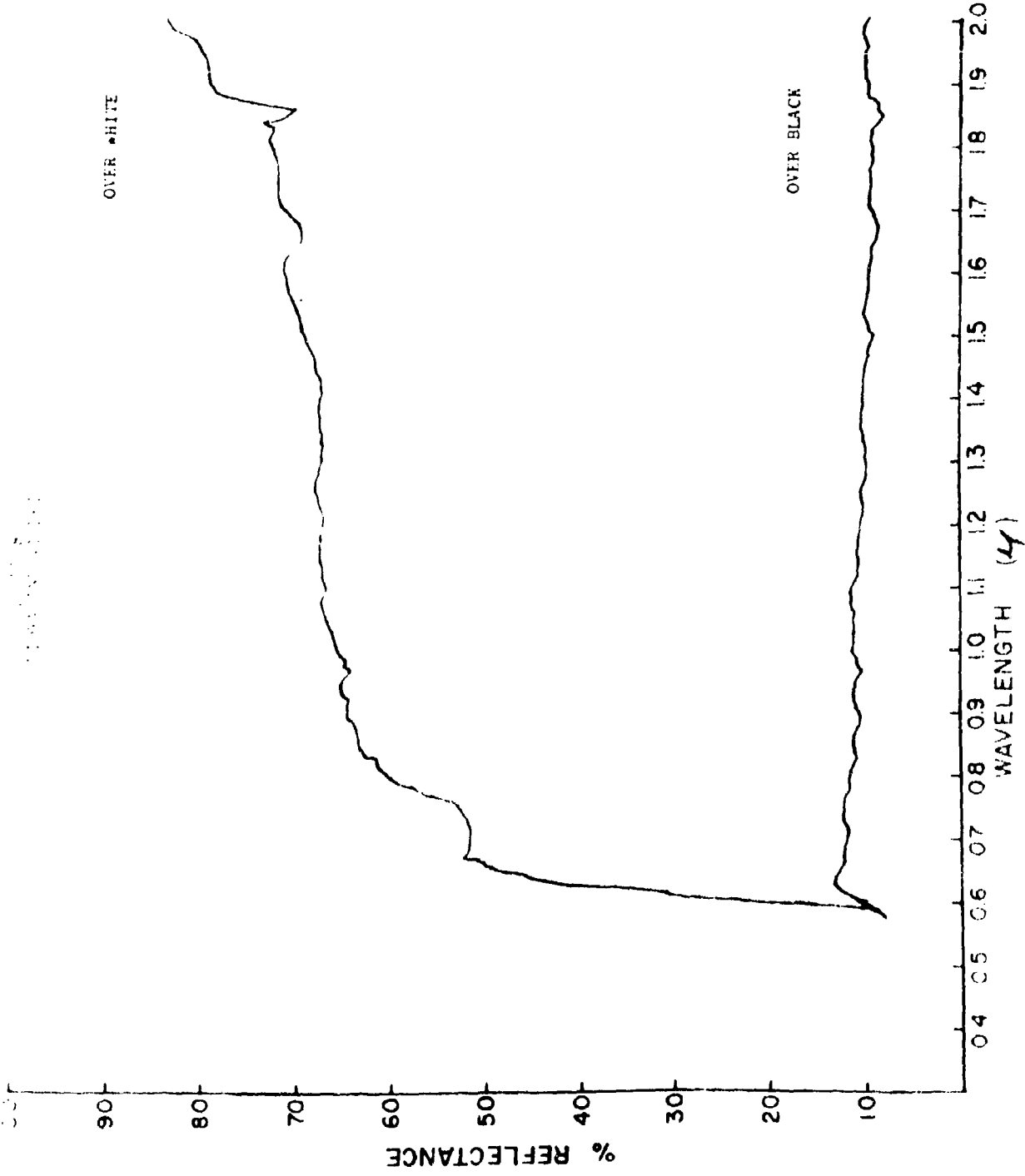


FIGURE 83  
DIONAZINE VIOLET

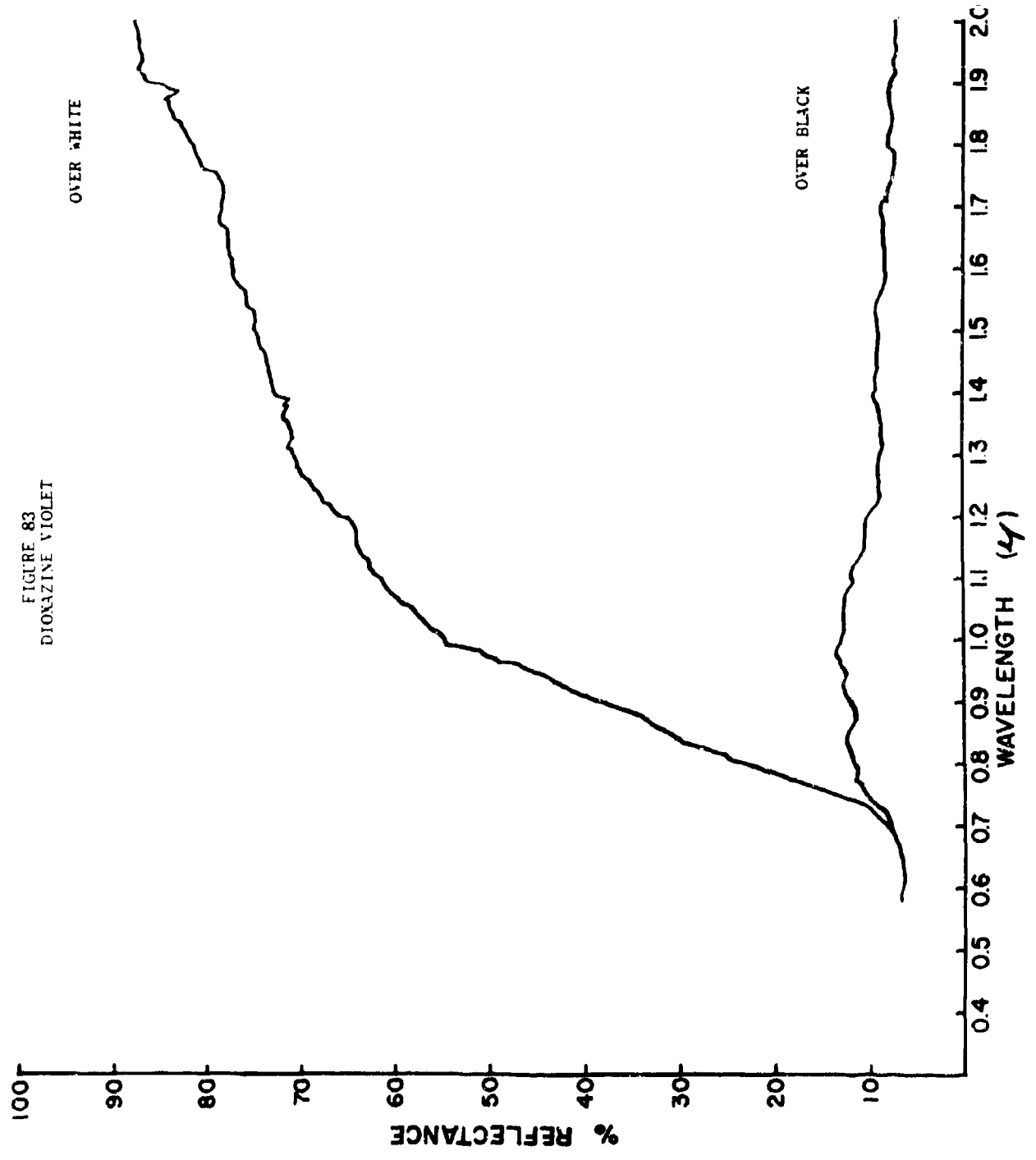


PLATE 84  
LAVINE FLOER

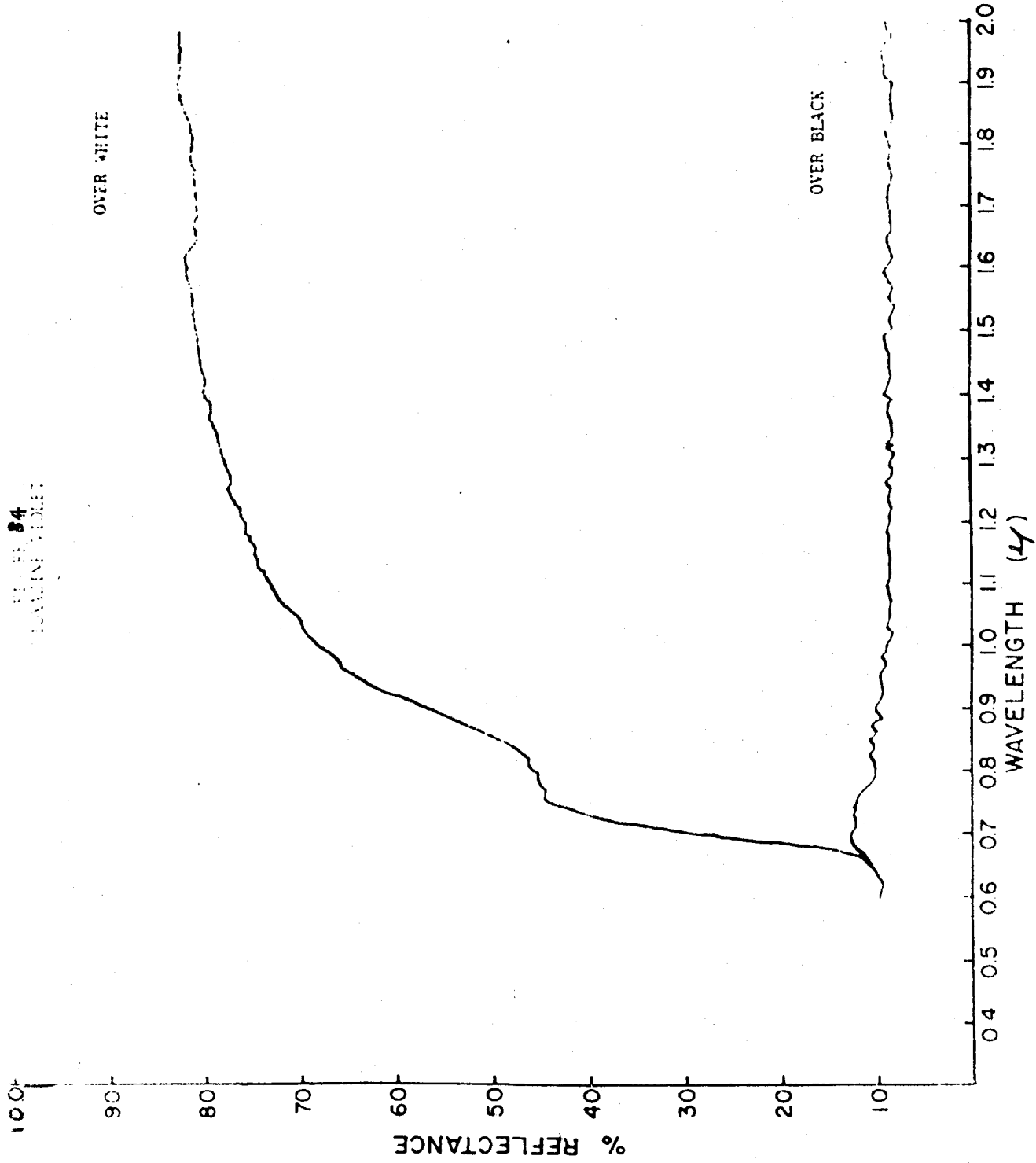
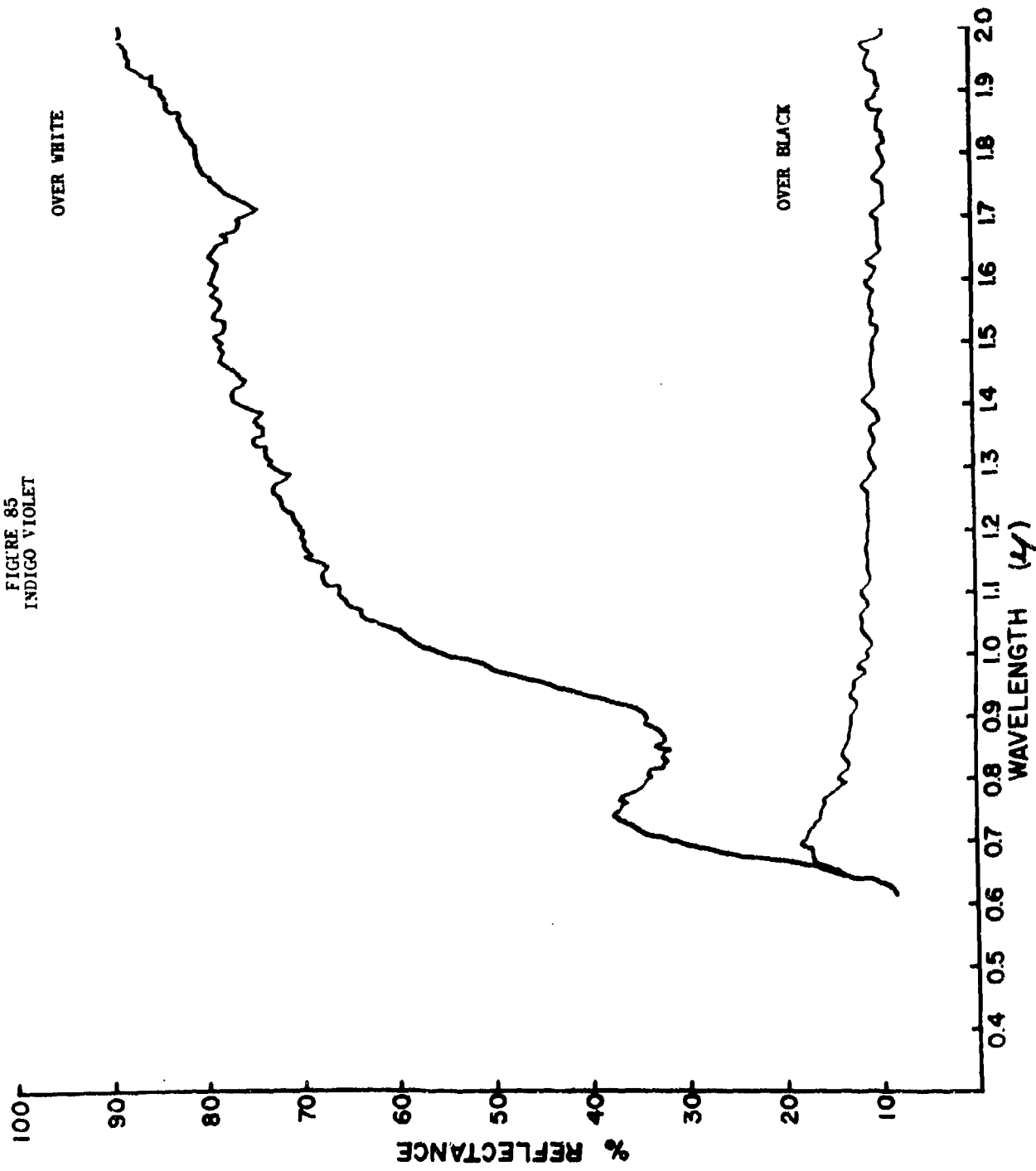


FIGURE 85  
INDIGO VIOLET



FLUORENE 86  
METHYL VIOLET

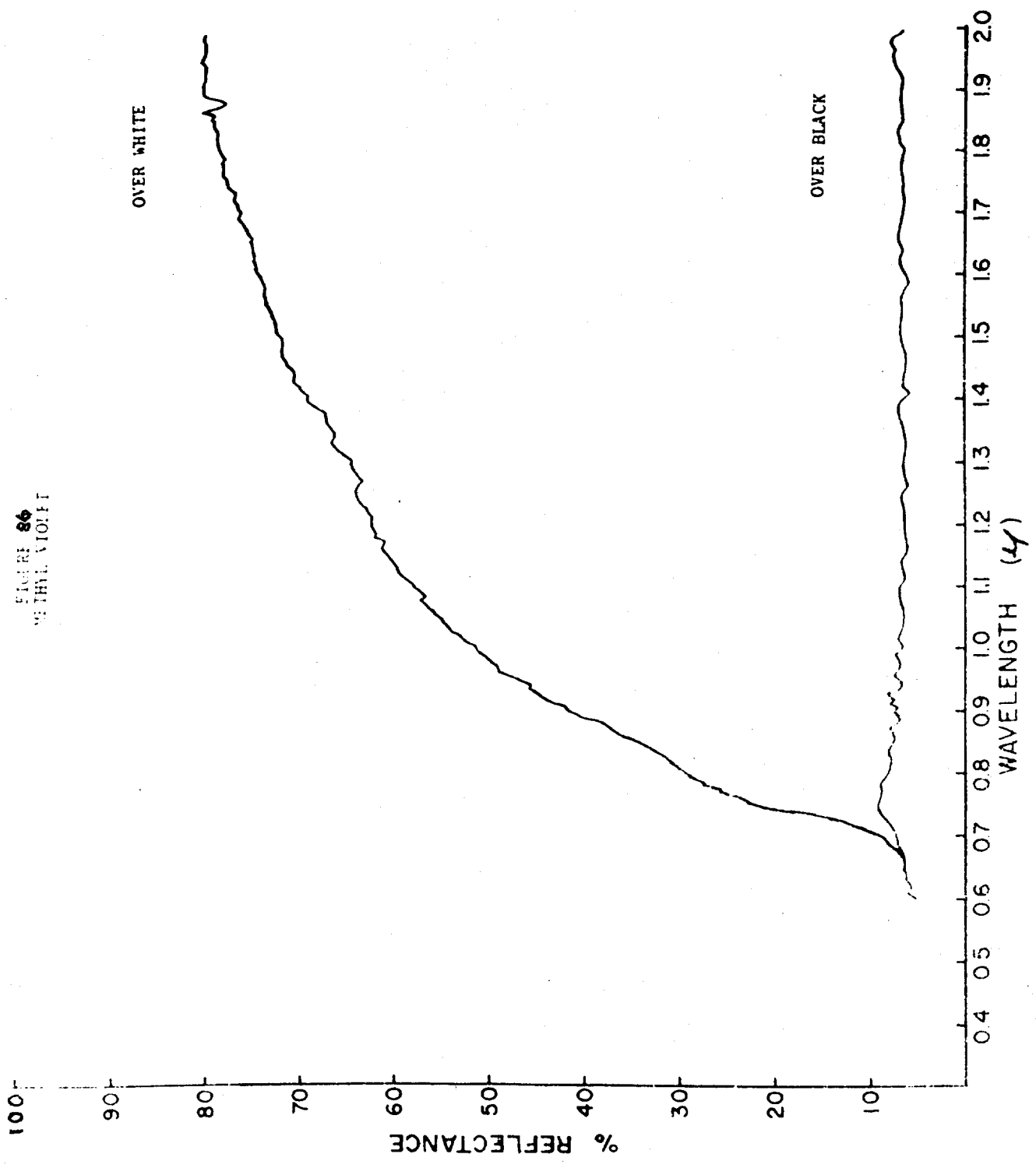


FIGURE 87  
PHOSPHO POLYEDIC ACID  
VIOLET

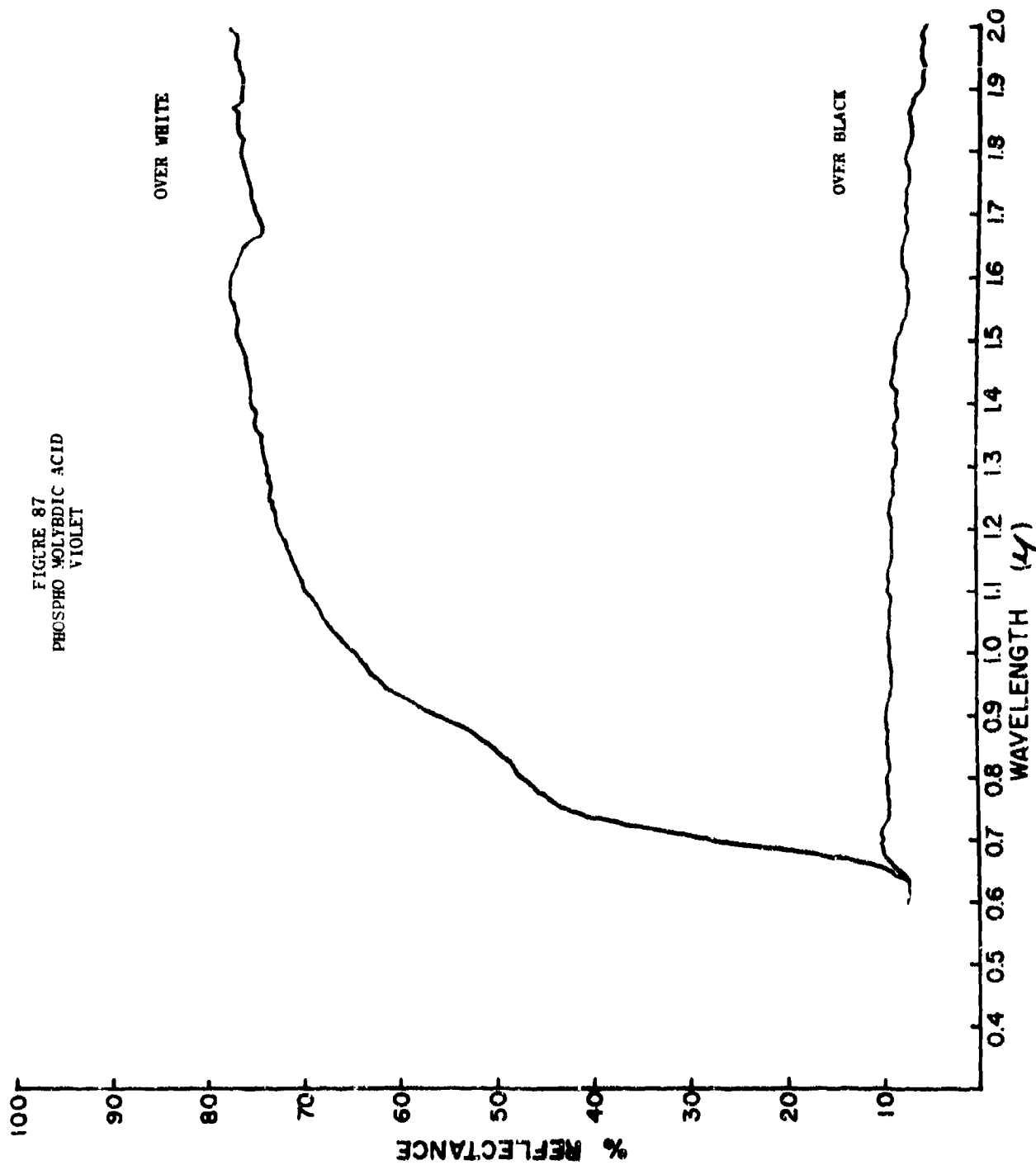




FIGURE NO.  
FRUSIHO D. NASTIC ACID  
VIOLET

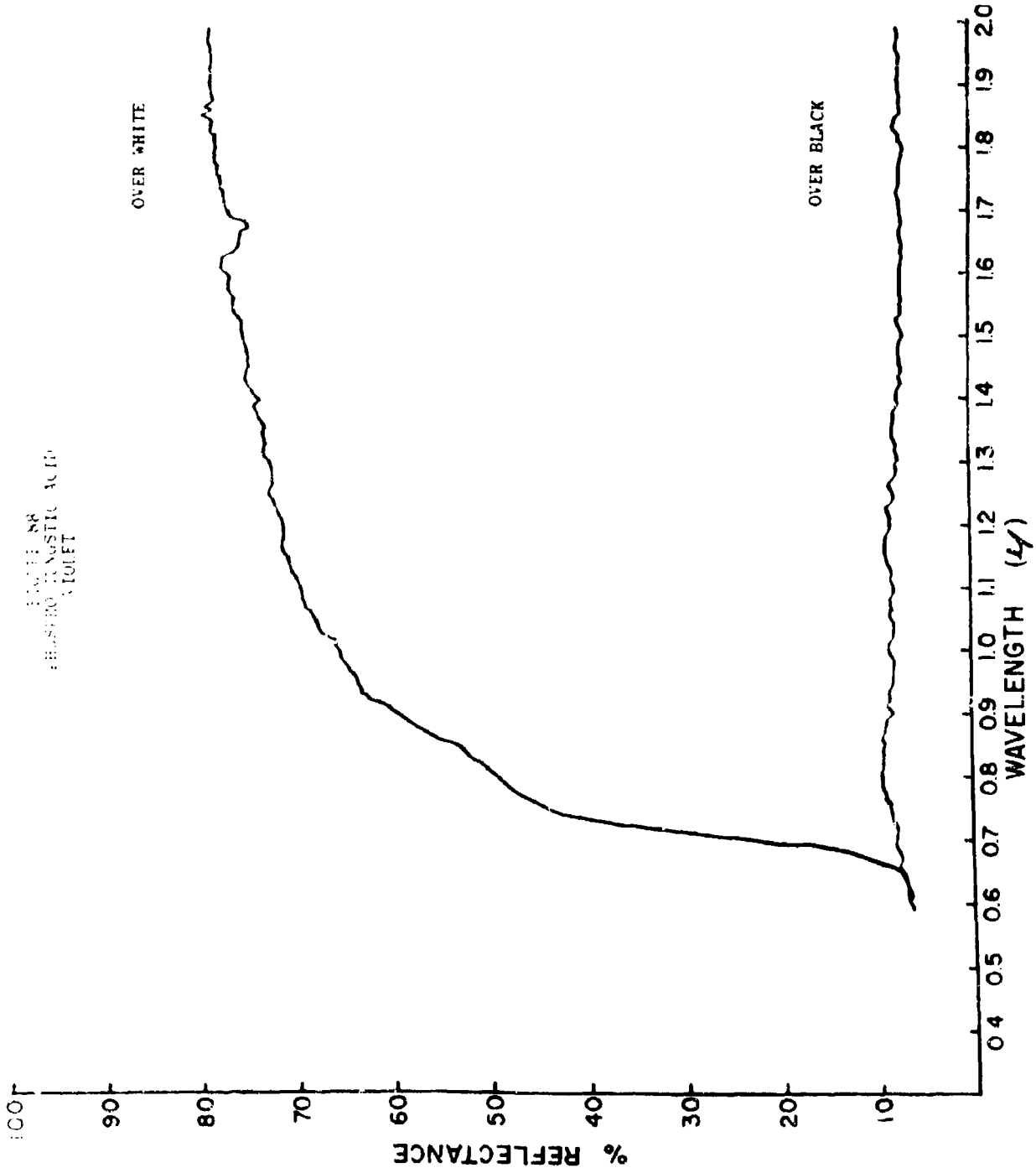


FIGURE 89  
ORGANIC VIOLET

