

AFCRL-68-[REDACTED] 0496 (II)

CONTRACT AF81(052)-833

7 MAY, 1968

AD 629565

FINAL SCIENTIFIC REPORT

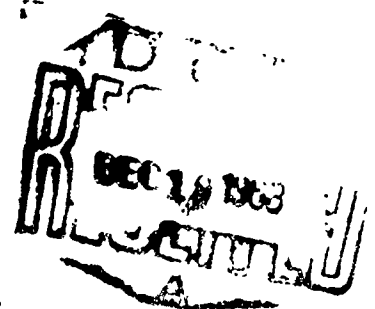
(IN TWO VOLUMES)

MULTILAYER FILTERS FOR THE REGION 0.8 TO 100 MICRONS

S. D. SMITH

J. S. SEELEY

VOLUME 2-ILLUSTRATIONS



UNIVERSITY OF READING
READING, ENGLAND

THIS DOCUMENT HAS BEEN APPROVED FOR PUBLIC RELEASE AND SALE; ITS
DISTRIBUTION IS UNLIMITED

157

ACCESSION BY	
SPCS	STATE SERVICE ☒
DDC	DDP, DDT, DDC ☐
PHARMACOLOGICAL	☐
JAN 1971	
BY	
ANTHONY, RICHARD W. 100	
DATE	DATE OF SPECIAL

AVAILABILITY NOTICE

Qualified requestors may obtain additional copies from the Defense Documentation Centre: all others should apply to the Clearinghouse for Federal Scientific and Technical Information.

0496(II)
AFCRL - 68 - [REDACTED]

CONTRACT AF 61(052)-833

7th MAY 1968

FINAL SCIENTIFIC REPORT

MULTILAYER FILTERS FOR THE REGION 0.8 TO 100 MICRONS

1st NOVEMBER 1964 - 7th MAY 1968

S.D. SMITH*

J.S. SEELEY†

* DEPT. OF PHYSICS

† DEPT. OF APPLIED PHYSICAL SCIENCES

UNIVERSITY OF READING

READING, ENGLAND.

THIS DOCUMENT HAS BEEN APPROVED FOR PUBLIC RELEASE
AND SALE. ITS DISTRIBUTION IS UNLIMITED.

THIS RESEARCH HAS BEEN SPONSORED BY THE AIR FORCE
CAMBRIDGE RESEARCH LABORATORIES UNDER CONTRACT
AF61(052)-833 THROUGH THE EUROPEAN OFFICE OF AERO-
SPACE RESEARCH, OAR, USAF, AS PART OF THE ADVANCED
PROJECTS AGENCY'S PROJECT VELA-UNIFORM.

LIST OF ILLUSTRATIONS

Section 2

- 2.1 Dispersion at an absorption peak
- 2.2 Energy gap of IV and III-V semiconductors

Section 3.1

- 3.1 Fringe amplitude for a Si substrate
- 3.2 PbTe films
- 3.3 PbTe film (cooling)
- 3.4 Optical thickness of PbTe films
- 3.5 Ge films
- 3.6 Optical thickness of Ge films
- 3.7 ZnS films
- 3.8 Optical thickness of ZnS films
- 3.9 SiO films
- 3.10 Optical thickness of SiO films
- 3.11 Film of CsI
- 3.12 Optical thickness of CsI film
- 3.13(a)-(j) Shortwave spectra of films of new low-index materials
- 3.14 Preliminary results on TlI, TlBr films
- 3.15 Preliminary results on CdI, InI films

Section 3.3

- 3.16 High Vapour Pressure deposition method
- 3.17 Gas flow deposition method
- 3.18 Comparison of ground and polished silicon substrates
- 3.19 Polyethylene spectrum
- 3.20 Polypropylene spectrum
- 3.21 Polystyrene spectrum
- 3.22 P. T. F. E. spectrum
- 3.23 Melinex spectrum

Section 3.3 contd.

3.24	Polycarbonate spectrum
3.25	Mica spectrum
3.26	Silicon/polyethylene-sandwich spectrum
3.27	Spectrosil B spectrum
3.28	Germanium/Spectrosil F. P.

Section 4.1

4.1(a) and (b)	Grubb Parsons Balzer-BA500 Plant (Photographs)
4.2(a) - (c)	Design performance of radiometer filters
4.3	Arrangement of sources in Grubb Parsons plant
4.4	Reflectance monitoring characteristics
4.5(a) - (b)	PbTe, ZnS deposition temperatures
4.6	F. P. filter deposited at optimum temperatures
4.7(a) - (b)	D. H. W. filters, temperature-cycled deposition
4.8	D. H. W. filter deposited at one temperature
4.9	Calculated distribution of evaporant
4.10	Uniformity of F. P. filter

Section 4.2

4.11	Transmittance of CsI film
4.12	Transmittance of thin plate of Spectrosil B
4.13	Ge/ZnS F. P. filter at 60 μ
4.14	Ge/ZnS D. H. W. filter at 80 μ
4.15	Ge/ZnS F. P. filter at 90 μ
4.16	Ge/ZnS filter by modified deposition
4.17	2-layer Ge/CsI stack
4.18	4-layer Ge/CsI stack
4.19	Ge/CsI F. P. filters at 75 μ

Section 4.2 contd.

- 4.20 Ge/CsI F. P. filters at 85 μ
- 4.21 Blocking filter (including quartz)
- 4.22 Longwave transmittance of blocking filter
- 4.23 Preliminary lowpass filter at 50 μ
- 4.24 Stop region of 53 μ lowpass filter
- 4.25 Lowpass filter with modified antireflection
- 4.26 Interferogram of combined F. P. /lowpass filter

Section 4.3

- 4.28 Shortwave transmittance of PbTe/ZnS single blocking stack.
- 4.29 Longwave transmittance of PbTe/ZnS stack
- 4.30 Shortwave transmission of PbTe/CsI stack
- 4.31 Longwave transmission of PbTe/CsI stack
- 4.32 CsI antireflection at 75 μ
- 4.33 CsI antireflection at 85 μ
- 4.34 Longwave transmission of PbTe/CsBr stack
- 4.35 Shortwave transmission of PbTe/CsBr stack
- 4.36 CsBr antireflection
- 4.37 Equal-ripple PbTe/ZnS lowpass filter
- 4.38 Comparison of antireflection systems on Ge

Section 4.4

- 4.39 Separate collection of PbTe and ZnS from a filter deposition
- 4.40 "Annealing" of F. P. filters containing PbTe
- 4.41 F. P. filter annealing at various temperatures
- 4.42 Annealing time vs temperature⁻¹
- 4.43 Calculated F. P. shift vs change in n in PbTe
- 4.44 F. P. maximum transmittance vs κ in PbTe
- 4.45 Resistance of PbTe during anneal at 319°C

Section 4.4

- 4.46 Anneal of PbTe in vacuo, nitrogen, air
- 4.47 PbTe monolayers with high and low free carrier absorption
- 4.48(a) Dispersion curves for PbTe
- 4.48(b) Reflectance of PbTe monolayer
- 4.49 Transmission of single mesh

Section 4.5

- 4.50 Finesse of mesh F.P. filters
- 4.51 Melinex-spaced mesh F.P. filter
- 4.52 Air-spaced improvement of 4.51
- 4.53 Mesh D.H.W. filter
- 4.54 Mesh filter construction
- 4.55 Effect of resolution on measurement of mesh filter
- 4.56 Uniformity of mesh filter
- 4.57 Mesh F.P. filters at 75, 85, 95 μ
- 4.58 D.H.W. filter using identical meshes
- 4.59 D.H.W. filter using 2 grades of mesh

Section 5.1

- 5.1 Idealised filter characteristics
- 5.2 Interface description
- 5.3 S - plane locus and construction
- 5.4 Tchebyshev circuit parameters
- 5.5 Computed Tchebyshev filters
- 5.6 Computed Tchebyshev narrowband filter

Section 5.3

- 5.7 Spectral sensitivity of layers in F.P. filter
- 5.8 Refinement of low pass design
- 5.9 Refinement of high pass design

Section 5. 4

- 5. 10(a) - (d) F. P. for 2% Standard Deviation in thicknesses
- 5. 11(a) - (d) D. H. W. for 2% Standard Deviation in Thicknesses
- 5. 12 Peak transmittance vs halfwidth, 2%, 1. 4% S. D.
- 5. 13 Peak transmittance, halfwidth, vs peak separation in D. H. W.
- 5. 14(a) - (d) D. H. W. for 1. 4% S. D. in thicknesses
- 5. 15 D. H. W. adjusted by final layer thickness

Section 6

- 6. 1 Long wave bandpass filters
- 6. 2 Long wave lowpass filter.

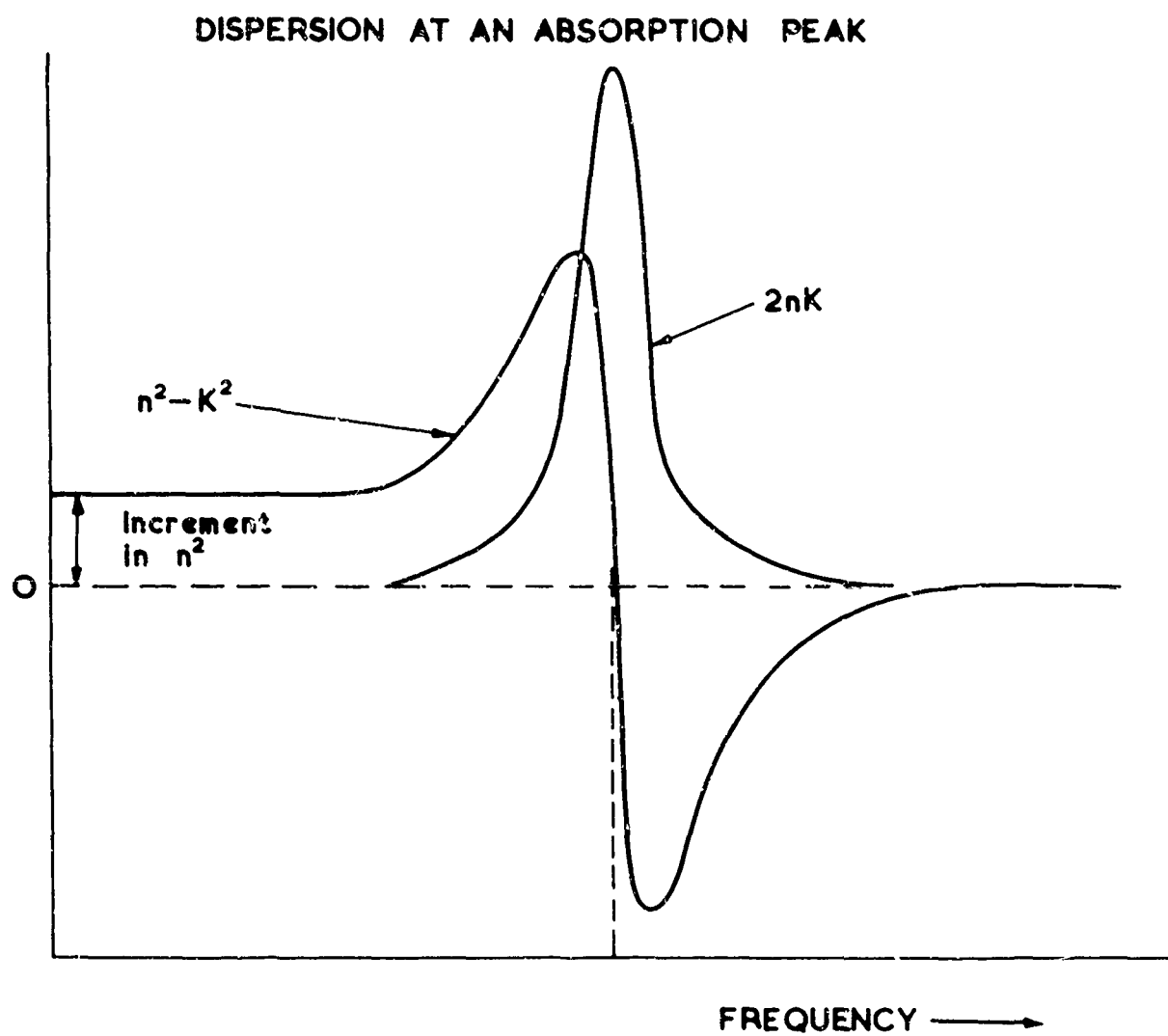
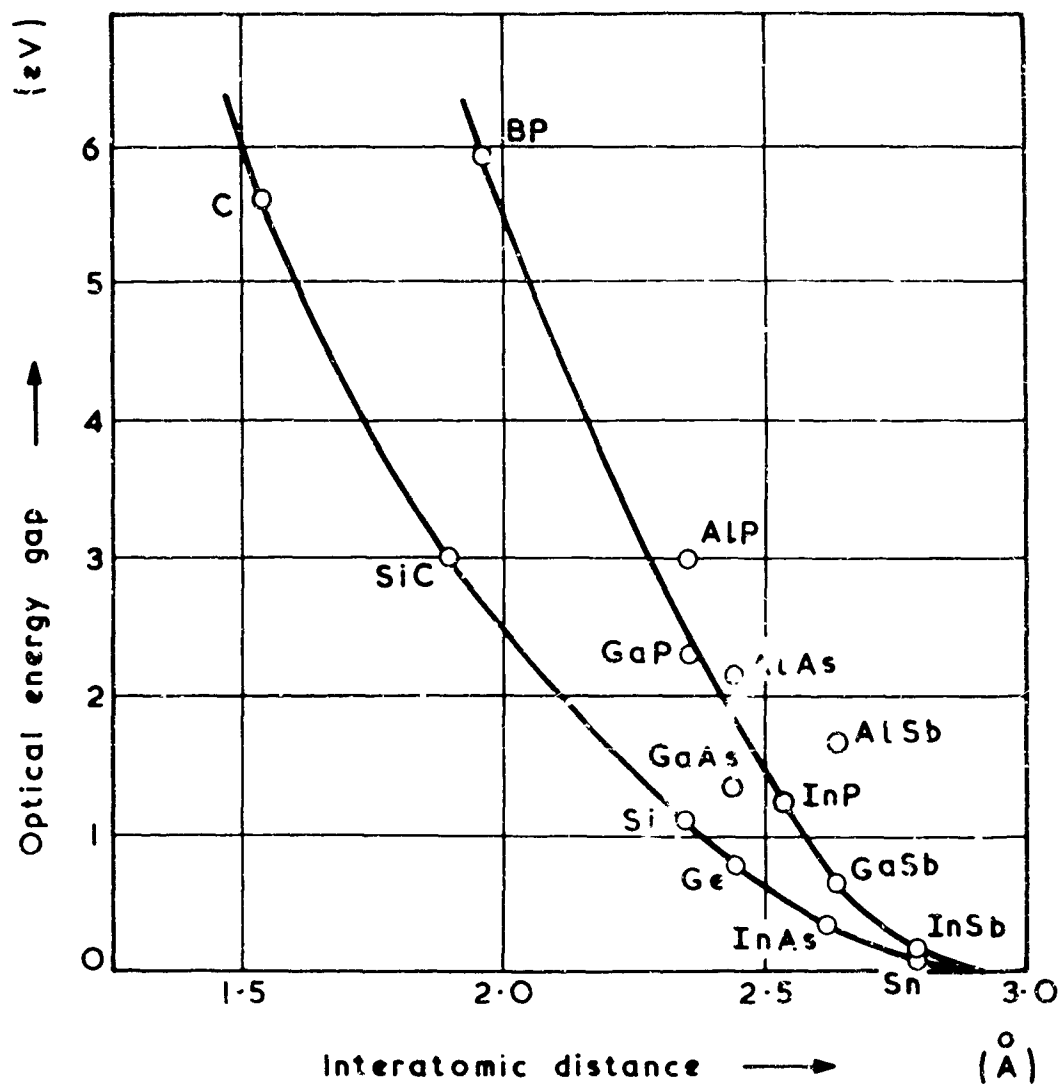


FIG. 2.1



Energy gap of semiconducting Group IV elements and Group III-V compounds of diamond and zinc blende structure

Fig. 2.2

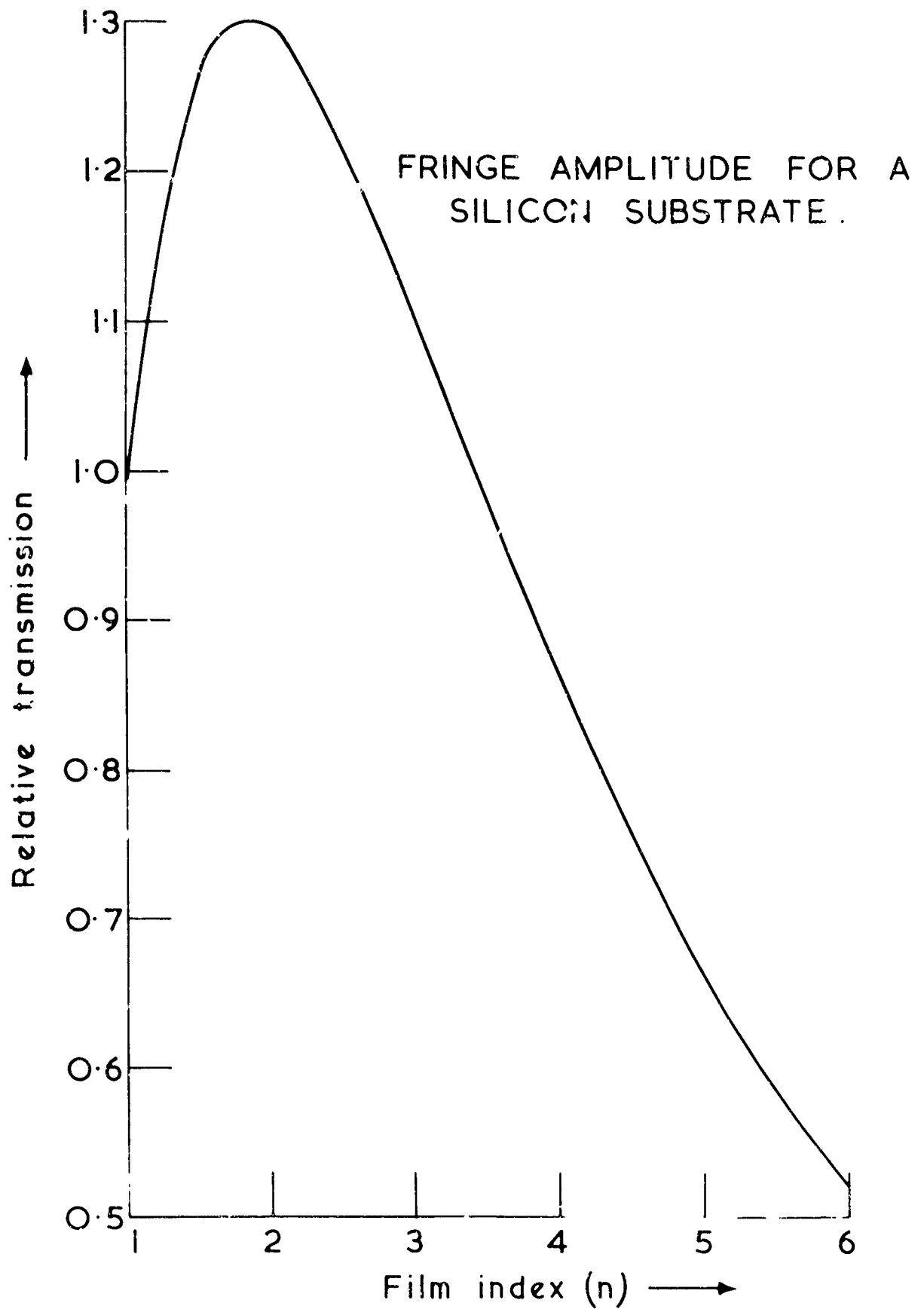


FIG. 3.1

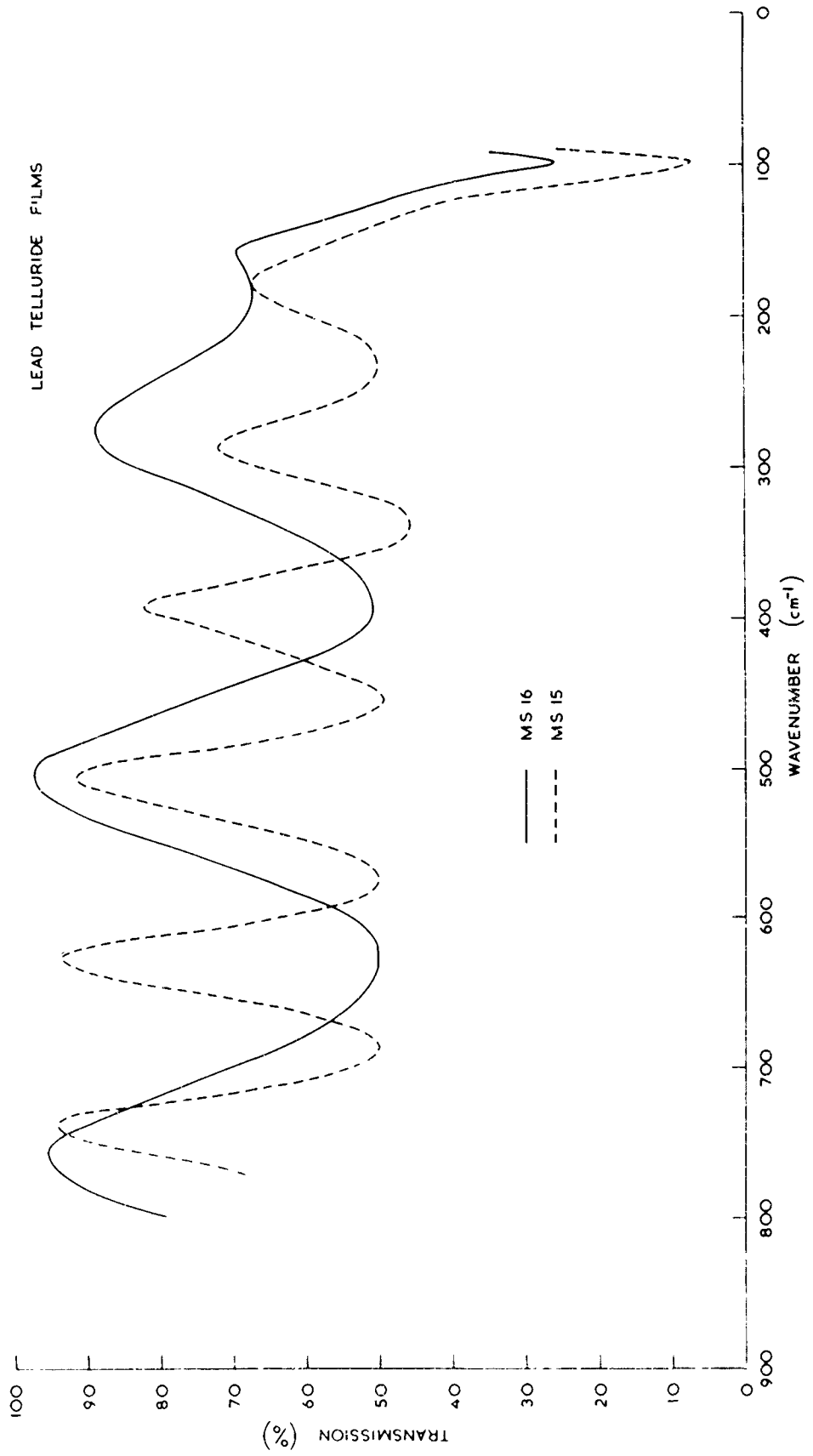


FIG 3 2

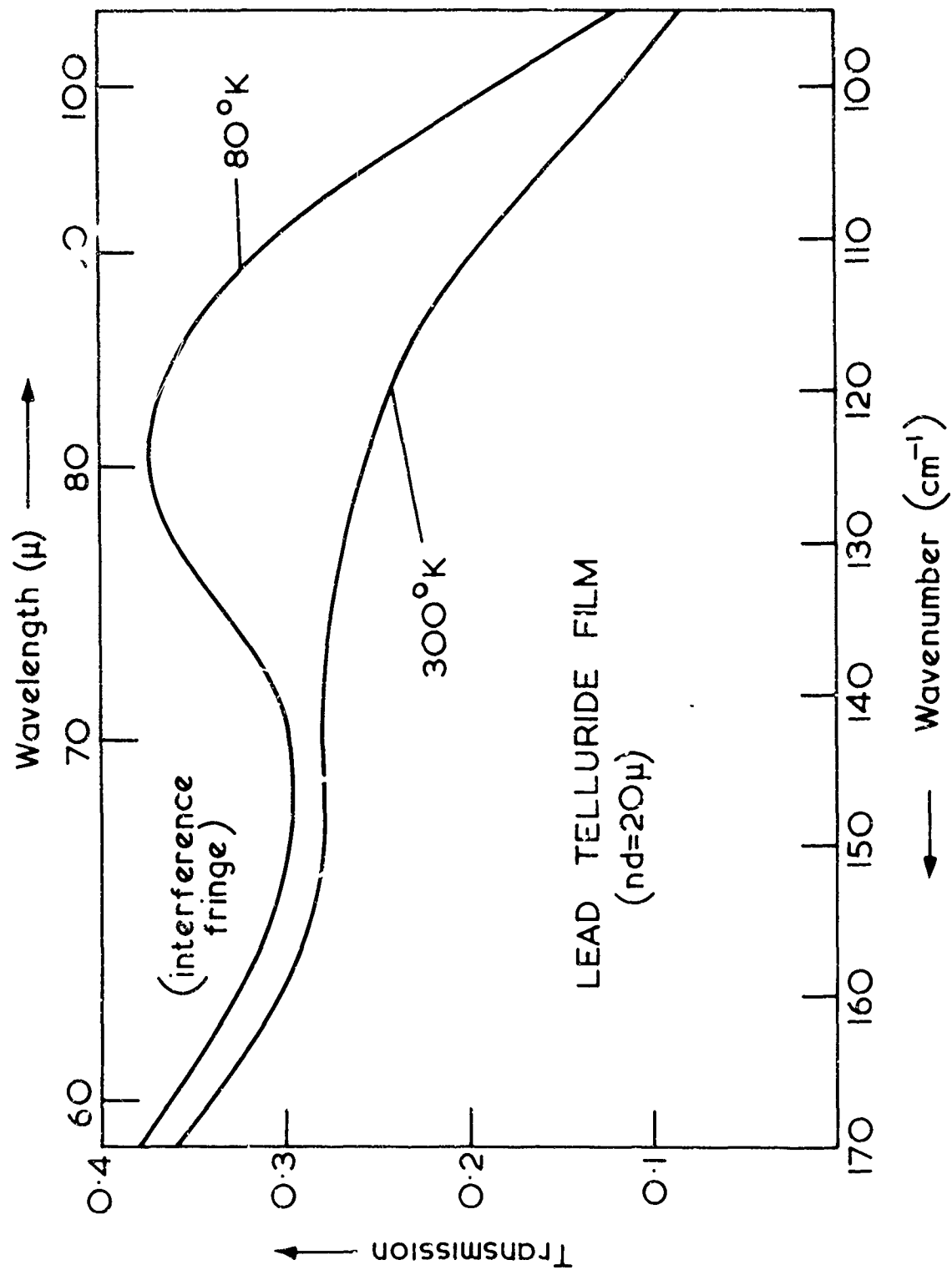


FIG. 3.3

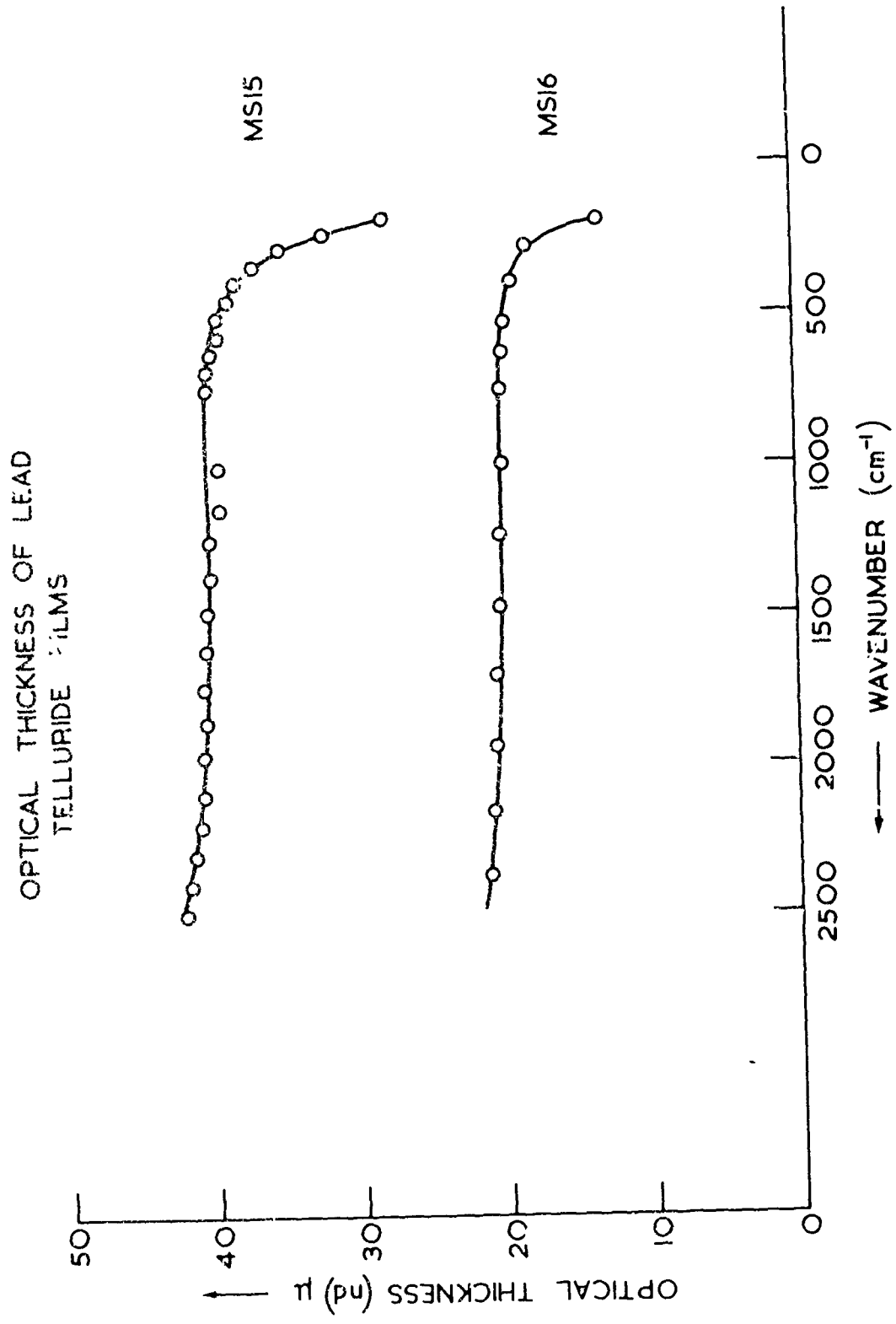


FIG. 3.4

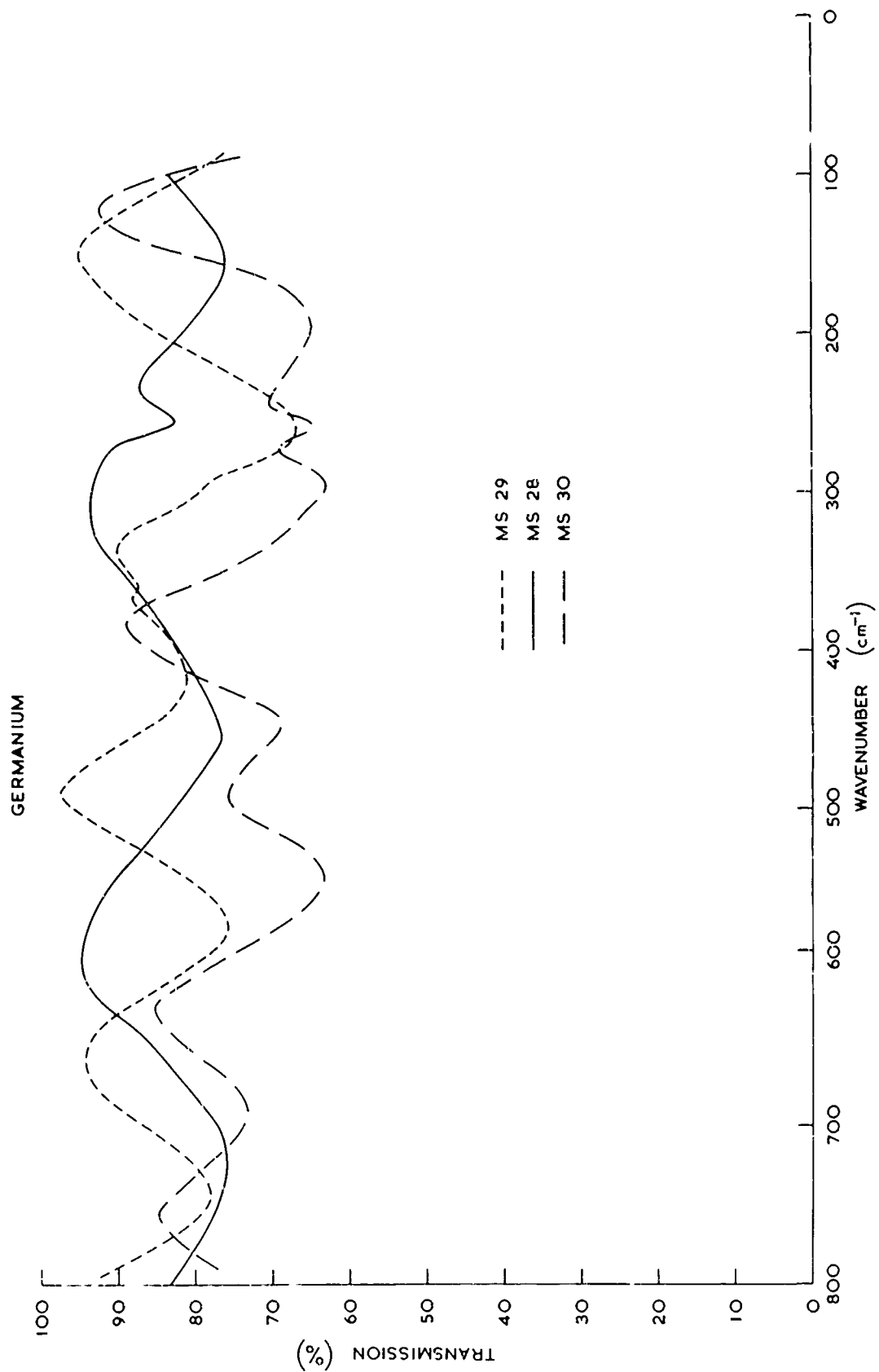


FIG 3 5

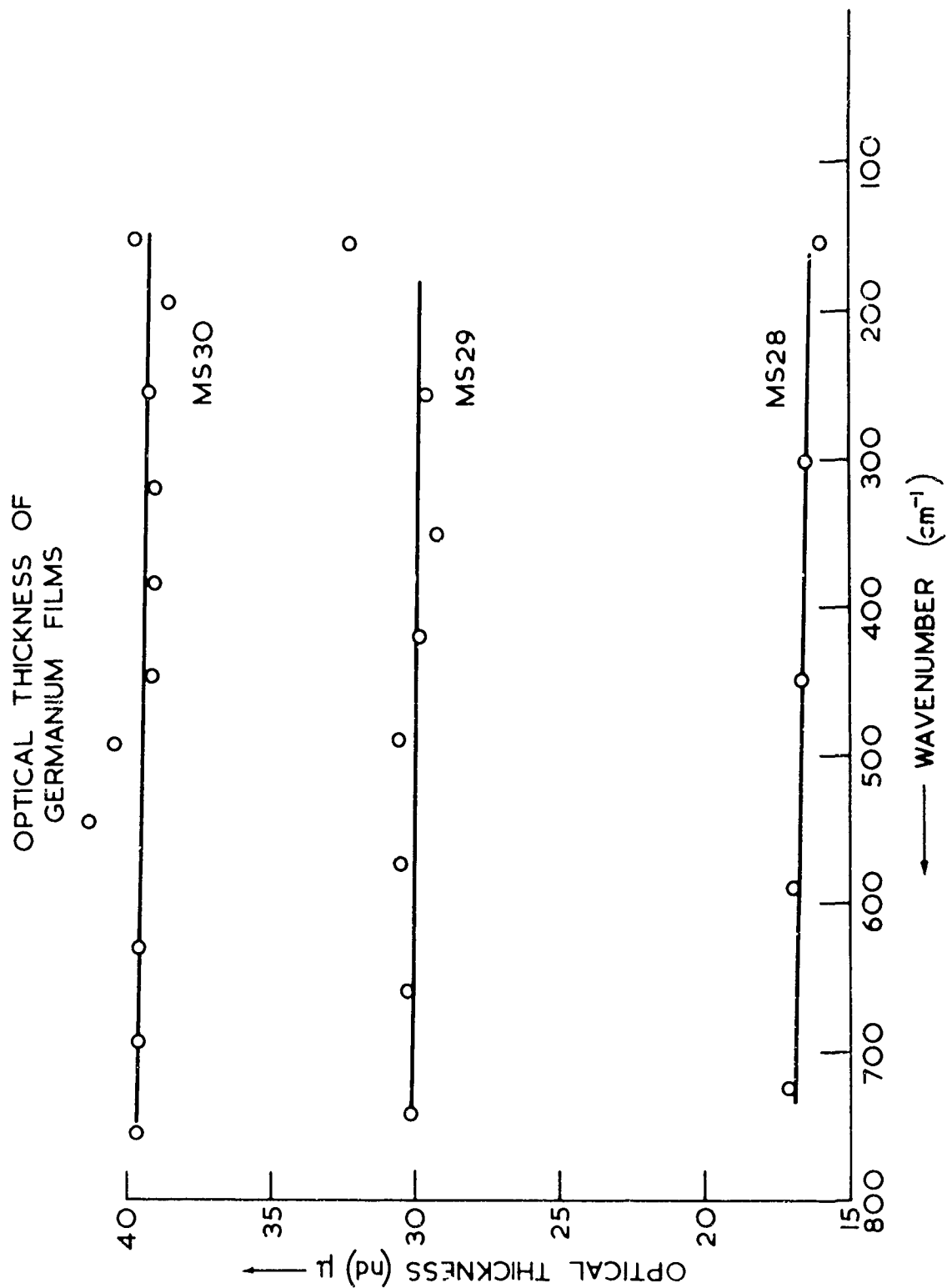


FIG. 3.6

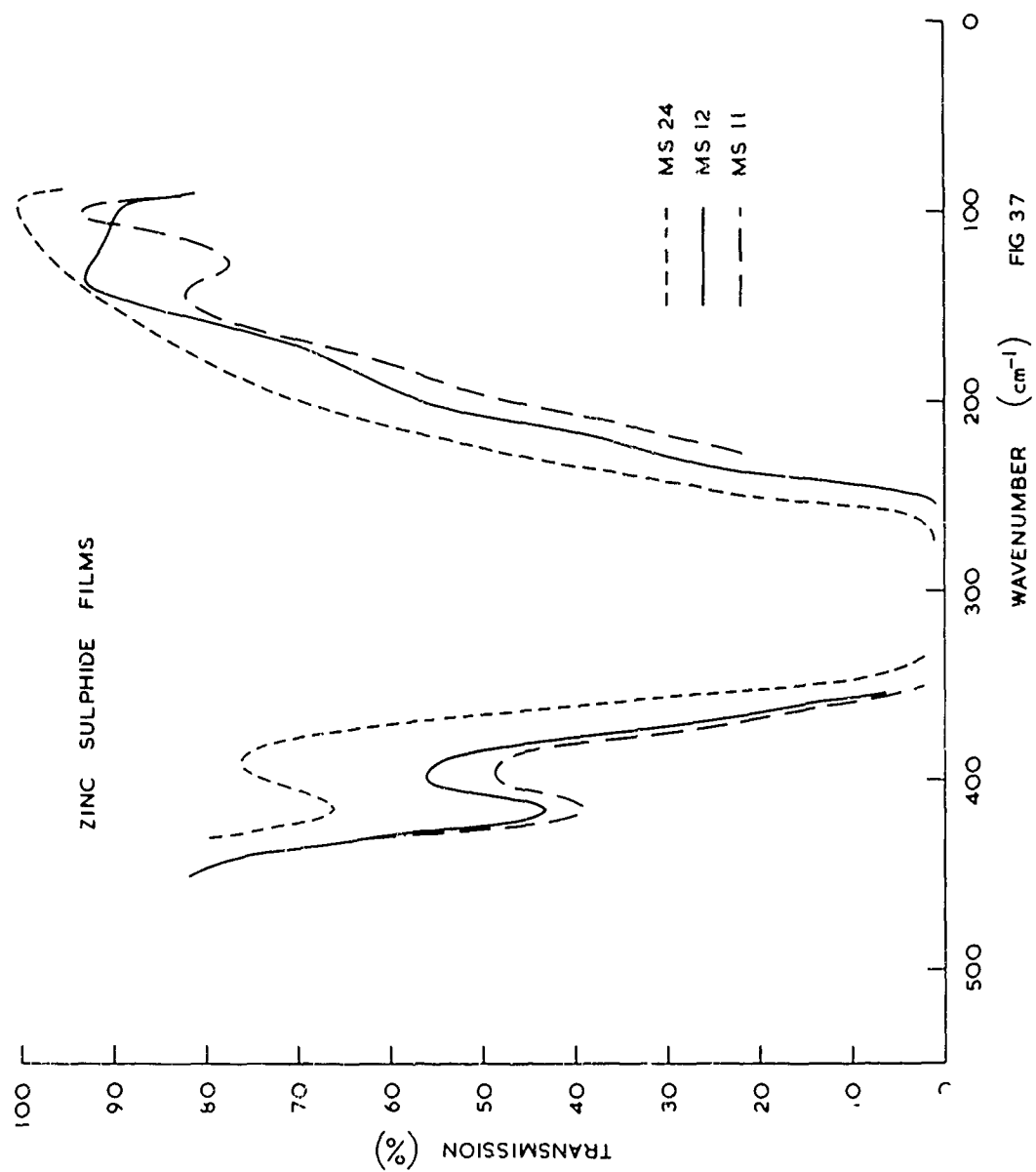


FIG 37

OPTICAL THICKNESS OF
ZINC SULPHIDE FILMS

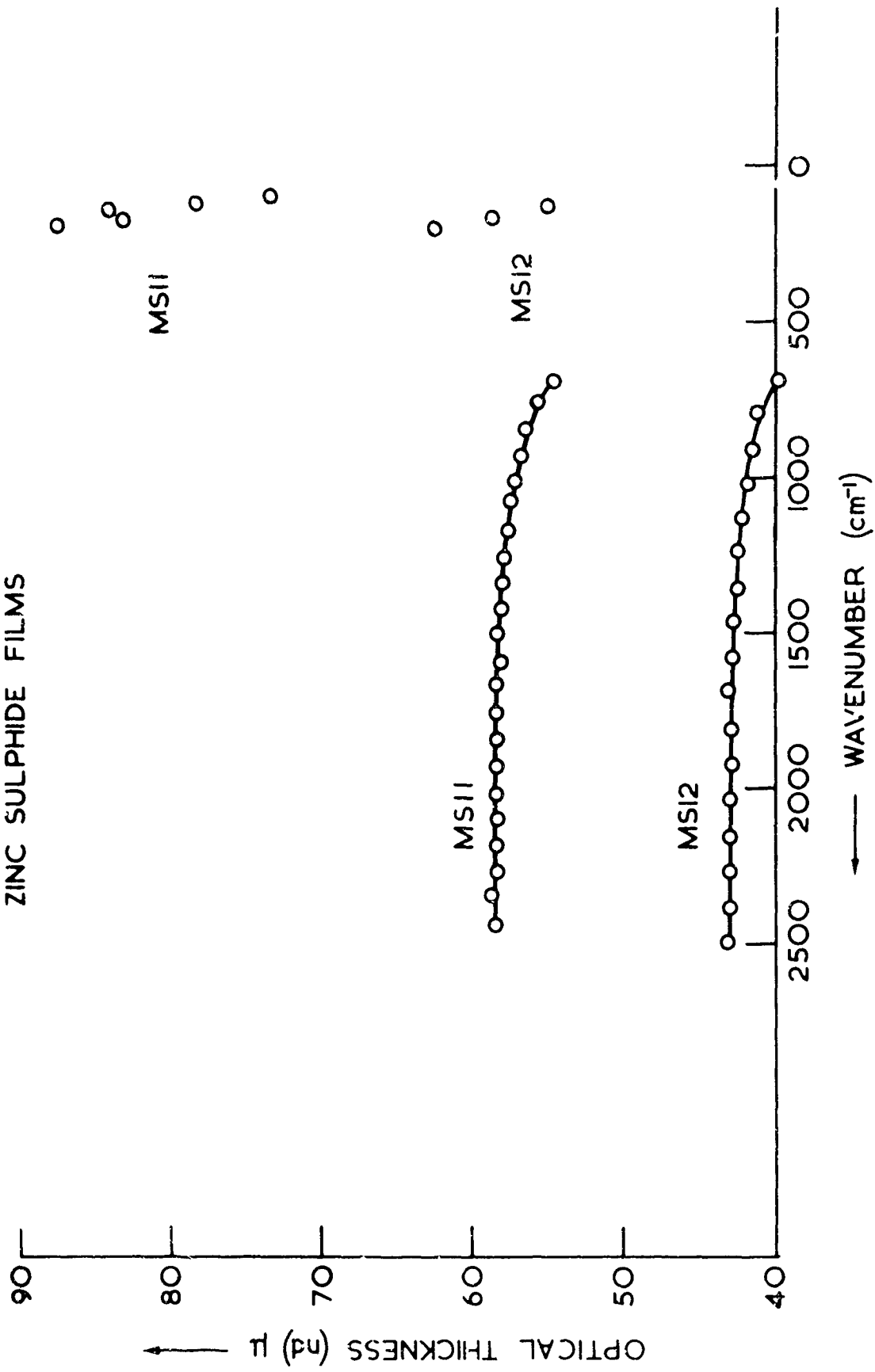


FIG. 3.8

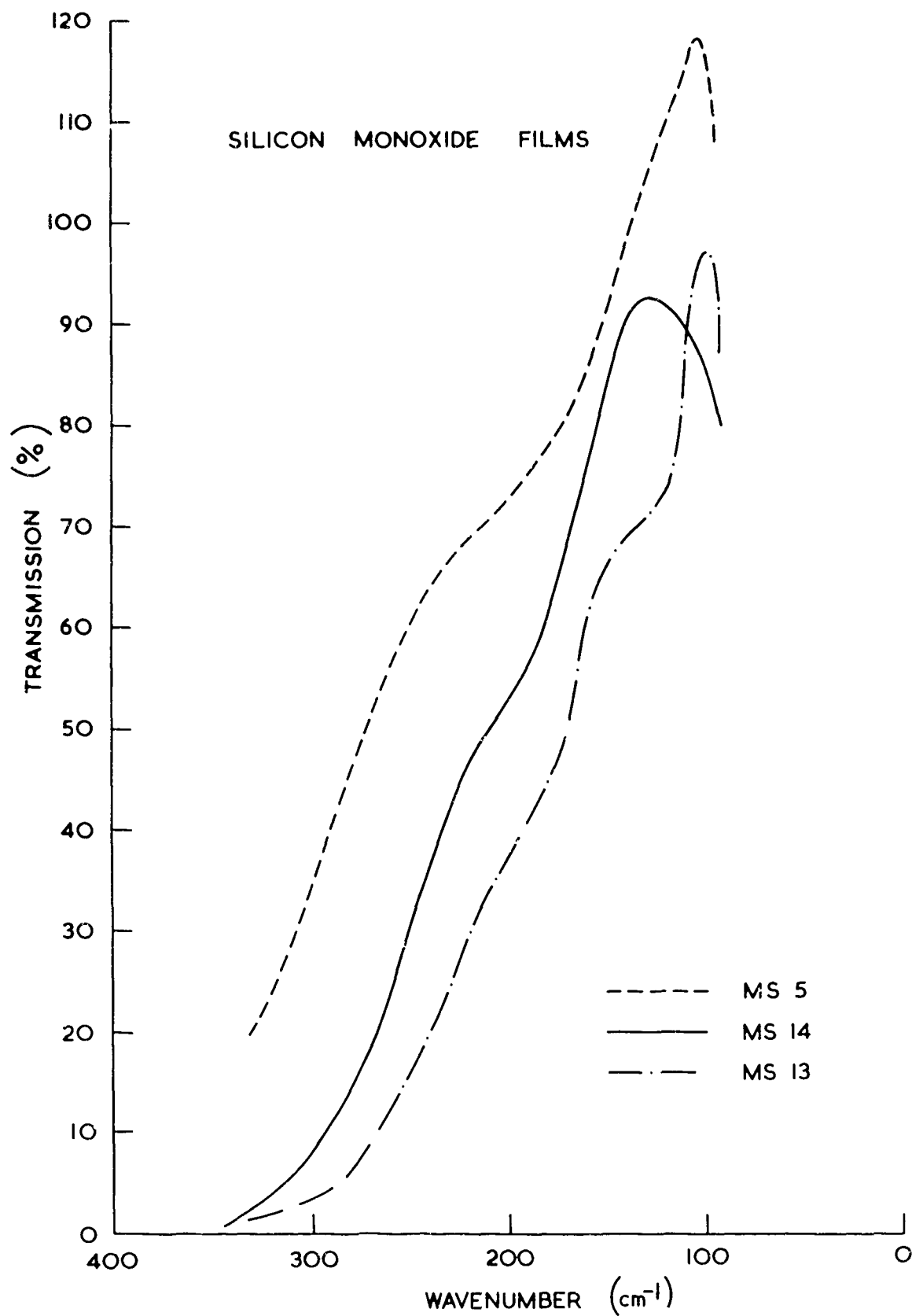
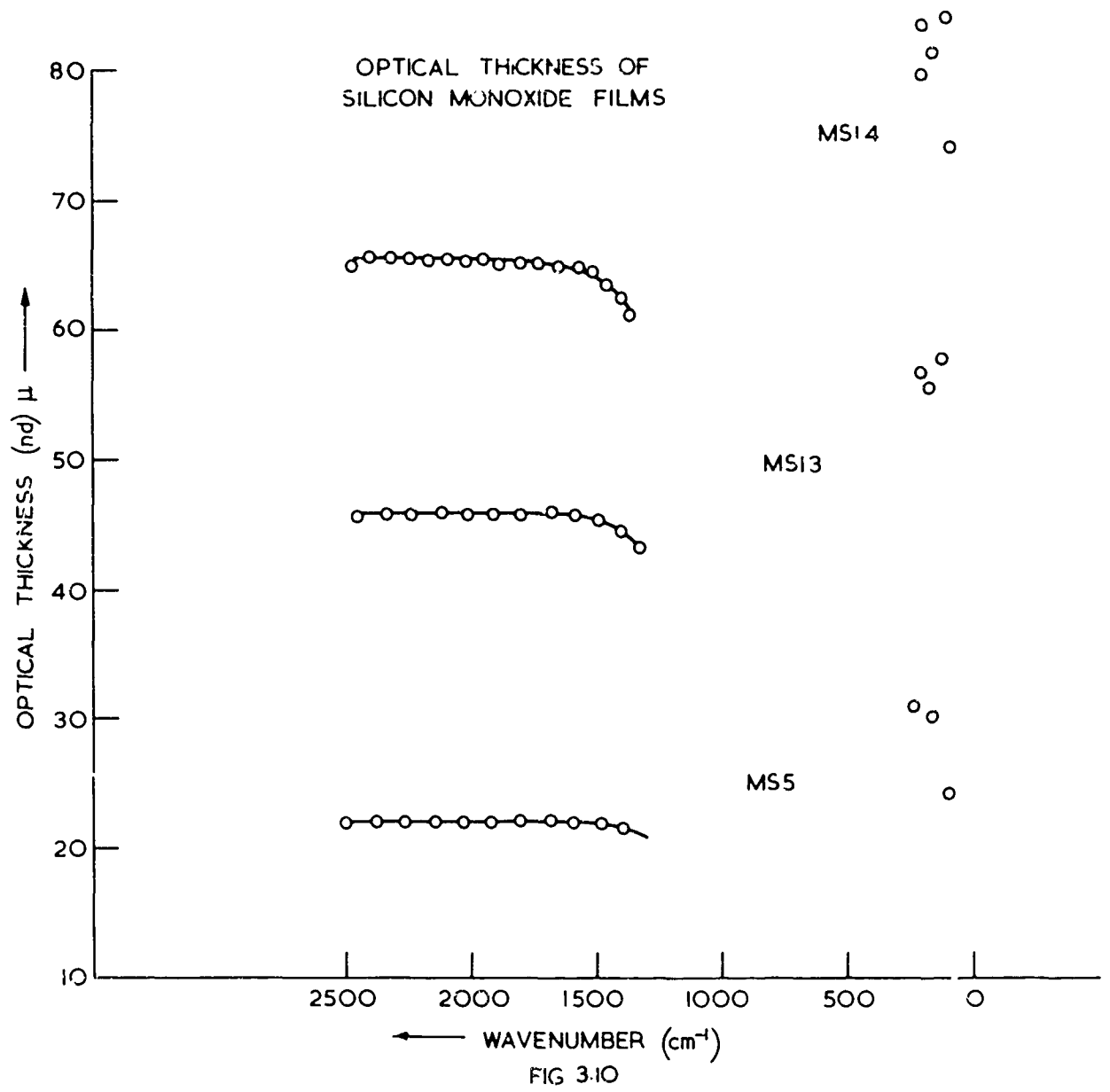


FIG. 3.9



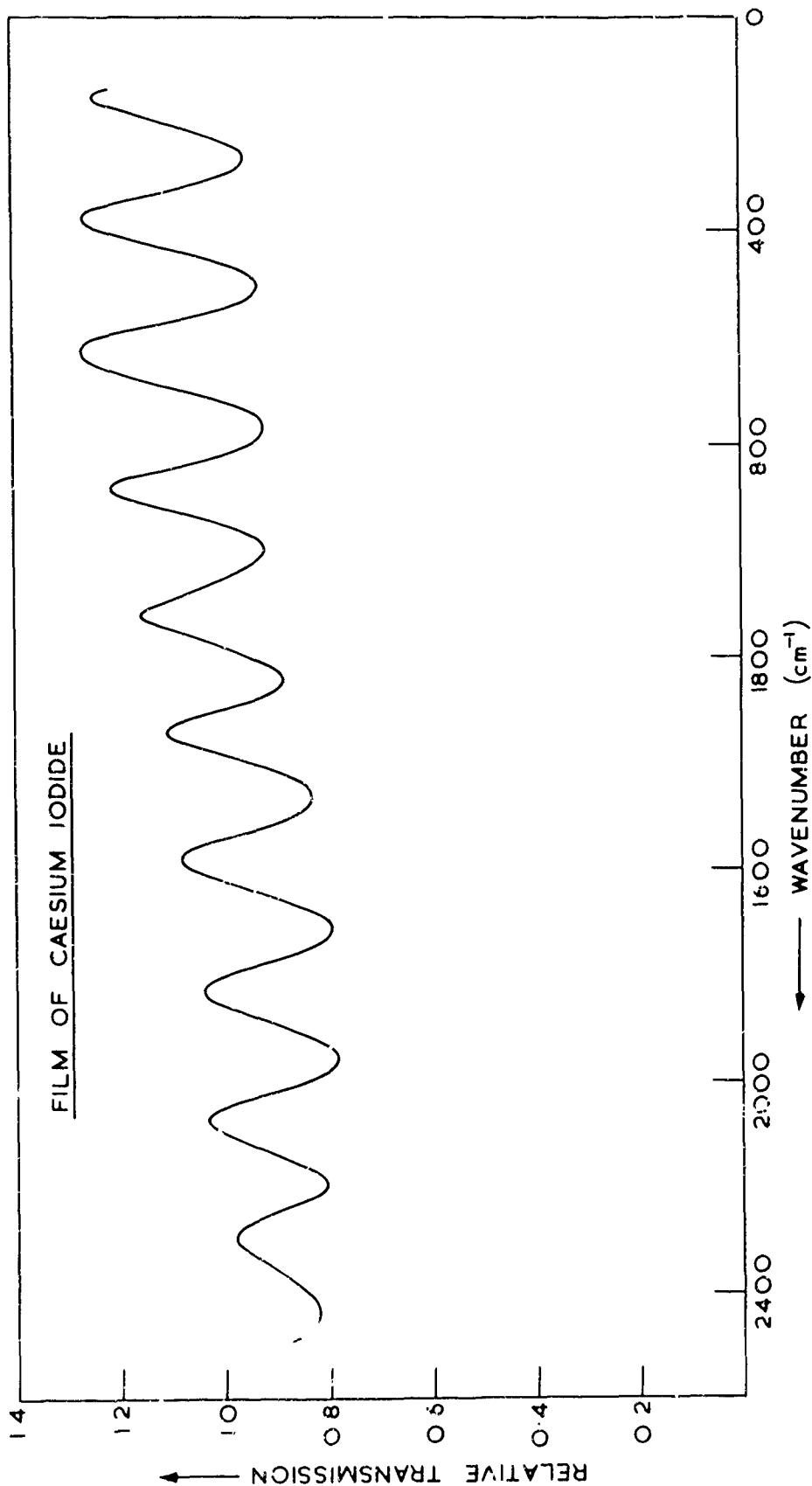


FIG. 3.11

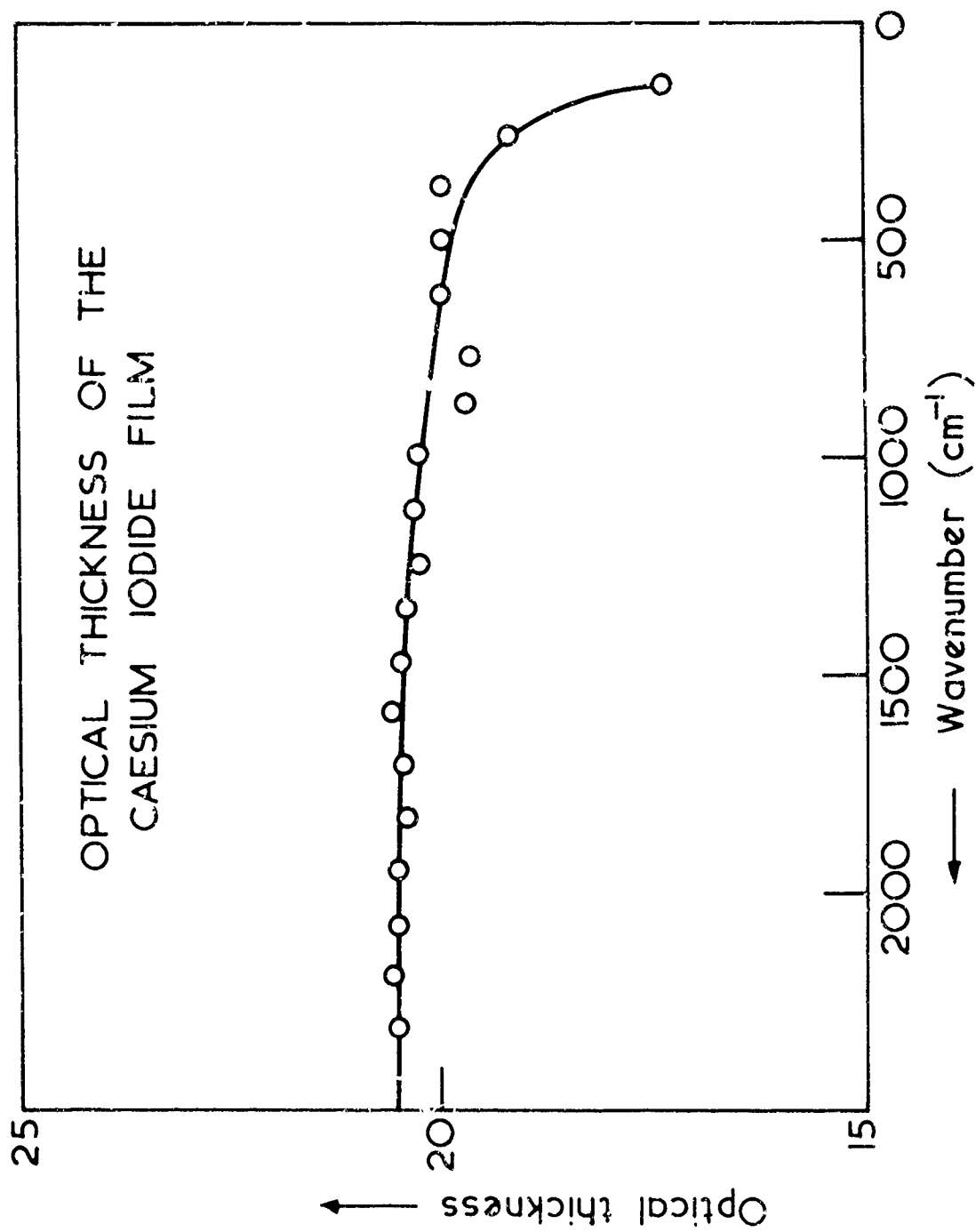
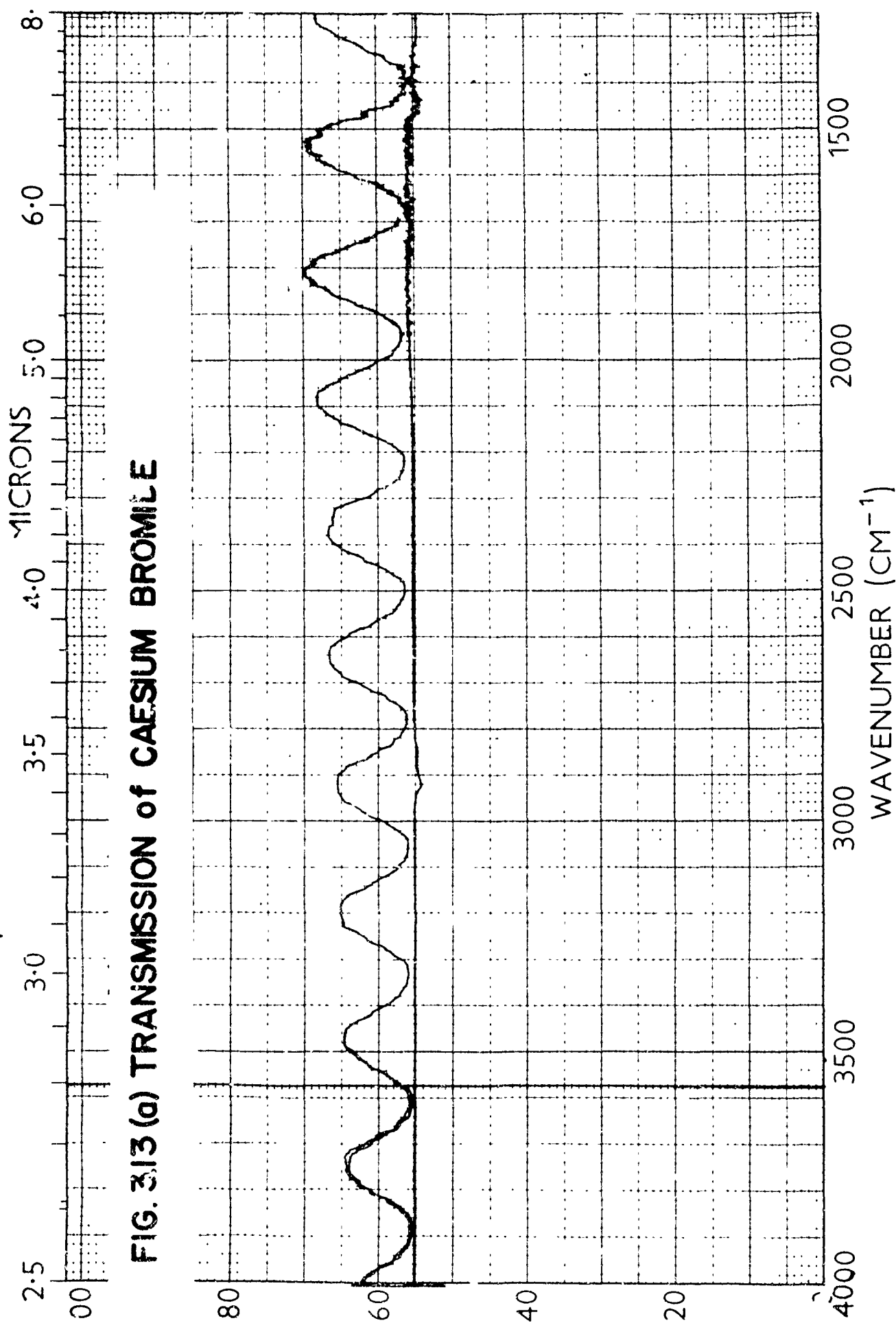


FIG. 3.12



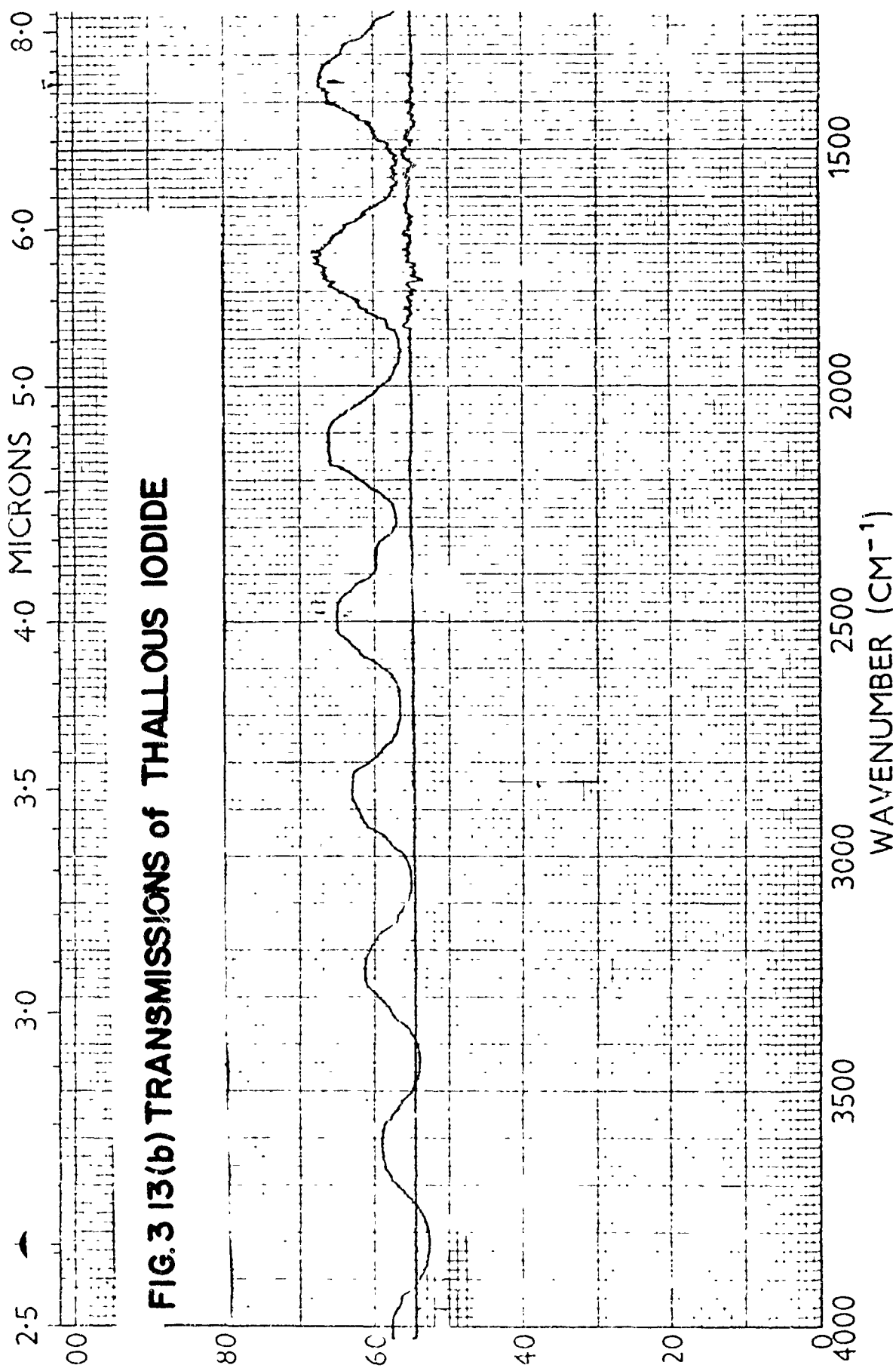
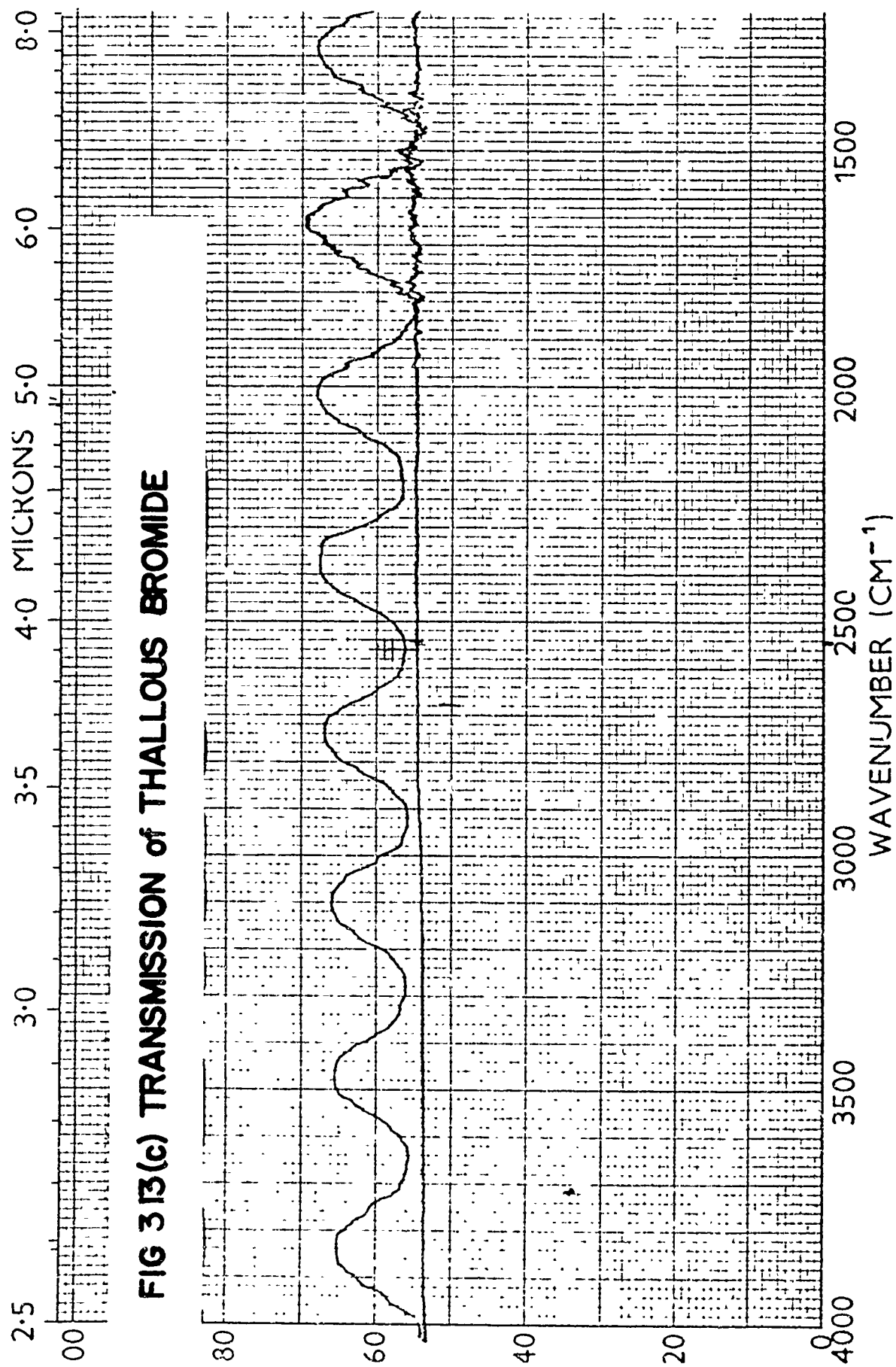
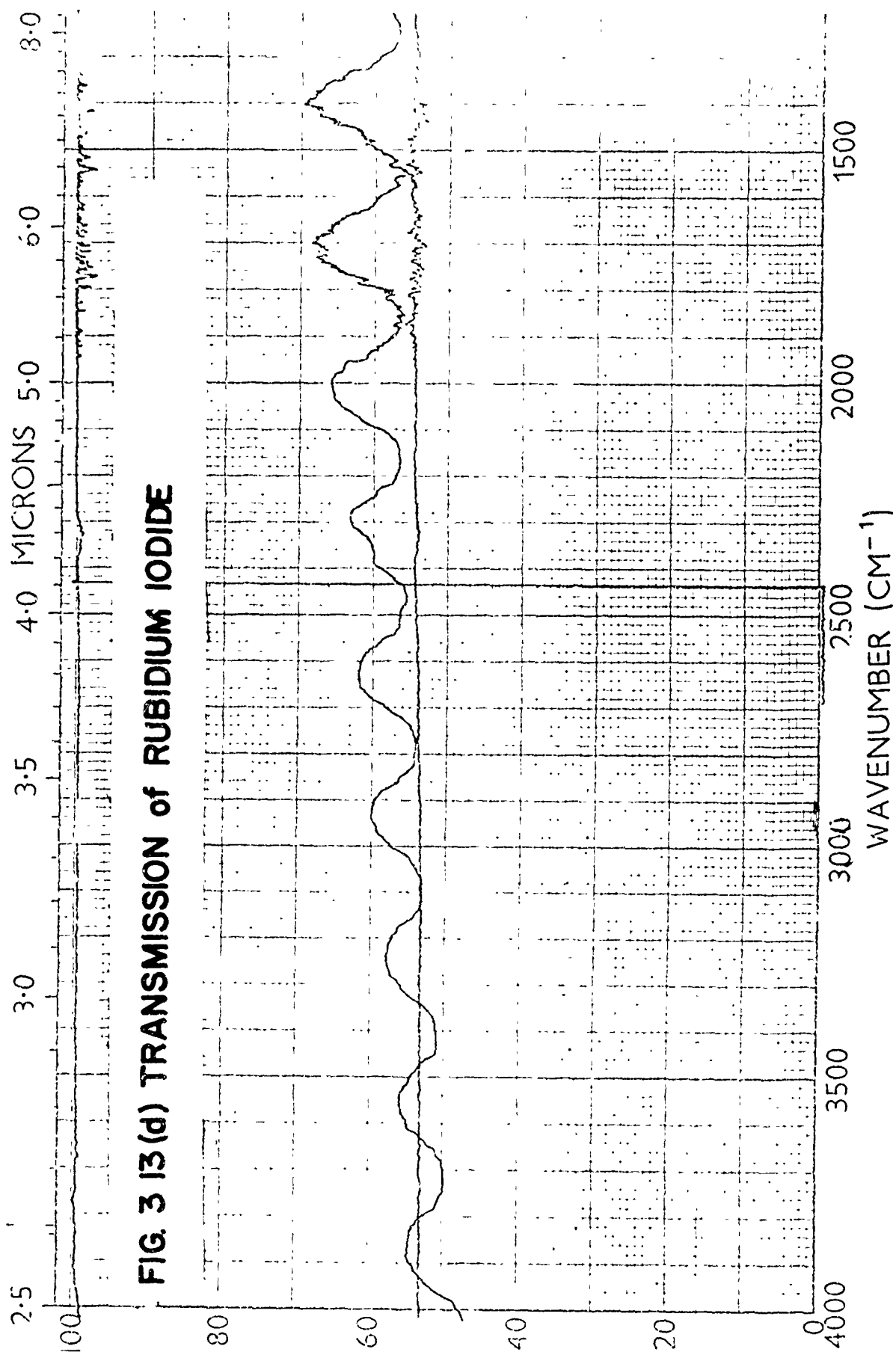
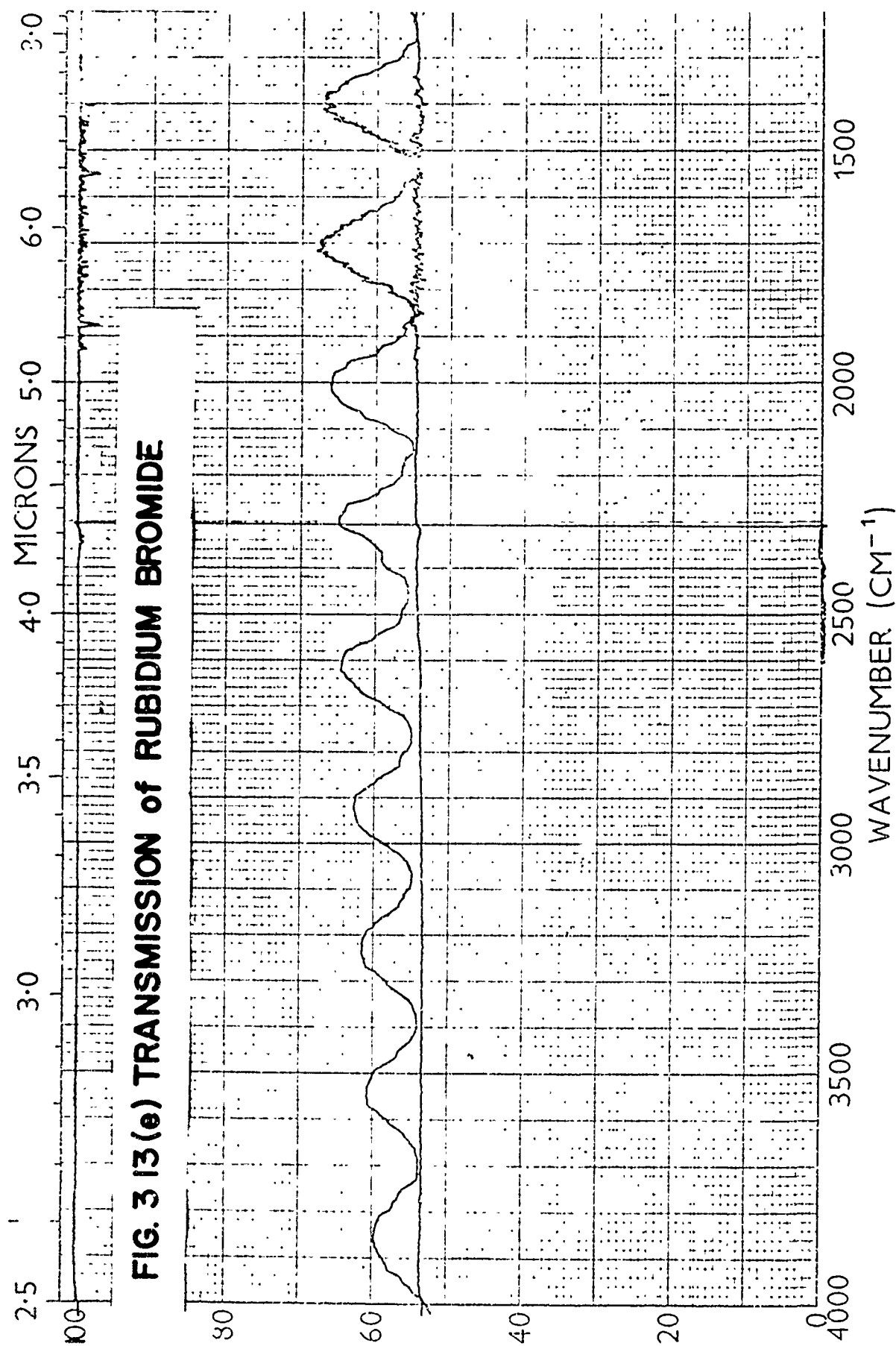
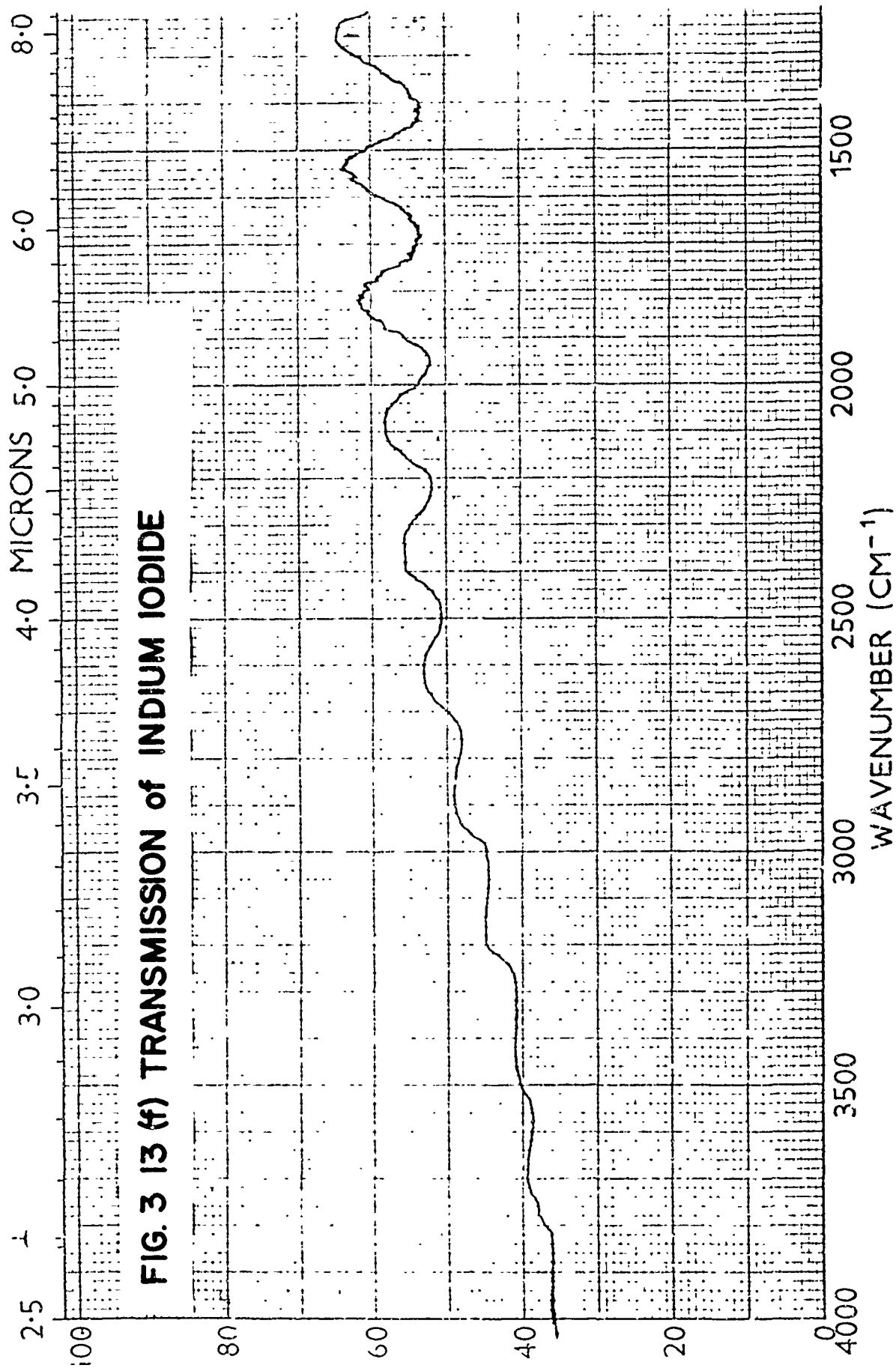


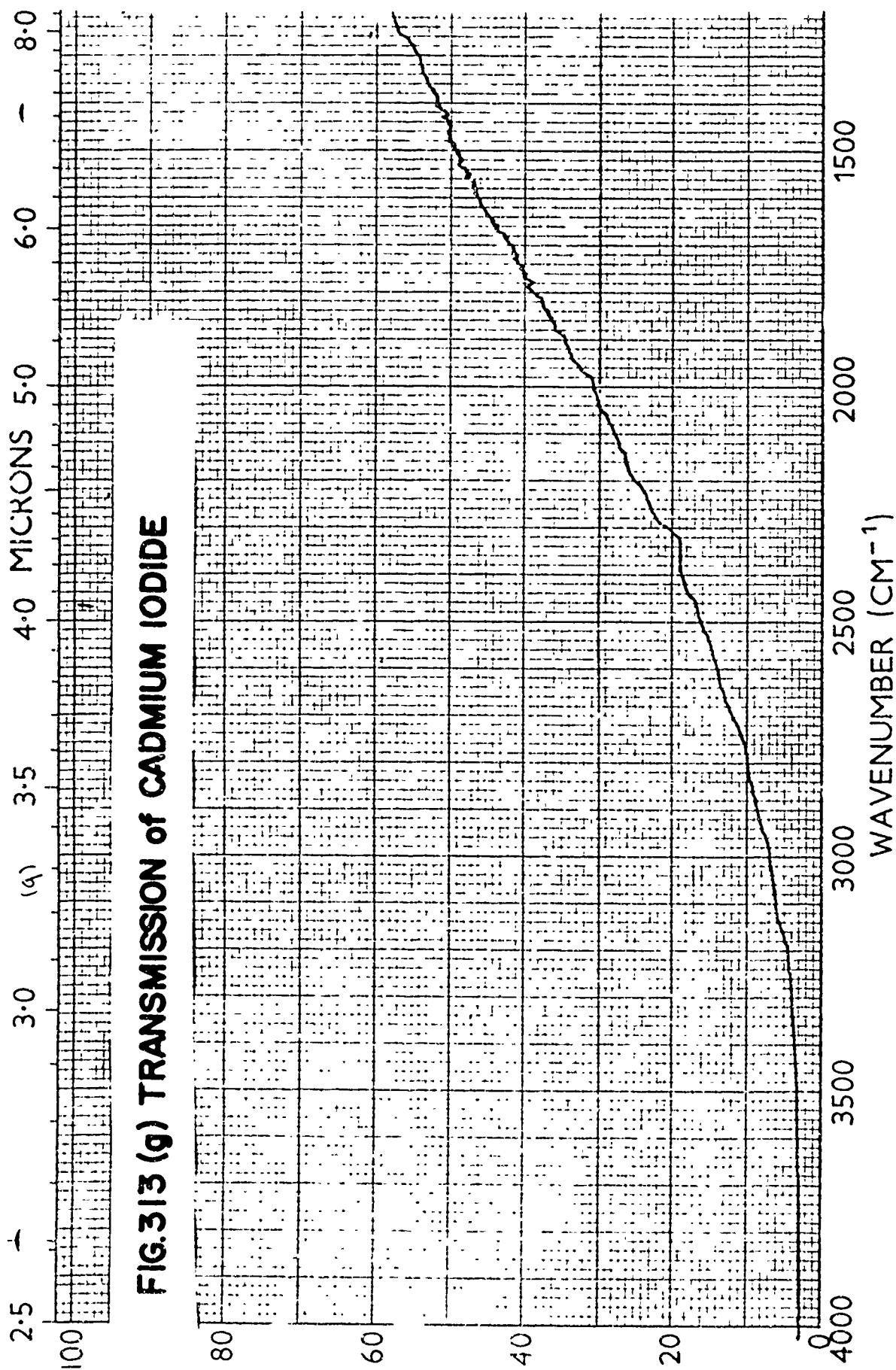
FIG. 3 13(b) TRANSMISSIONS of THALLOUS IODIDE

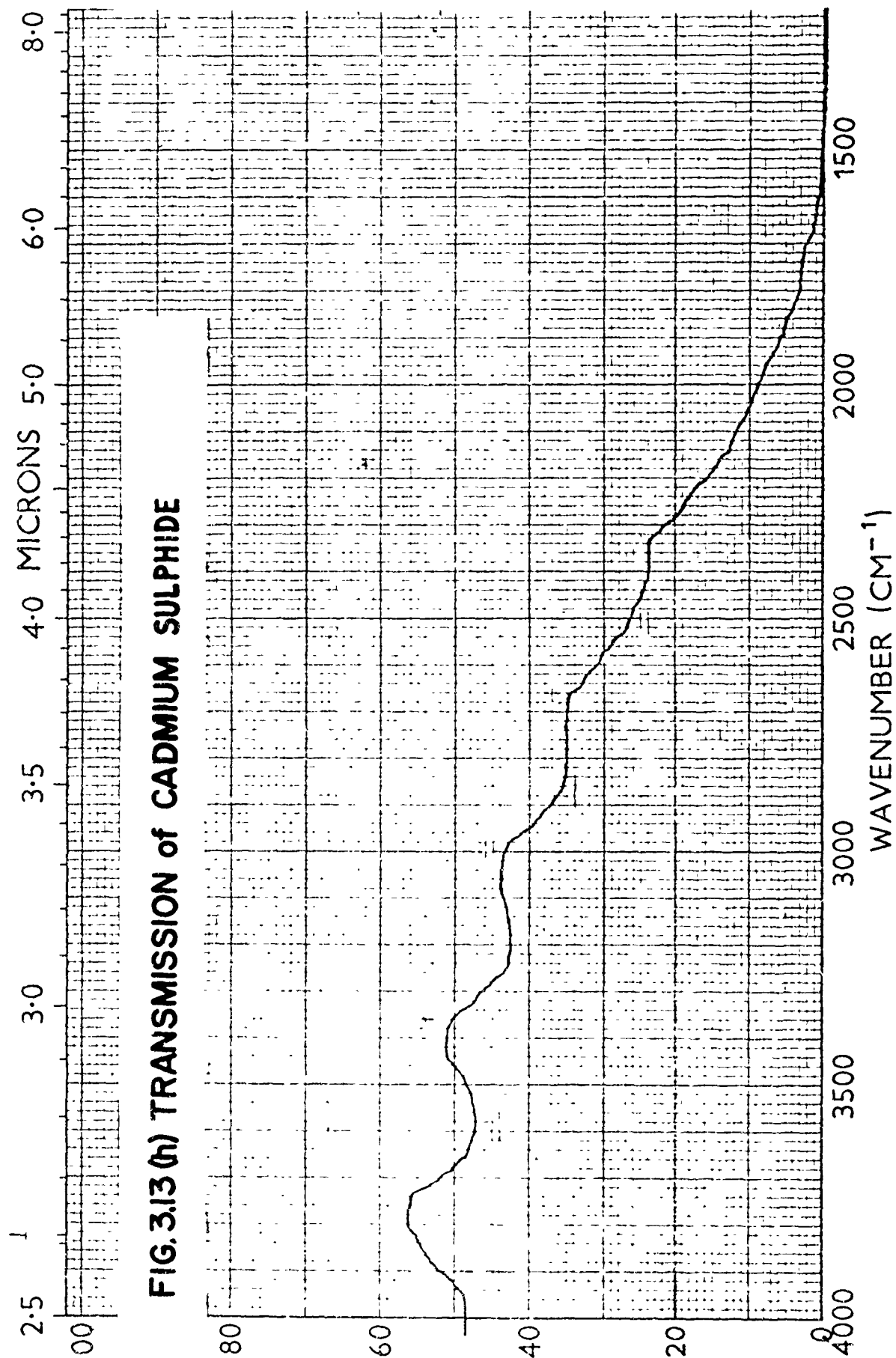


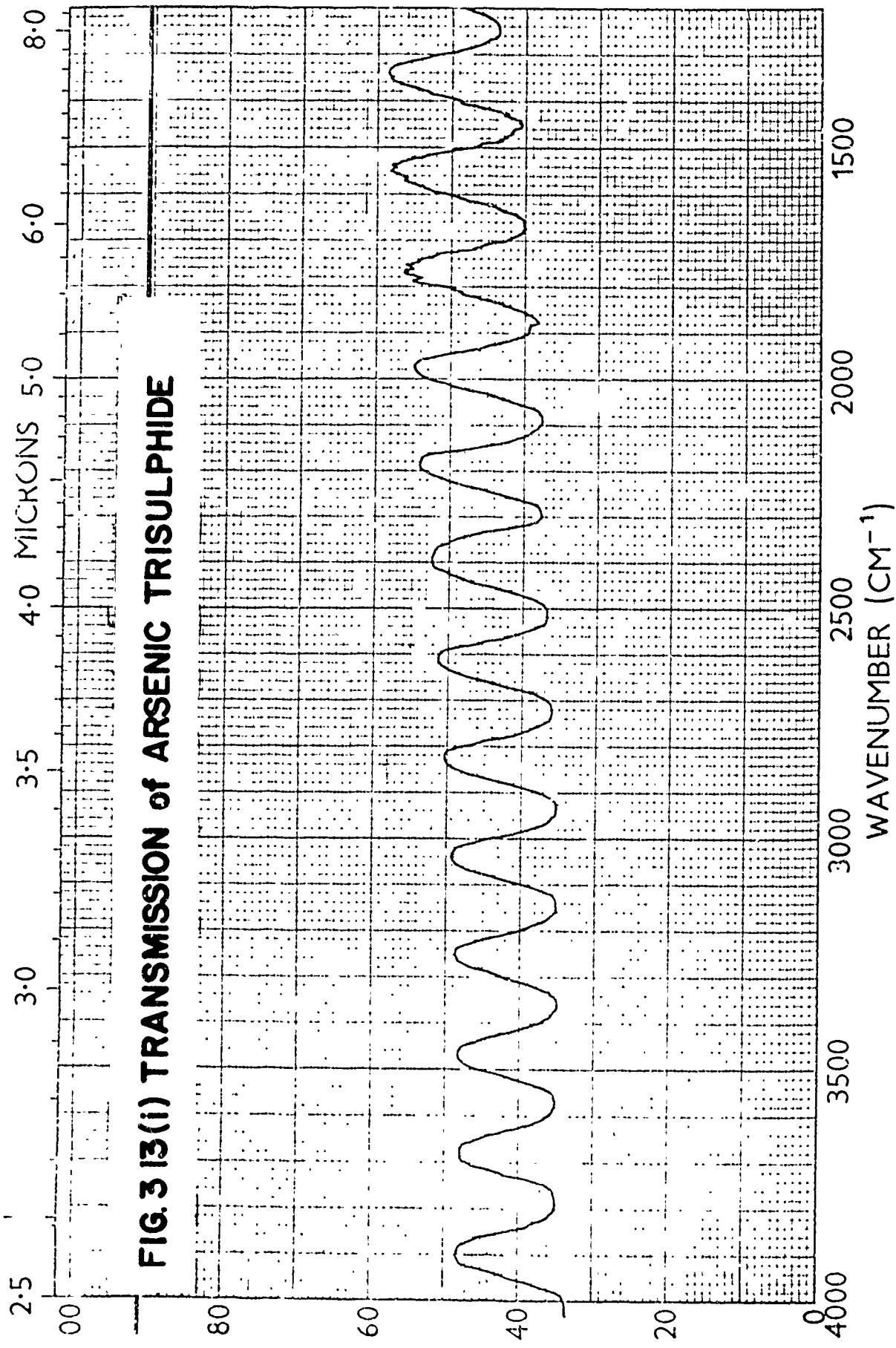


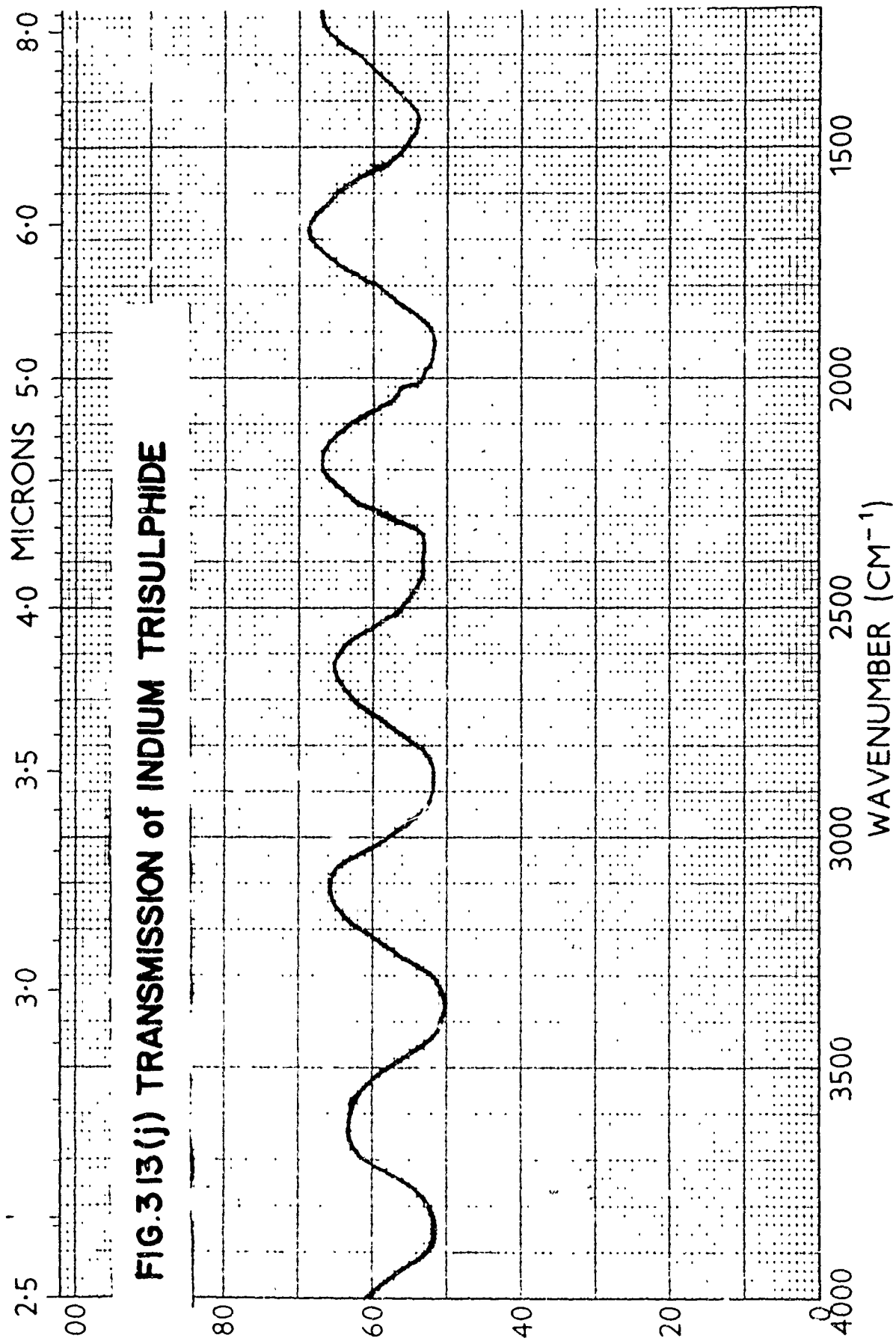












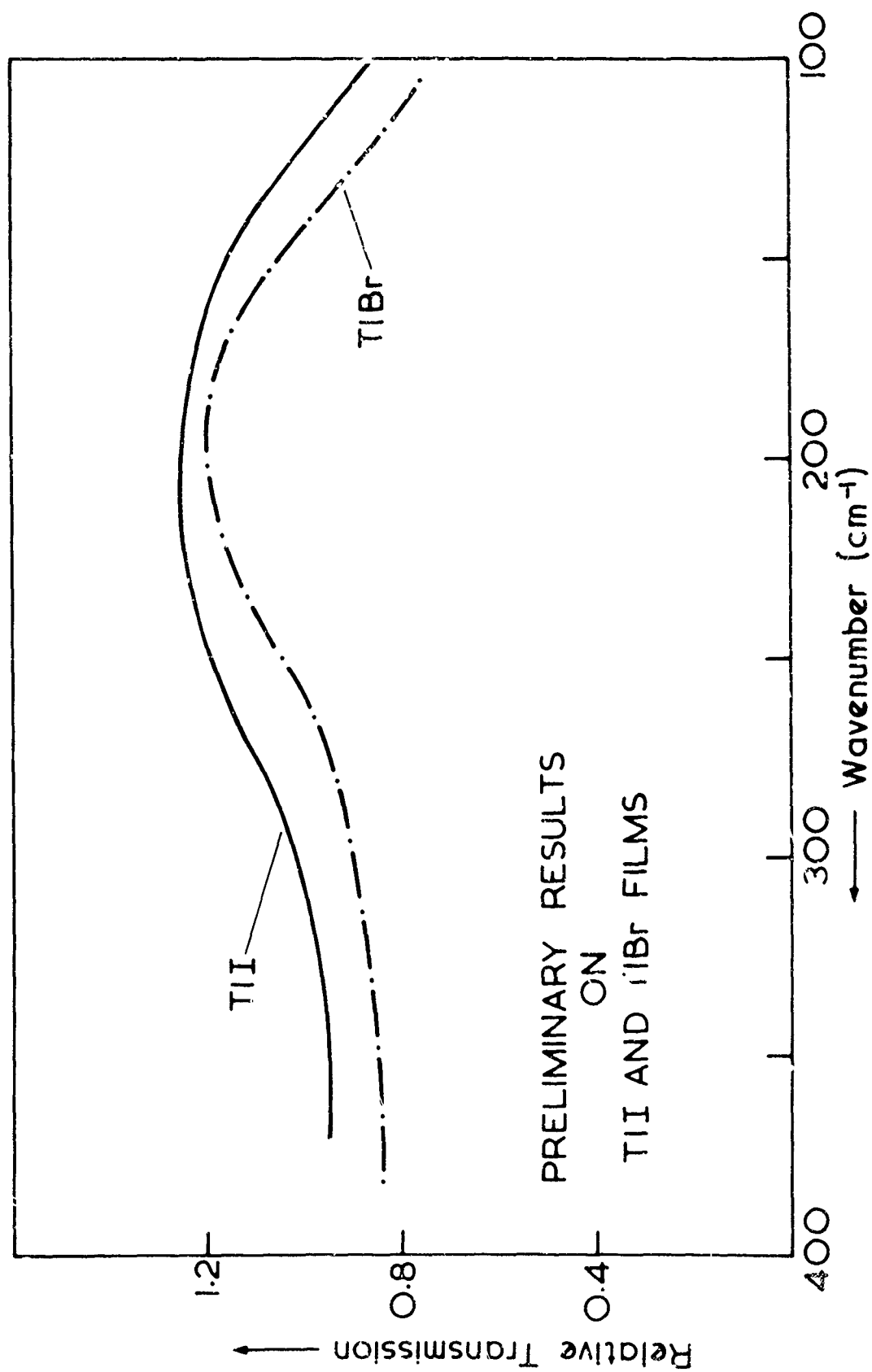


FIG. 3.14

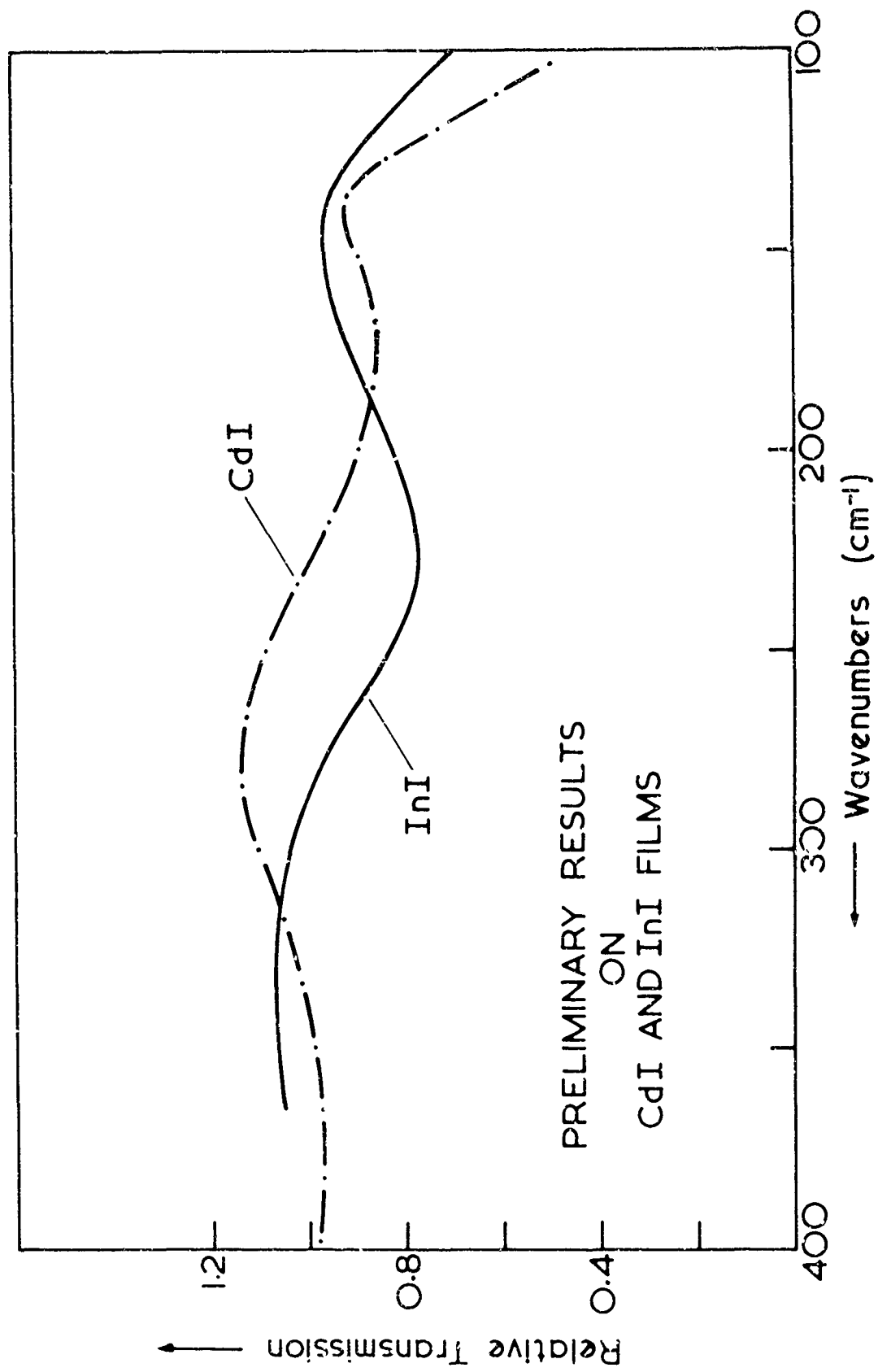


FIG. 3.15

HIGH VAPOUR PRESSURE METHOD

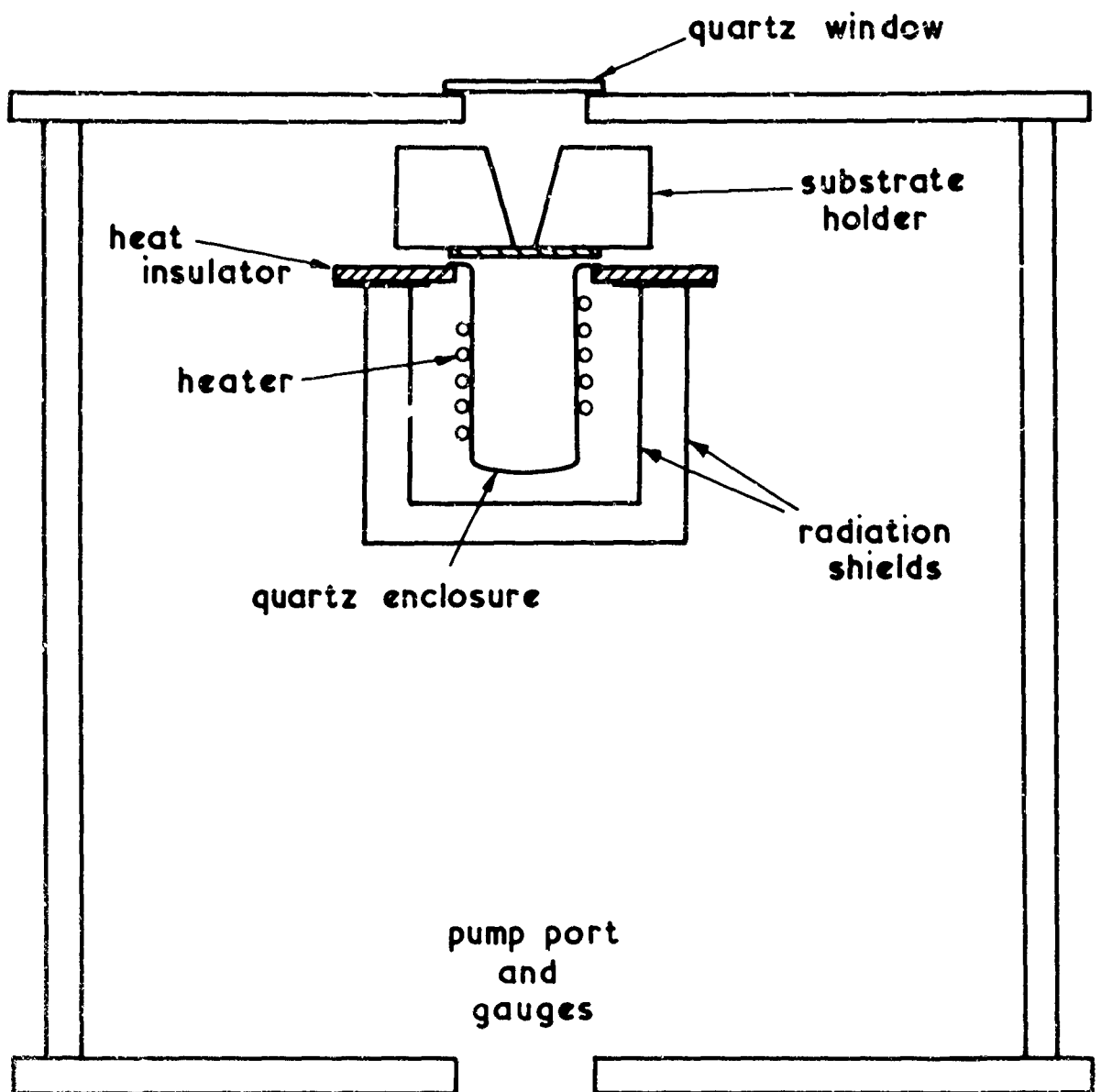


FIG. 3-16

GAS FLOW METHOD

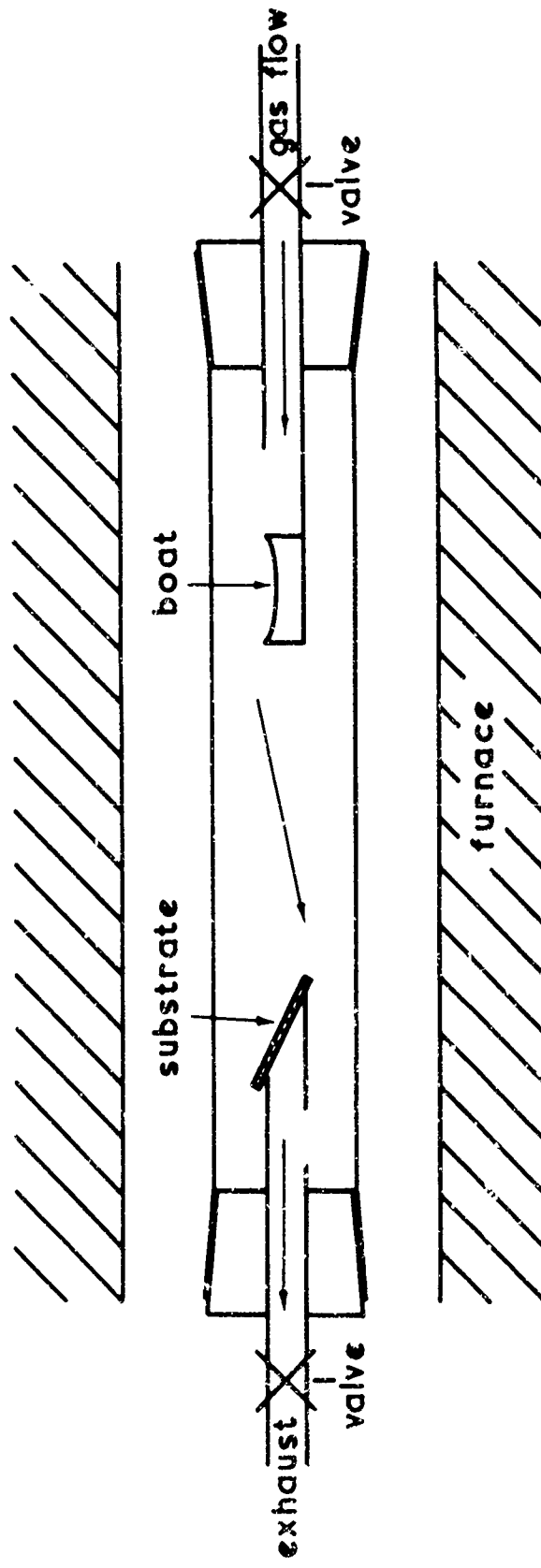


FIG. 3.17

COMPARISON OF GROUND AND POLISHED SILICON SUBSTRATES

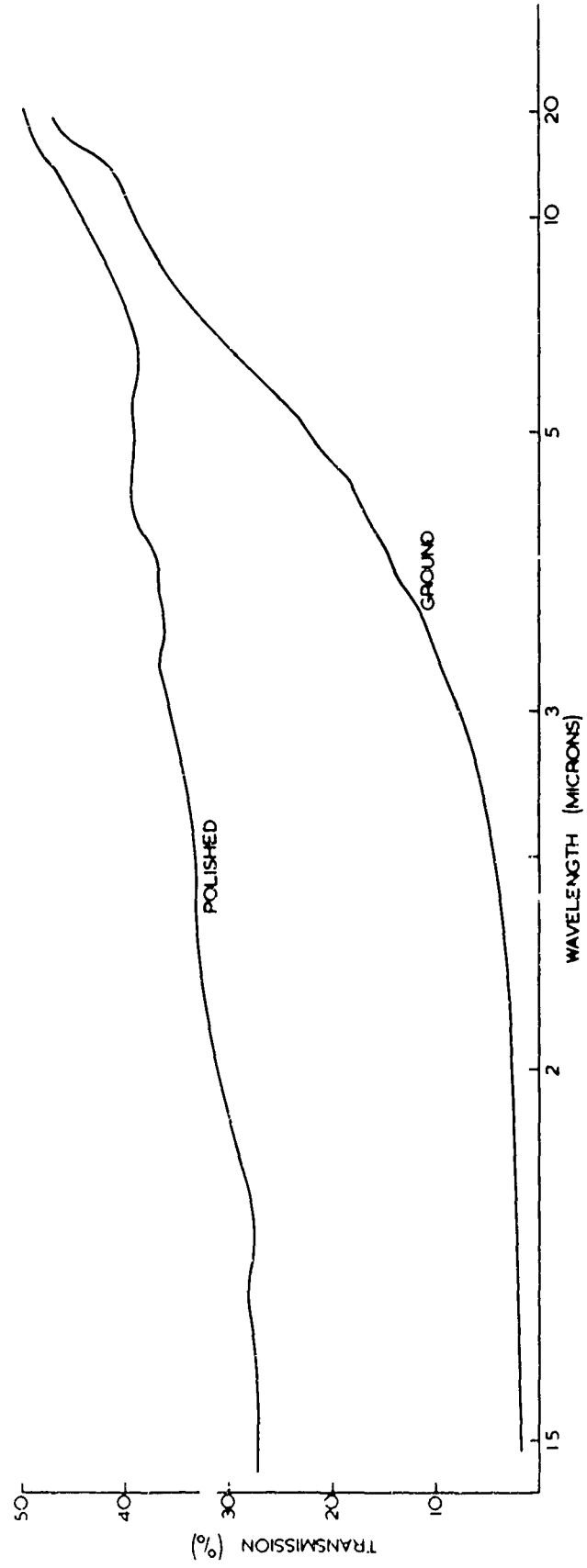


FIG 3.18

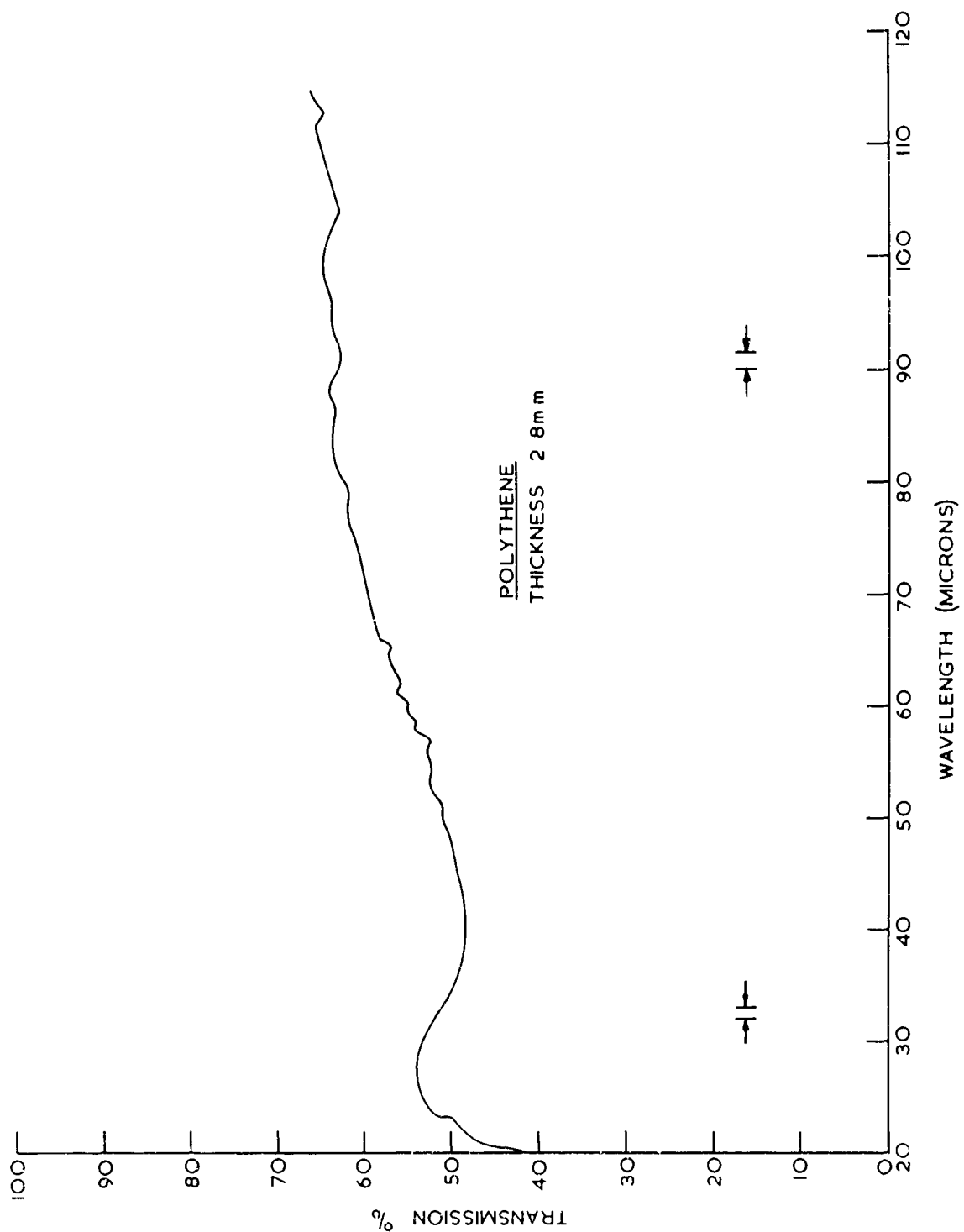


FIG 3.19

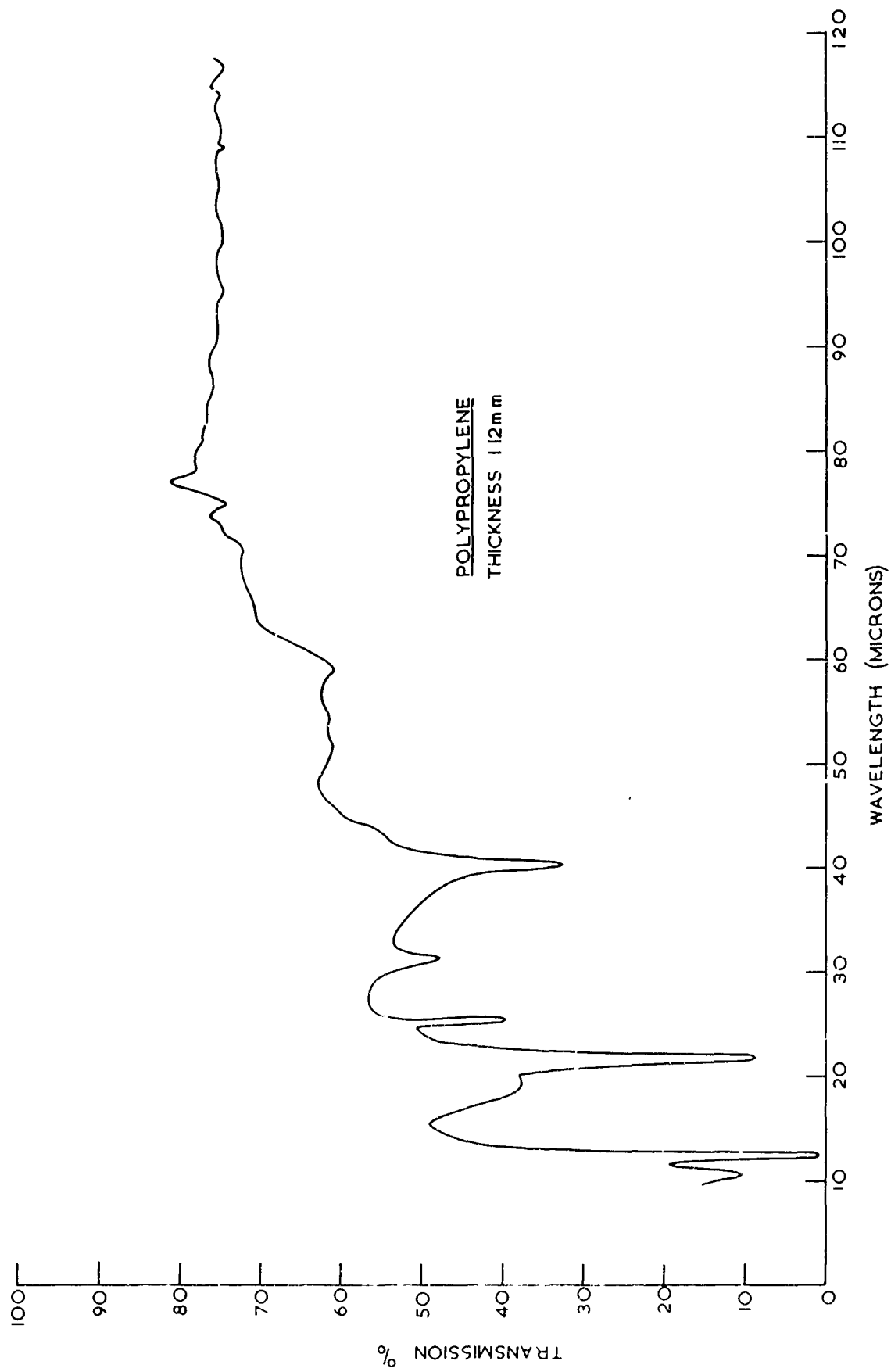


FIG. 3.20

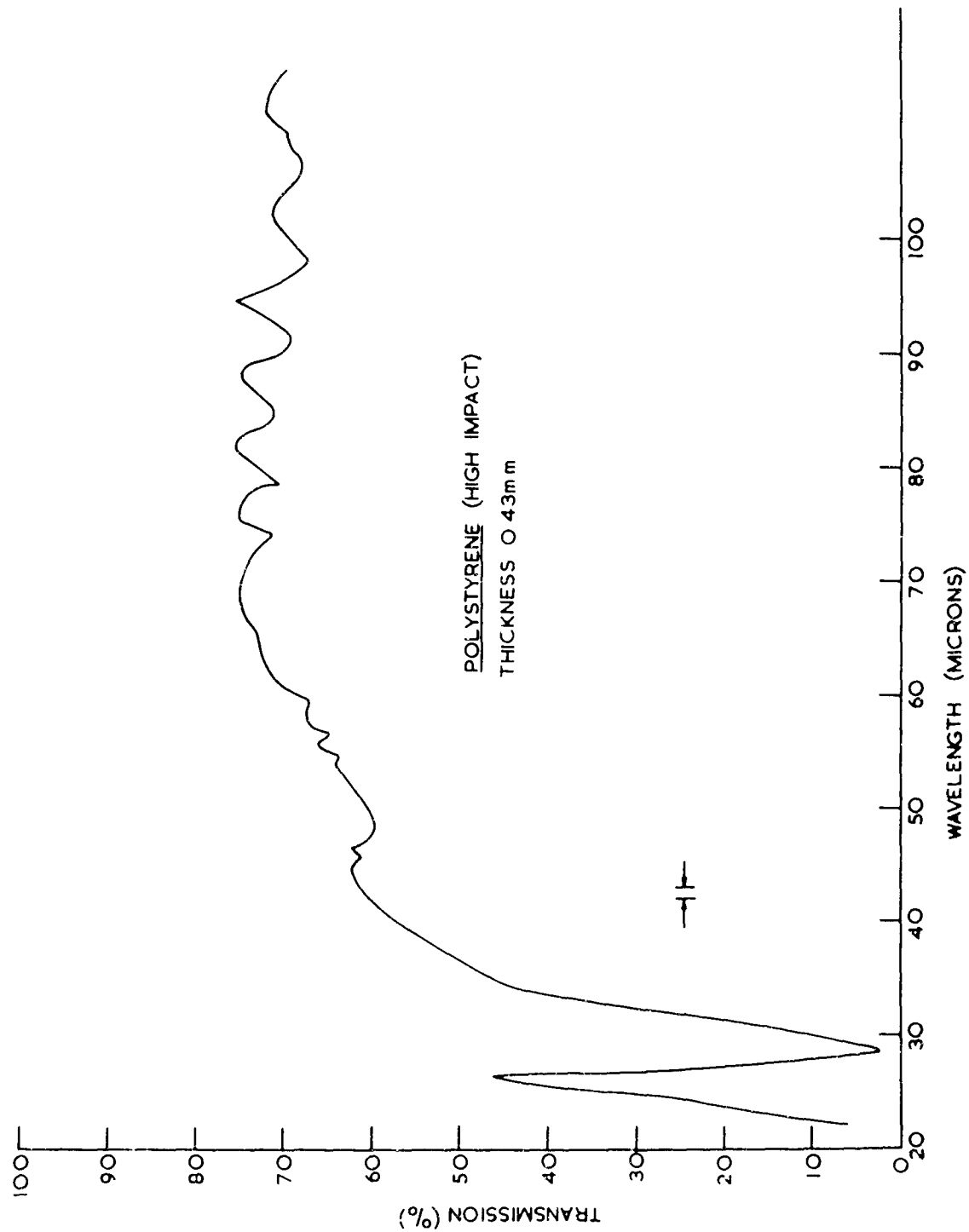


FIG. 3.21

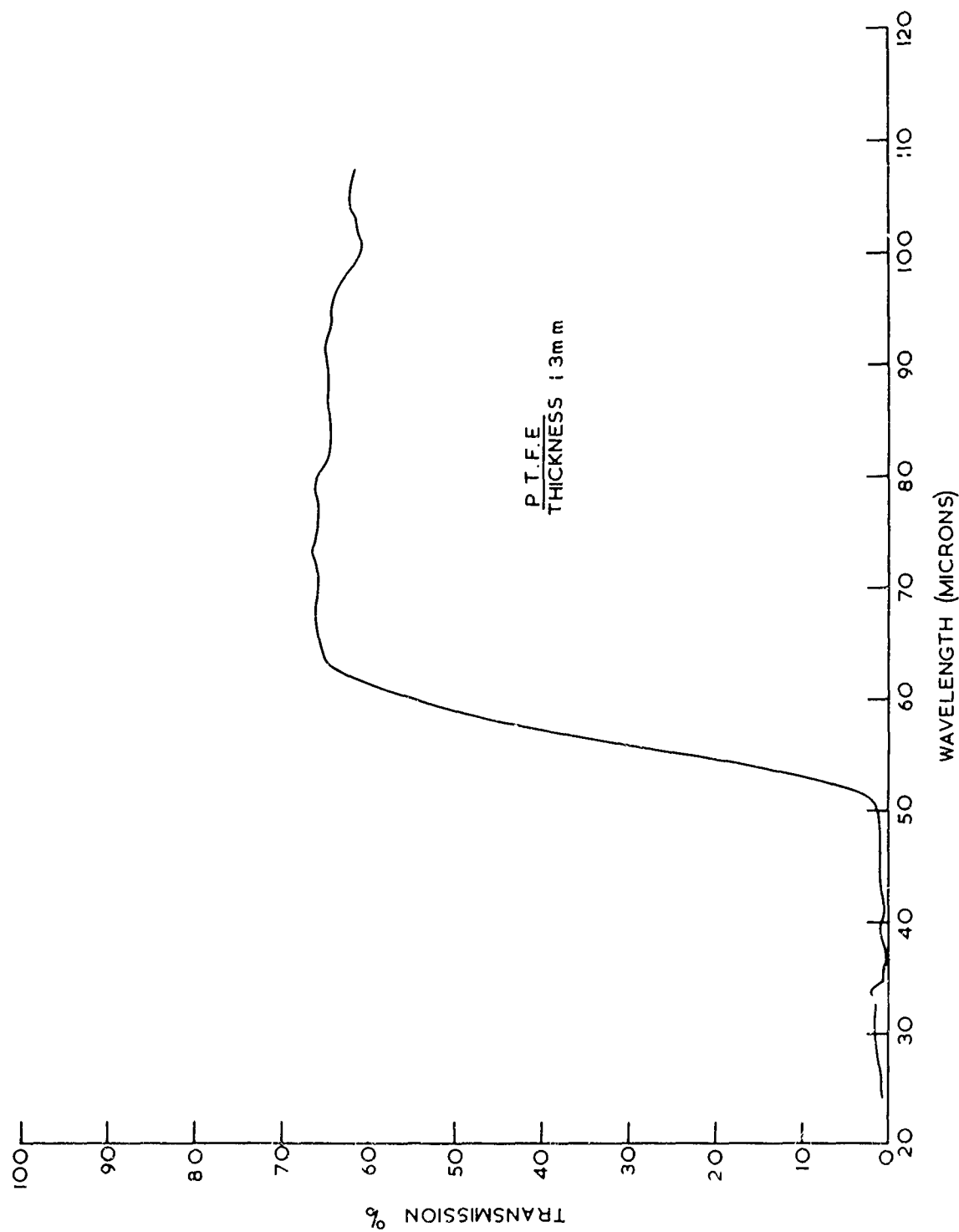


FIG 3-22

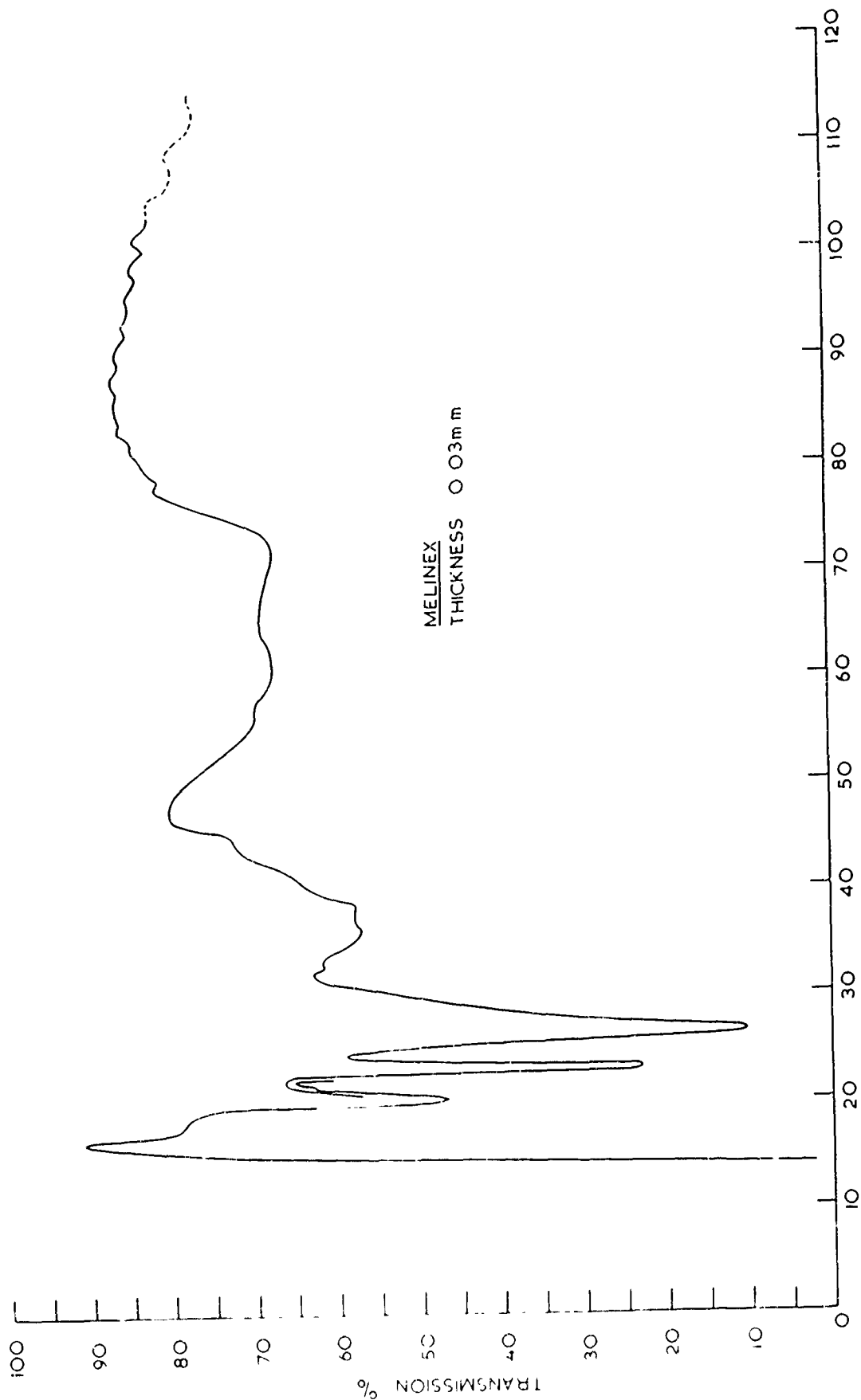


FIG. 3.23

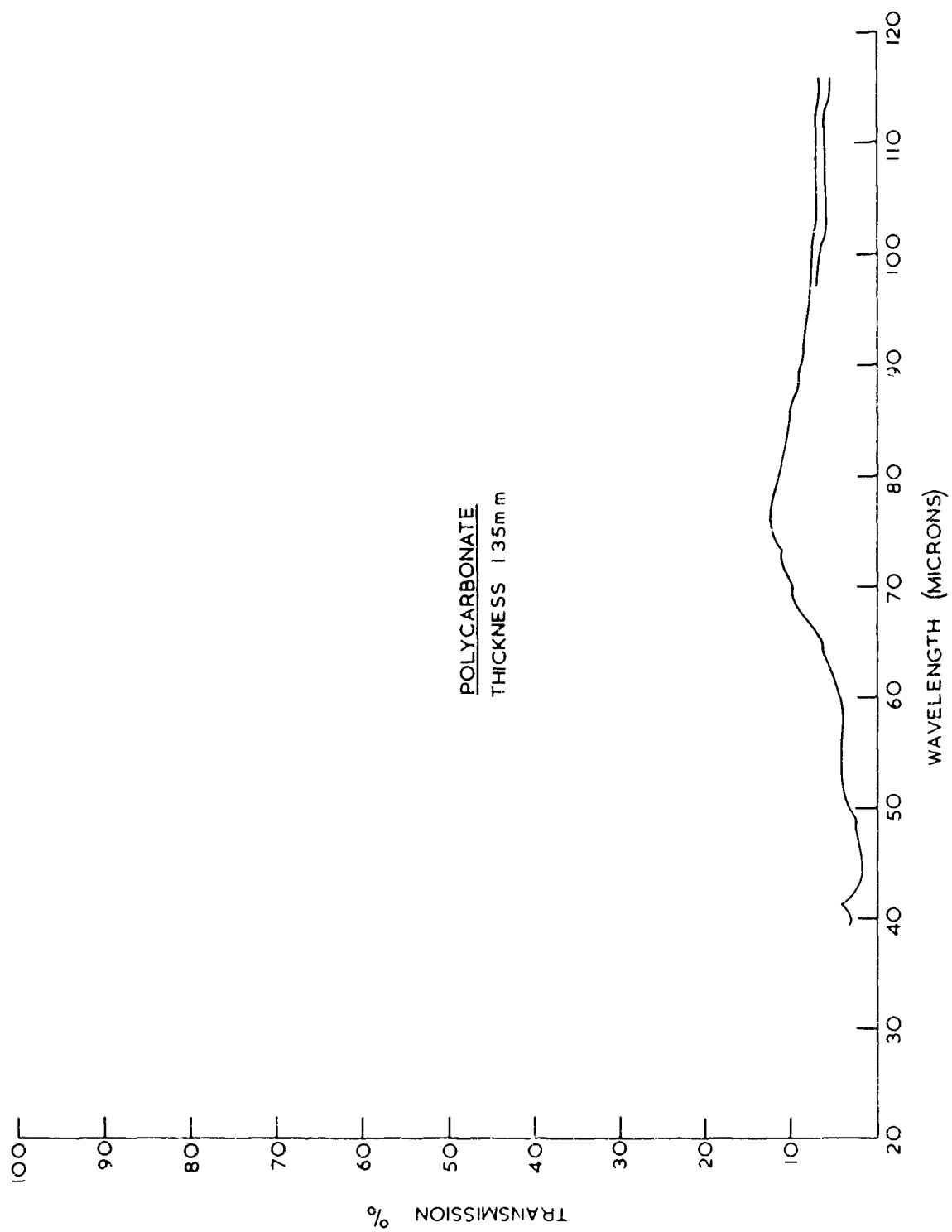
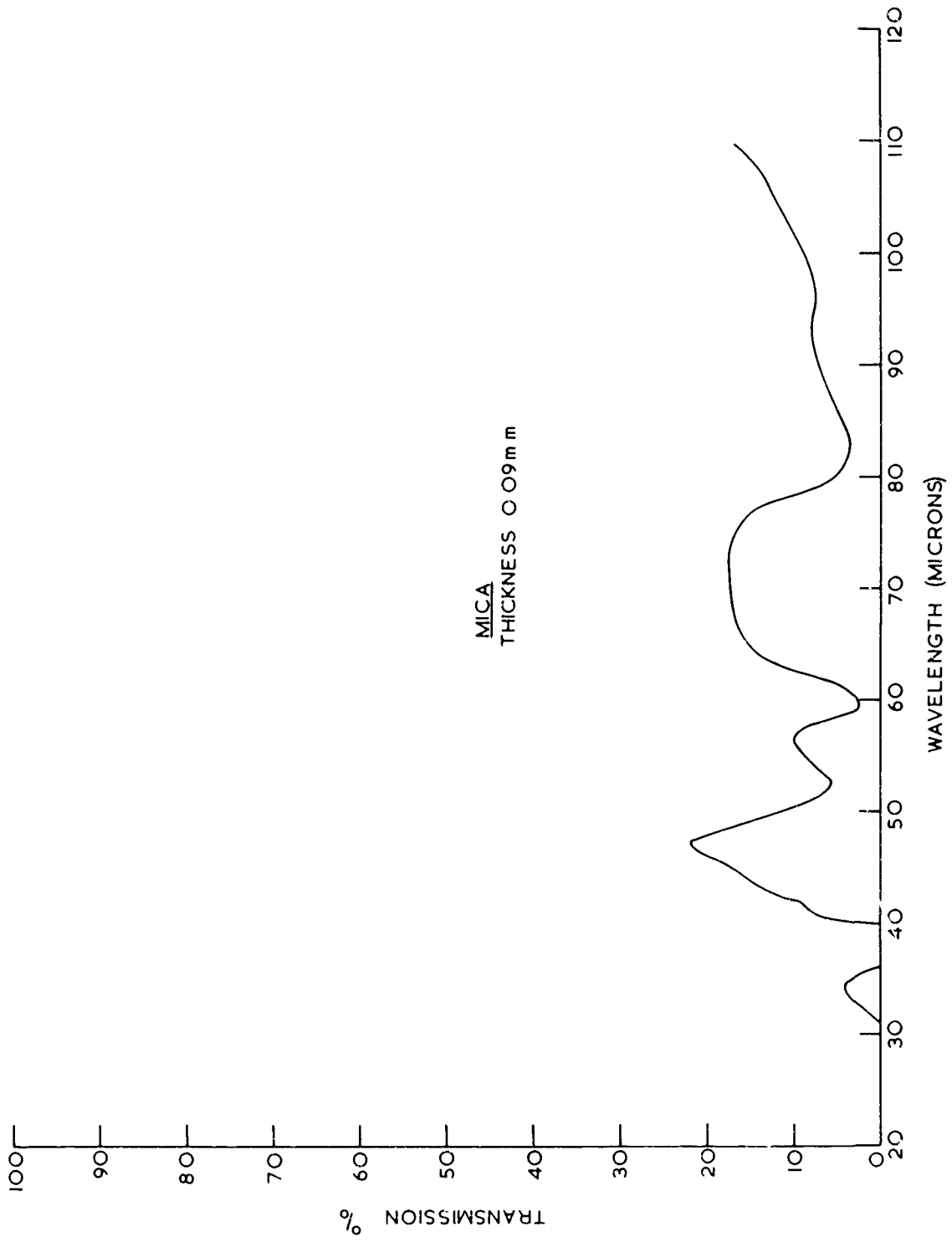


FIG 3 24



MICA
THICKNESS 0.09 mm

FIG 3 25

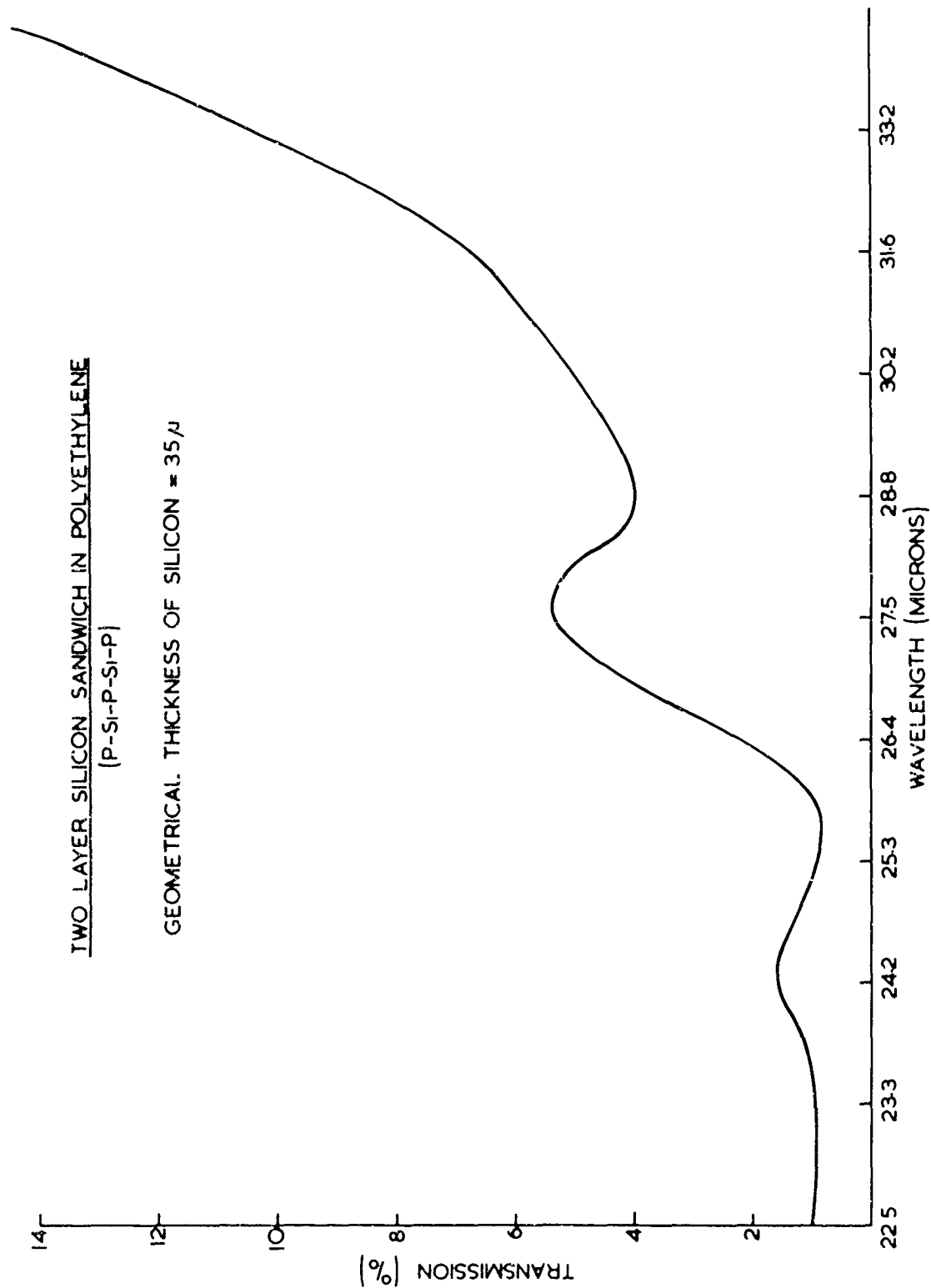


FIG 3 26

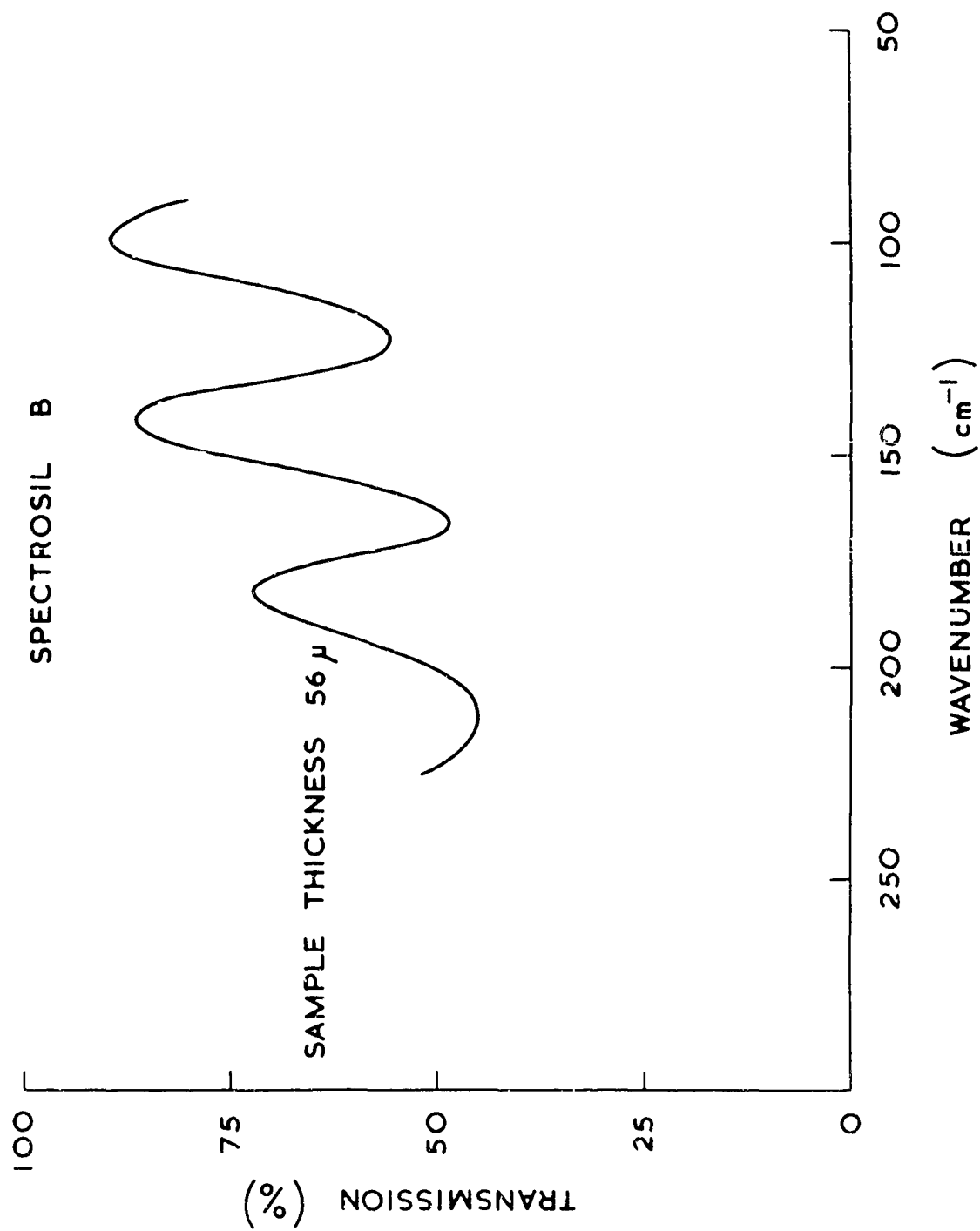


FIG. 3.27

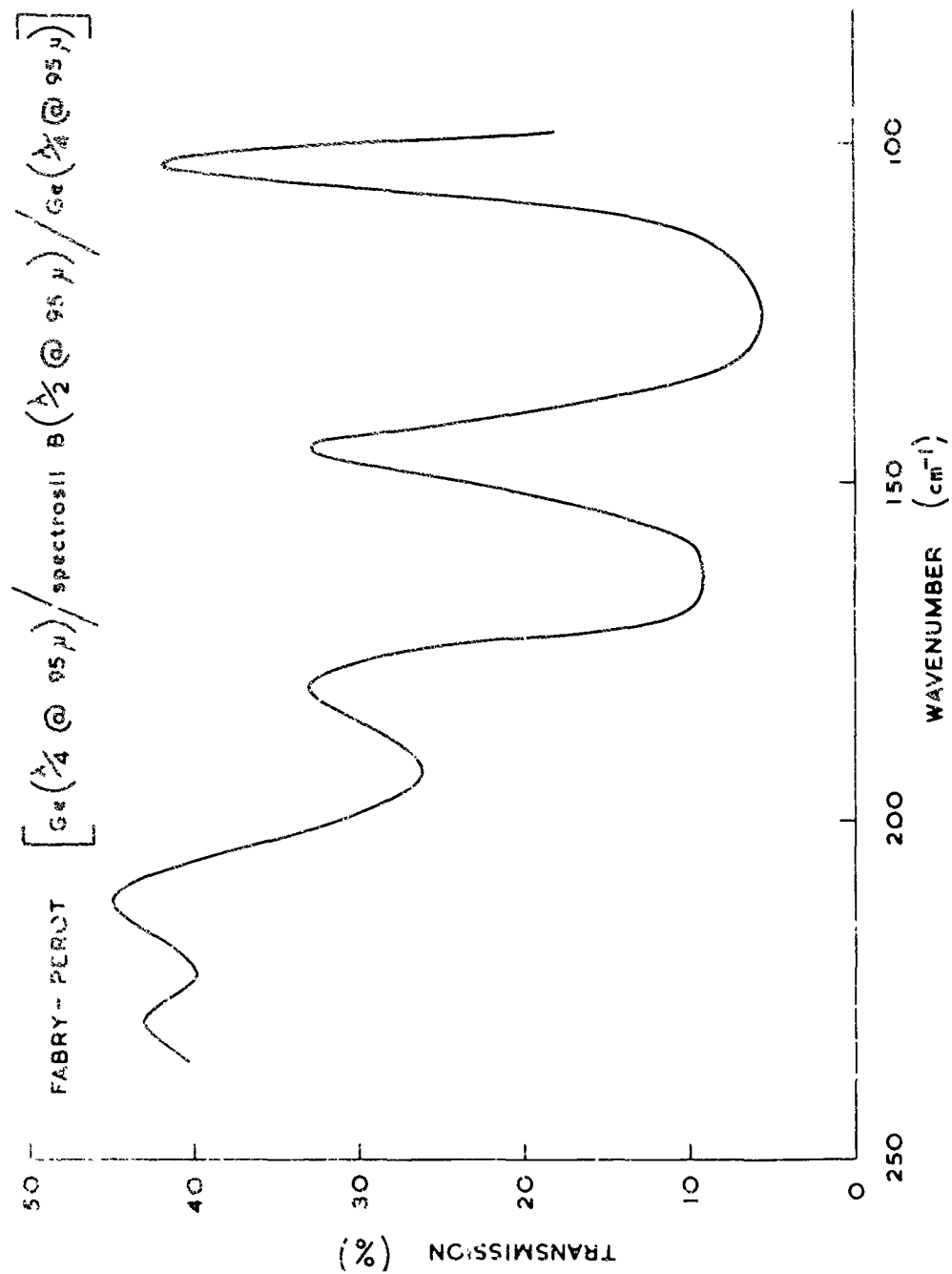


FIG 3:28

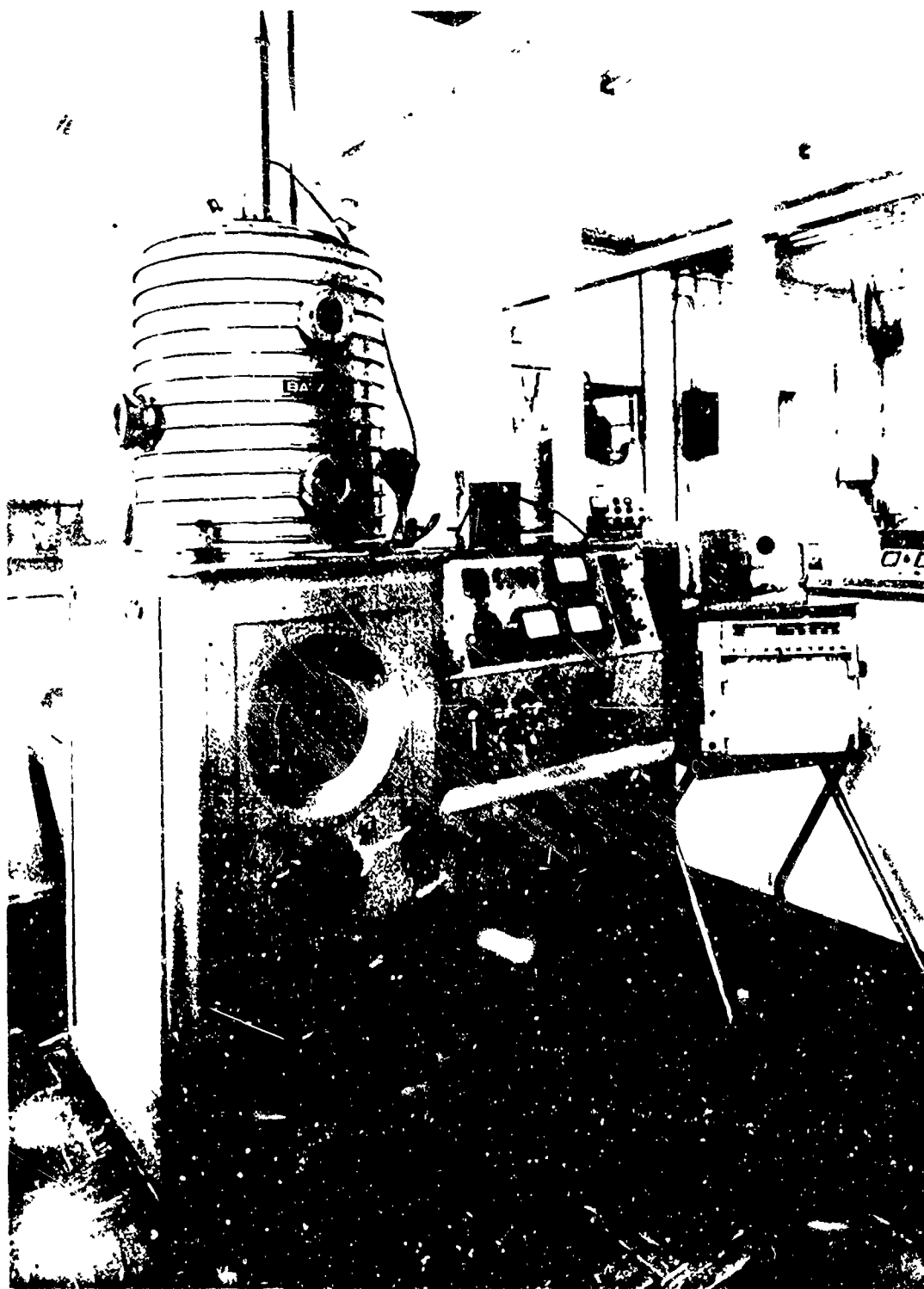
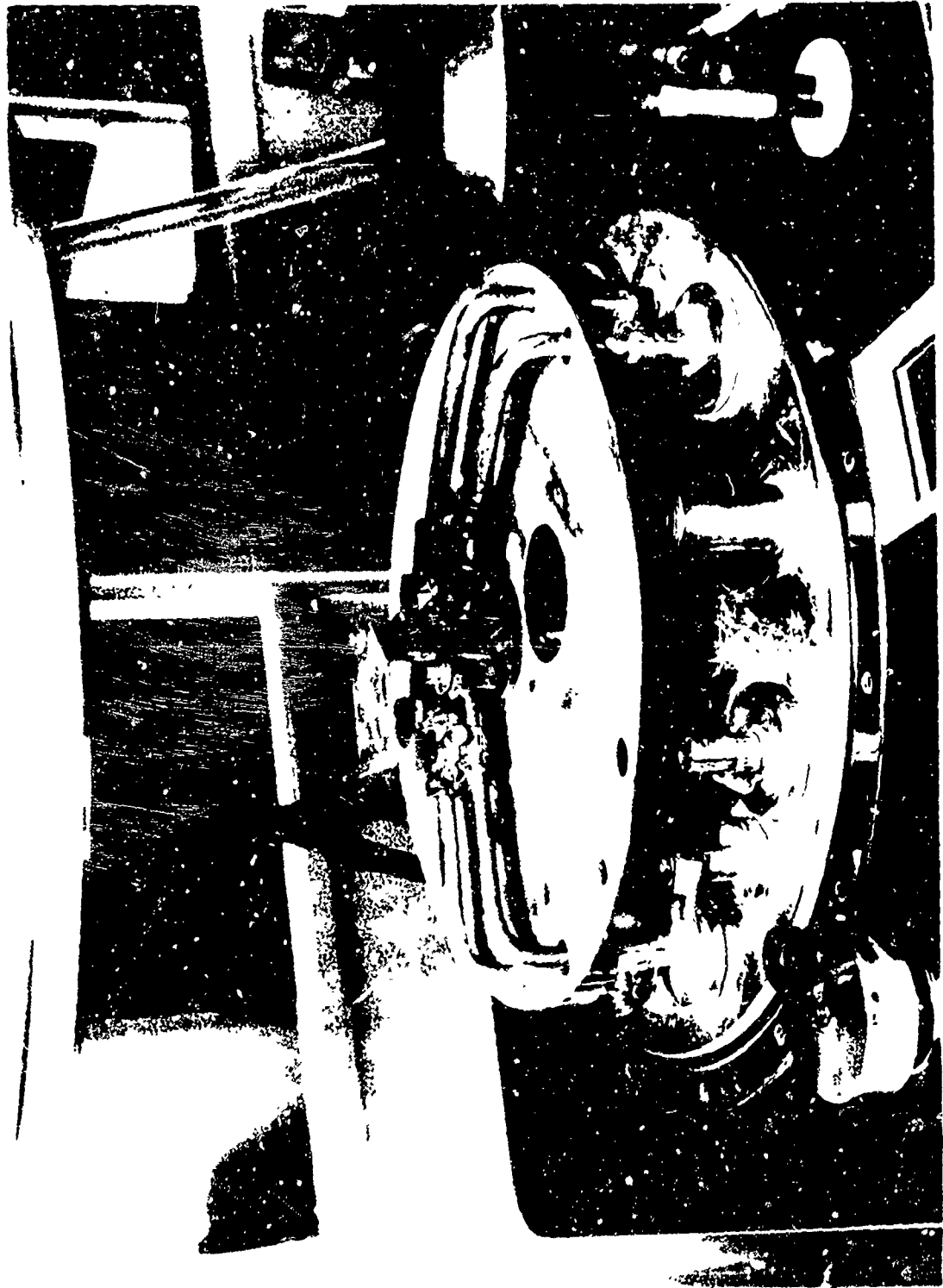


FIG: 4.1(a) BA 500 PLANT USED at GRUBB PARSONS

FIG:4.1 (b) ARRANGEMENT of FIXED SOURCES



DESIGN	GE/LH LHL HH LHLH	REFRACTIVE INDEX	Ns = 4.0
		NL = 2.35	
		NH = 5.3	

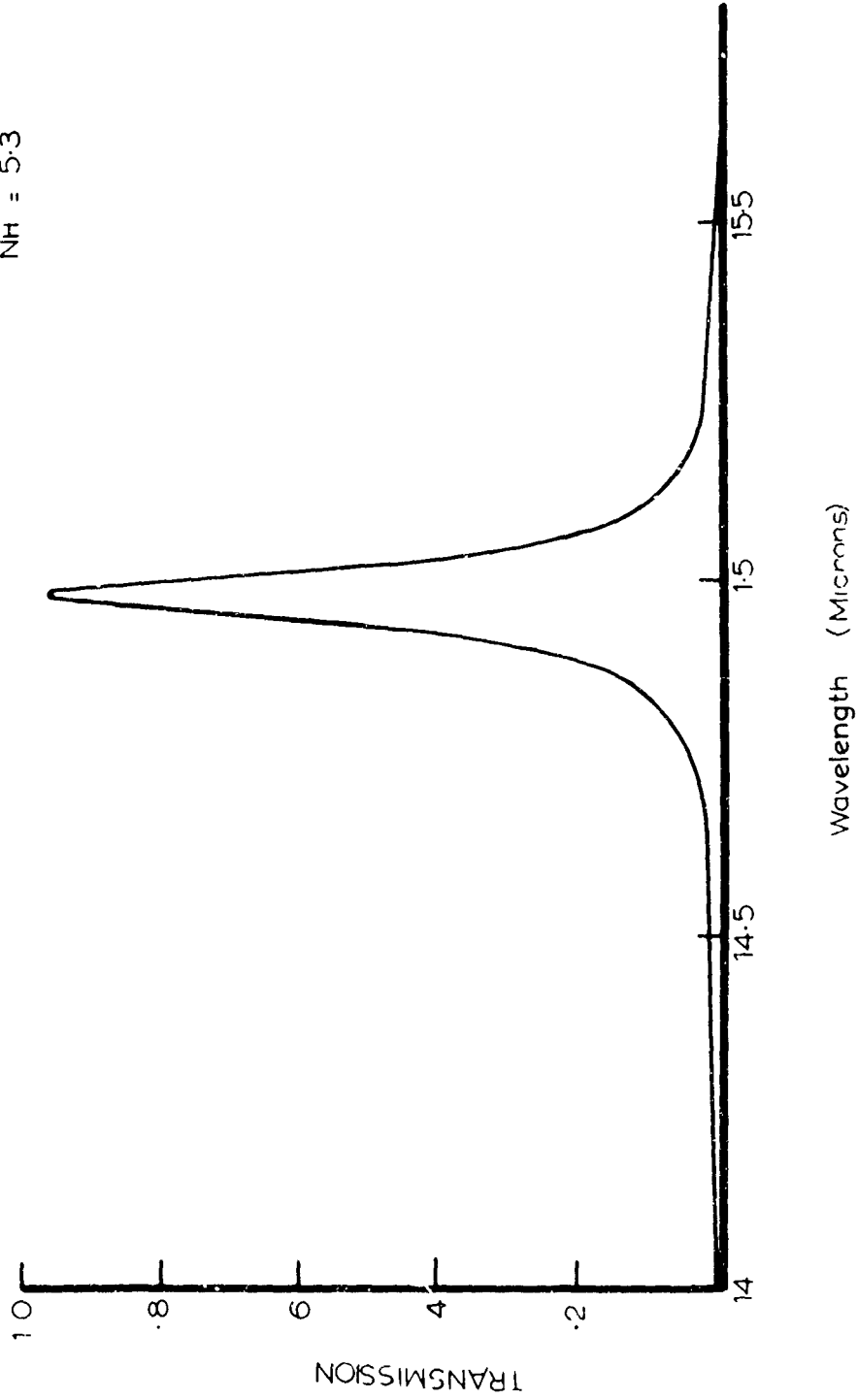


FIG 4.2 (a) COMPUTED TRANSMISSION OF FABRY PEROT AT 15μ

DESIGN Ge/LHL HHLHLH LH LHL HH LH

REFRACTIVE INDEX
 $N_s = 4.0$
 $N_L = 2.35$
 $N_H = 5.3$

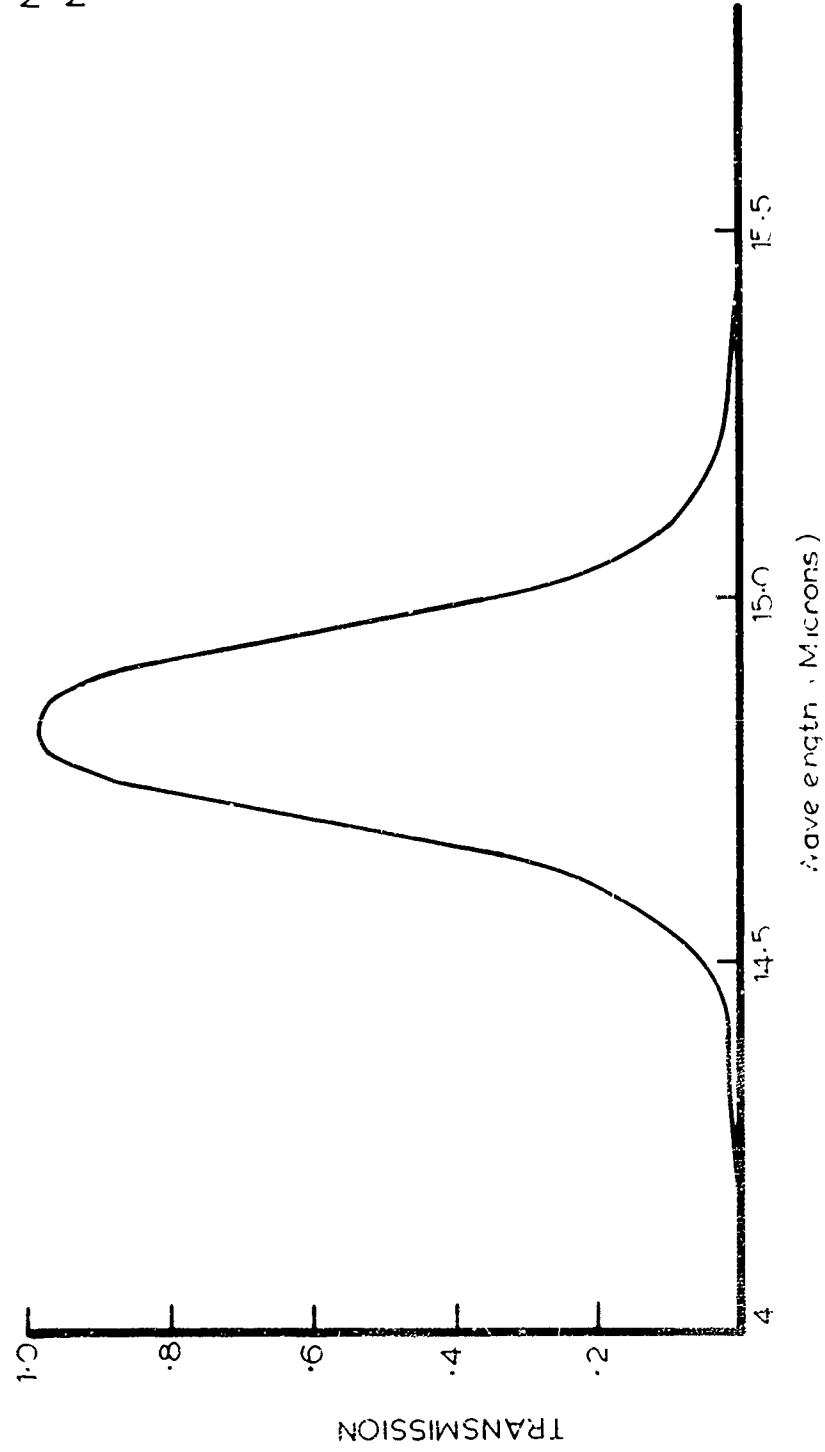


FIG 4.2 (b) COMPUTED TRANSMISSION OF D.H.W. AT 14.83 μ

DESIGN

Ge/L HH L H L H L HH L H

REFRACTIVE INDEX $N_s = 4.0$
 $N_L = 2.35$
 $N_H = 5.3$

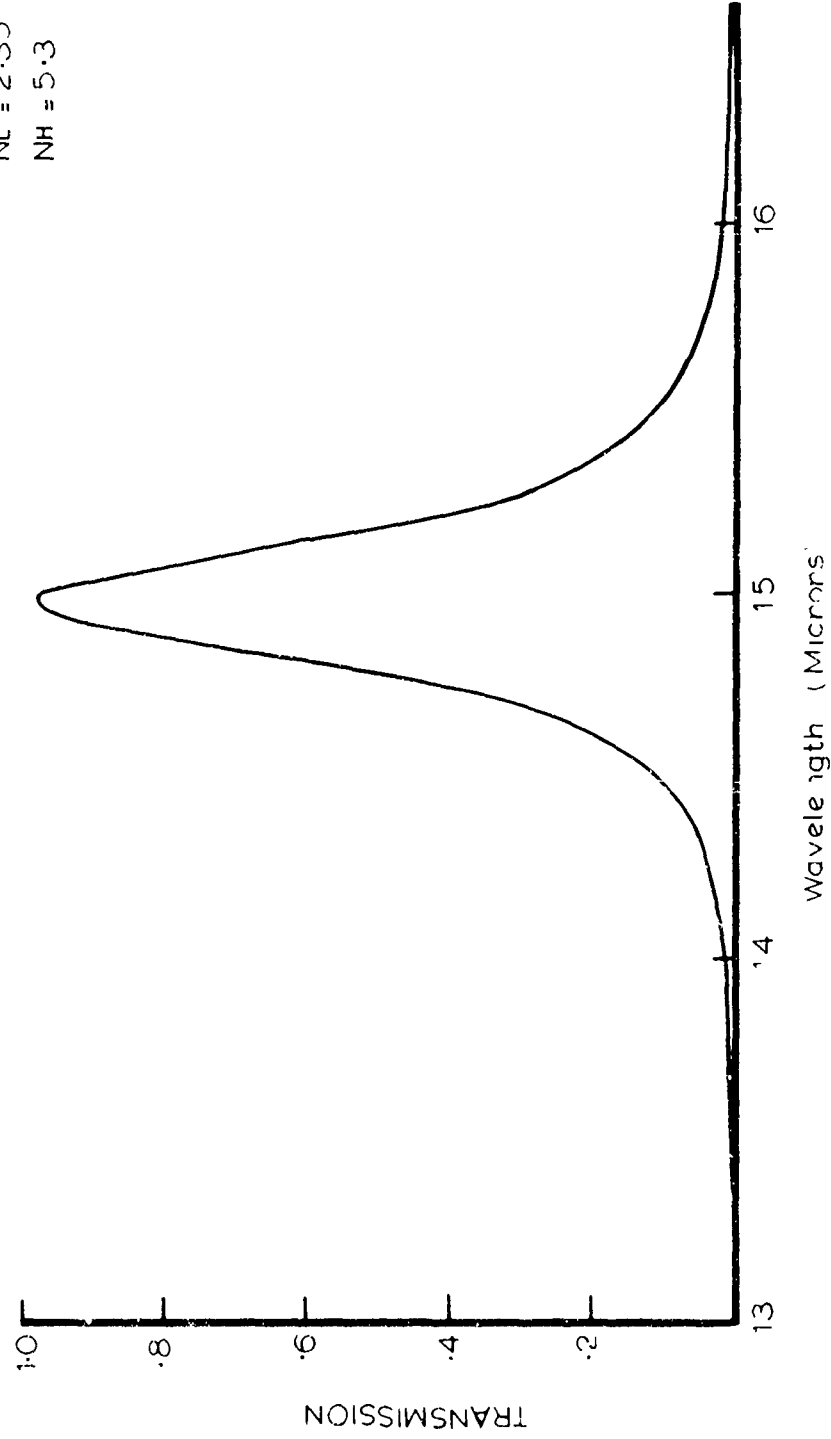
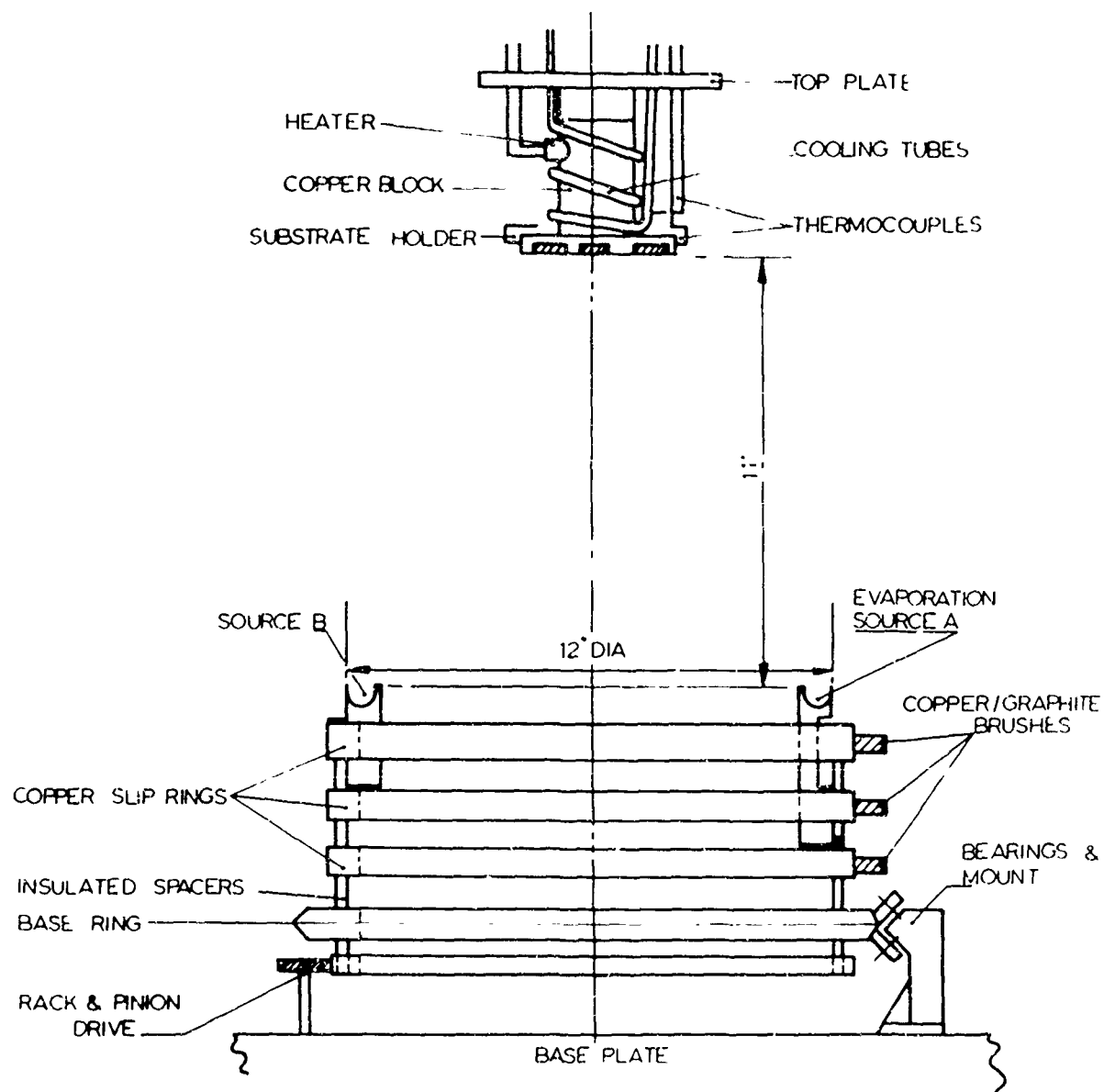
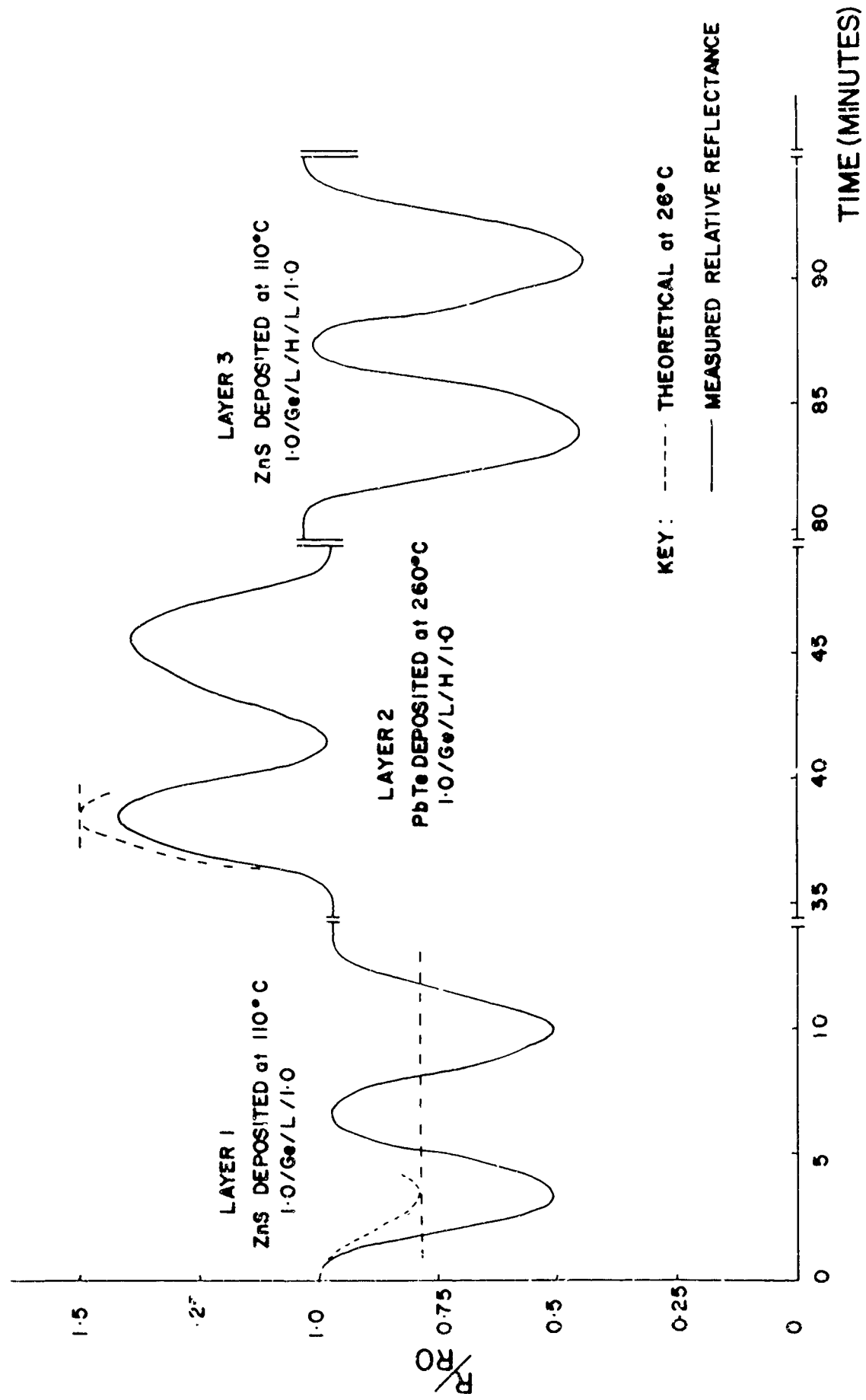


FIG 4.2(C) COMPUTED TRANSMISSION OF D.H.W. AT 15μ



SCHEMATIC DIAGRAM OF ROTATING SOURCE
ASSEMBLY & SUBSTRATE HOLDER

FIG 4.3



ZnS DEPOSITION TEMPERATURE
100 °C

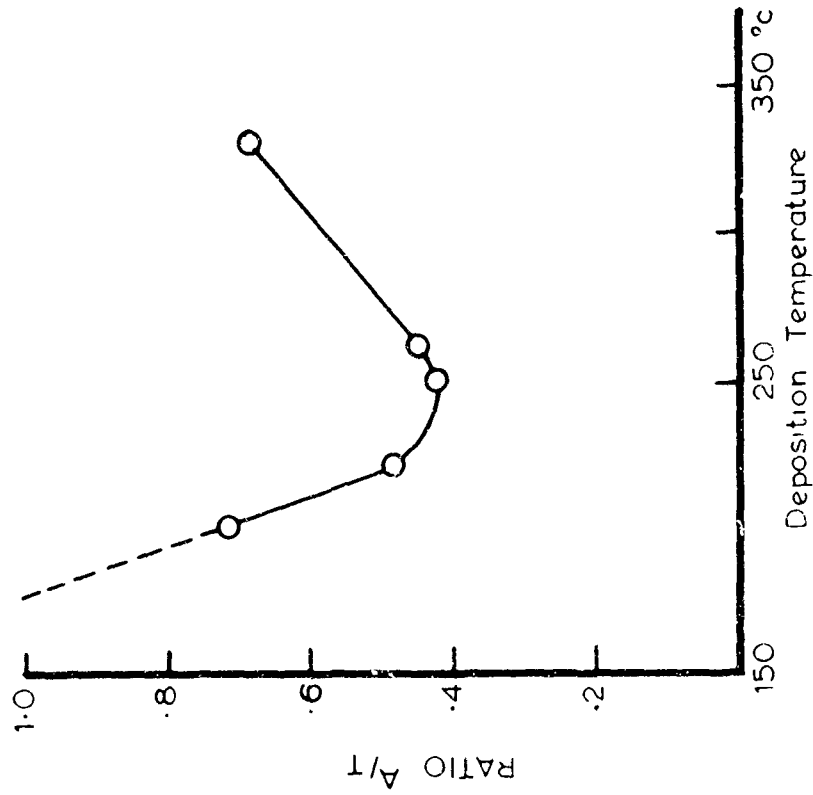


FIG 4.5 (a) VARIATION IN FABRY PEROT ABSORPTION WITH PbTe DEPOSITION TEMPERATURE.

PbTe DEPOSITION TEMPERATURE
250 °C

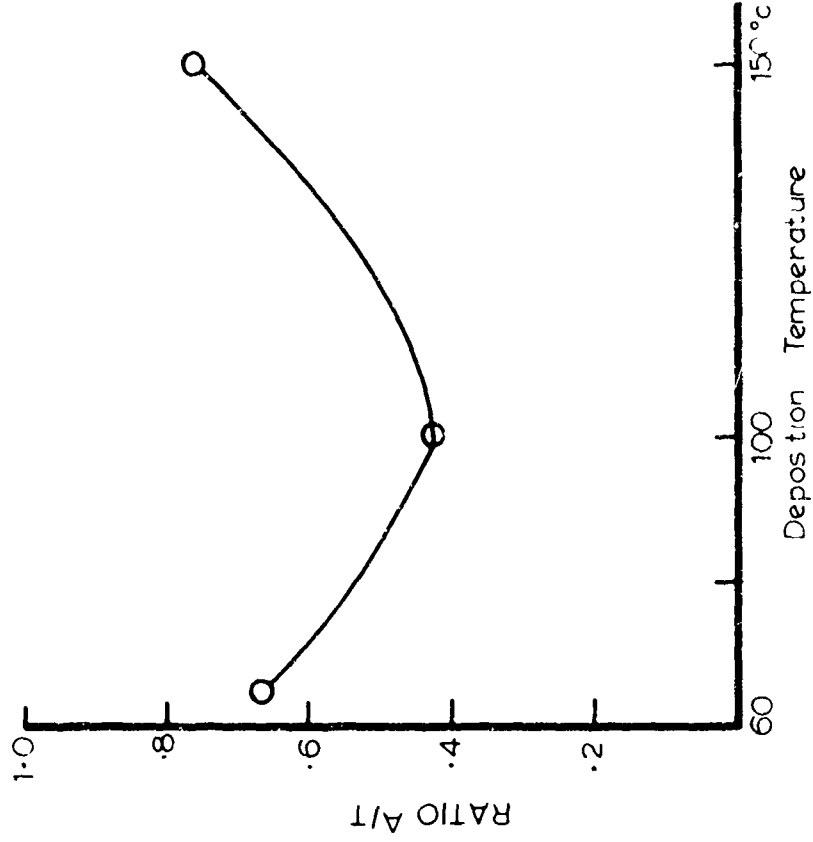


FIG 4.5 (b) VARIATION IN FABRY PEROT ABSORPTION WITH ZnS DEPOSITION TEMPERATURE.

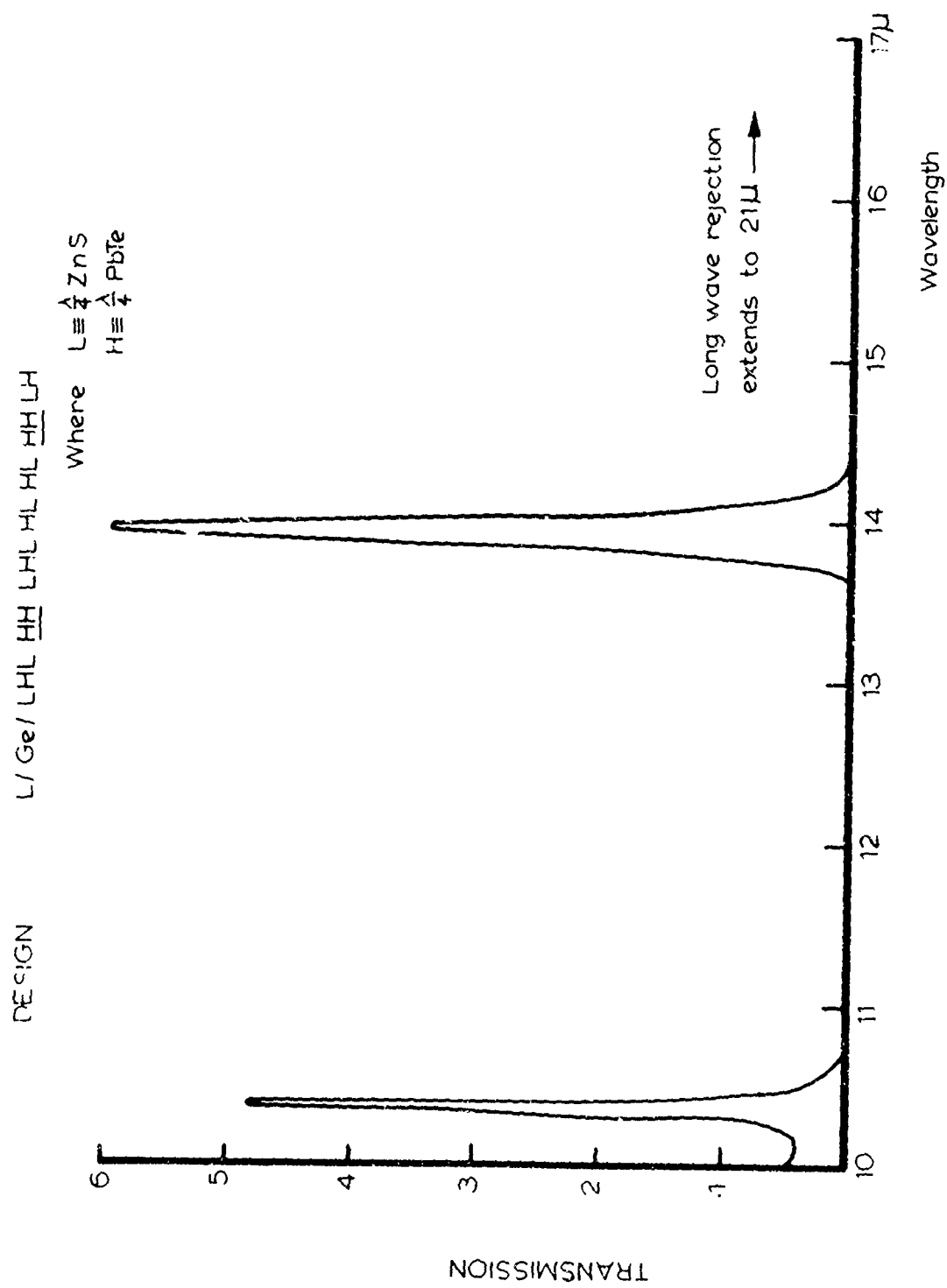


FIG. 4.7(a) MEASURED TRANSMISSION OF D.H.W.5.

DESIGN L / Ge / L HL LHL HL HL LHL

L $\equiv \frac{\lambda}{4}$ ZnS

H $\equiv \frac{\lambda}{4}$ PbTe

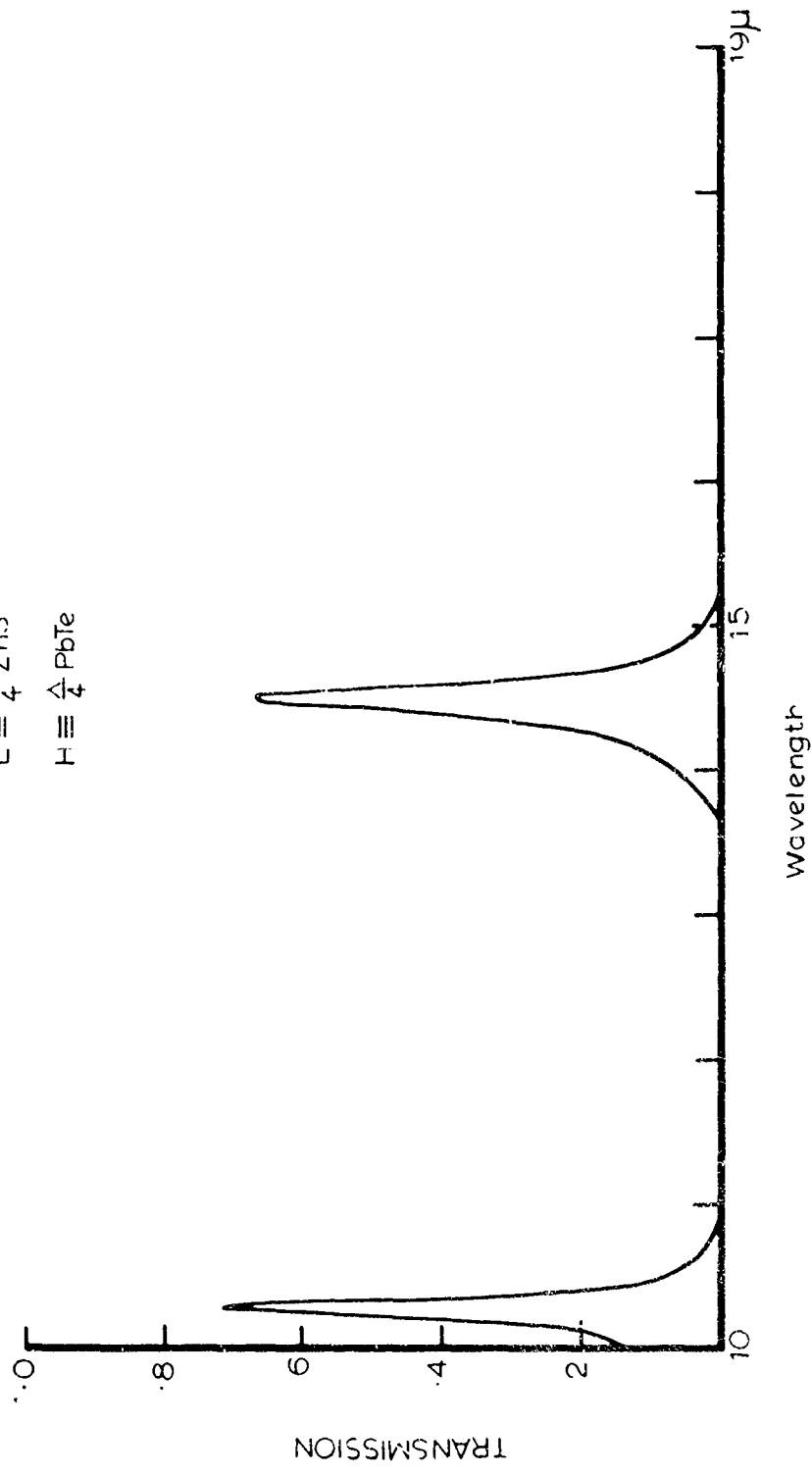


FIG 4.7(b) MEASURED TRANSMISSION OF D.H.W. 13.

DESIGN L / Ge / LHH LH LHL HH LH

$L \equiv \frac{\lambda}{4} \text{ ZnS}$

$H \equiv \frac{\lambda}{4} \text{ PbTe}$

Deposited at 160 °C

" " " "

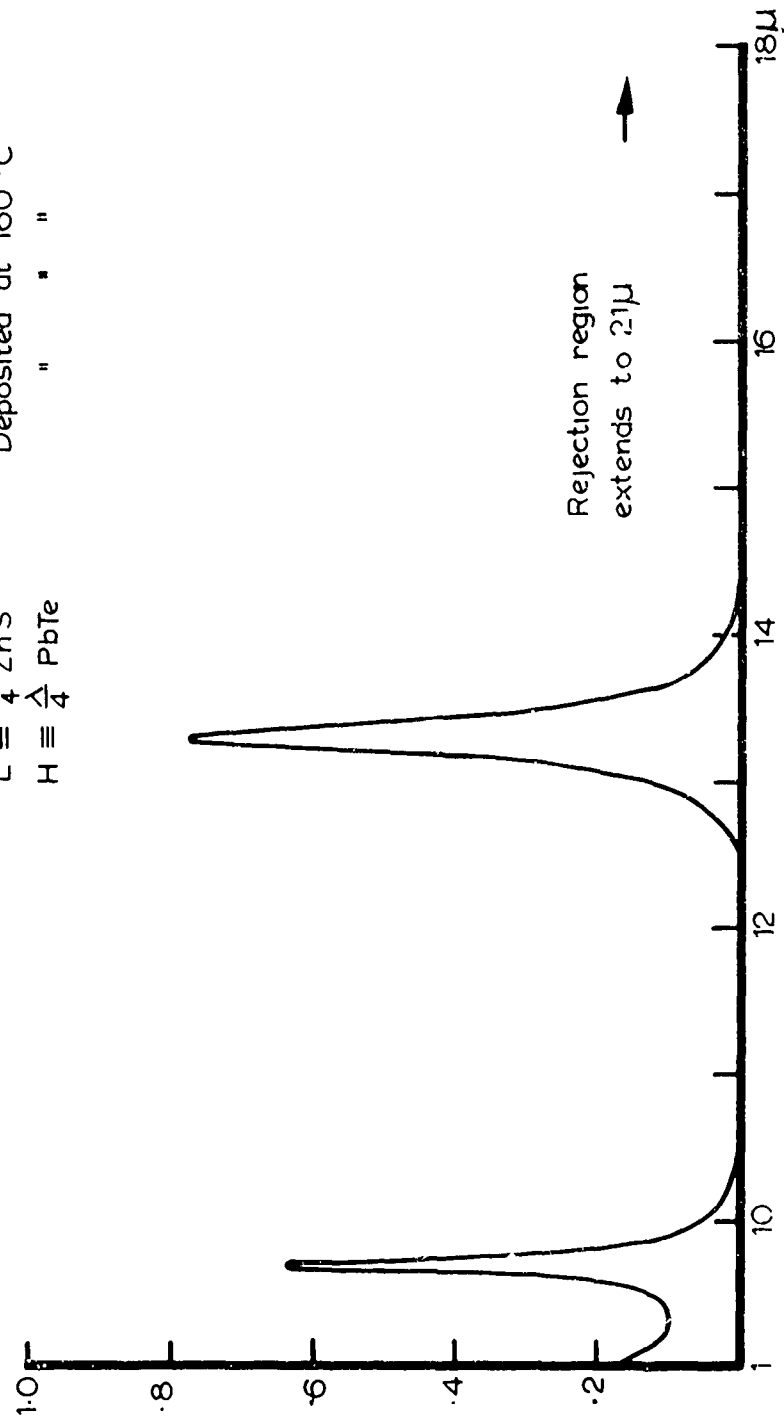
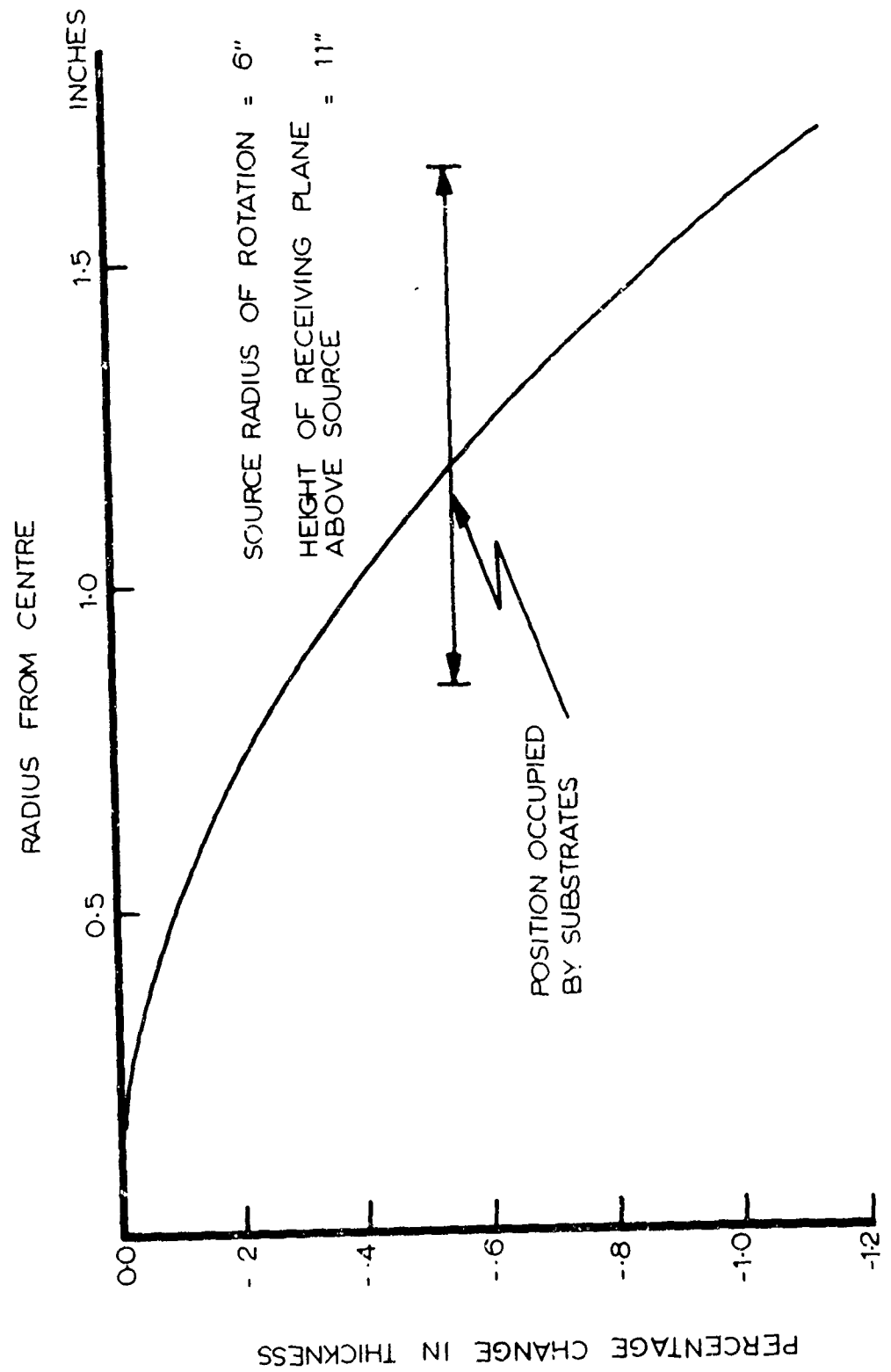


FIG. 4.8. MEASURED TRANSMISSION OF D.H.W.19.

FIG 4.9. THEORETICAL DISTRIBUTION OF EVAPORANT FROM A SMALL ROTATING SURFACE SOURCE.



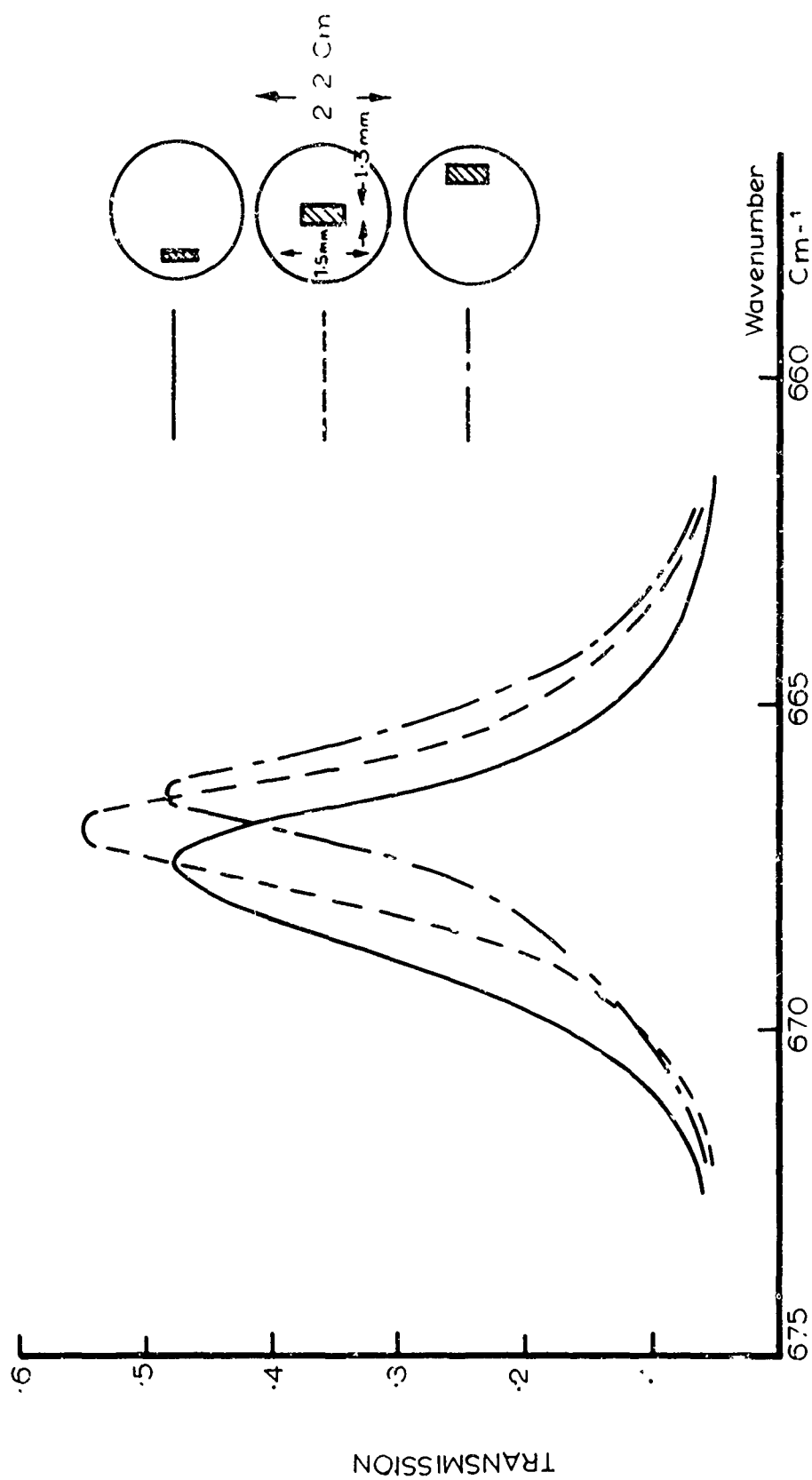


FIG. 4.10. F.P. FILTER 8180/4/MONITOR. MEASUREMENTS TAKEN AT 3 DIFFERENT PLACES ON FILTER SURFACE AT A FOCUS POSITION & AT NORMAL INCIDENCE.

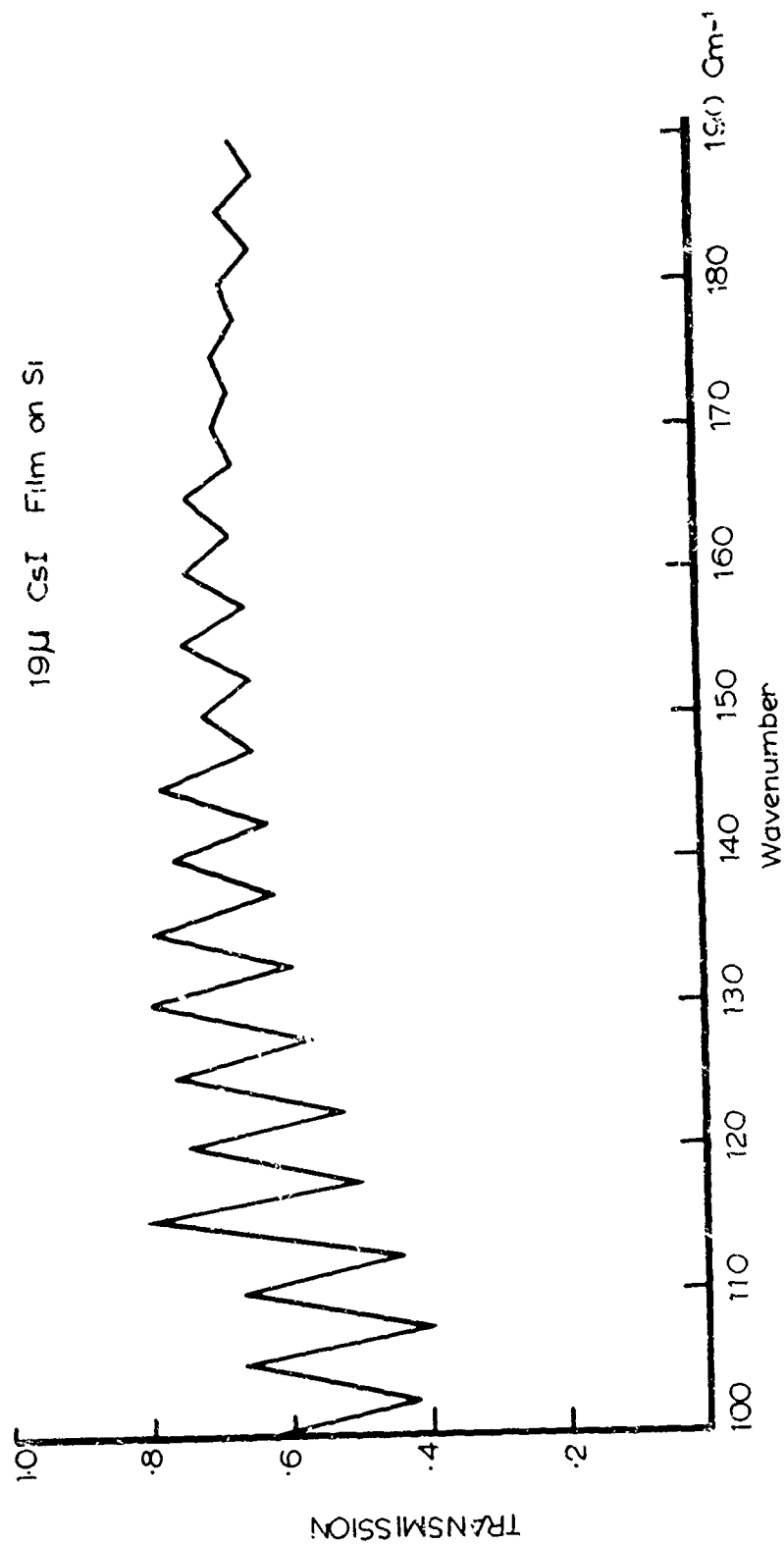


FIG. 4.11. INTERFEROMETRIC MEASUREMENT OF A CsI FILM ON Si SUBSTRATE AT 2.5 cm^{-1} RESOLUTION SHOWING FRINGES DUE TO SUBSTRATE INTERFERENCE.

SPECTROSIL B

Thickness $\pm .003$ "

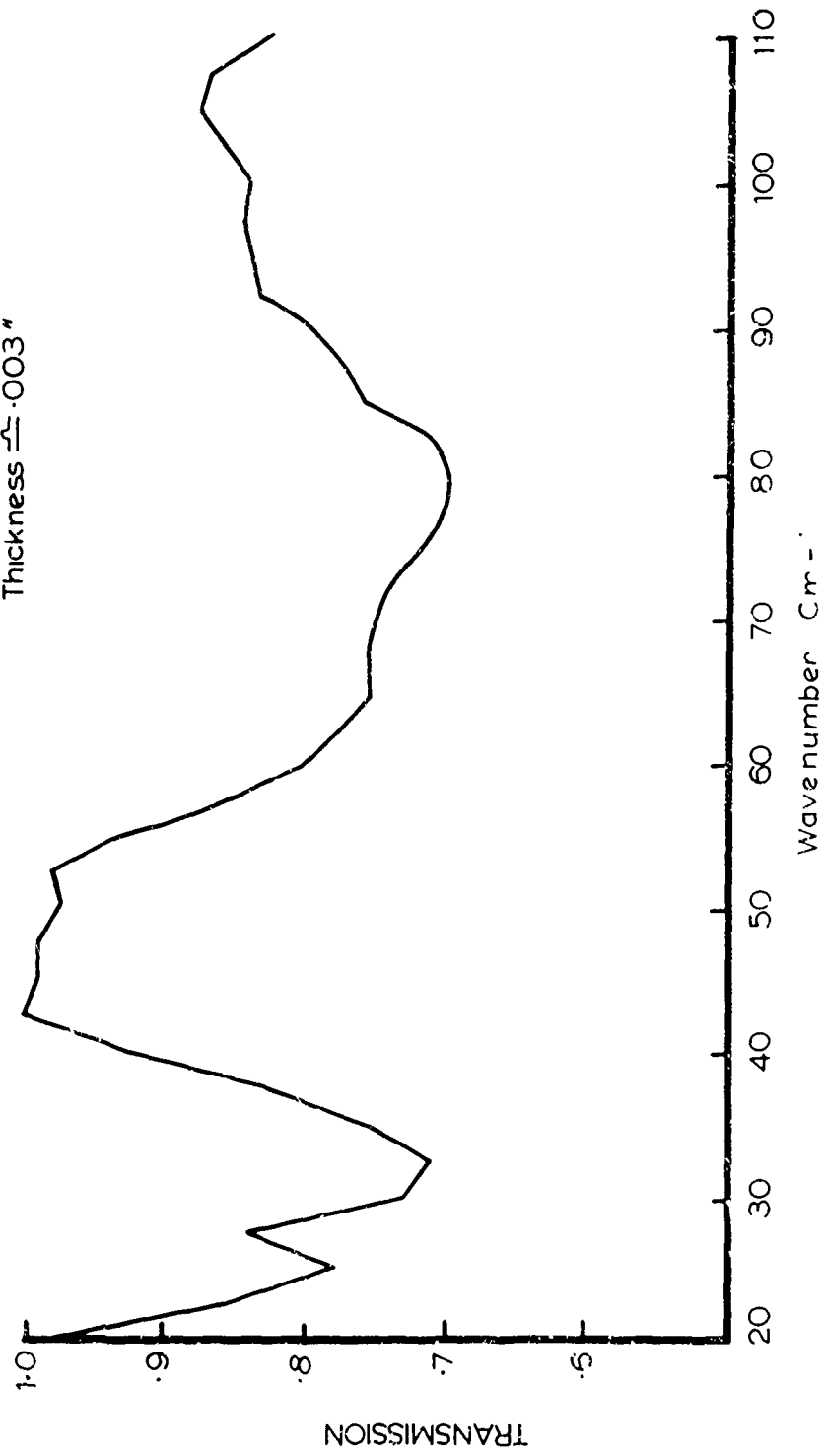


FIG 4.12. TRANSMISSION OF THIN (.003IN) SPECTROSIL B
PLATE AS MEASURED BY IRIS INTERFEROMETER.

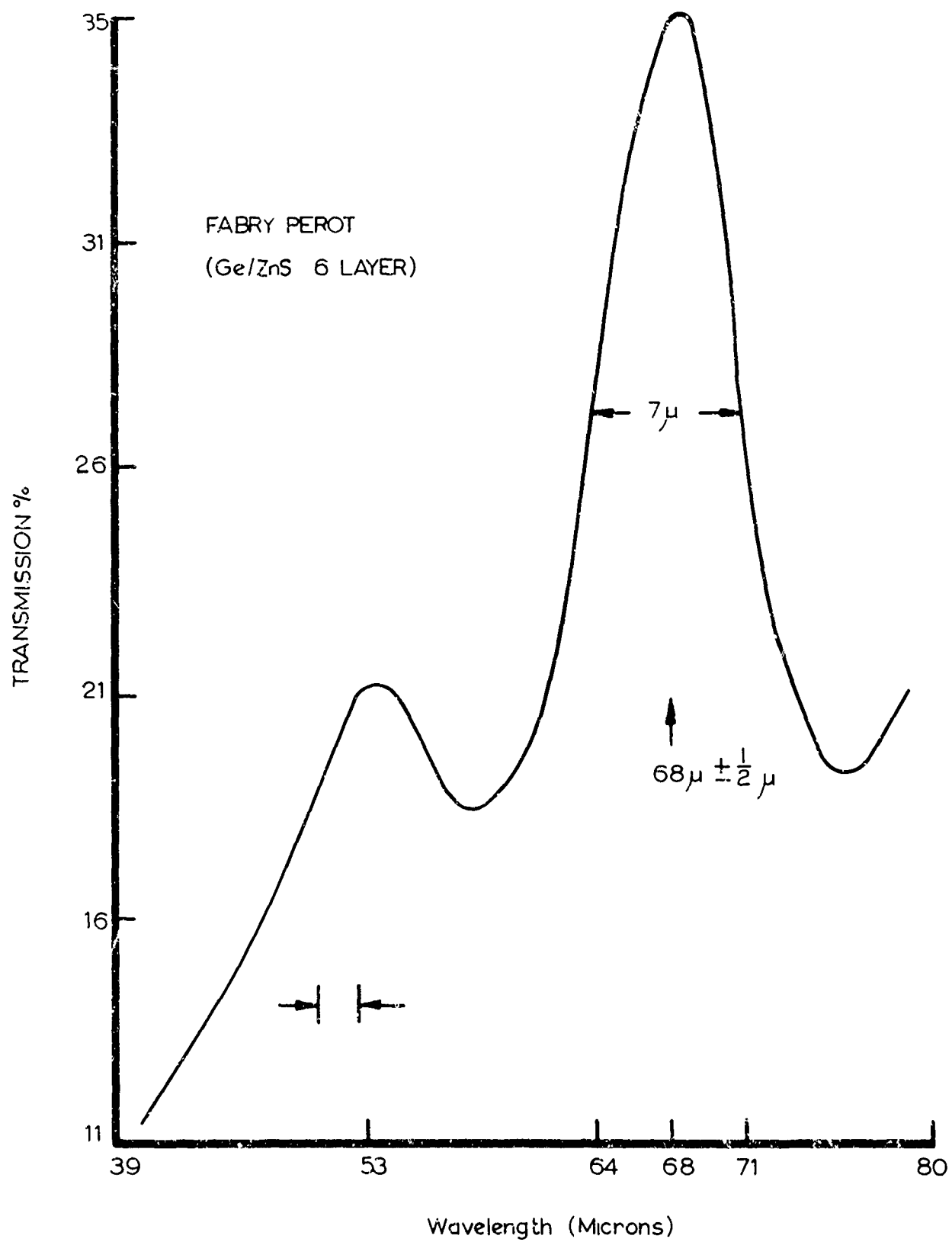


FIG. 4.13.

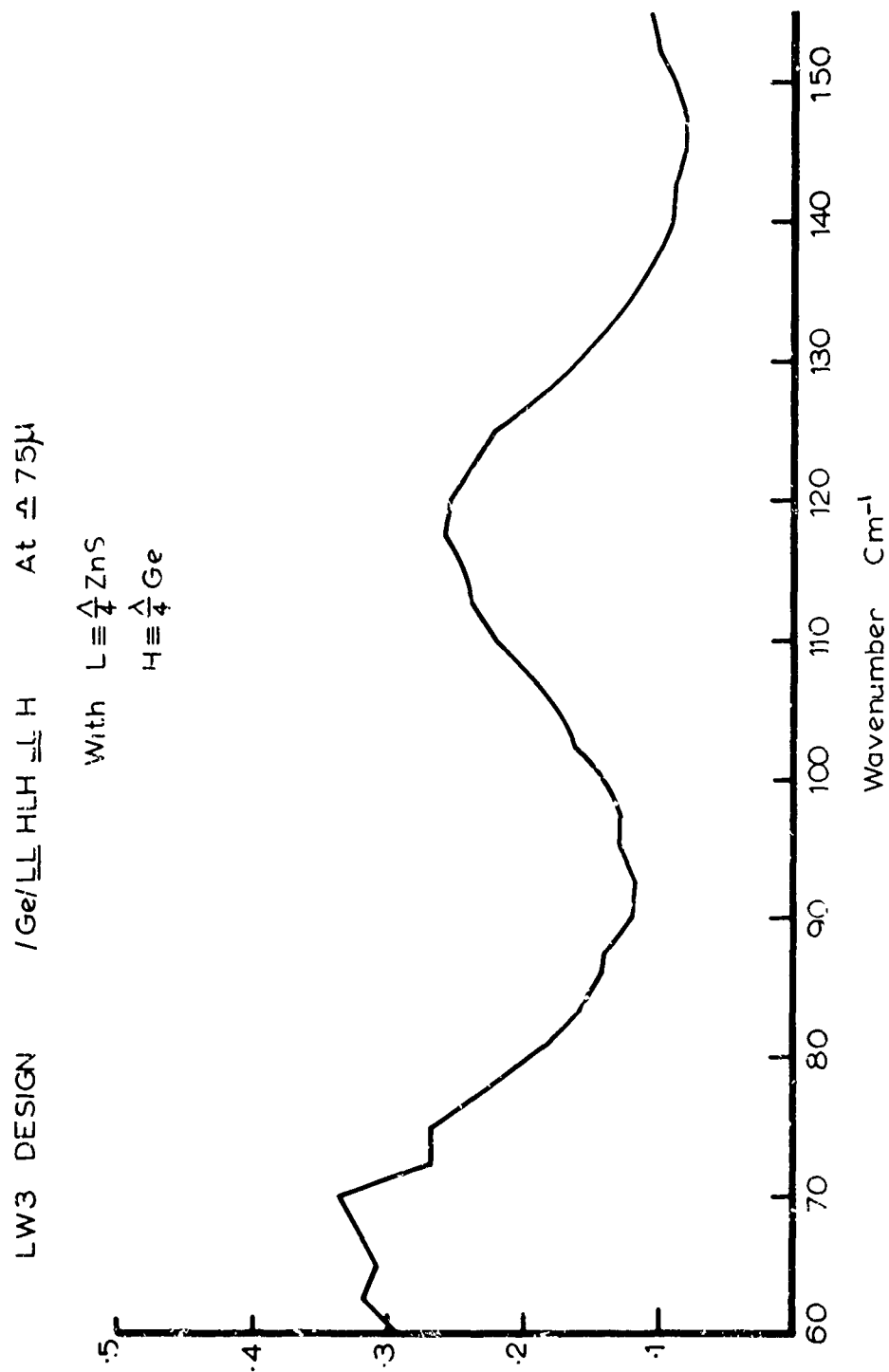


FIG 4.14. MEASURED TRANSMISSION OF FILTER LW3 ON A Ge SUBSTRATE (NOT ANTI-REFLECTED)

FILTER LW.4. DESIGN $\text{Ge/LH LH } \underline{\text{LL}} \text{ HLH}$
 With $L \equiv \frac{\lambda}{4} \text{ ZnS}$ } At $\lambda \approx 90\mu$
 $H \equiv \frac{\lambda}{4} \text{ Ge}$

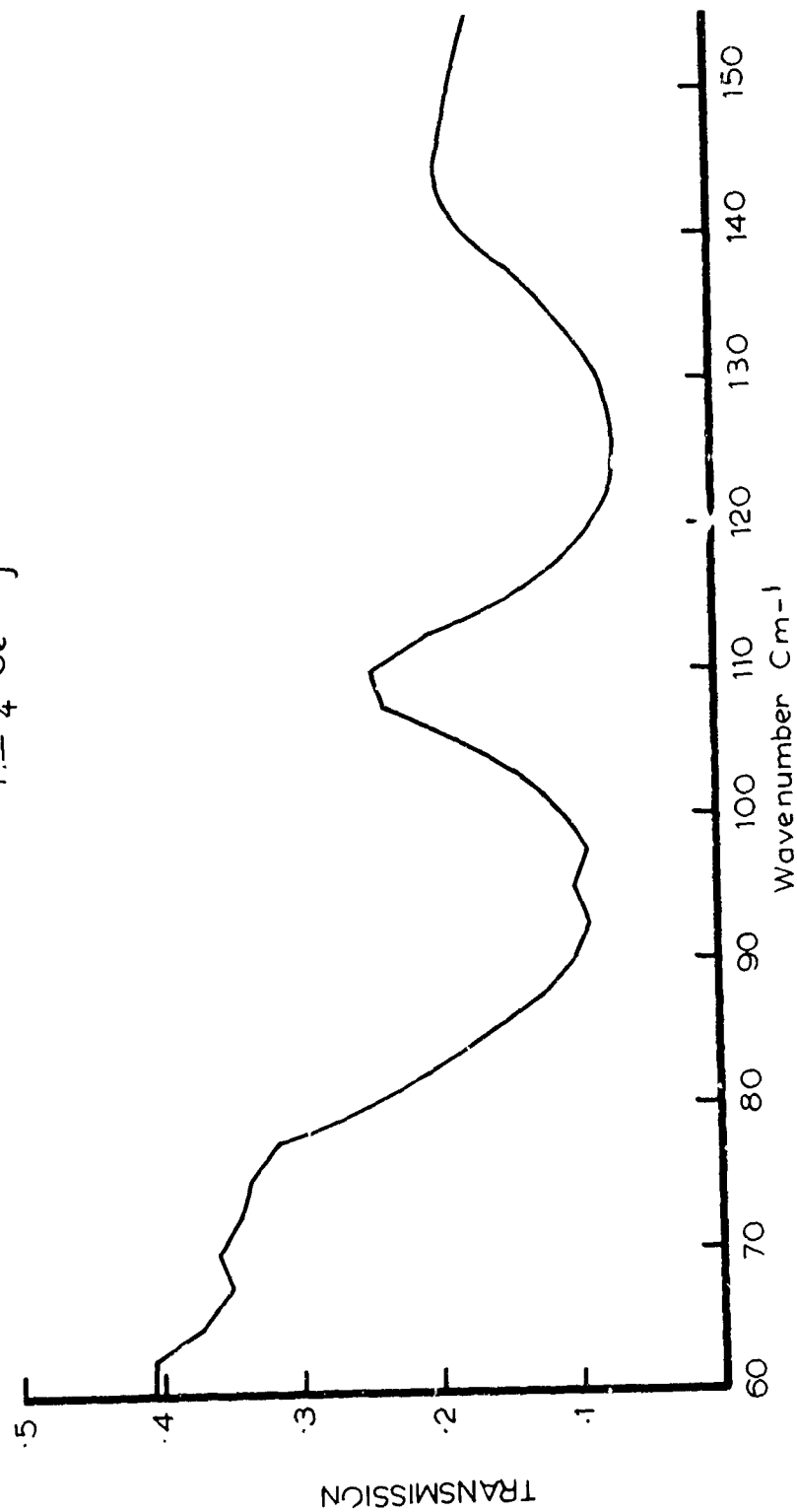


FIG 4.15. TRANSMISSION OF FILTER LW.4 ON Ge SUBSTRATE AS MEASURED BY IRIS INTERFEROMETER.

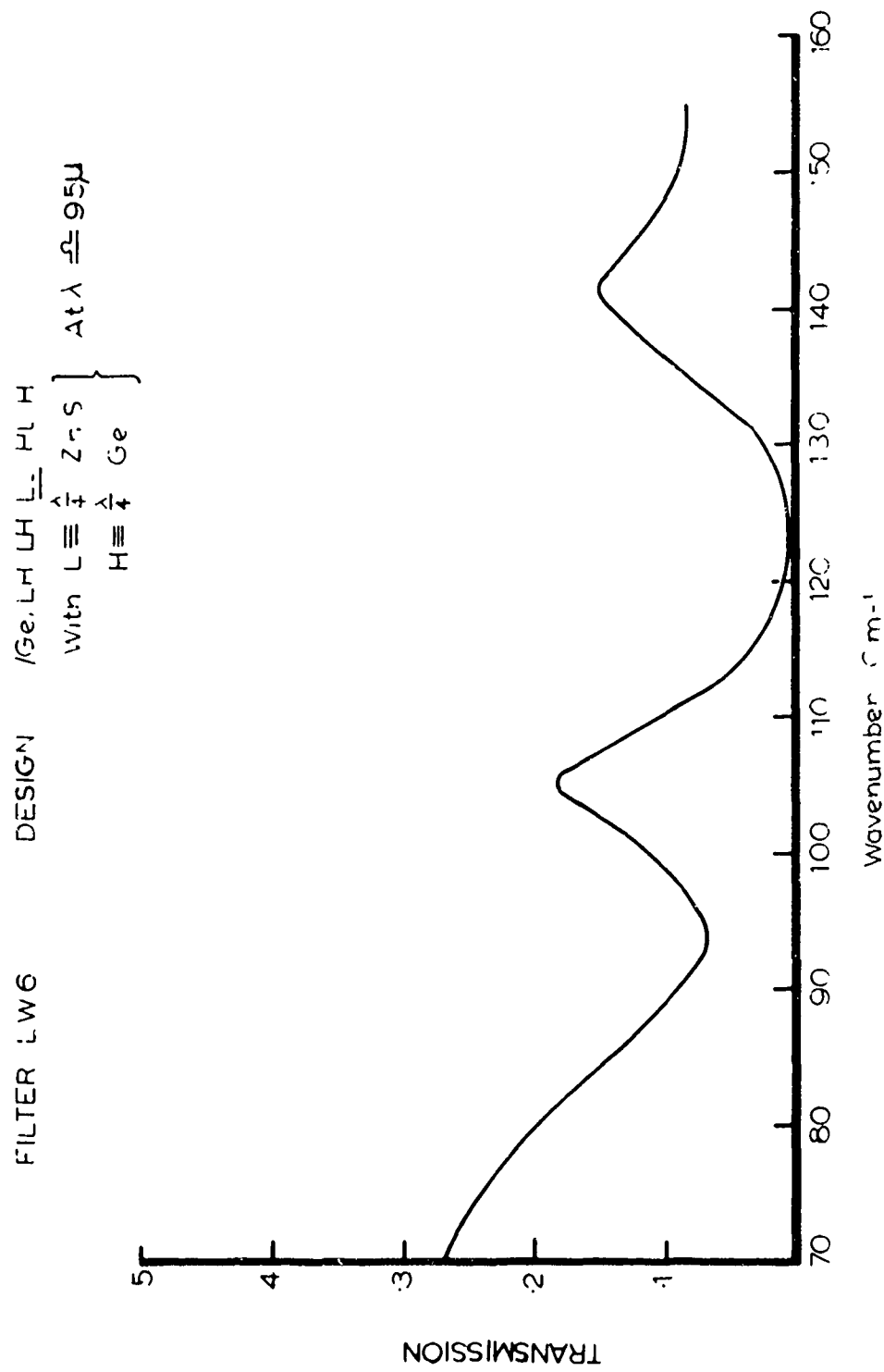


FIG. 4-16 TRANSMISSION OF LW6 ON Ge SUBSTRATE AS MEASURED BY THE GM3 SPECTROMETER.

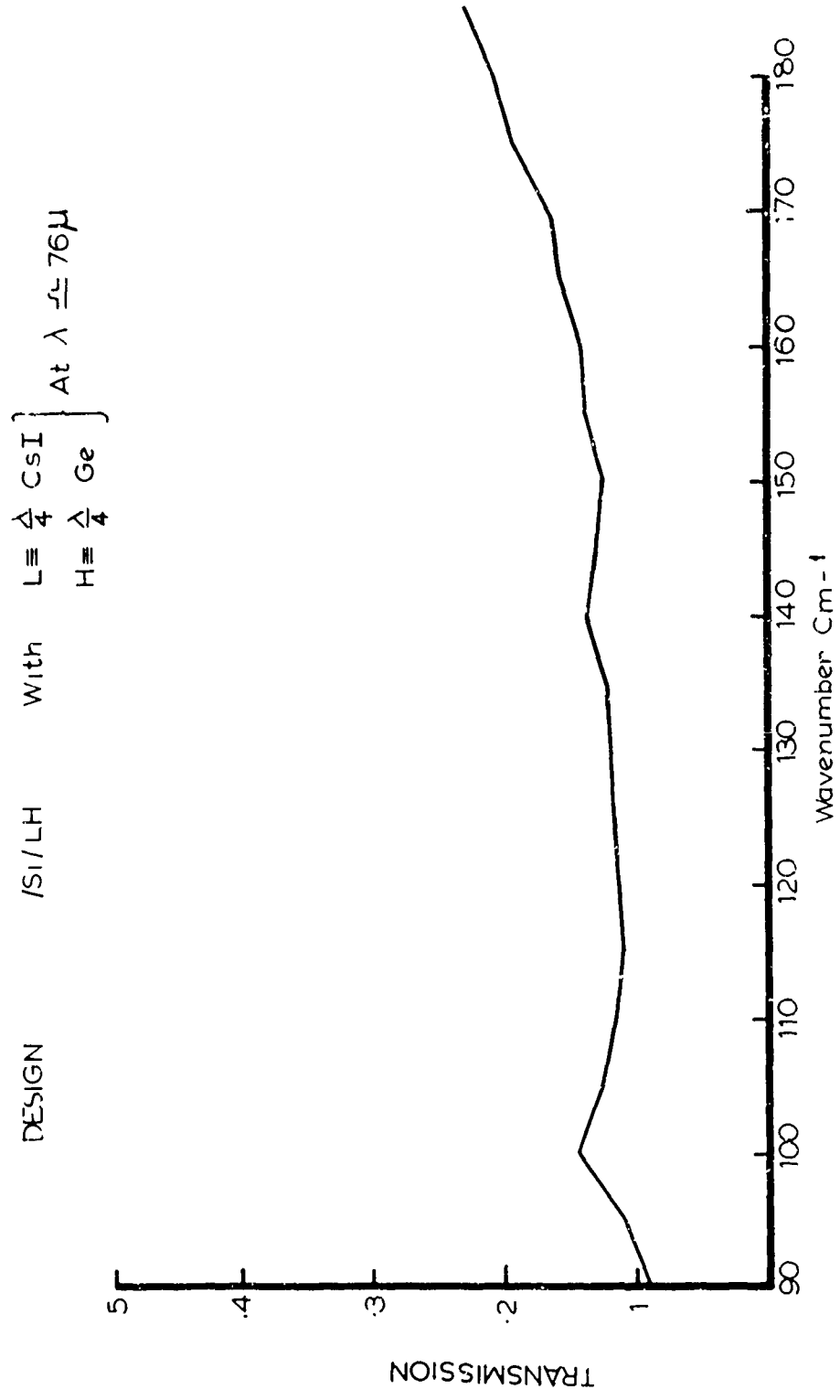


FIG 4.17. TRANSMISSION OF / Si/LH AS MEASURED BY THE IRIS INTERFEROMETER

FILTER DESIGN

$L/SL/LH/LLH$
 With $L = \frac{\lambda}{4}$ CsI
 $H = \frac{\lambda}{4}$ Ge

At $\lambda = 75\mu$

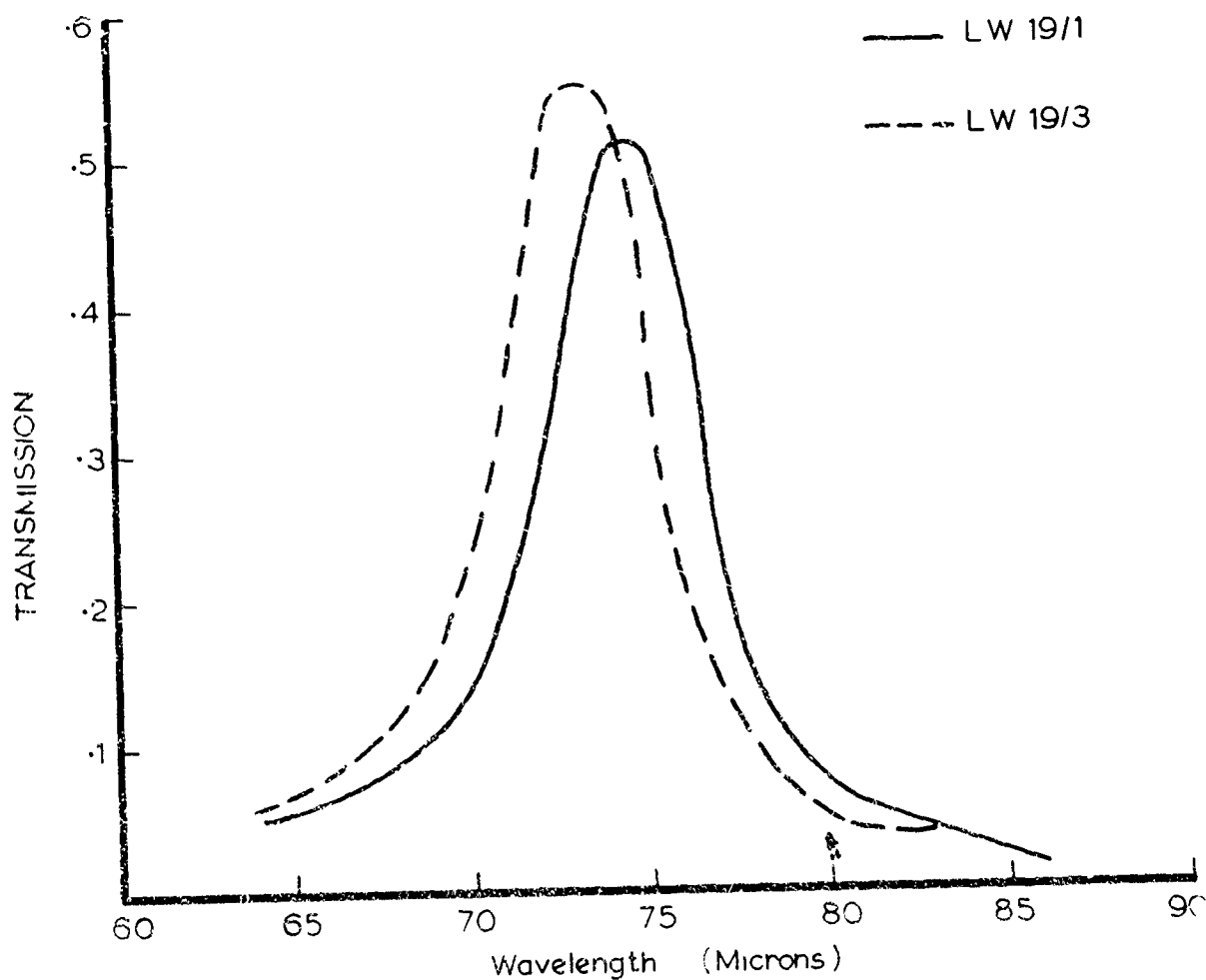


FIG. 4.19. MEASURED TRANSMISSION OF NARROW BAND PASS FILTERS LW19/1 & LW19/3.

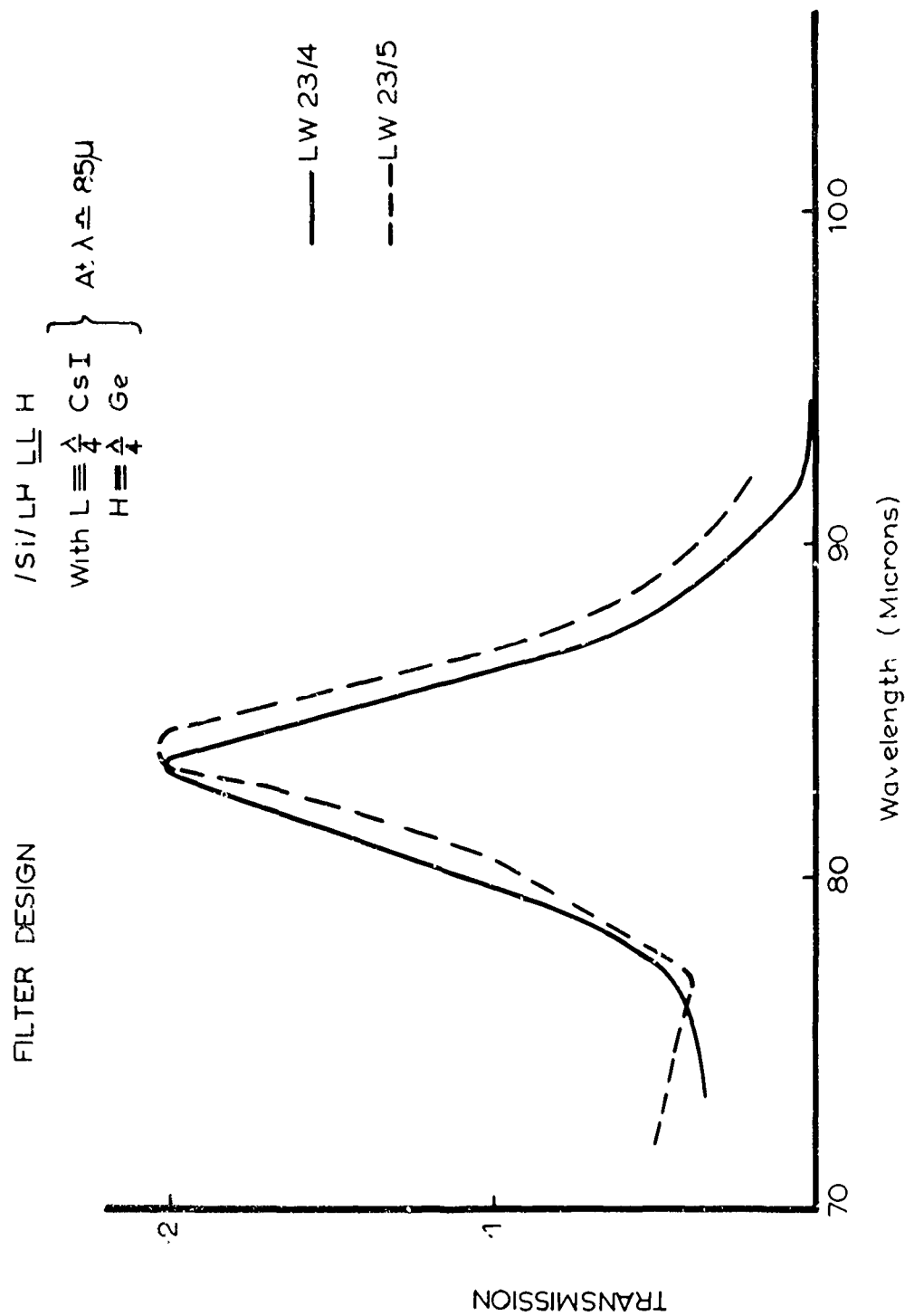


FIG. 4.20. MEASURED TRANSMISSION OF NARROW BAND PASS FILTERS LW 23/4 & LW 23/5

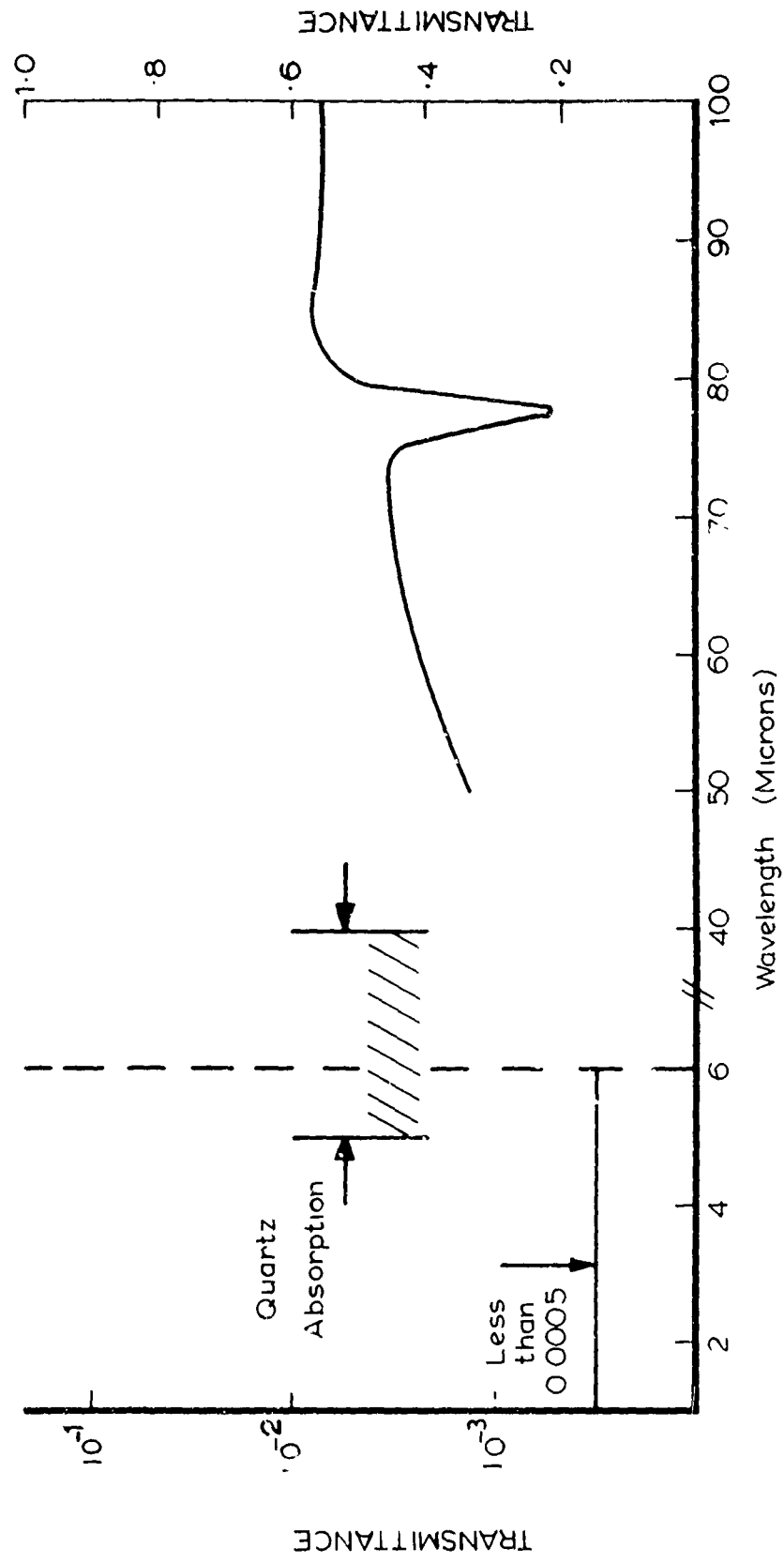


FIG. 4.21. TRANSMISSION OF QUARTZ LOW PASS FILTER AQ/2.

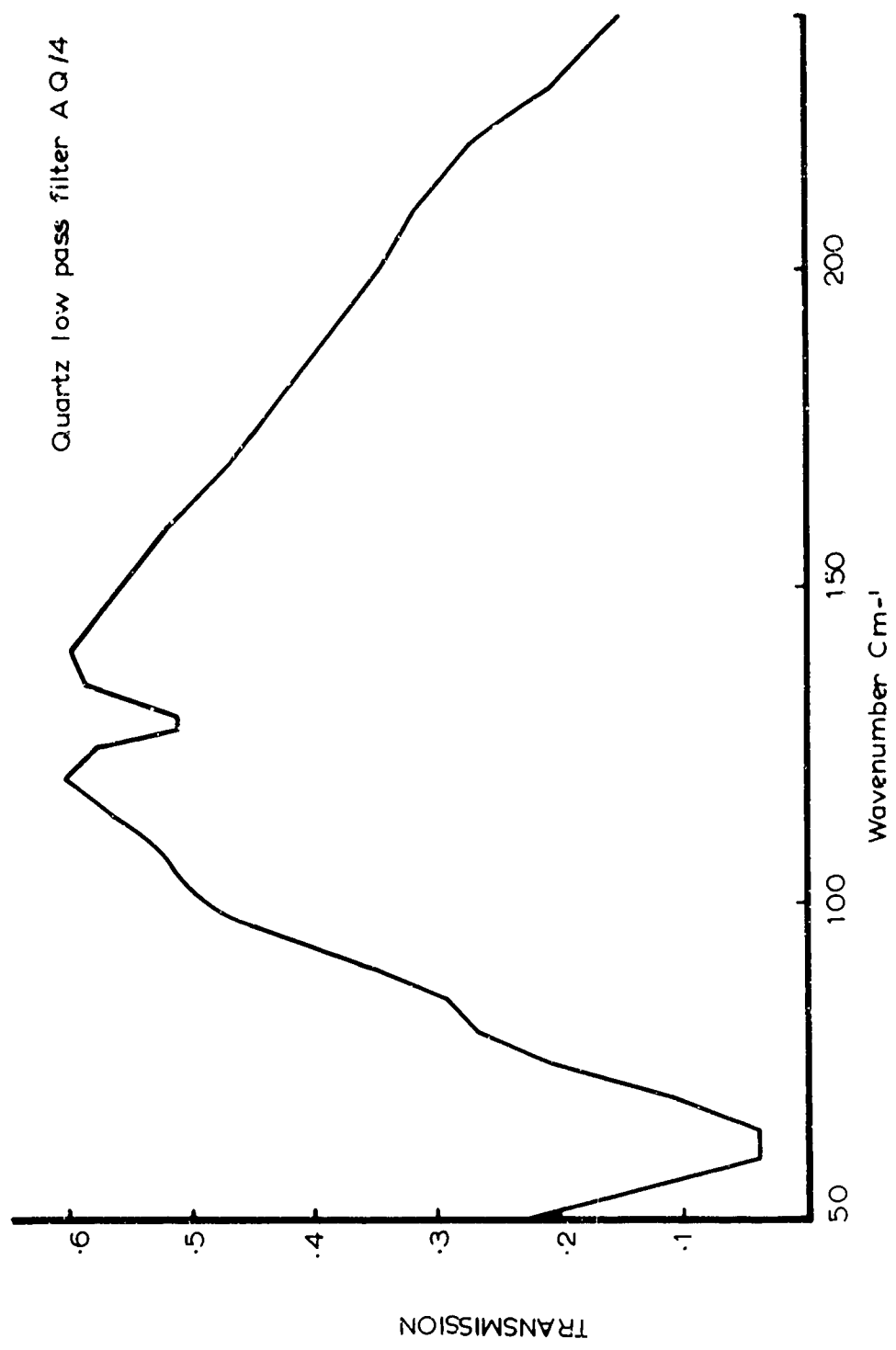


FIG.4.22. FAR INFRARED TRANSMISSION OF QUARTZ LOW PASS FILTER A Q / 4 AS MEASURED BY CUBE INTERFEROMETER. AT 5 C_m^{-1} RESOLUTION.

$L/S/1/2$ H L H L H L H L H $\frac{5}{2}$ }
 With $L = \frac{1}{4} Cs I$ At $\lambda = 38\mu$
 $H = \frac{1}{4} Ge$

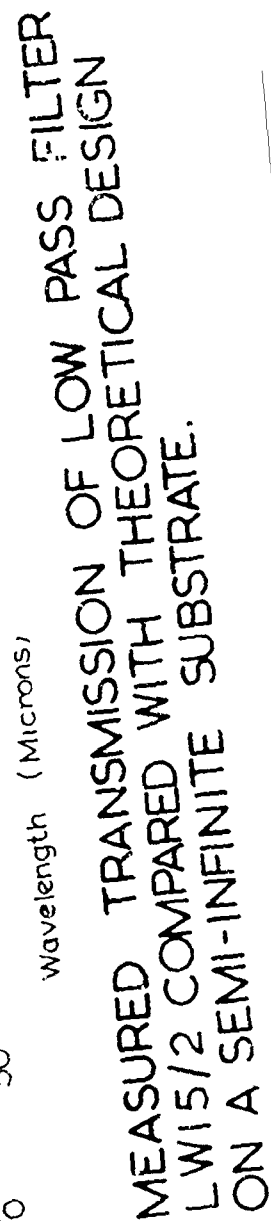


FIG 4.23.

FILTER LW26/2 DESIGN. $L/S_1/\frac{1}{2}$ HL HL HL HL HL $H \frac{S_1}{2}$
 With $L = \frac{1}{4}$ CsI }
 $H = \frac{1}{4}$ Ge } $\Delta t \lambda \approx 45\mu$

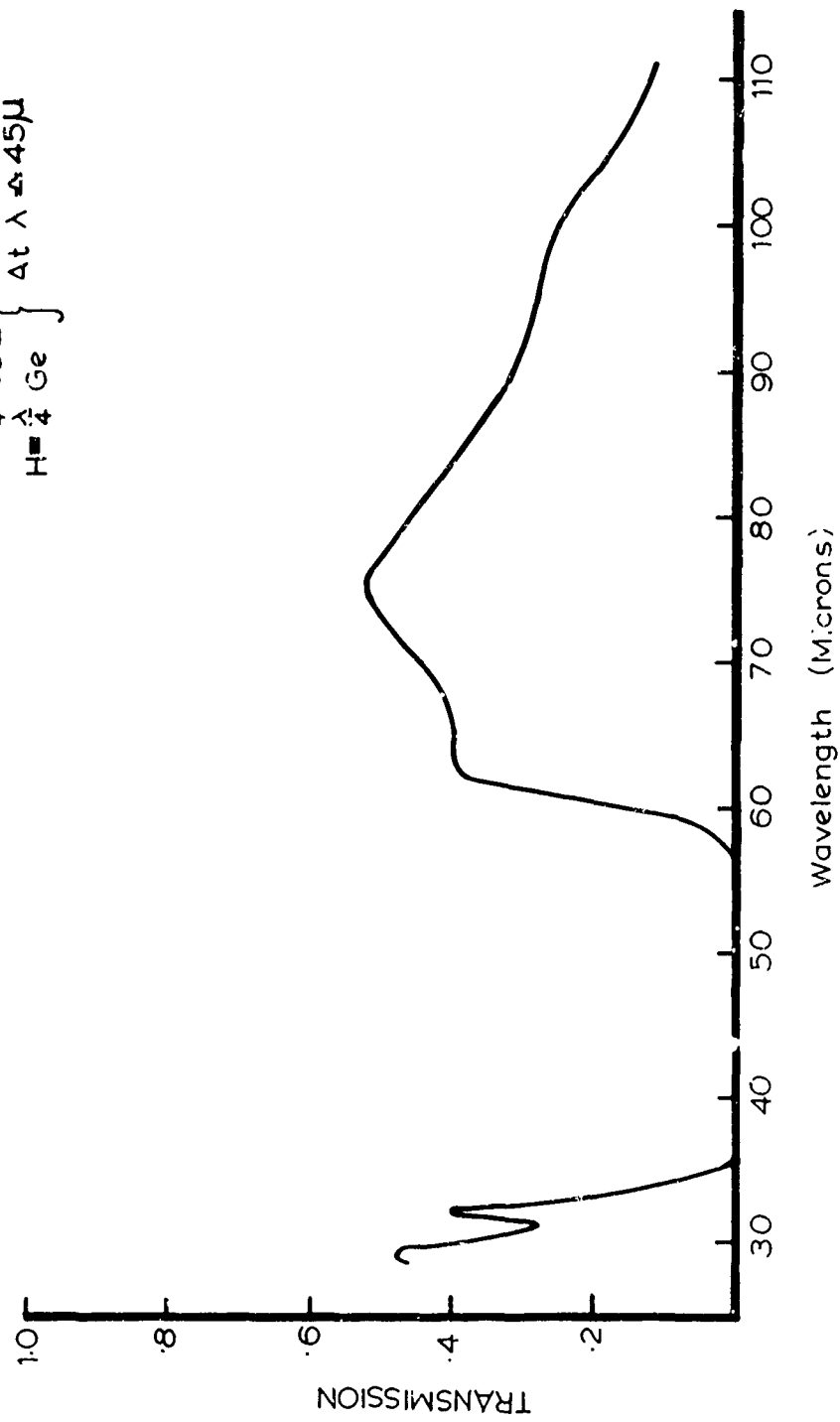


FIG. 4.24. MEASURED TRANSMISSION OF LOW PASS FILTER LW26/2 SHOWING EXTENT OF STOP REGION.

FILTER DESIGN

$$\frac{H_1}{2} \quad L' \quad \frac{H_1}{2} \quad / \quad Si \quad / \quad \frac{1}{2} \quad H_1 \quad HL \quad HL \quad HL \quad H \quad \frac{1}{2} \quad \frac{H_1}{2} \quad L' \quad \frac{H_1}{2}$$

With $L \equiv \frac{\lambda}{4}$ $\left. \begin{array}{l} CsI \\ Ge \end{array} \right\}$ AT $\lambda = 45\mu$
 $H \equiv \frac{\lambda}{4}$
 $L' \equiv \frac{\lambda}{4}$ $\left. \begin{array}{l} CsI \\ Ge \end{array} \right\}$ AT $\lambda = 38\mu$
 $H' \equiv \frac{\lambda}{4}$

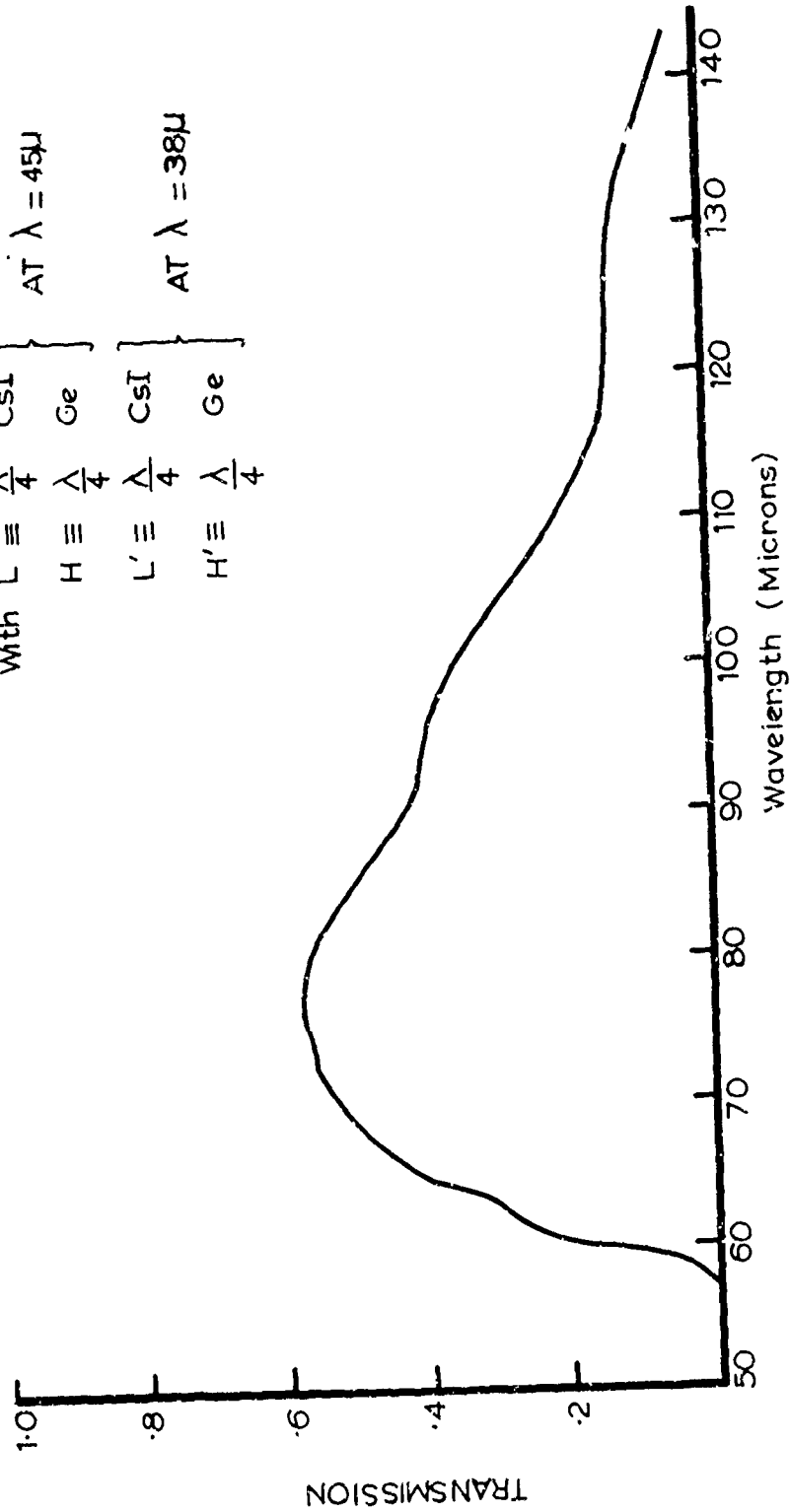
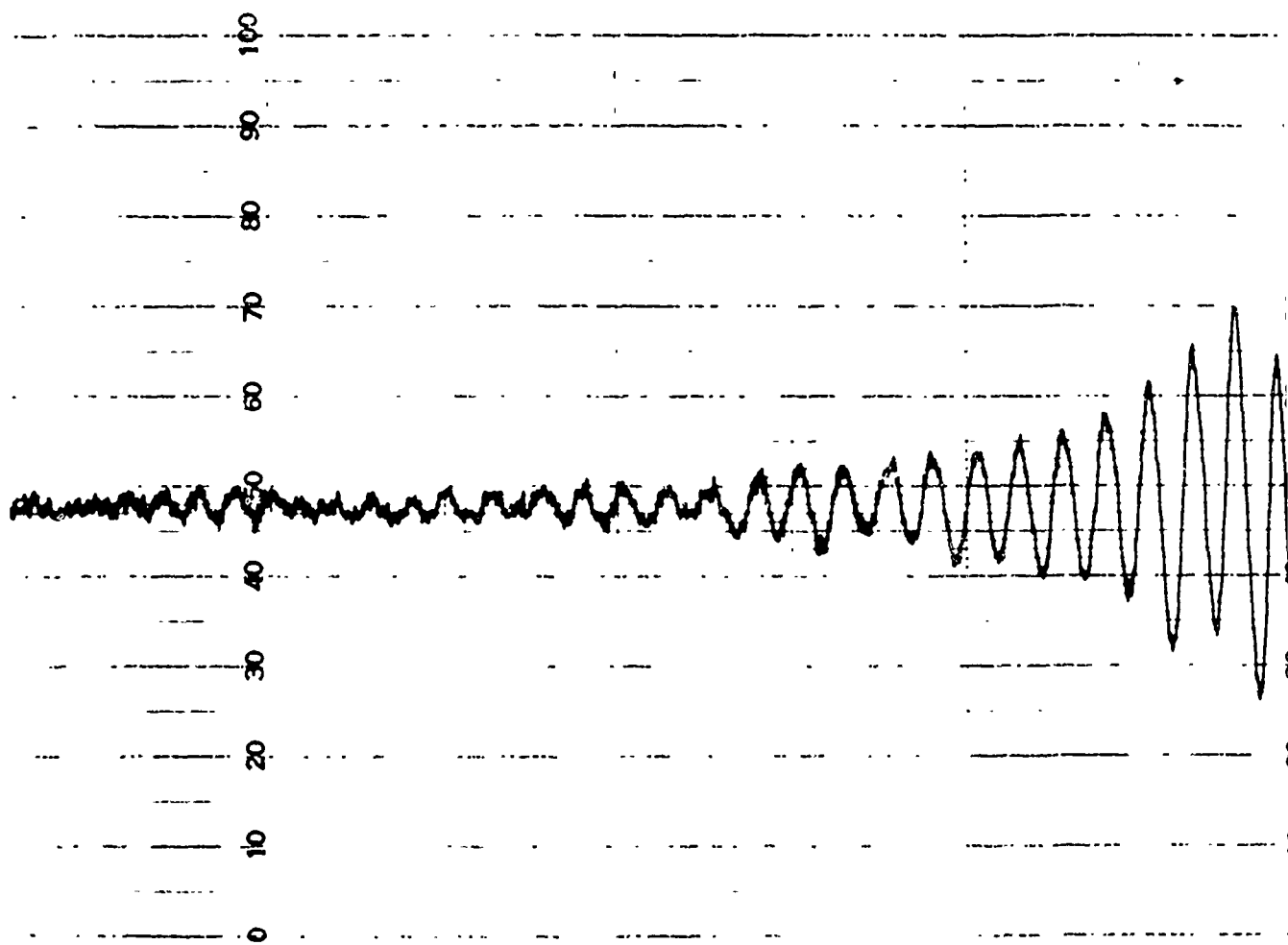


FIG. 4.25. TRANSMISSION OF LOW PASS FILTER LW28/1 AS MEASURED BY THE CUBE INTERFEROMETER



D. CALIFORNIA

CHART NO. 52

A

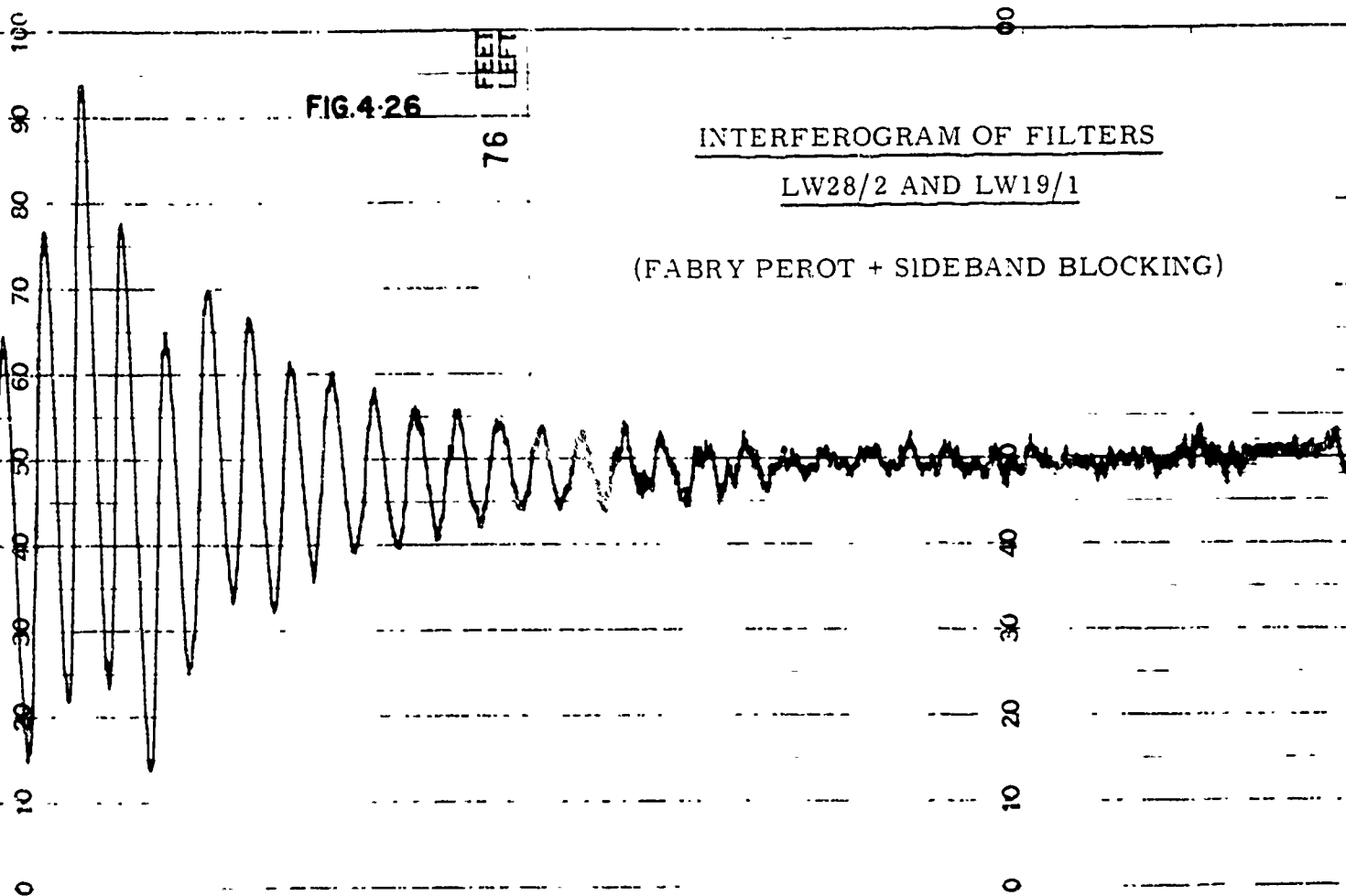
FIG. 4-26

FEET
LEFT
76

INTERFEROGRAM OF FILTERS

LW28/2 AND LW19/1

(FABRY PEROT + SIDEBAND BLOCKING)



MESCO INSTRUMENTS, DIVISION OF DATAPULSE INCORPORATED INGLEWOOD CALIFORNIA

GRAPH NO 5R

(12)

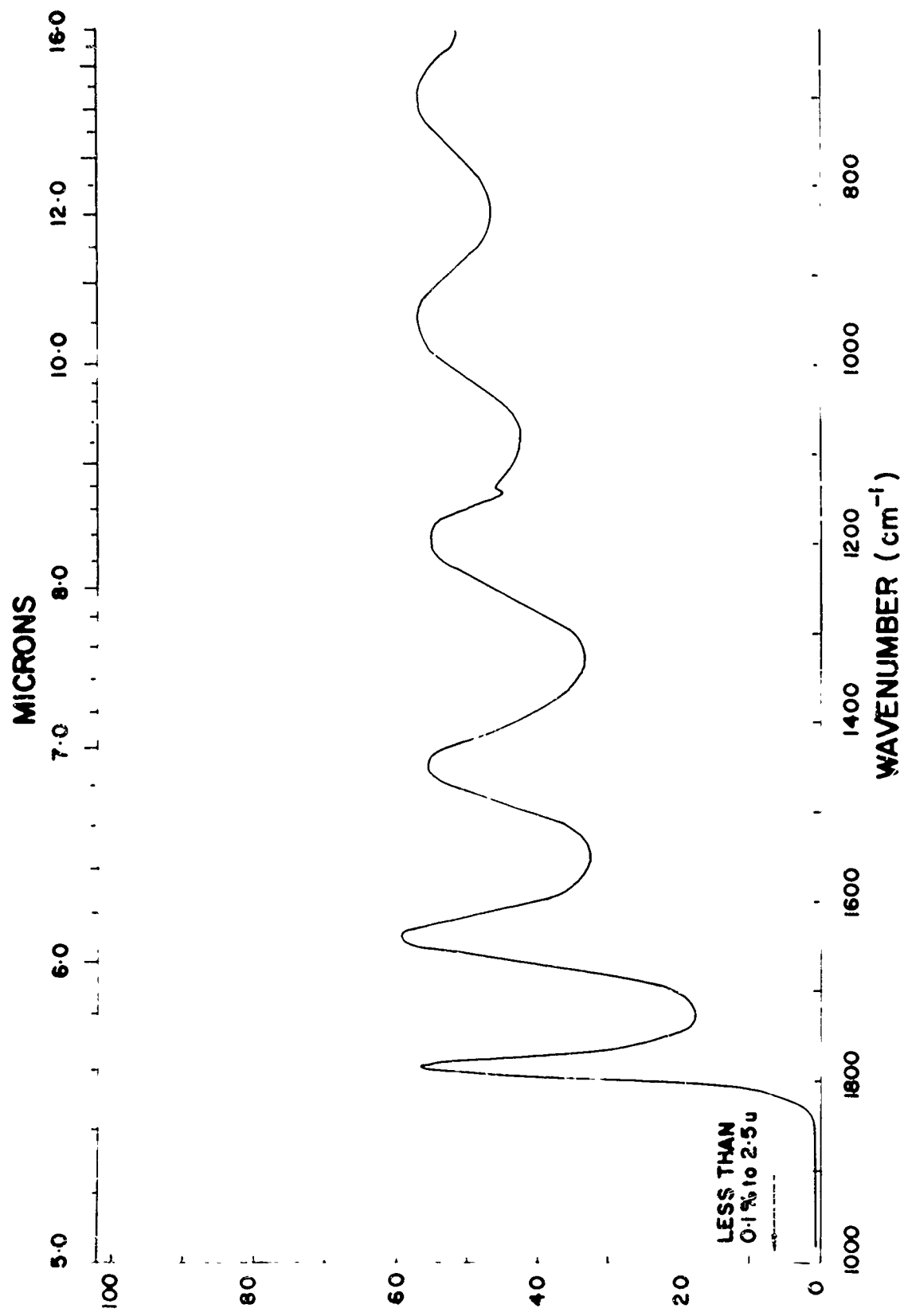


FIG. 4-28 SHORTWAVE TRANSMISSION OF 16 LAYER PbTe/ZnS
BLOCKING STACK (on Ge)

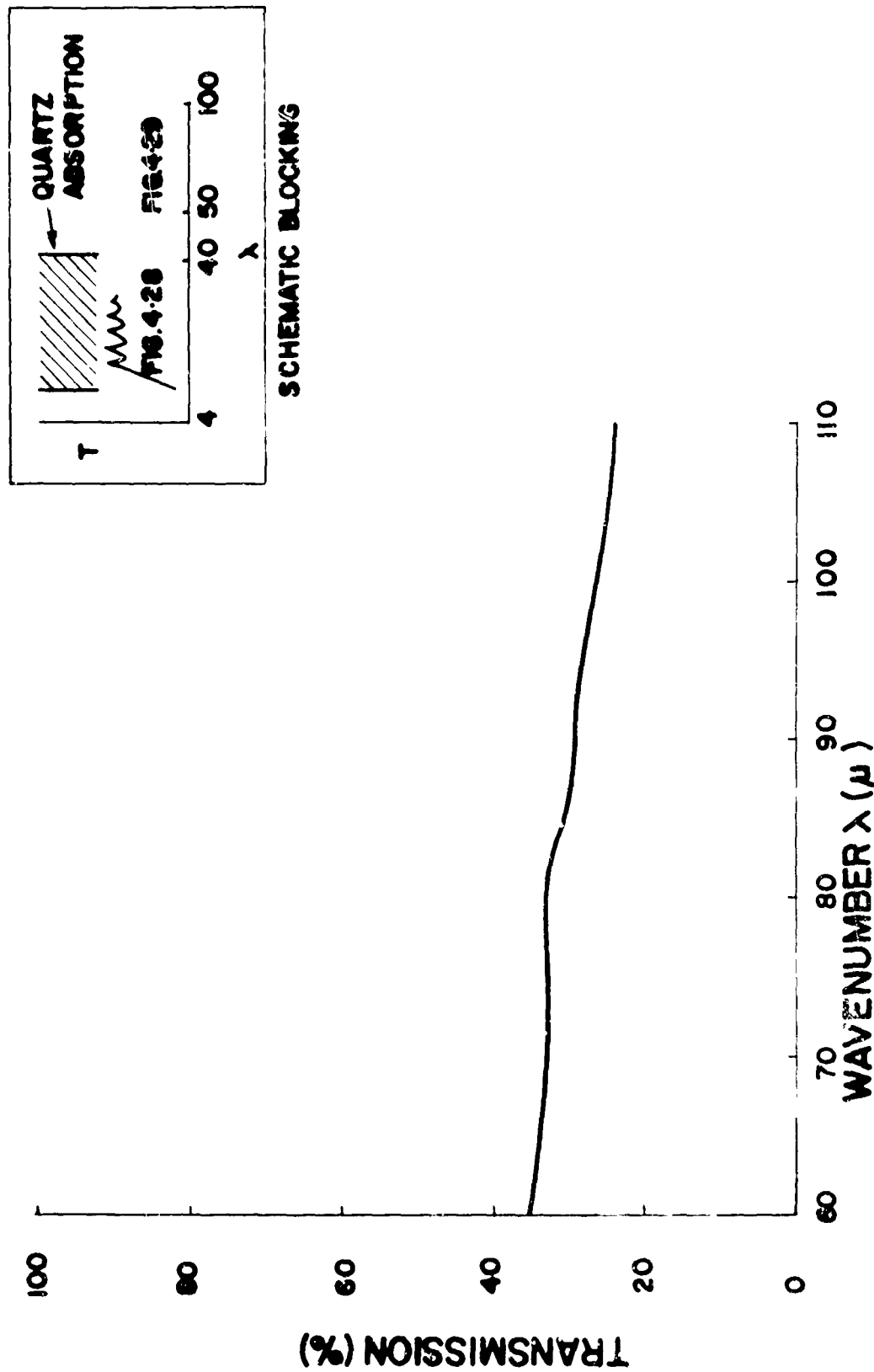


FIG. 4.29 LONGWAVE TRANSMITTANCE of PbTe/ZnS STACK

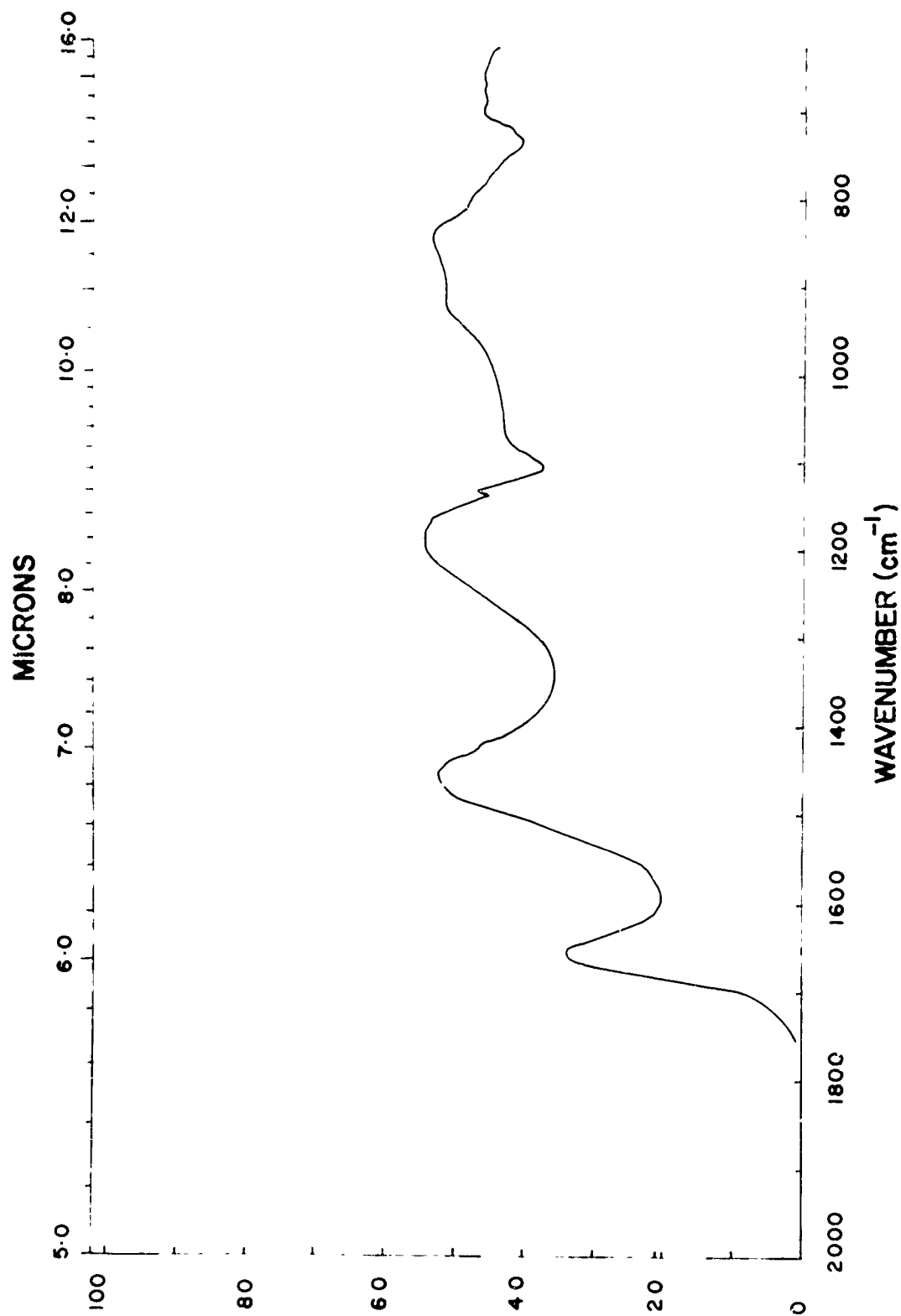


**FIG. 4-30 SHORTWAVE TRANSMISSION OF 12 LAYER PbTe/CsI
STACK (on Si)**

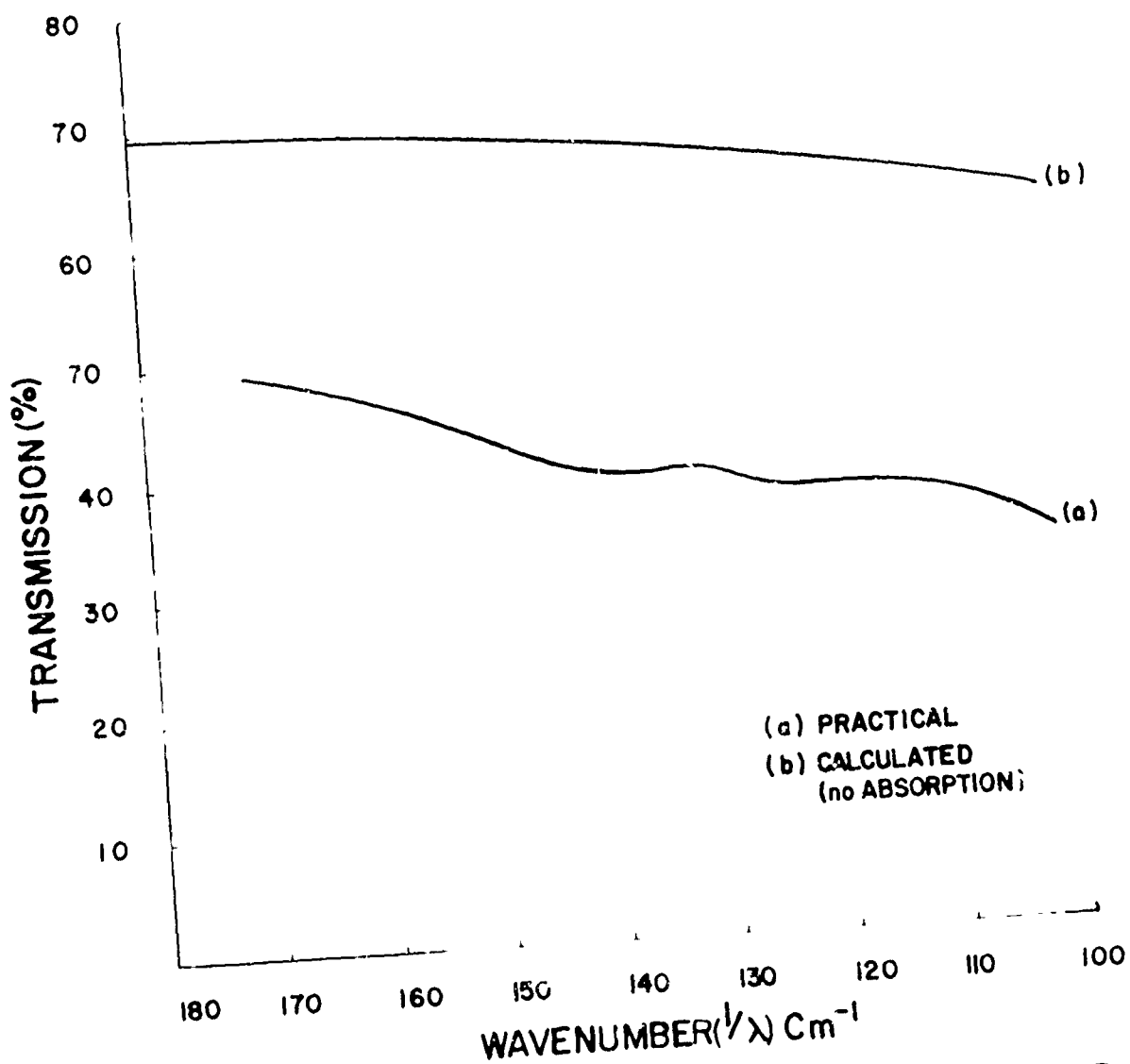


FIG. 4-31 LONGWAVE TRANSMISSION of Pb Te/CsI
STACK NO. 048/1

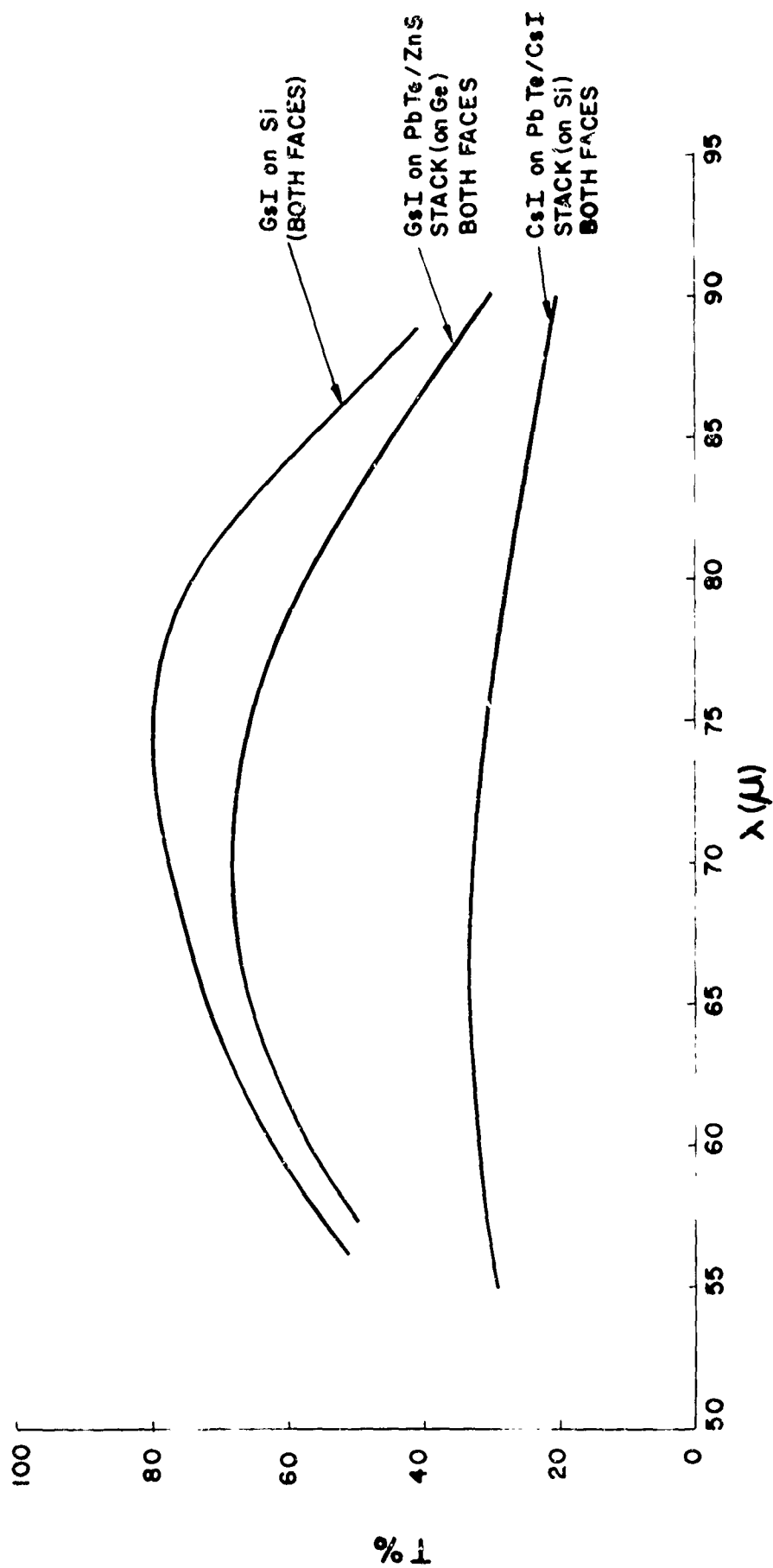


FIG. 4-32 CsI ANTIREFLECTION at 75 μ
(27 QWOT at 3.93 μ)

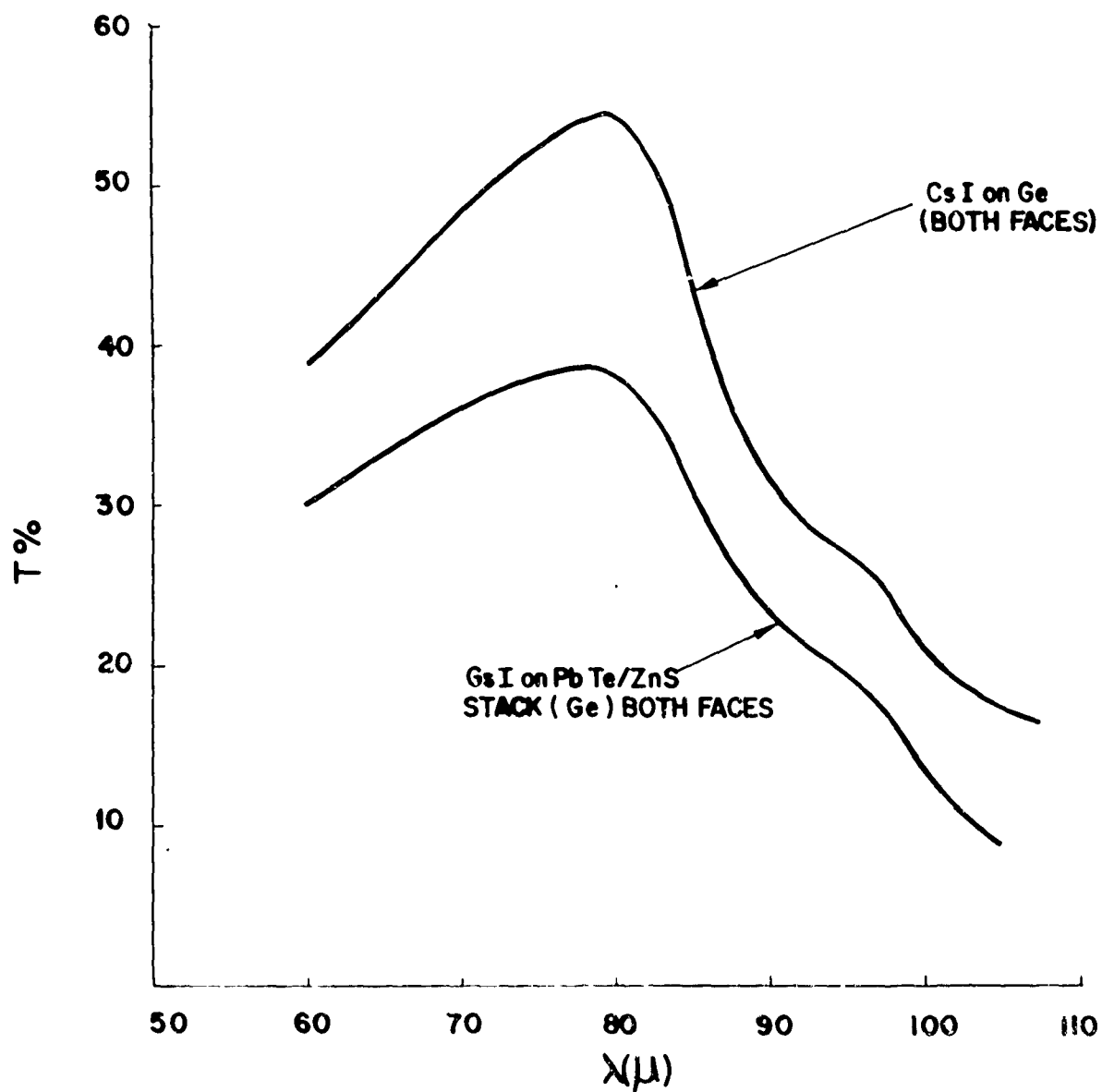


**FIG. 4-33 Cs I ANTIREFLECTION at 85 μ
(33 QWOT at 3.93 μ)**

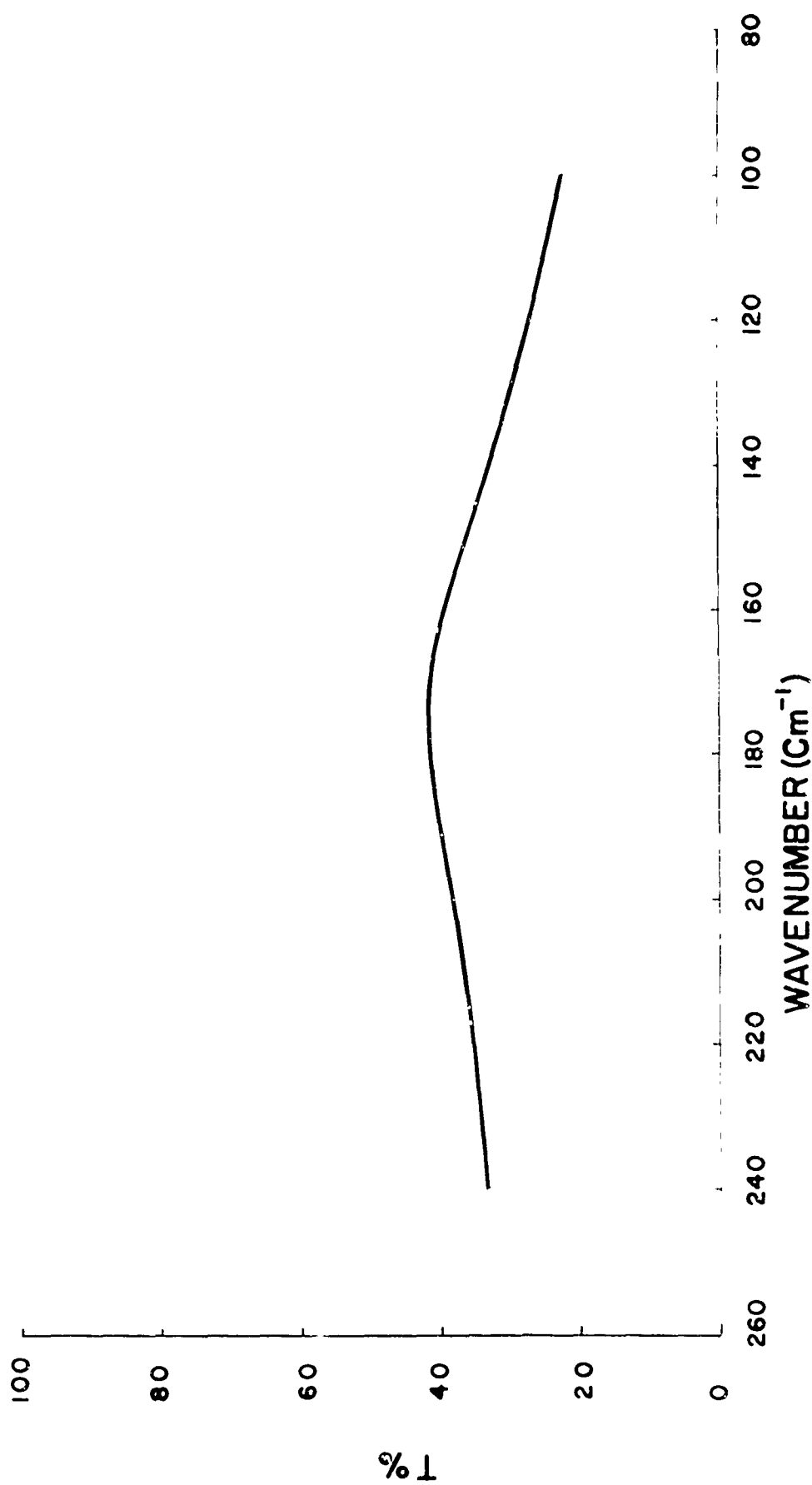


**FIG 4-34 LONGWAVE TRANSMITTANCE of 16 LAYER
Pb Te/Cs Br STACK (WITHOUT ANTIREFLECTION)**

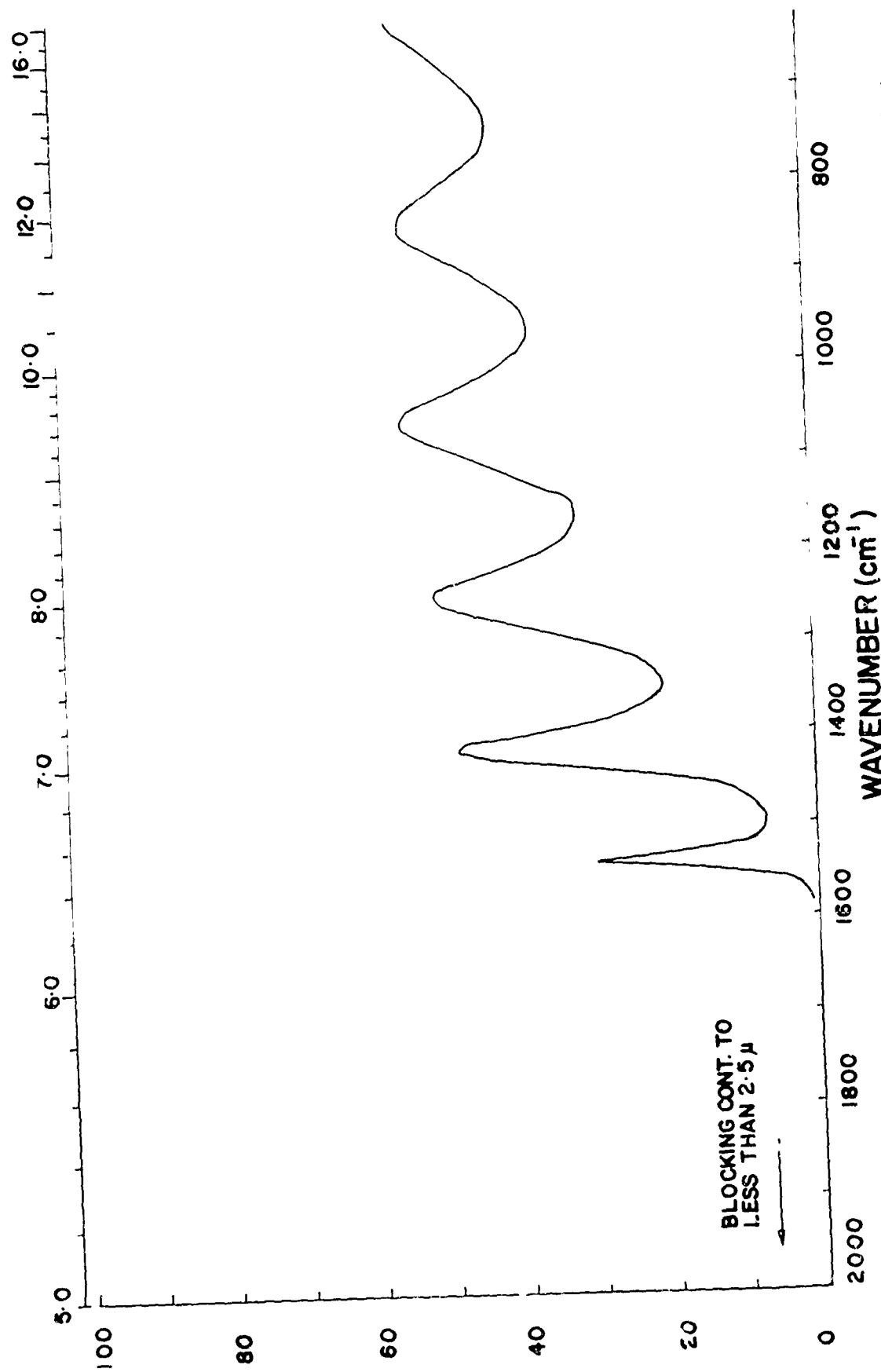


FIG. 4-35 SHORTWAVE TRANSMISSION of Pb Te/CsBr STACK

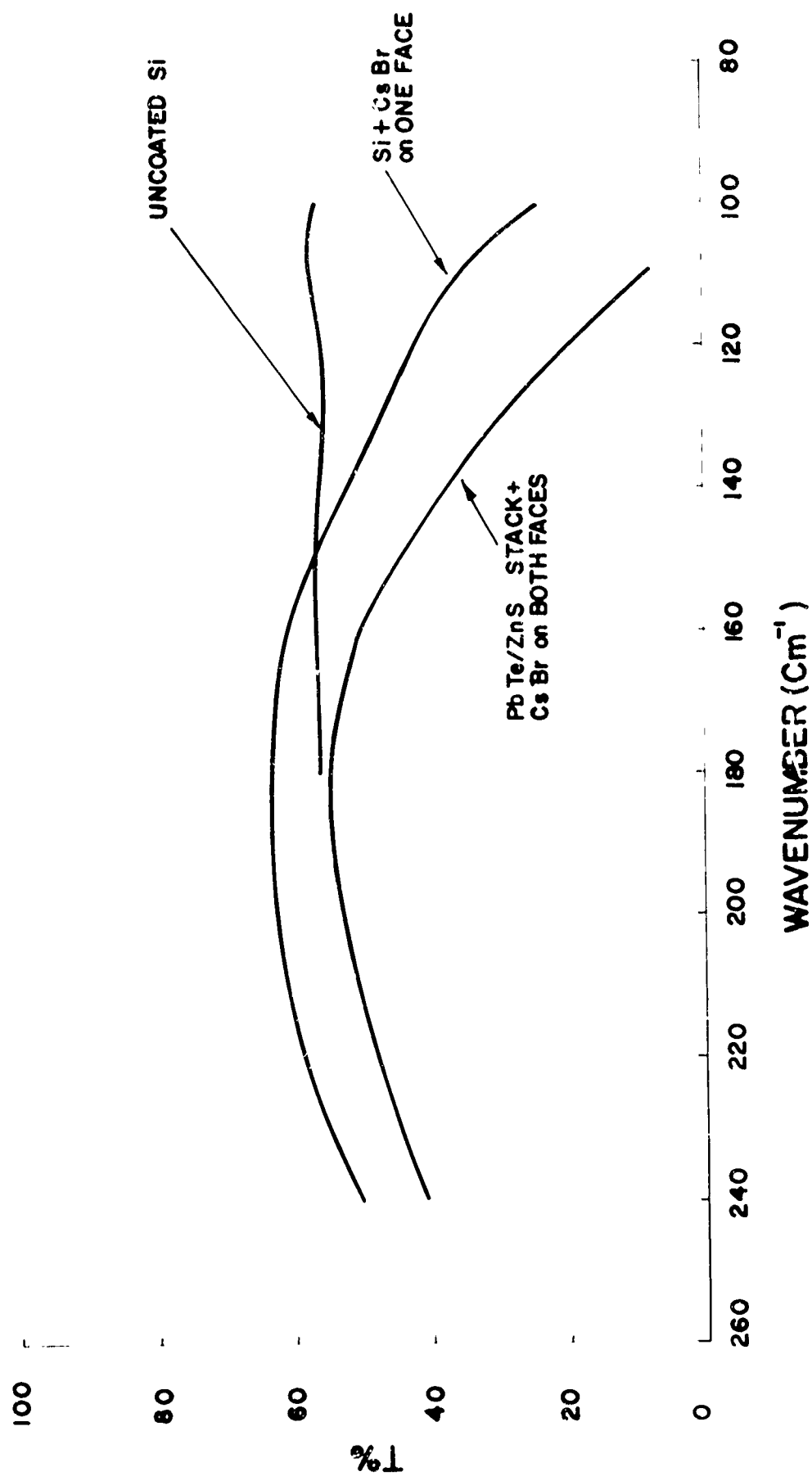


FIG. 4-36 CsBr ANTIREFLECTION (19 QWOT at 3.93 μ)

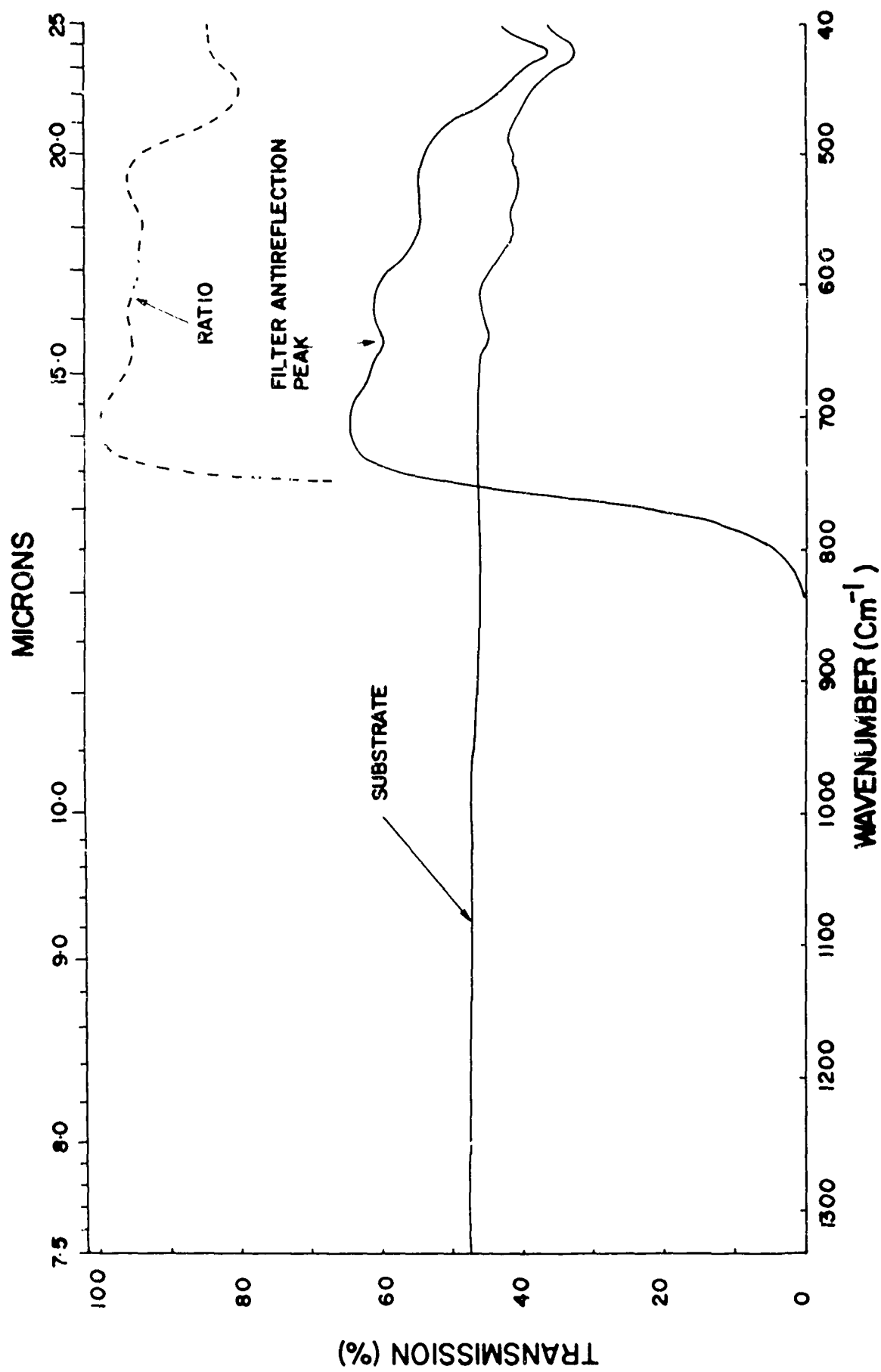


FIG. 4-37 EQUAL-RIPPLE PbTe / ZnS LOWPASS FILTER

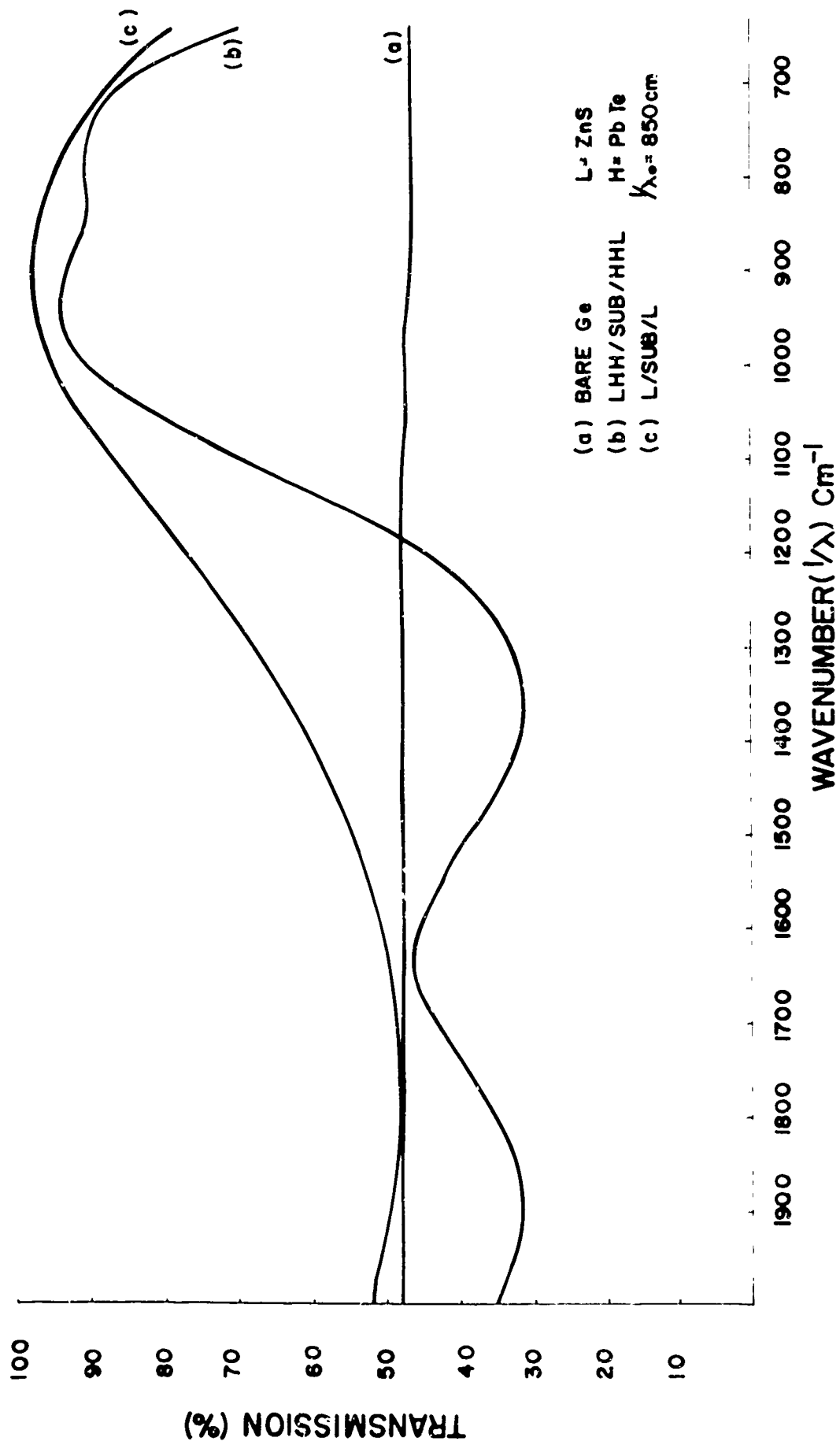


FIG. 4-38 ANTIREFLECTION of GERMANIUM

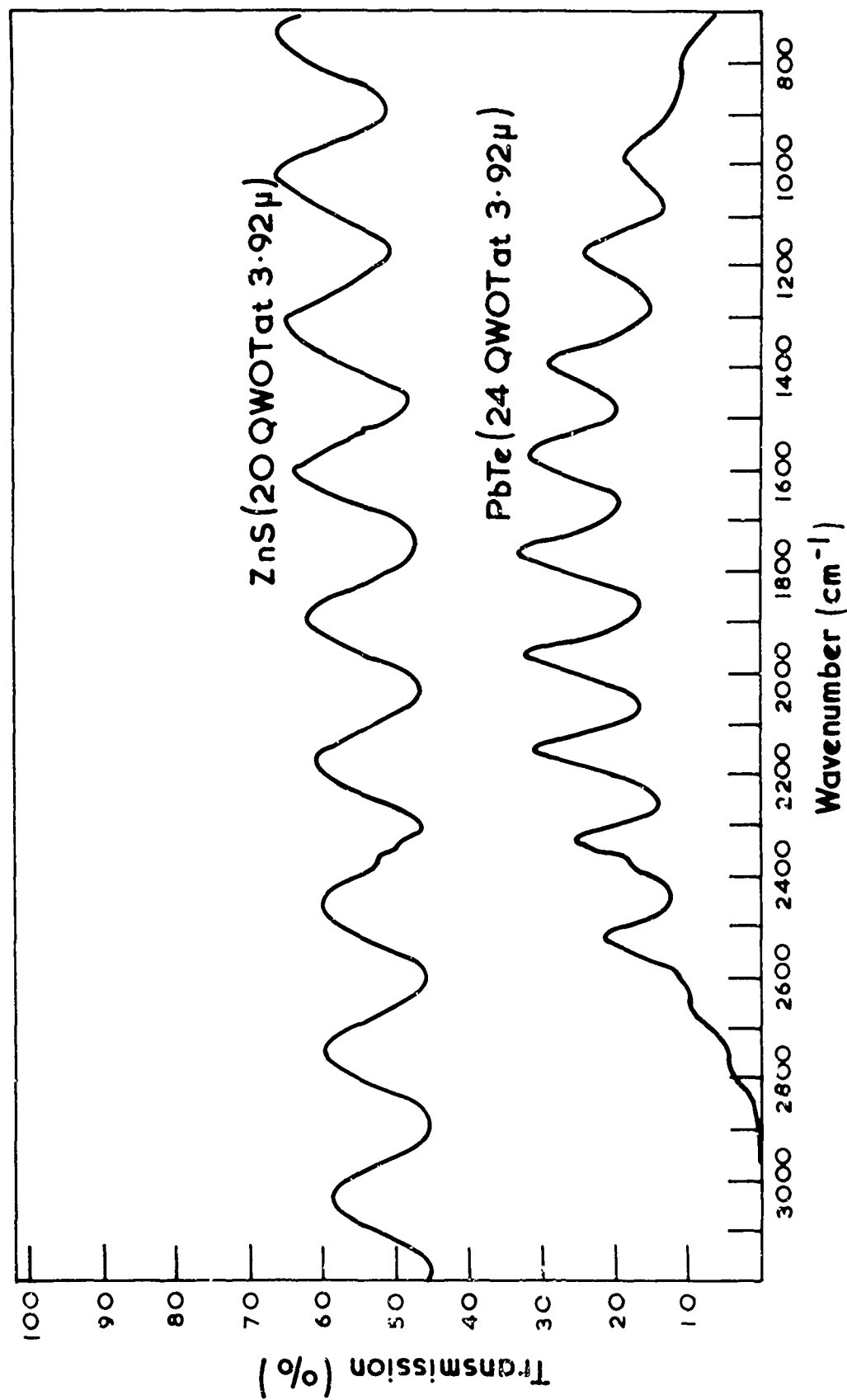


Fig: 4.39 TRANSMISSION OF PbTe AND ZnS COLLECTED SEPARATELY DURING A FILTER DEPOSITION

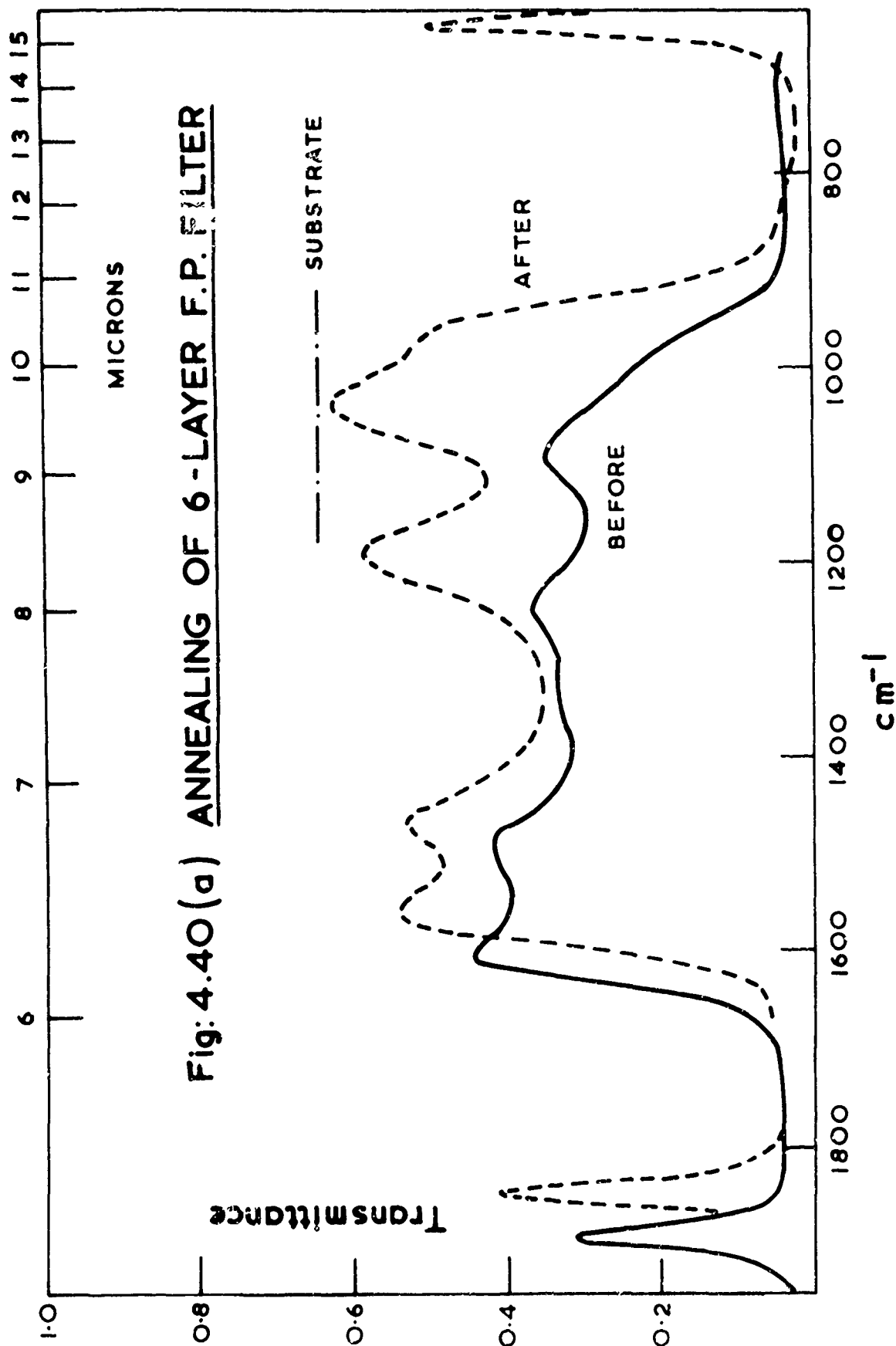


Fig: 4.40(a) ANNEALING OF 6-LAYER F.P. FILTER

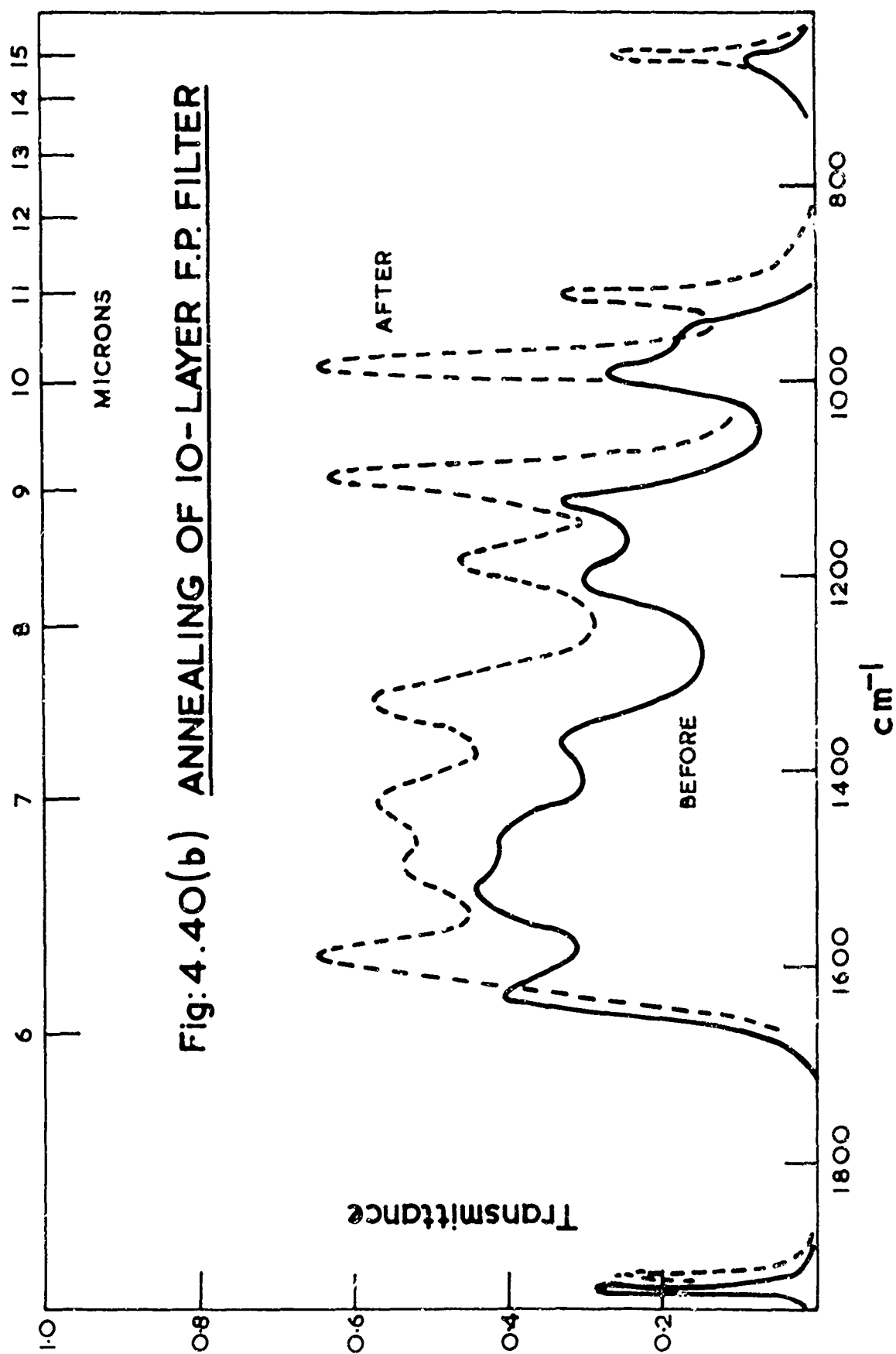
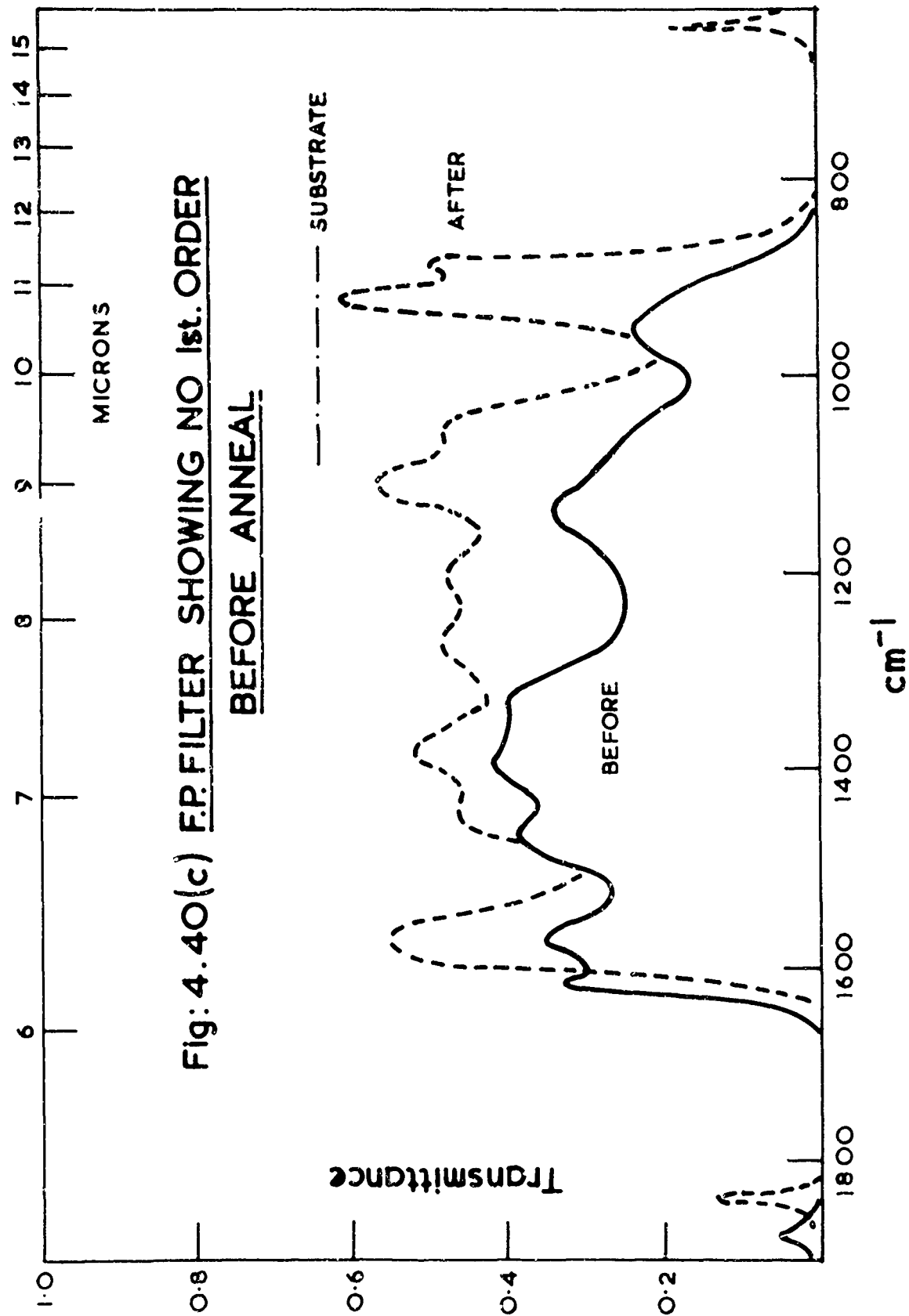


Fig: 4.40(b) ANNEALING OF 10-LAYER F.P. FILTER



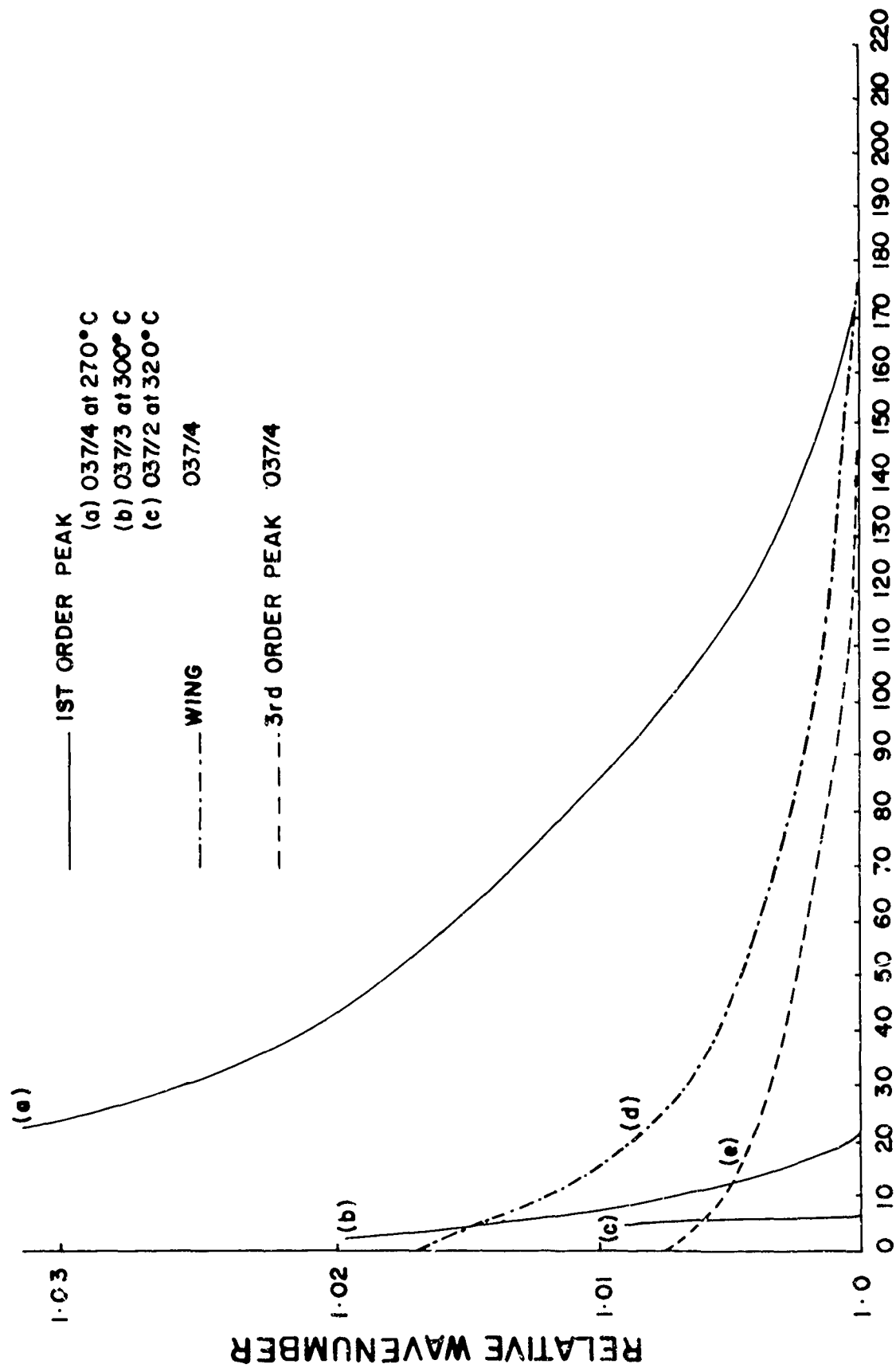


FIG. 4.41 (a) SPECTRAL SHIFT of F.P. PEAKS at VARIOUS TEMPERATURES

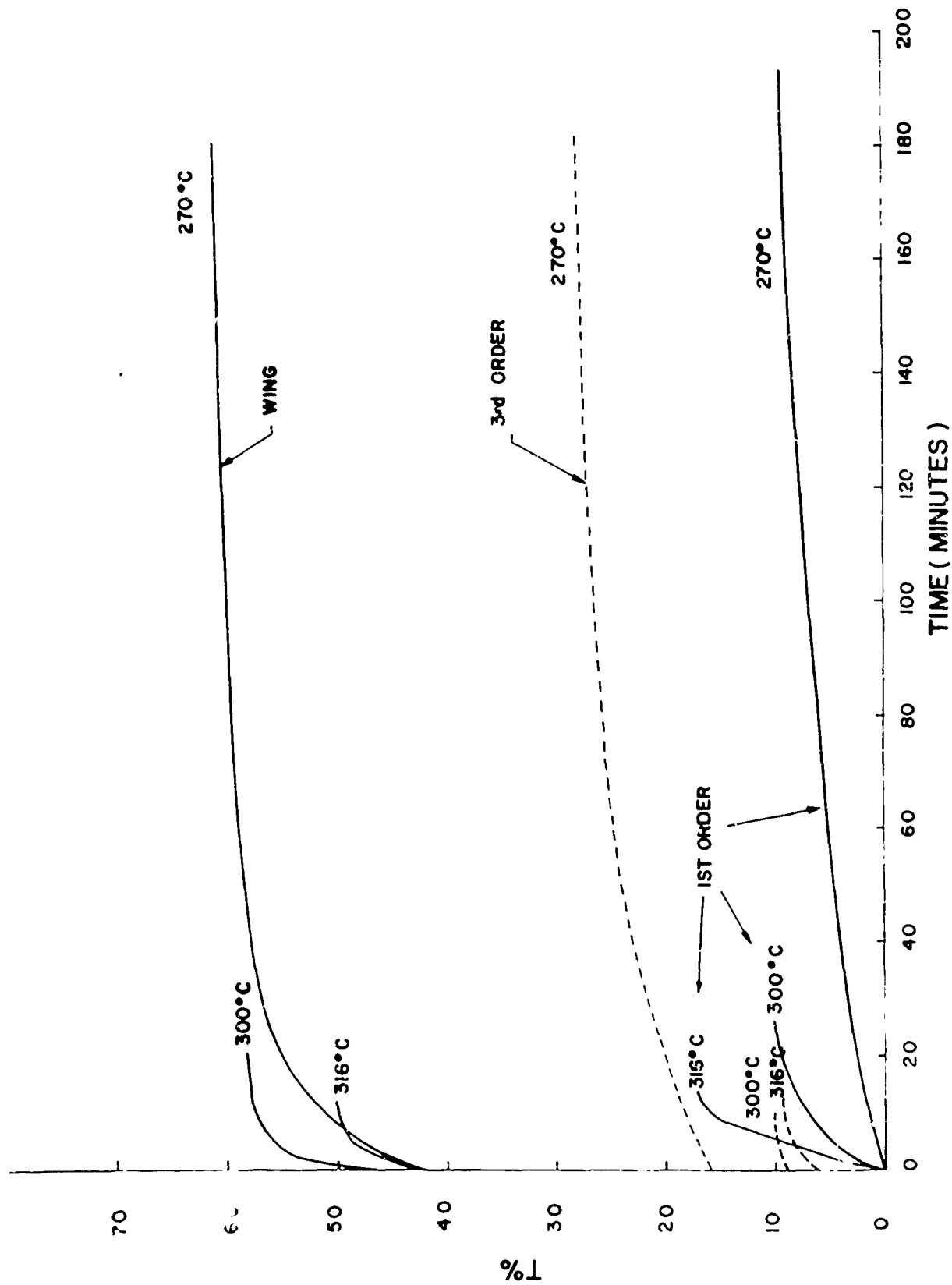


FIG. 4-41(b) FP INCREASED TRANSMITTANCE at VARIOUS TEMPERATURES

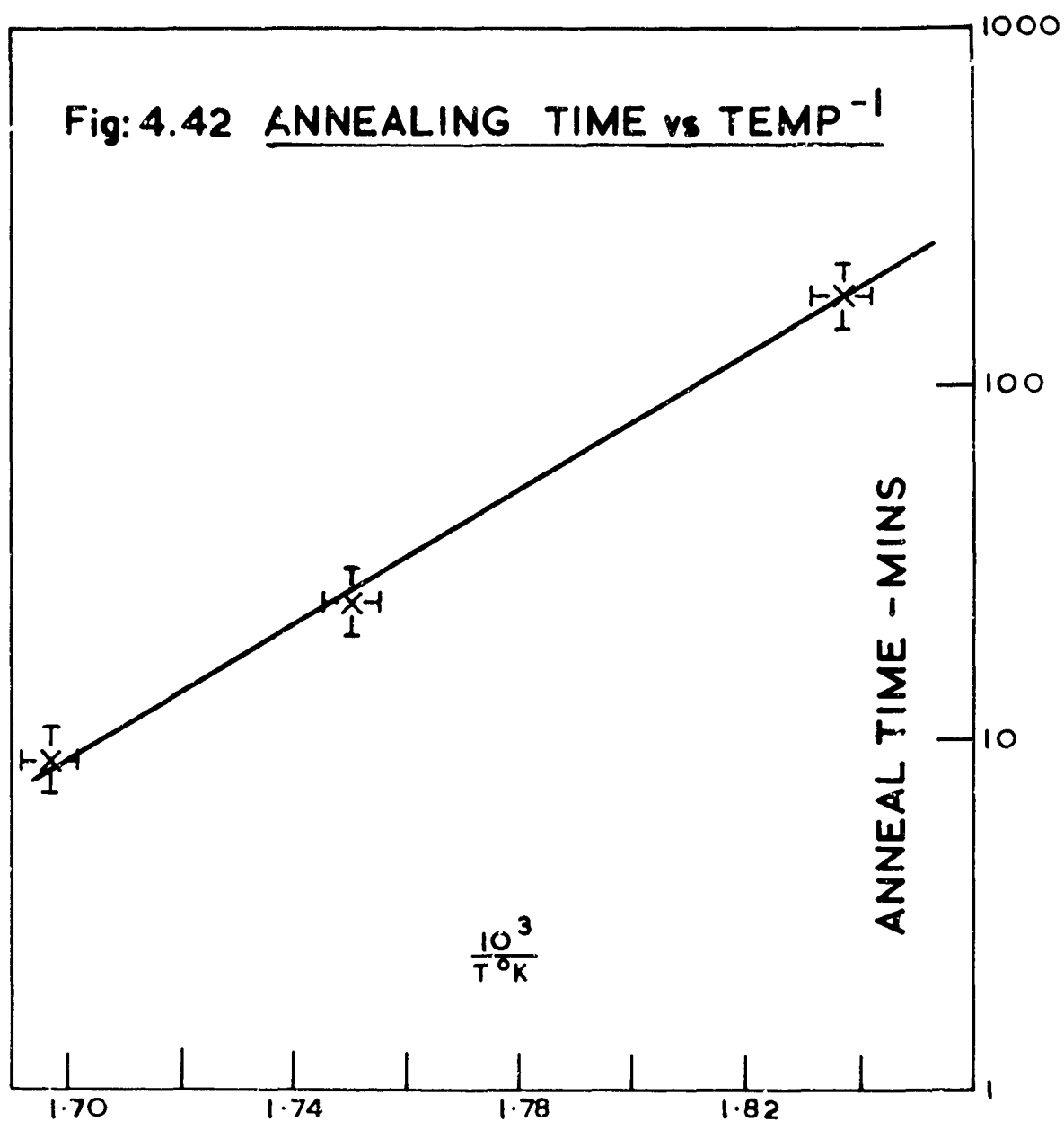


Fig: 4.43 CALCULATED 1st. ORDER SHIFT
vs CHANGE IN PbTe INDEX

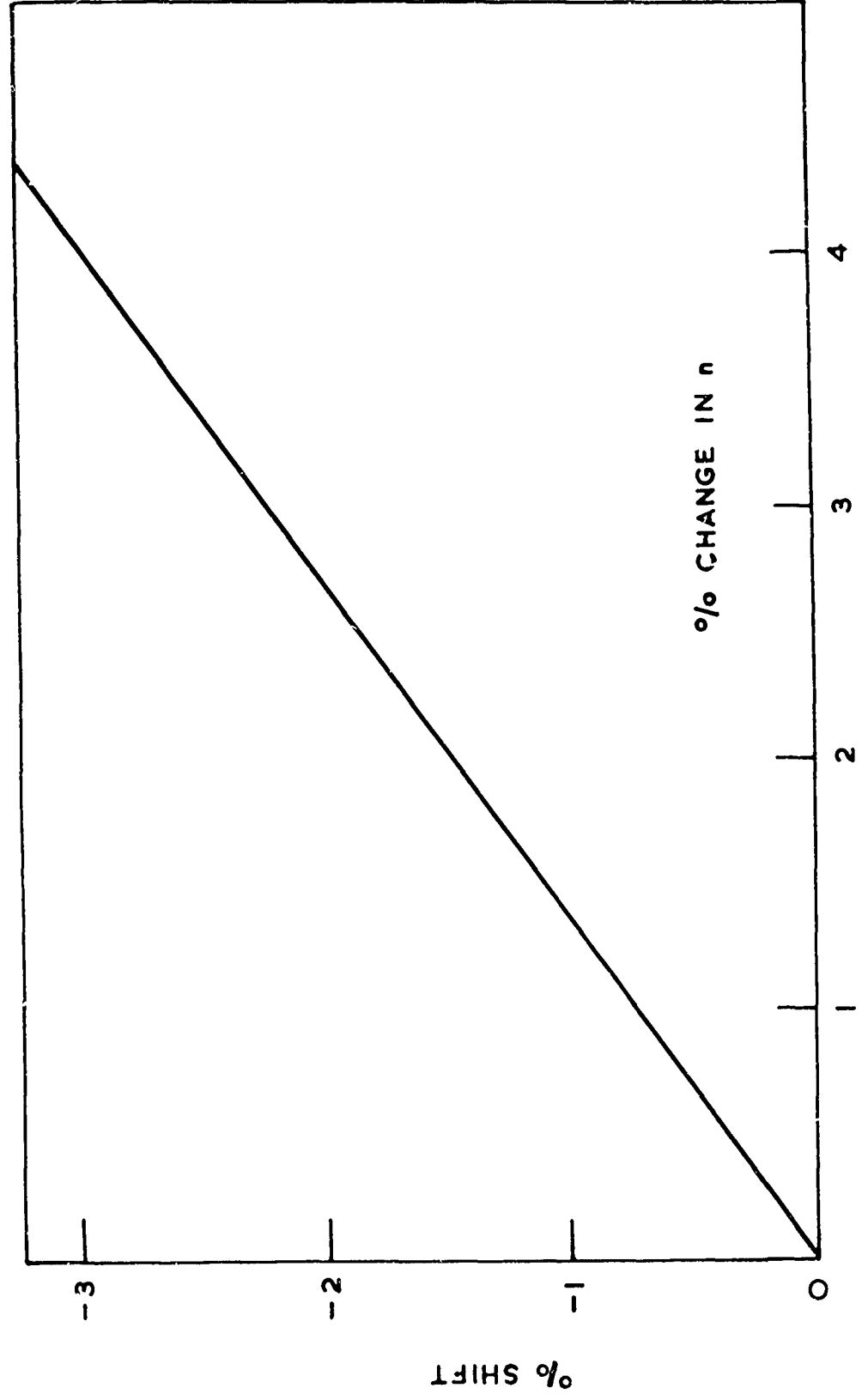
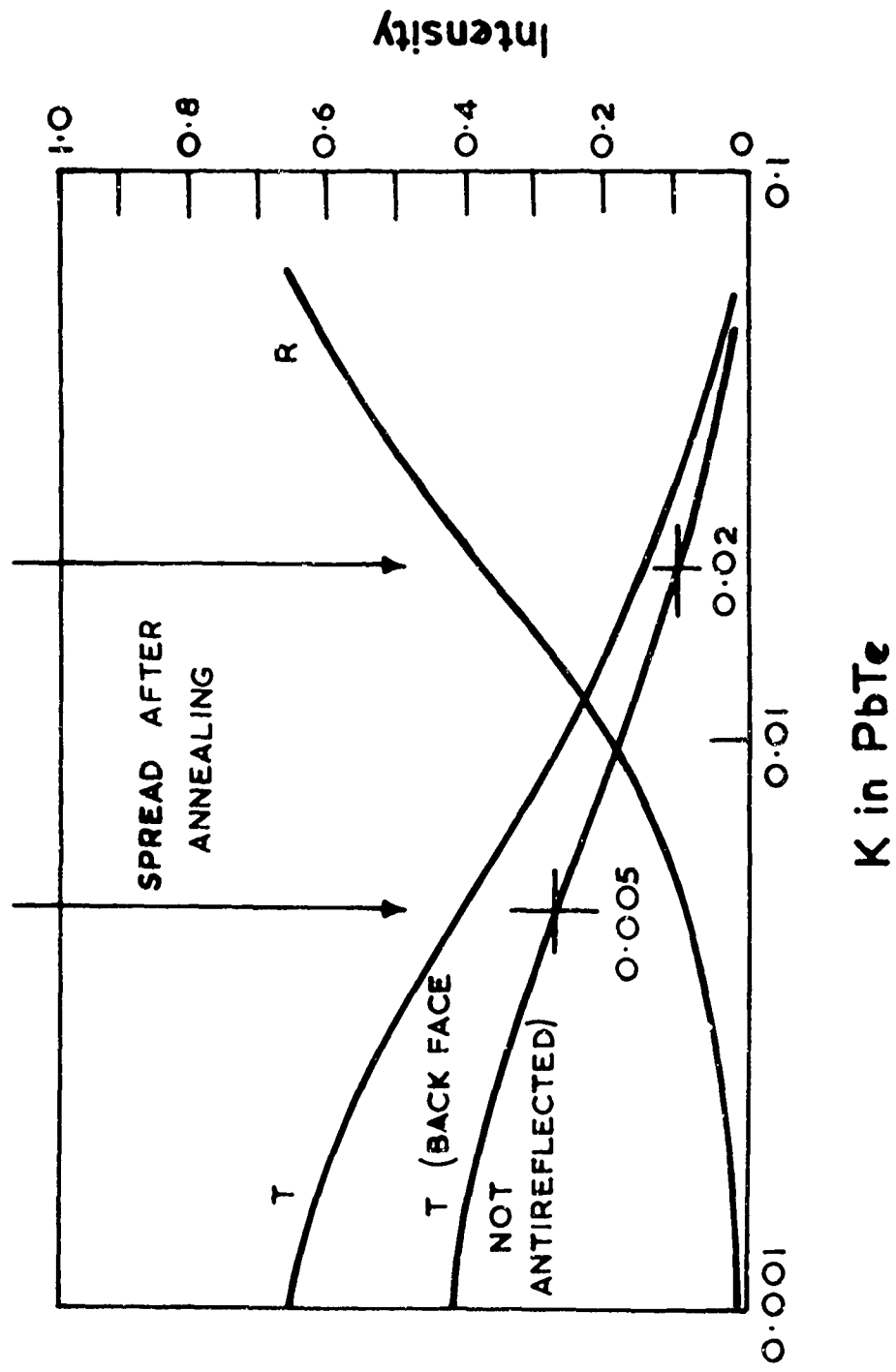
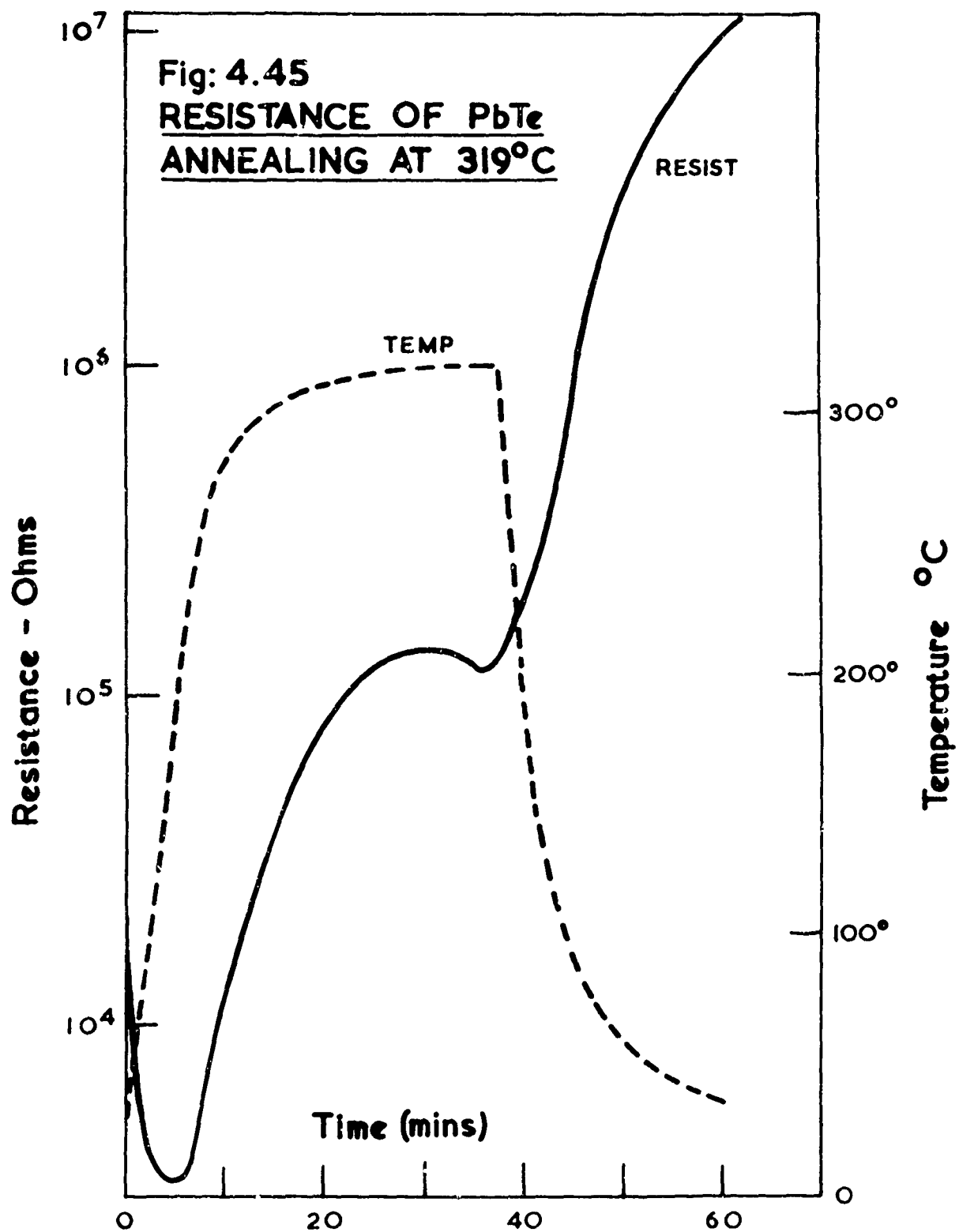
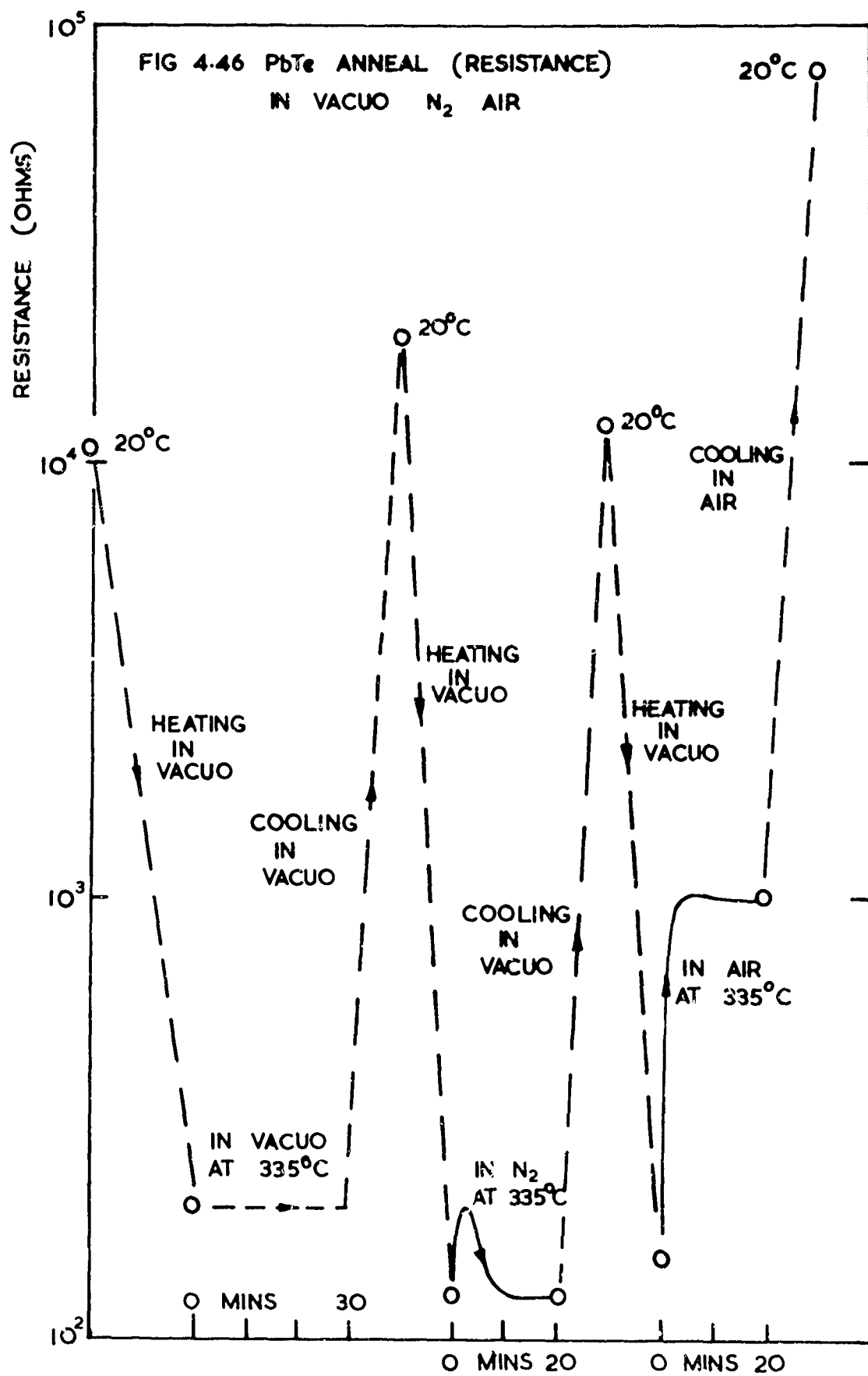


**Fig: 4.44 CALCULATED TRANSMITTANCE/REFLECTANCE
IN F.P. FILTER vs ABSORPTION IN PbTe**







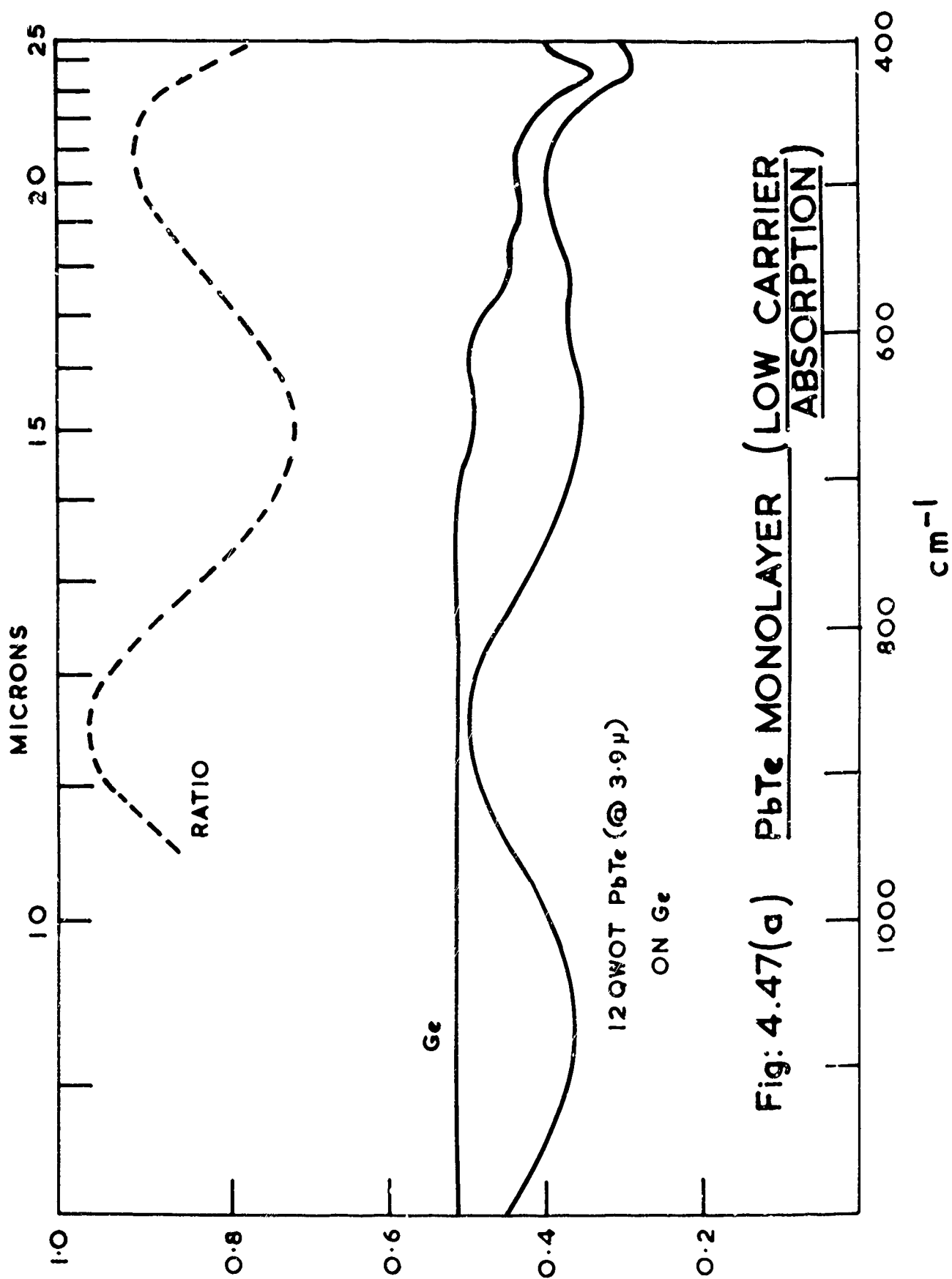


Fig: 4.47(a) PbTe MONOLAYER (LOW CARRIER ABSORPTION)

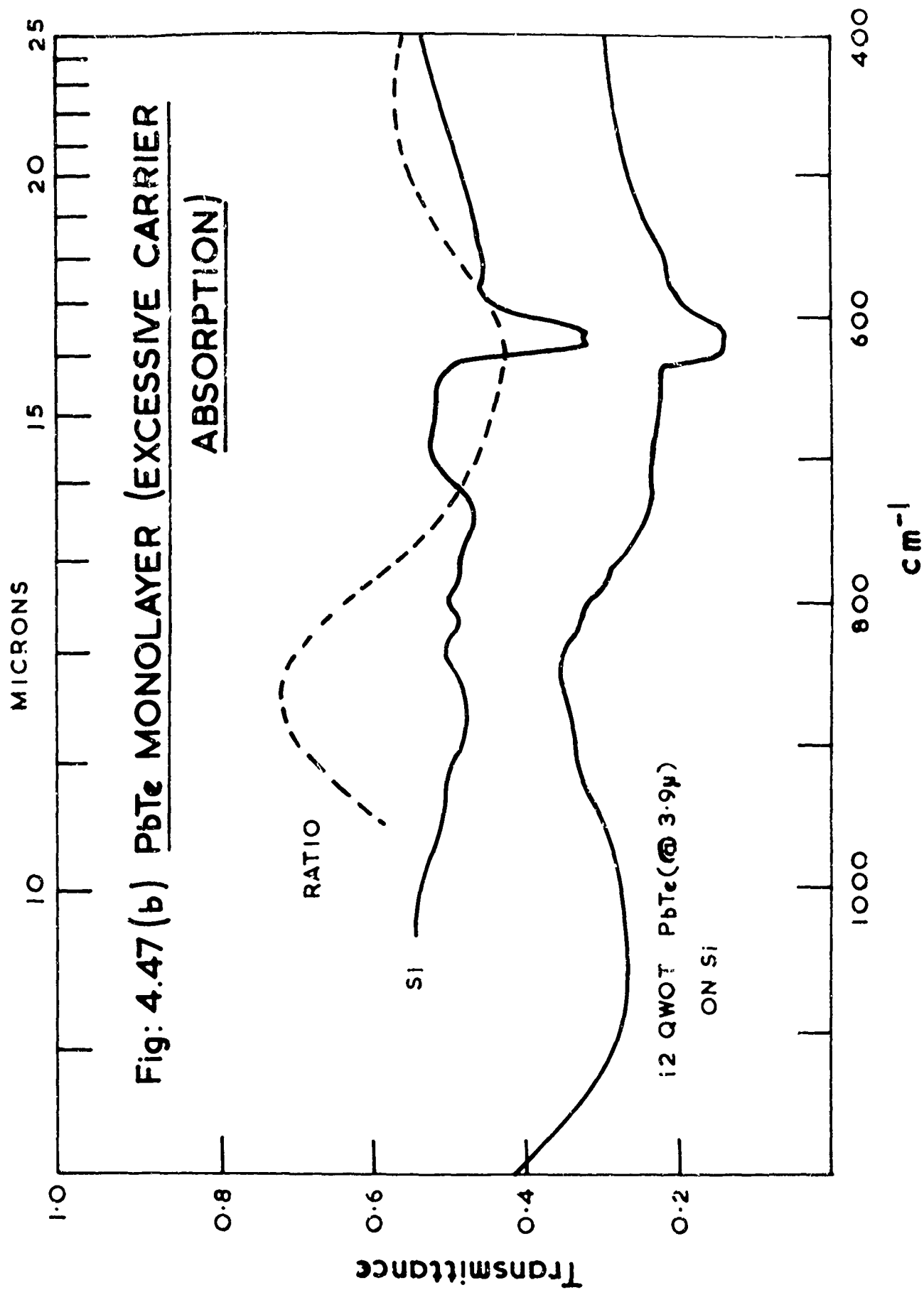


FIG 4.48 a DISPERSION CURVES FOR PbTe FOR VARIOUS NO OF CARRIERS

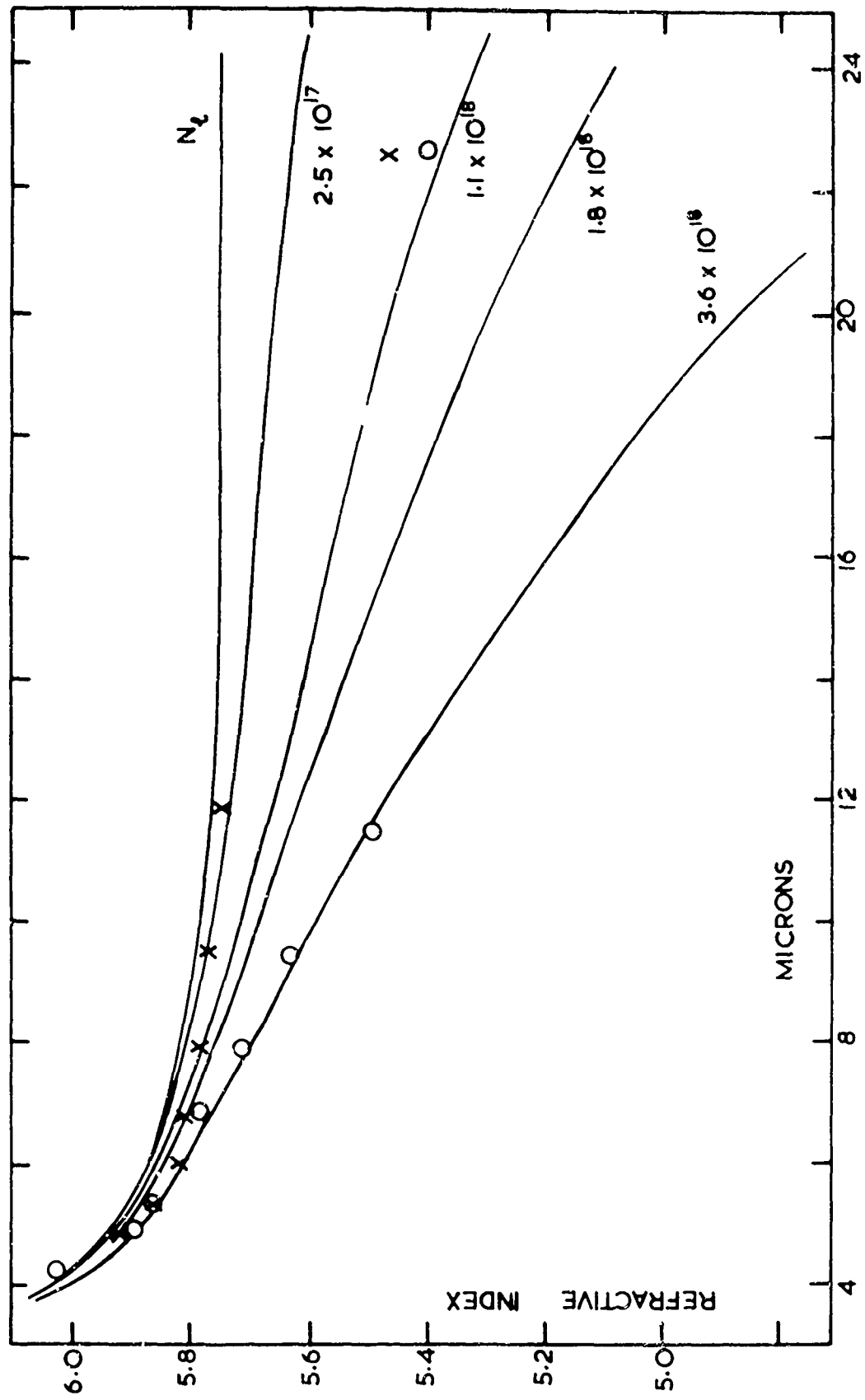
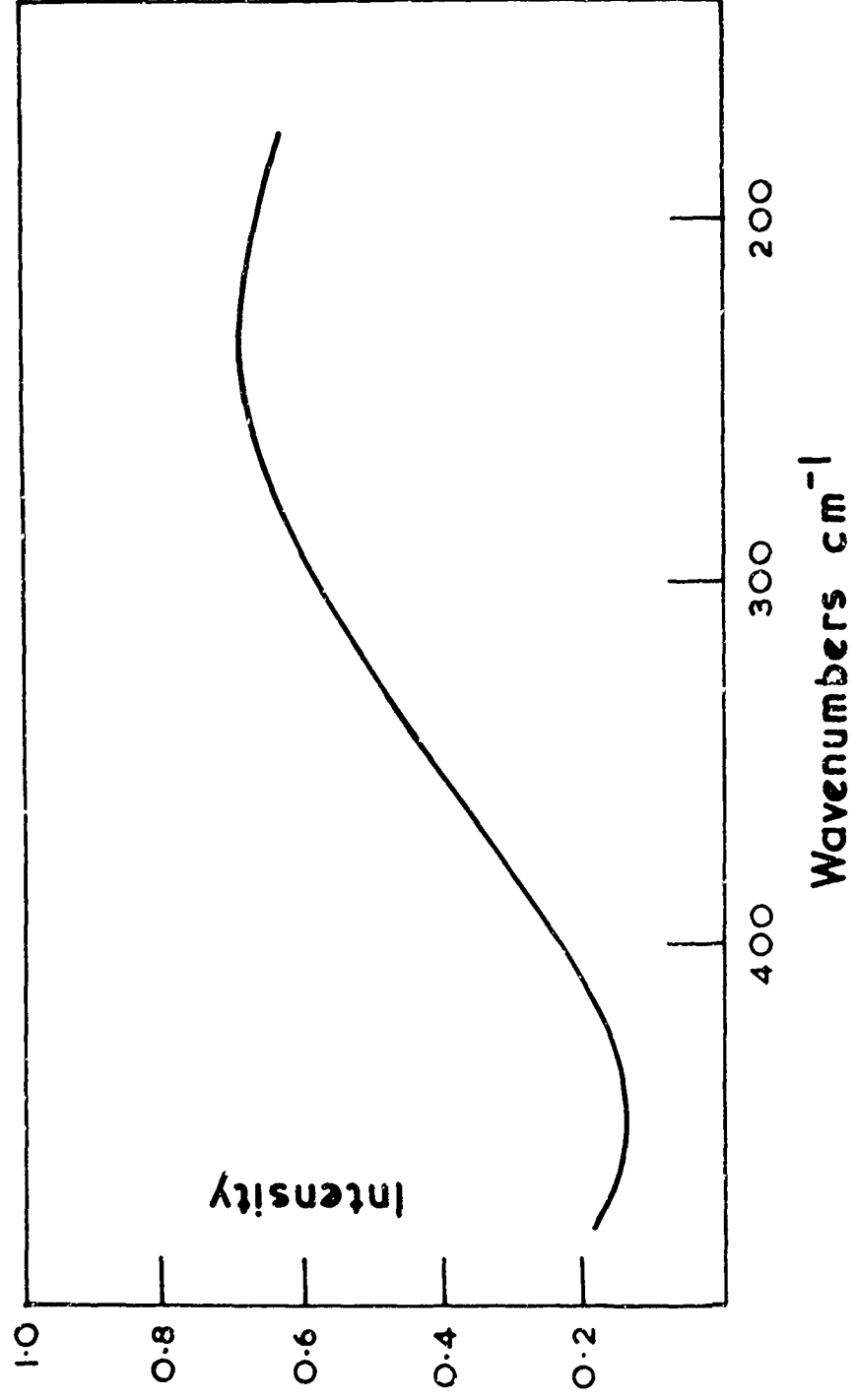


Fig:4.48(b) REFLECTANCE OF PbTe MONOLAYER
(AS FRACTION OF REFLECTANCE OF Si MIRROR)



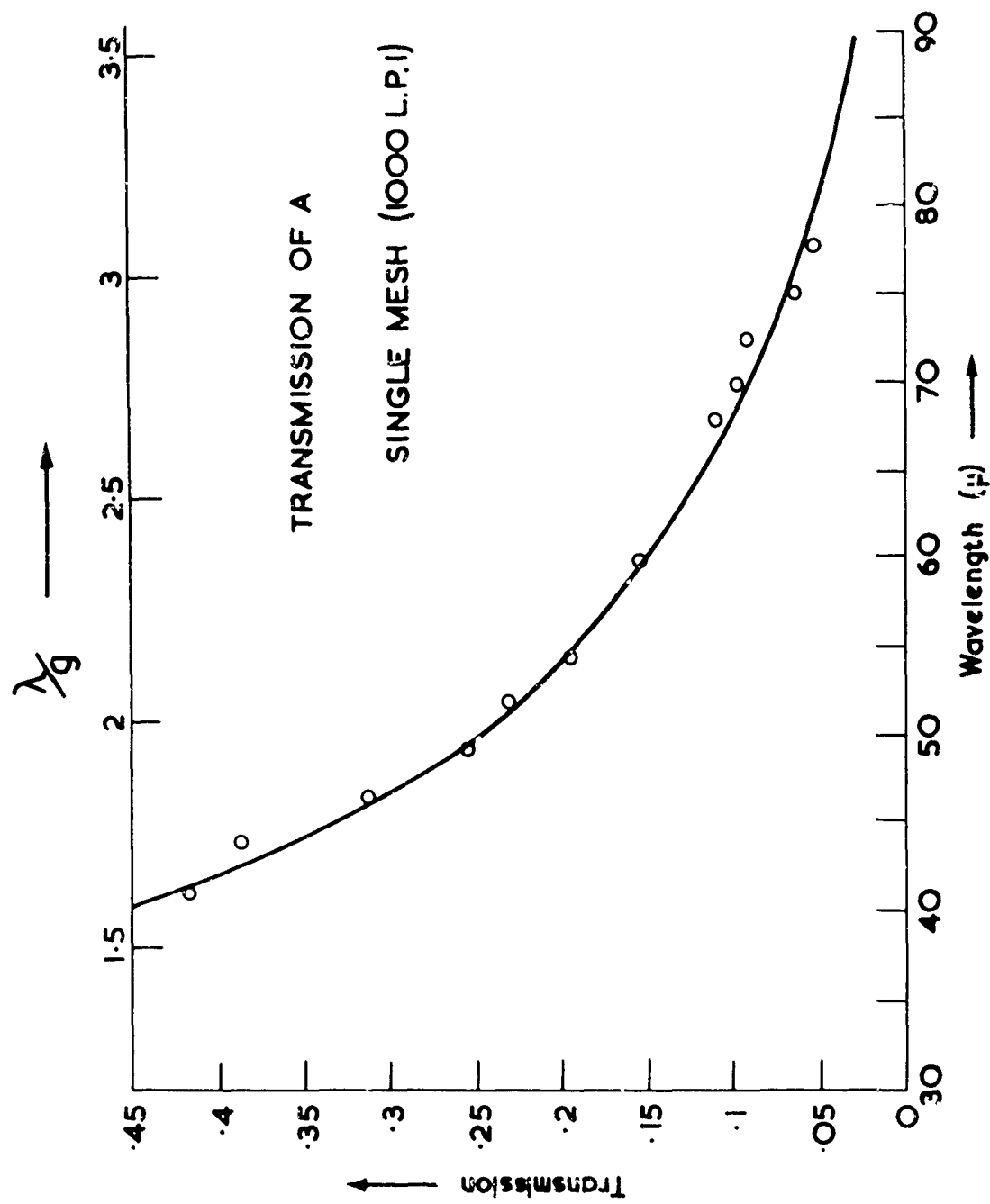


FIG. 4.49

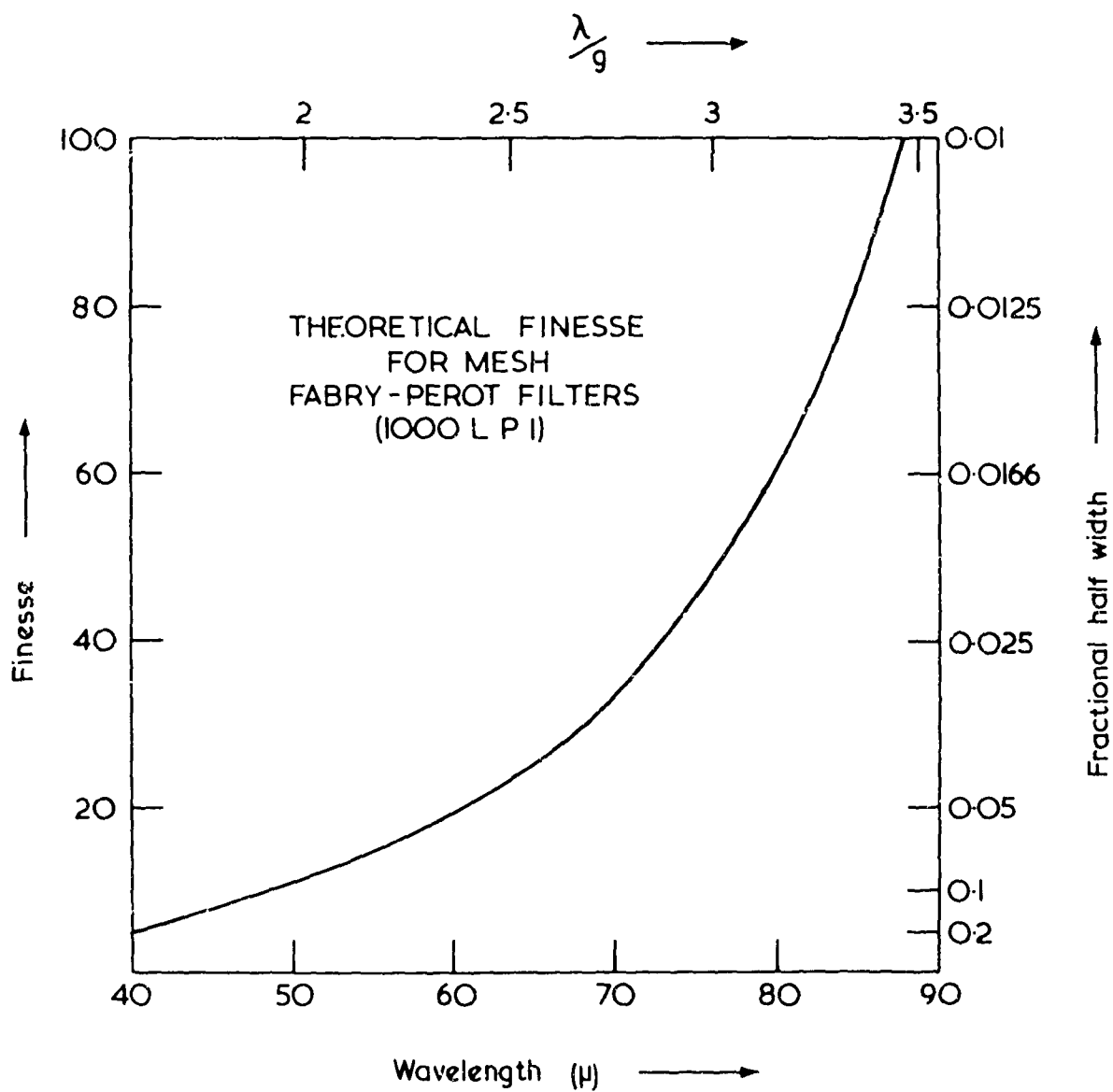


FIG . 4.50

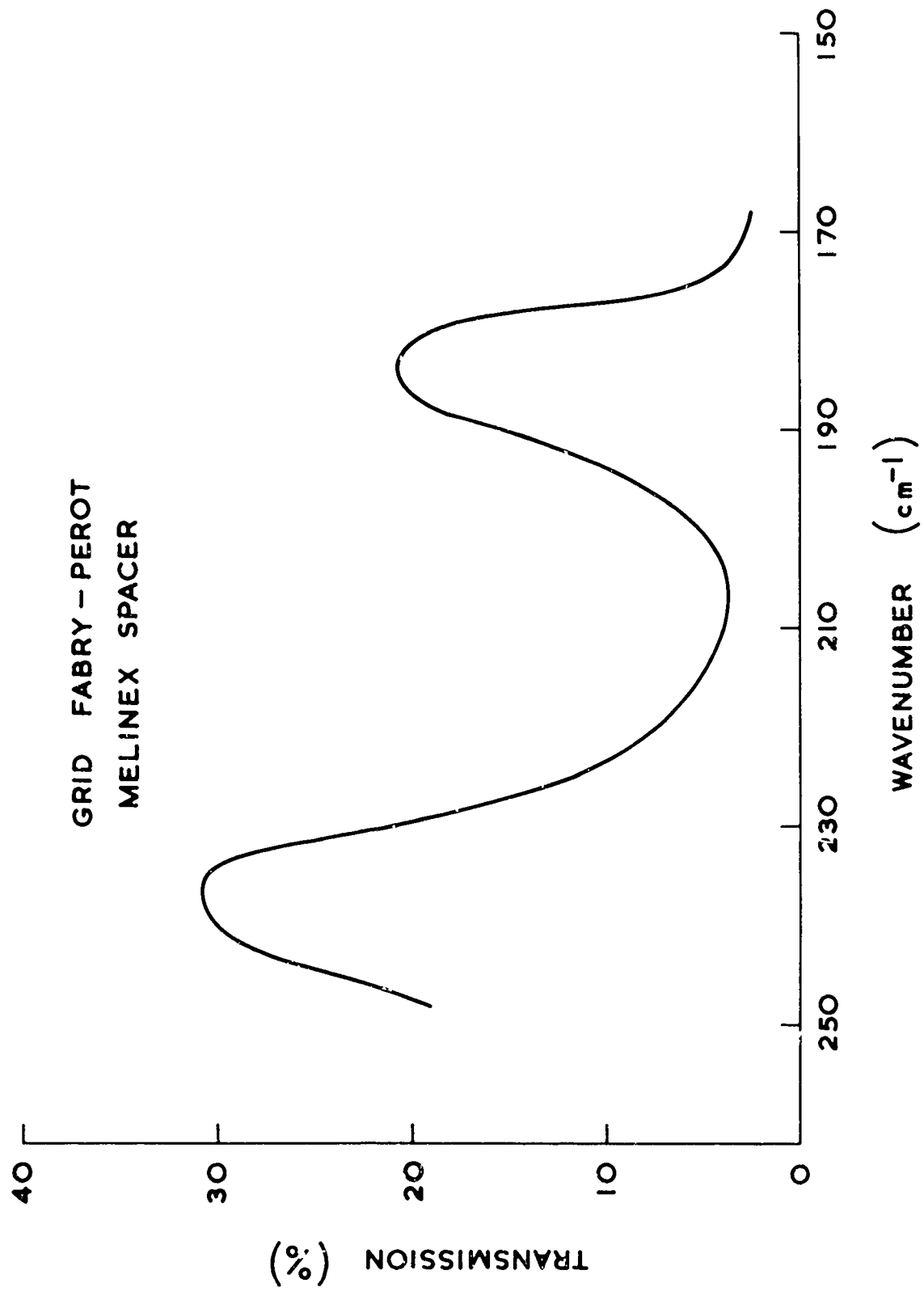


FIG. 4.51

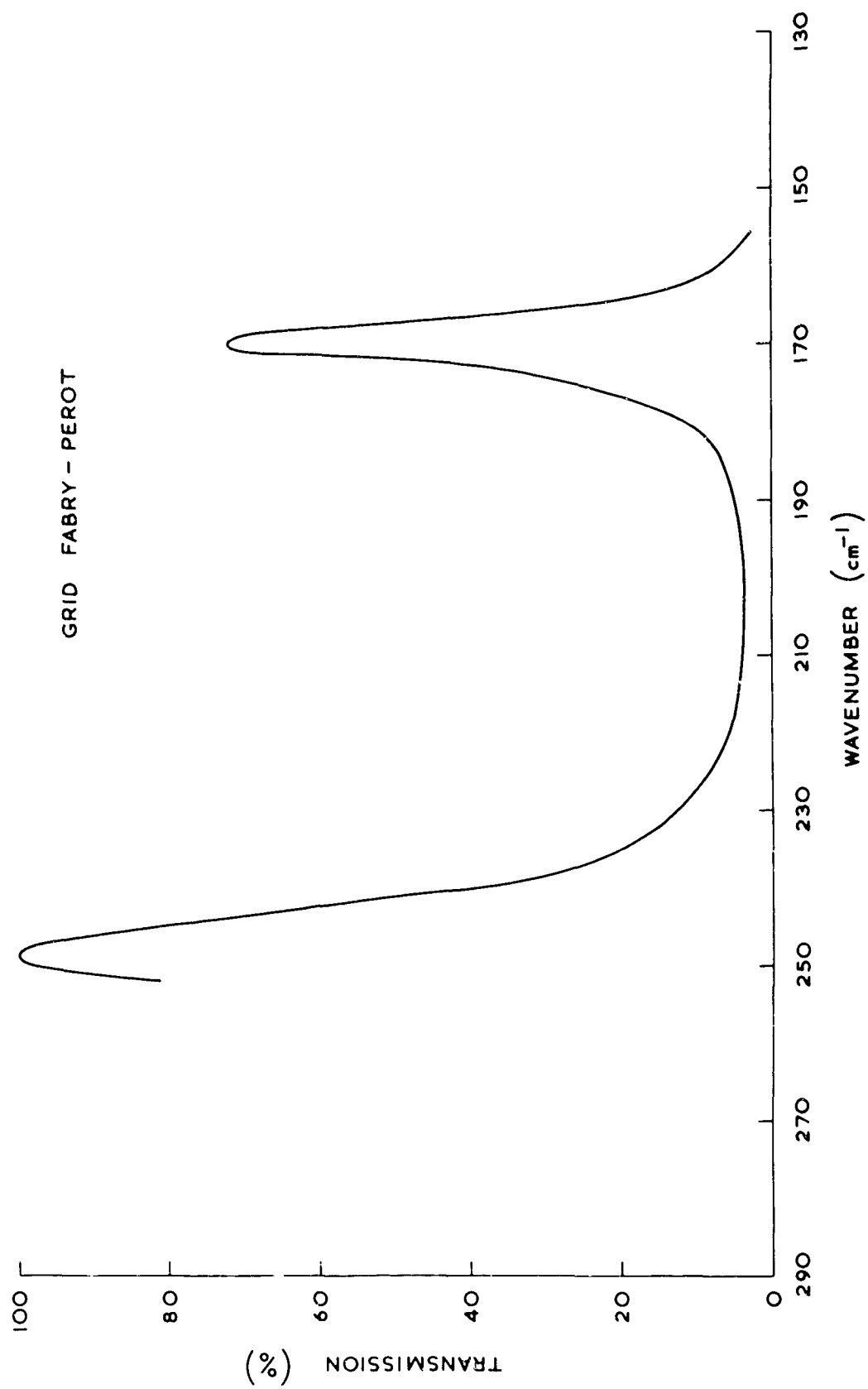
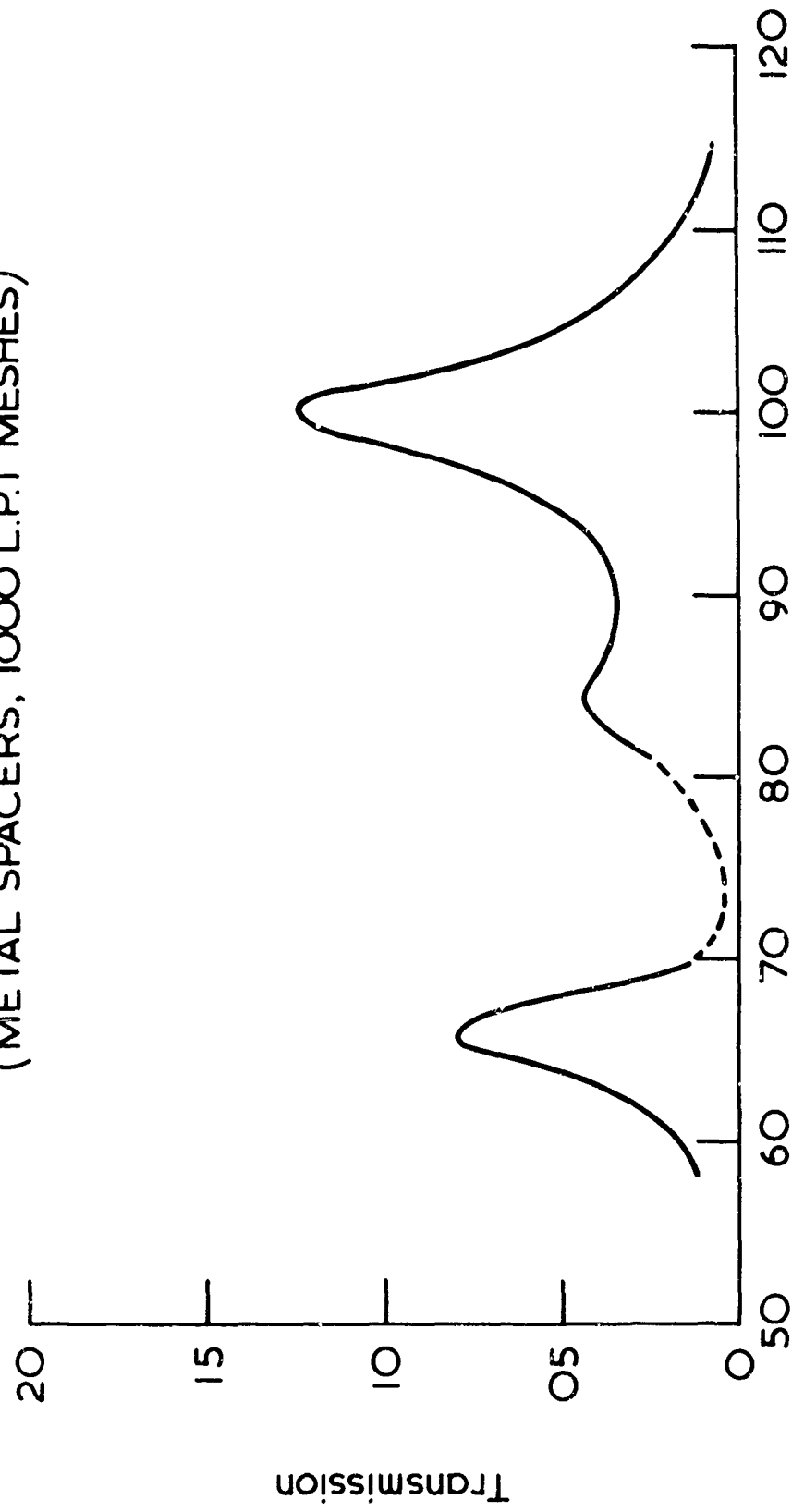


FIG. 4-52

MESH DOUBLE HALF-WAVE
(METAL SPACERS, 1000 L.P.I MESHES)



Wavelength (μ) FIG. 4.53

FILTER FABRICATION—EXPLODED VIEW

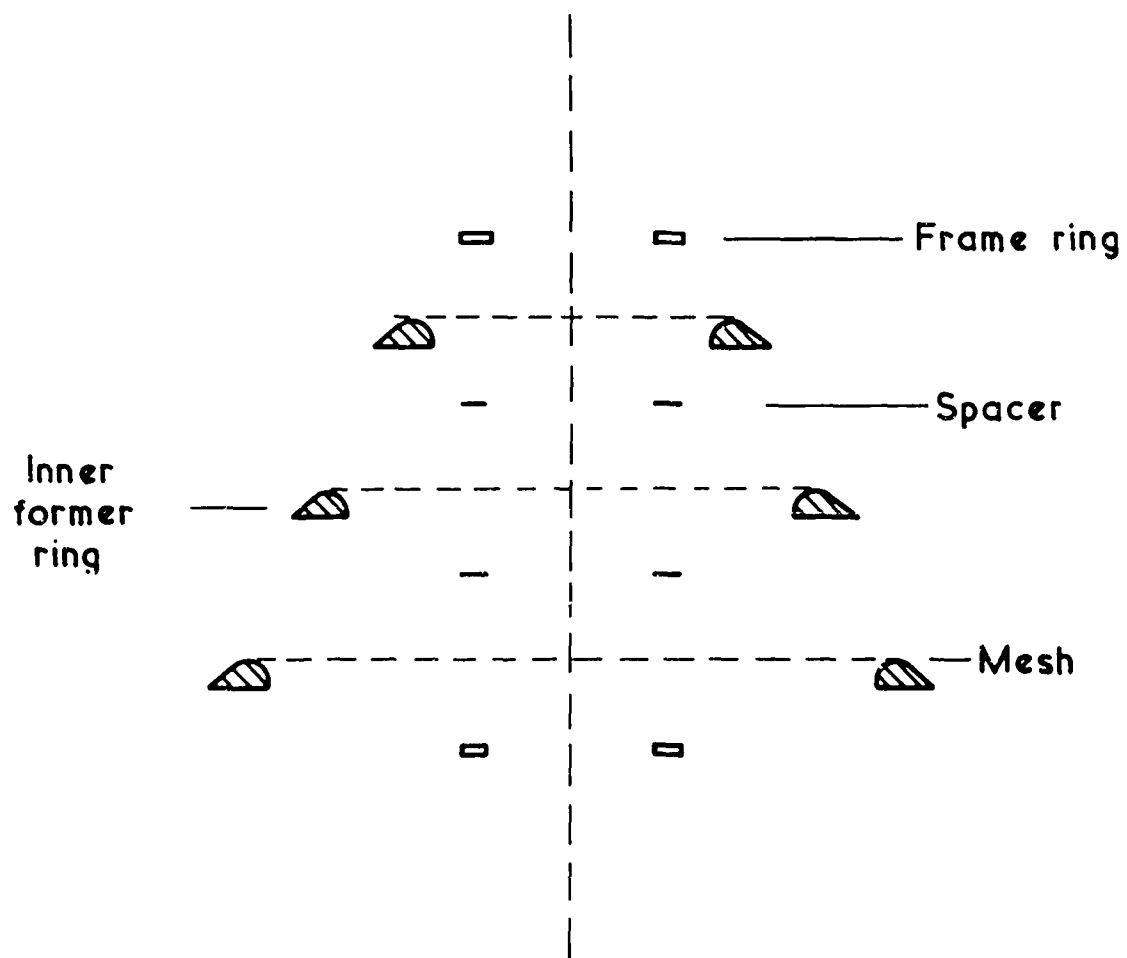


FIG. 4.54

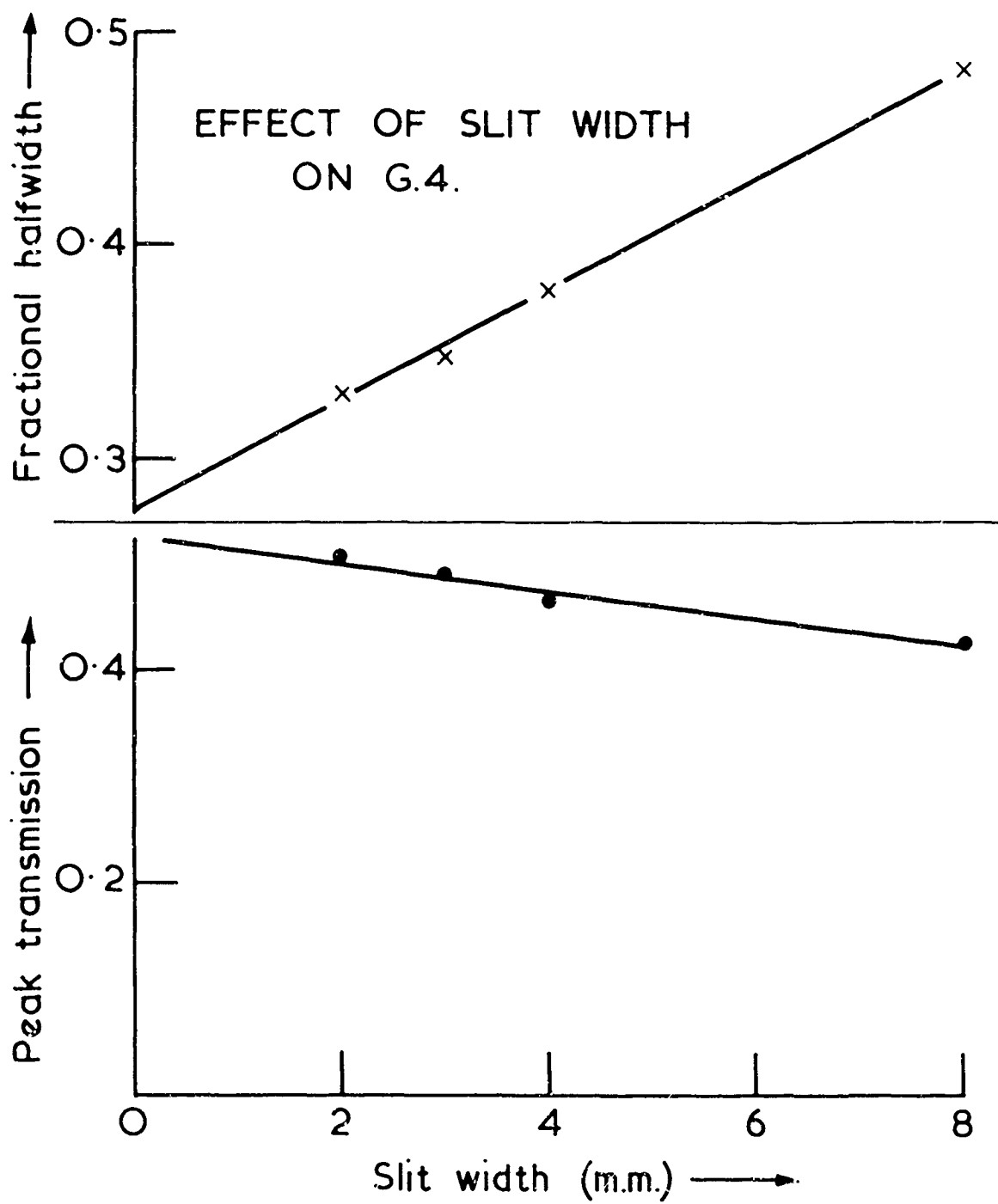


FIG. 4.55

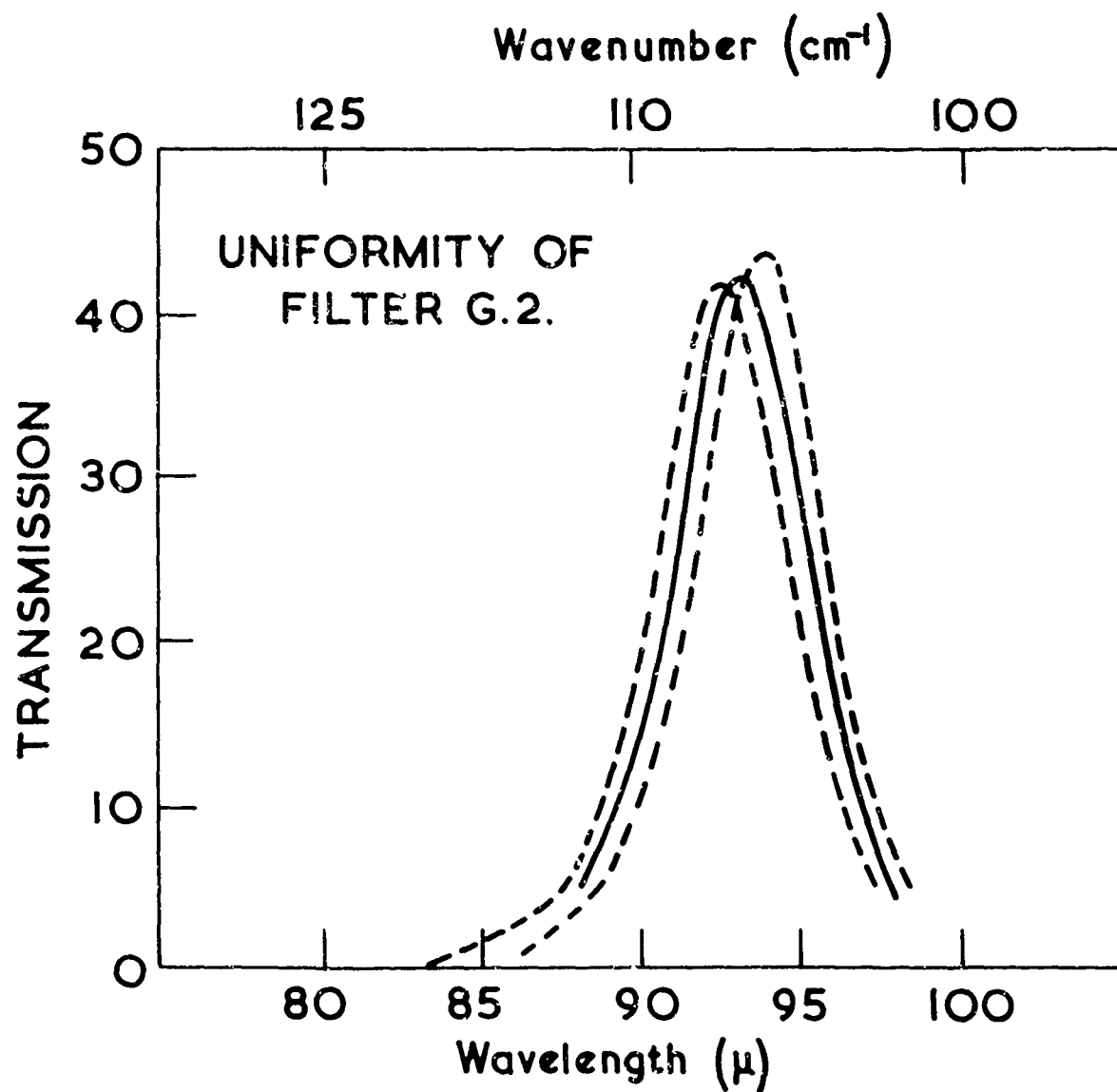


FIG. 4-56

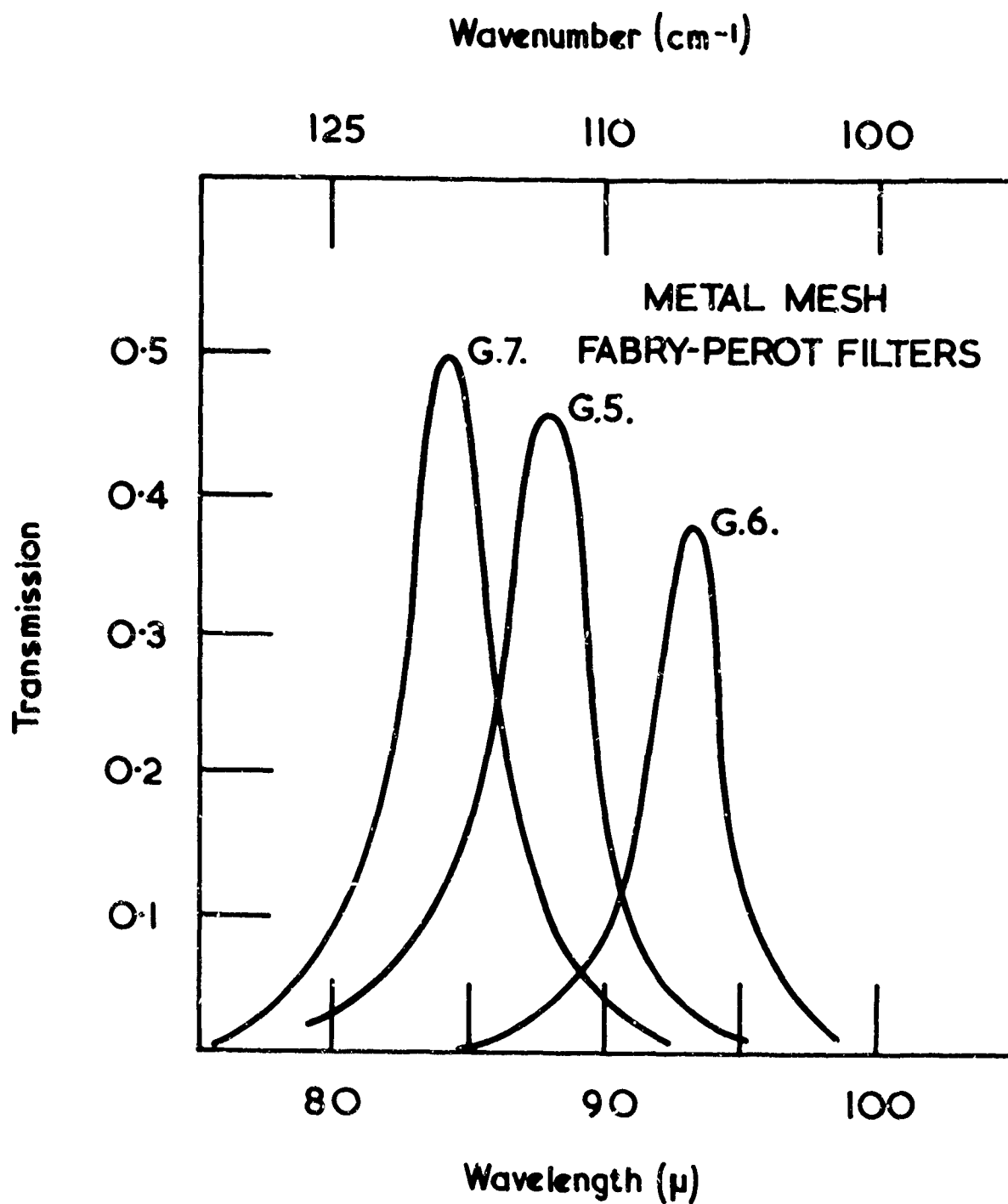


FIG. 4.57

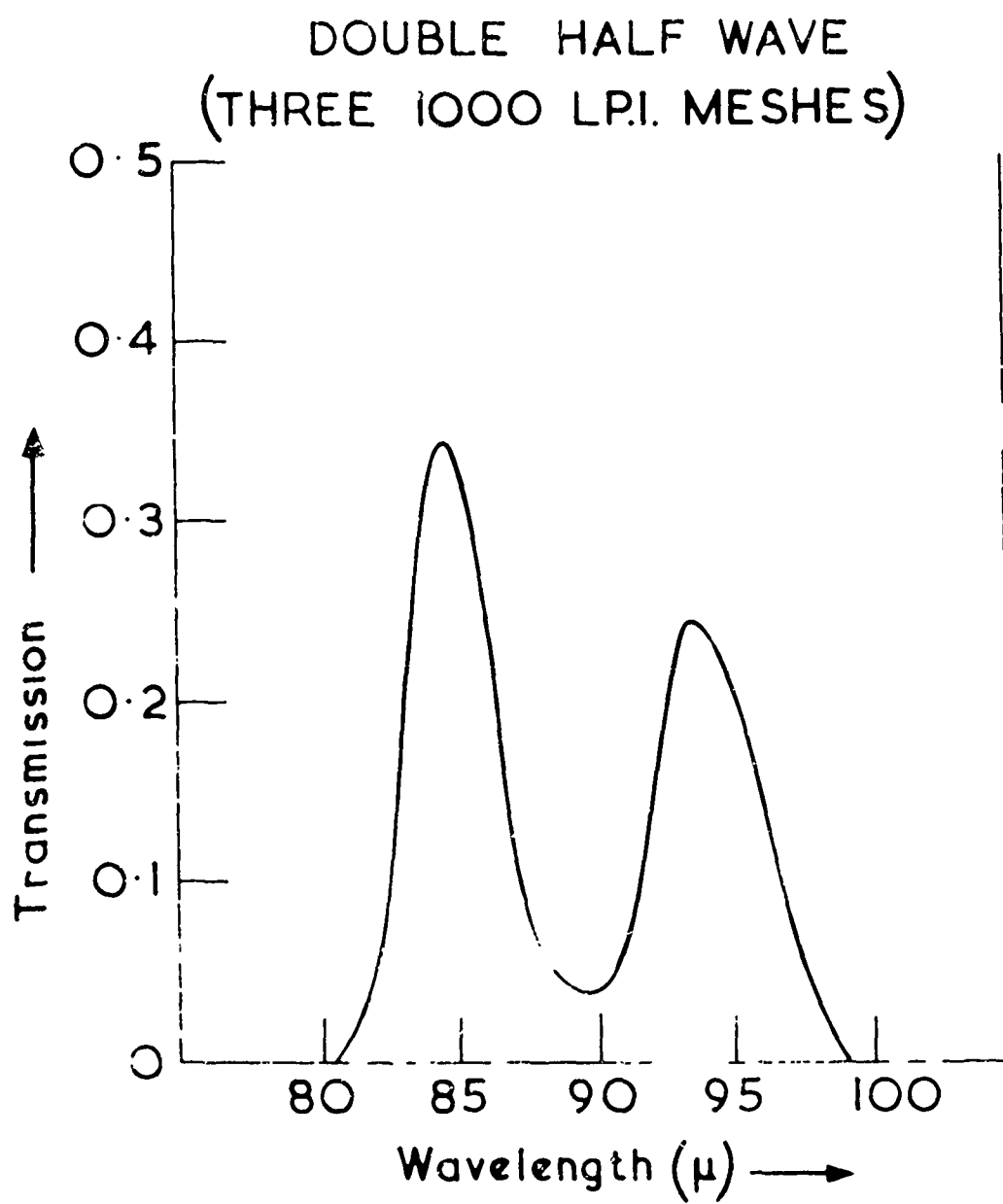


FIG. 4.58

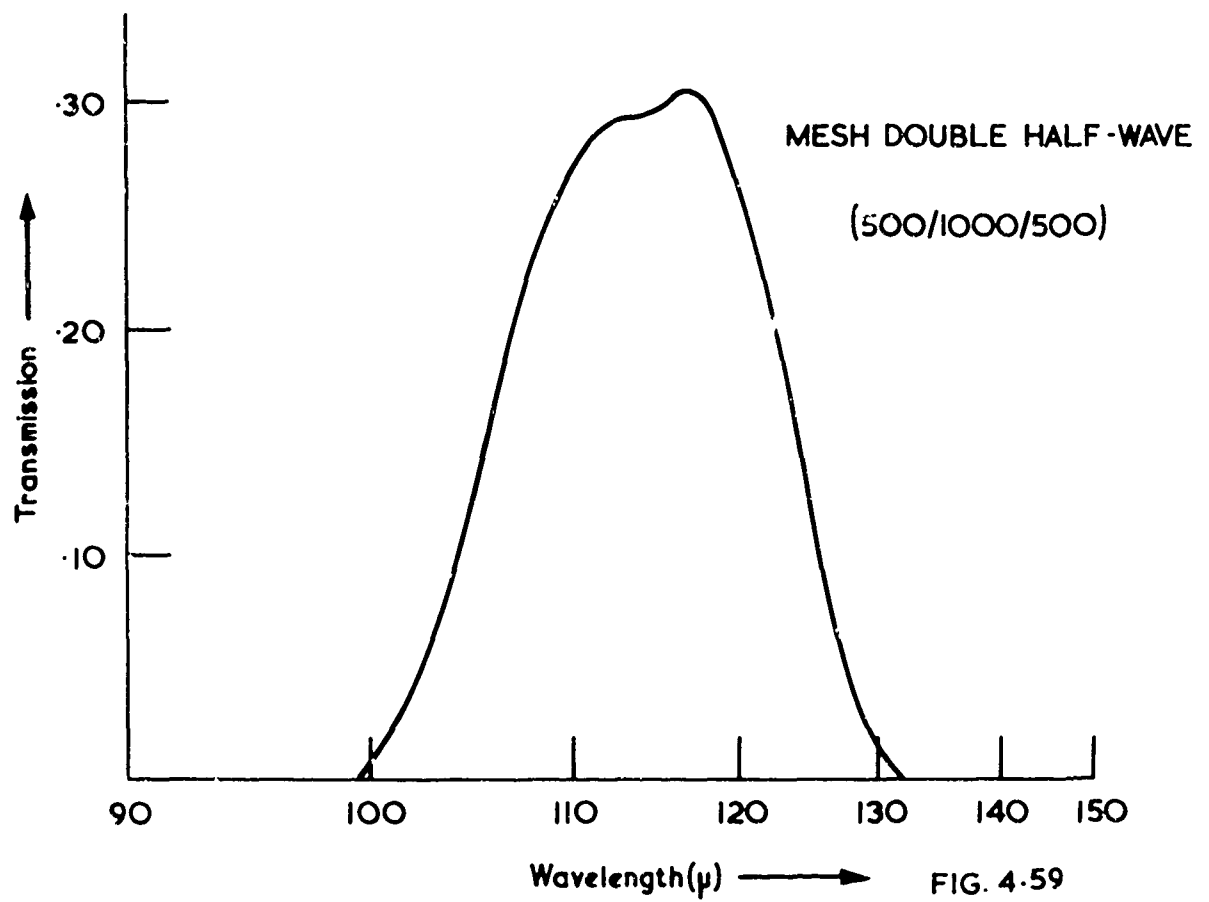
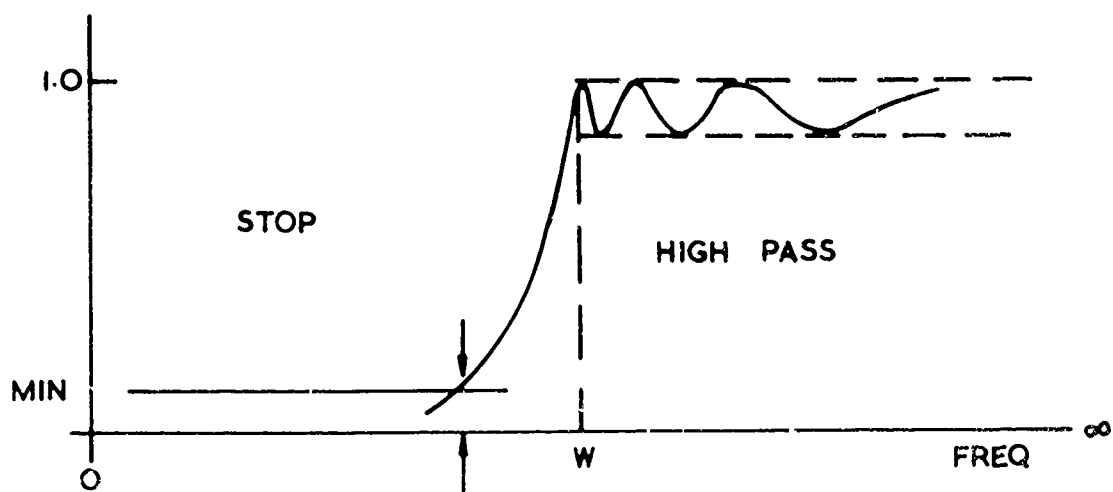
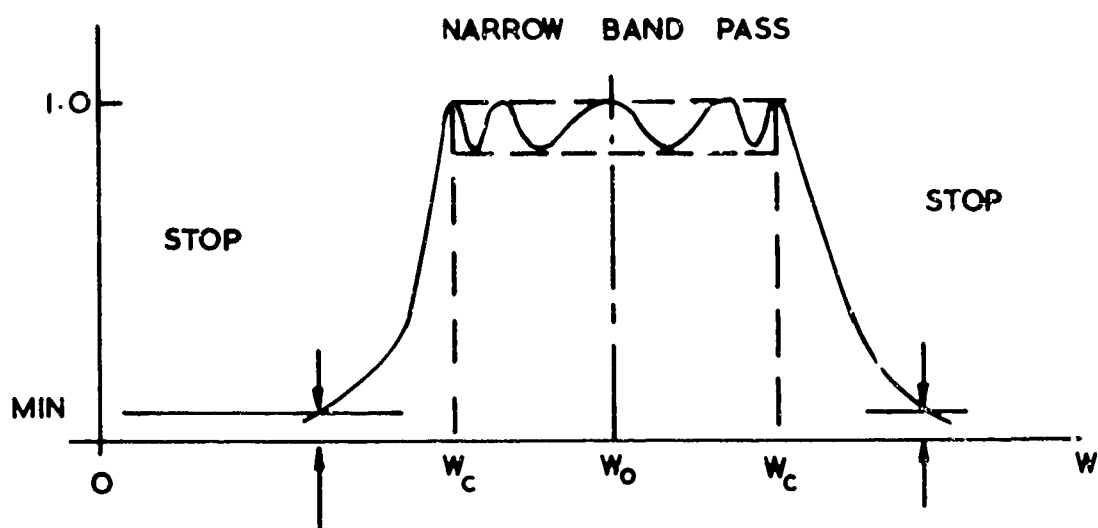
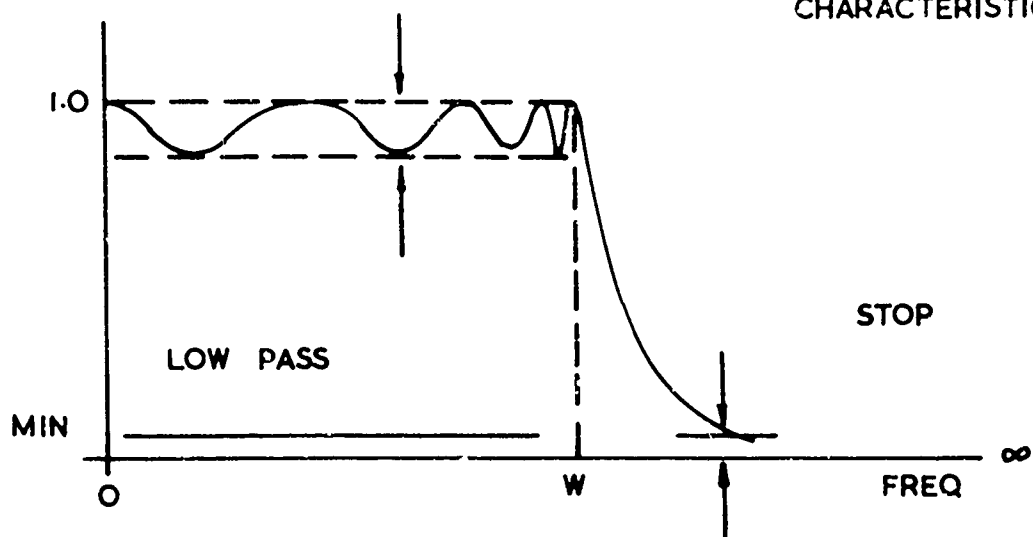


FIG 5.1 IDEALISED FILTER CHARACTERISTICS



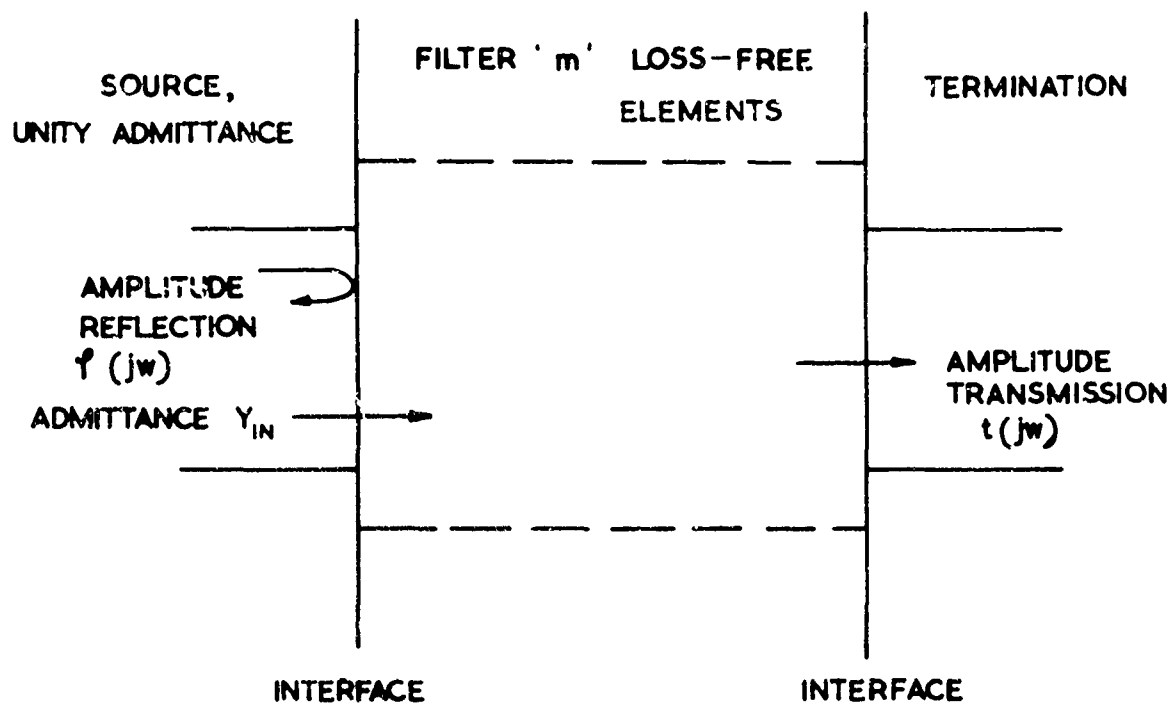


FIG 5.2 INTERFACE DESCRIPTION

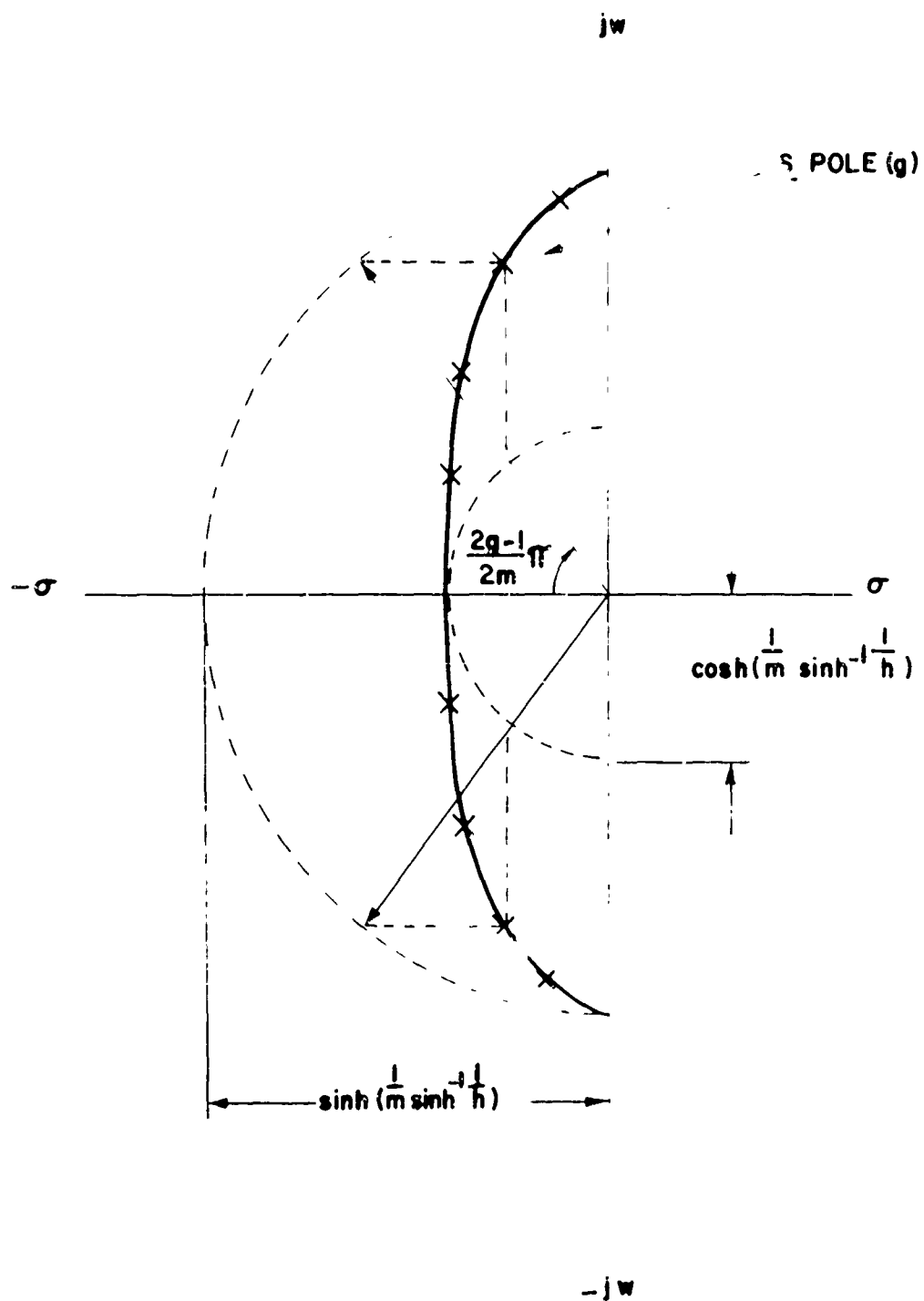
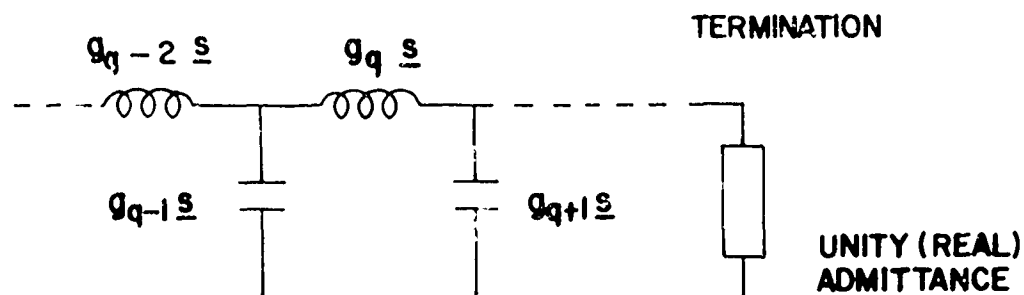


FIG. 5-3 S - PLANE LOCUS AND CONSTRUCTION



IN FIG.5-3,

$$\begin{aligned} \frac{s}{\text{POLE}(q)} &= -\sin \frac{(2q-1)\pi}{2m} \sinh \left(m^{-1} \sinh^{-1} \frac{1}{h} \right) \\ &\quad + j \cos \frac{(2q-1)\pi}{2m} \cosh \left(m^{-1} \sinh^{-1} \frac{1}{h} \right) \quad \text{ETC.} \end{aligned}$$

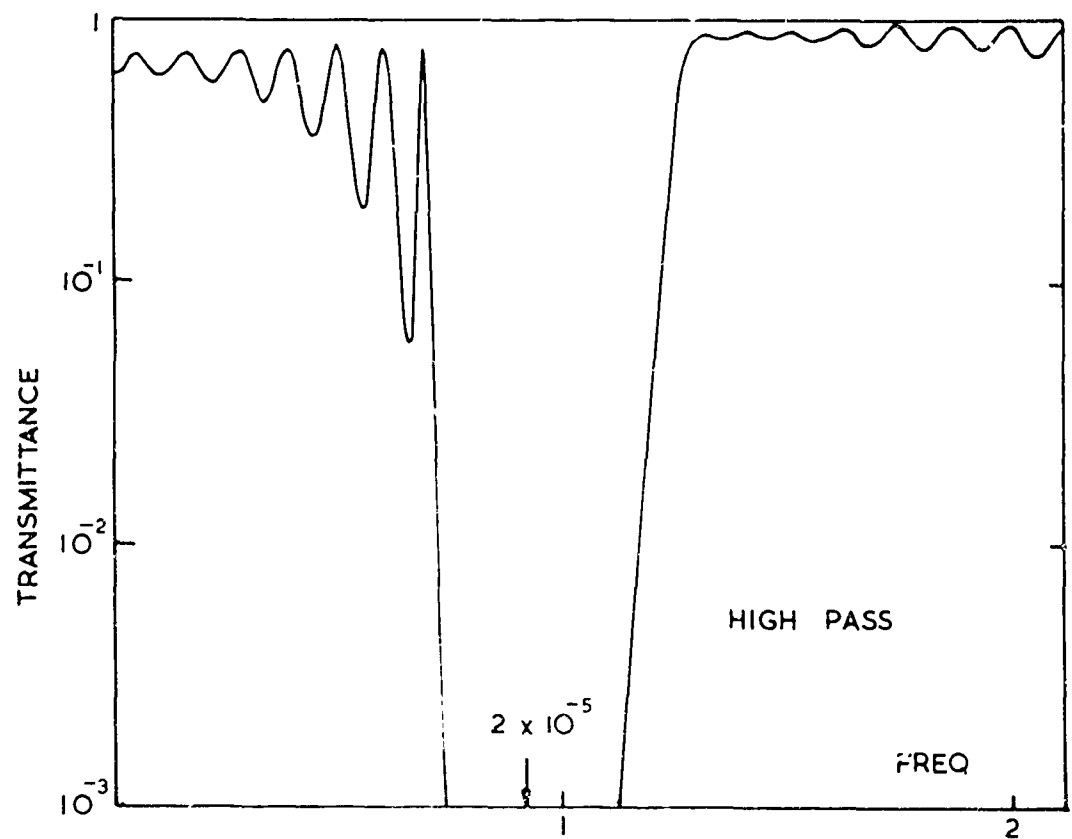
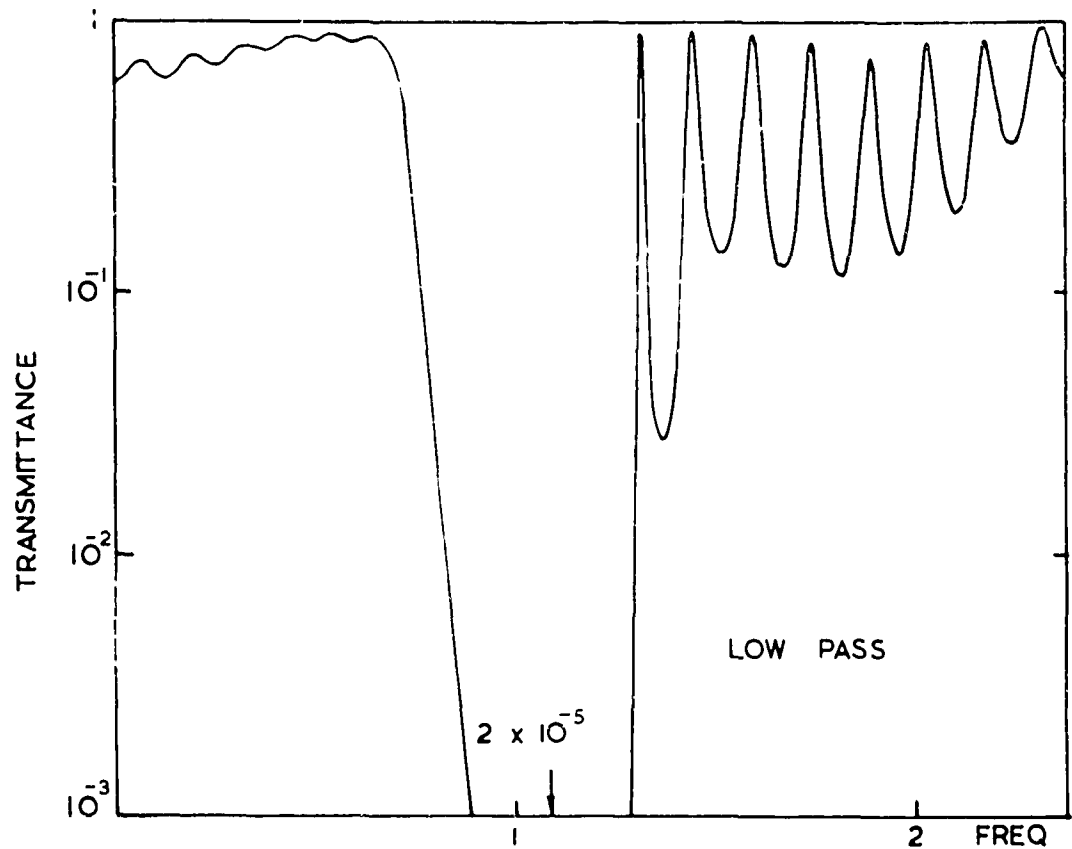
FOR the SIMPLEST LOW PASS EQUIVALENT CIRCUIT (as SHOWN)
IMPEDANCE is GIVEN for SERIES ELEMENTS, ADMITTANCE for
SHUNT ELEMENTS,

$$\text{WHERE } q_1 = \frac{2 \sin \frac{\pi}{2m}}{\sinh \left(\frac{1}{m} \sinh^{-1} \frac{1}{h} \right)}$$

$$g_{q-1} g_q = \frac{4 \sin \frac{(2q-1)\pi}{2m} \sin \frac{(2q+1)\pi}{2m}}{\sinh^2 \left(\frac{1}{m} \sinh^{-1} \frac{1}{h} \right) + \sin^2 \frac{q\pi}{m}} \quad \text{ETC.}$$

FIG.5-4 TCHEBYSHEV CIRCUIT PARAMETERS

FIG 5 5 COMPUTED TCHEBYSHEV FILTERS
(PARAMETERS IN TABLE 5.1)



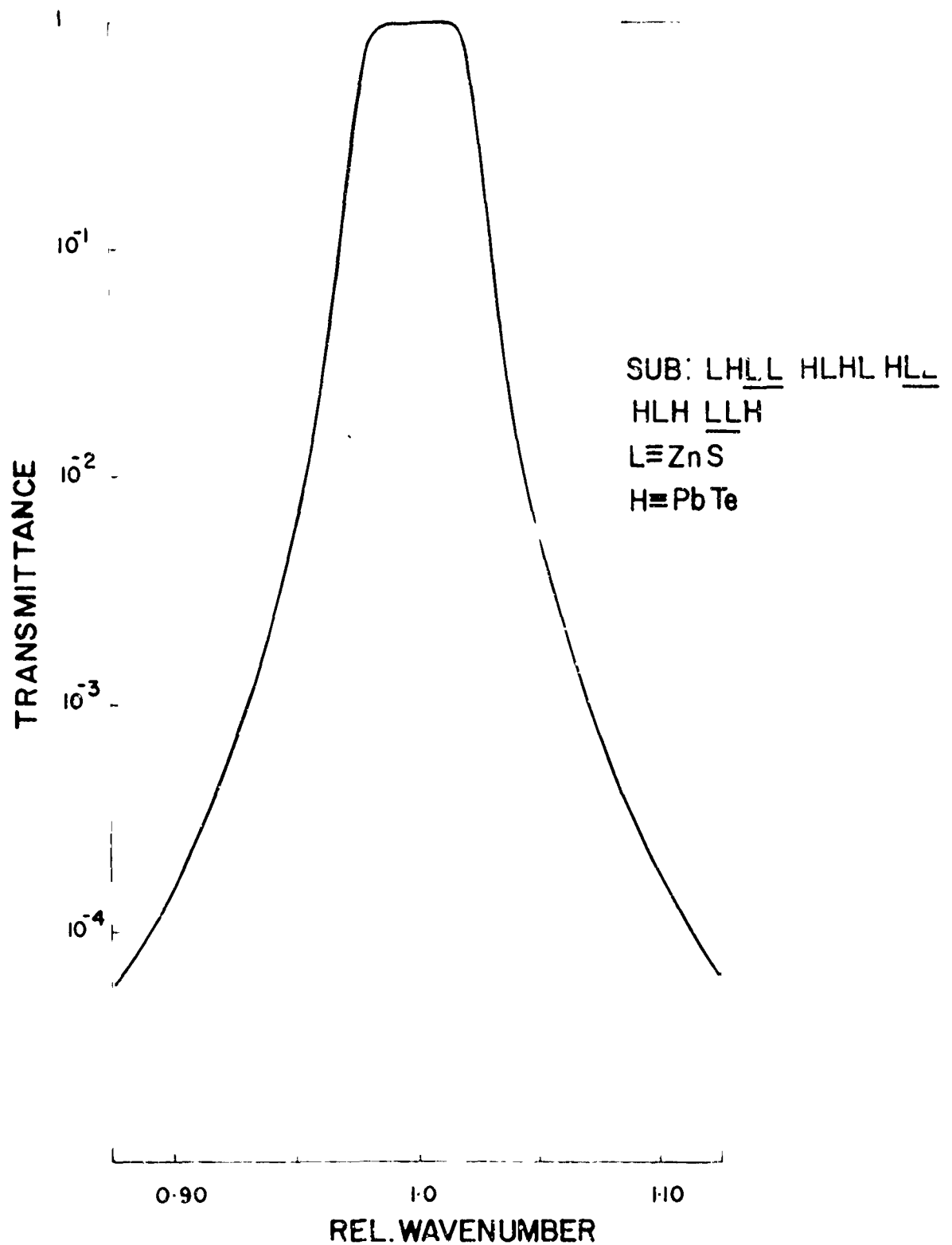


FIG. 5-6 COMPUTED TCHEBYSHEV NARROWBAND FILTER(16 LAYER,TRIPLE HALF WAVE DESIGN)

Fig:5.7 SPECTRAL SENSITIVITY (REFLECTIVITY) OF
LAYERS IN 10-LAYER RADIOMETER F.P. FILTER

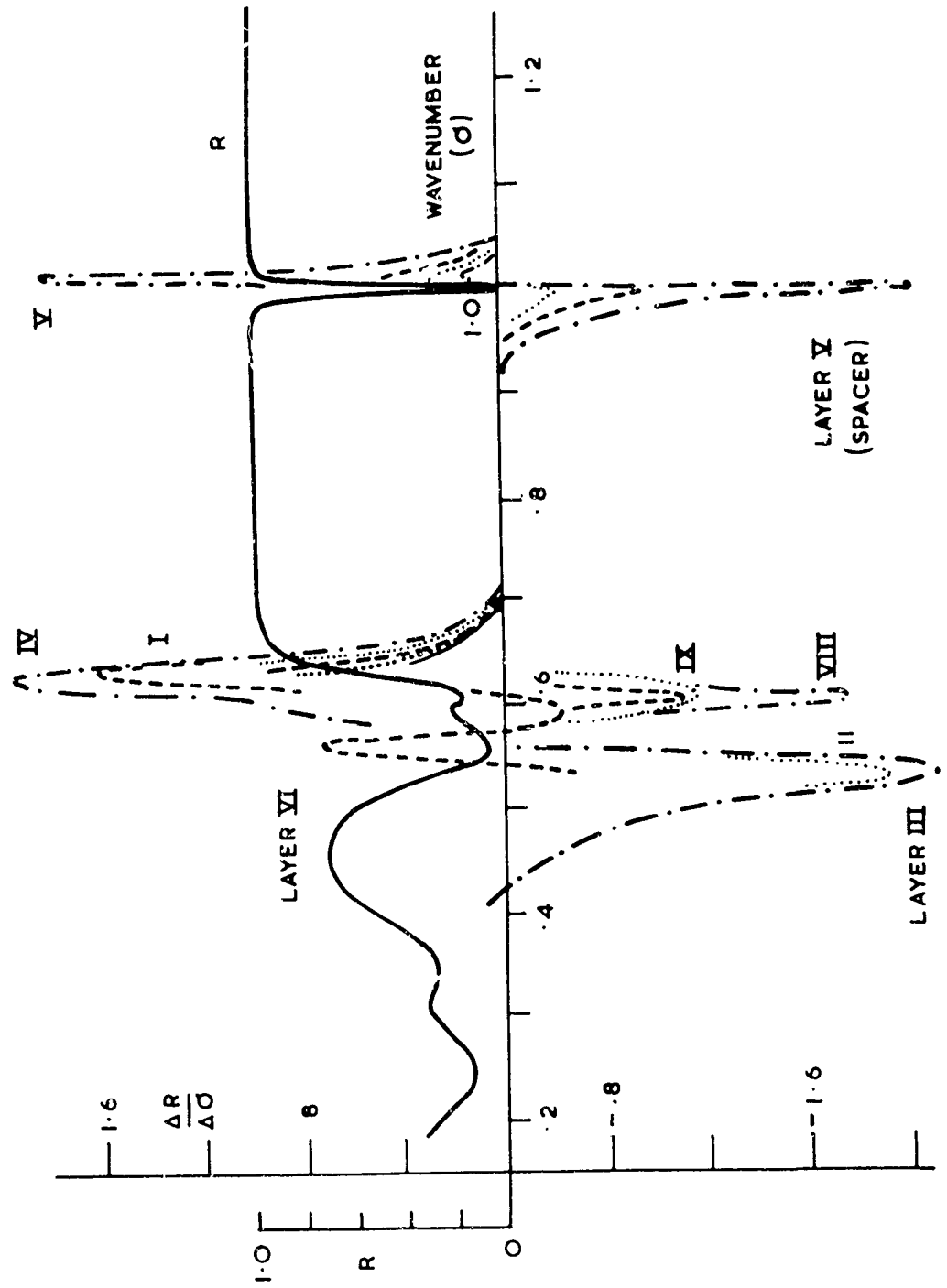
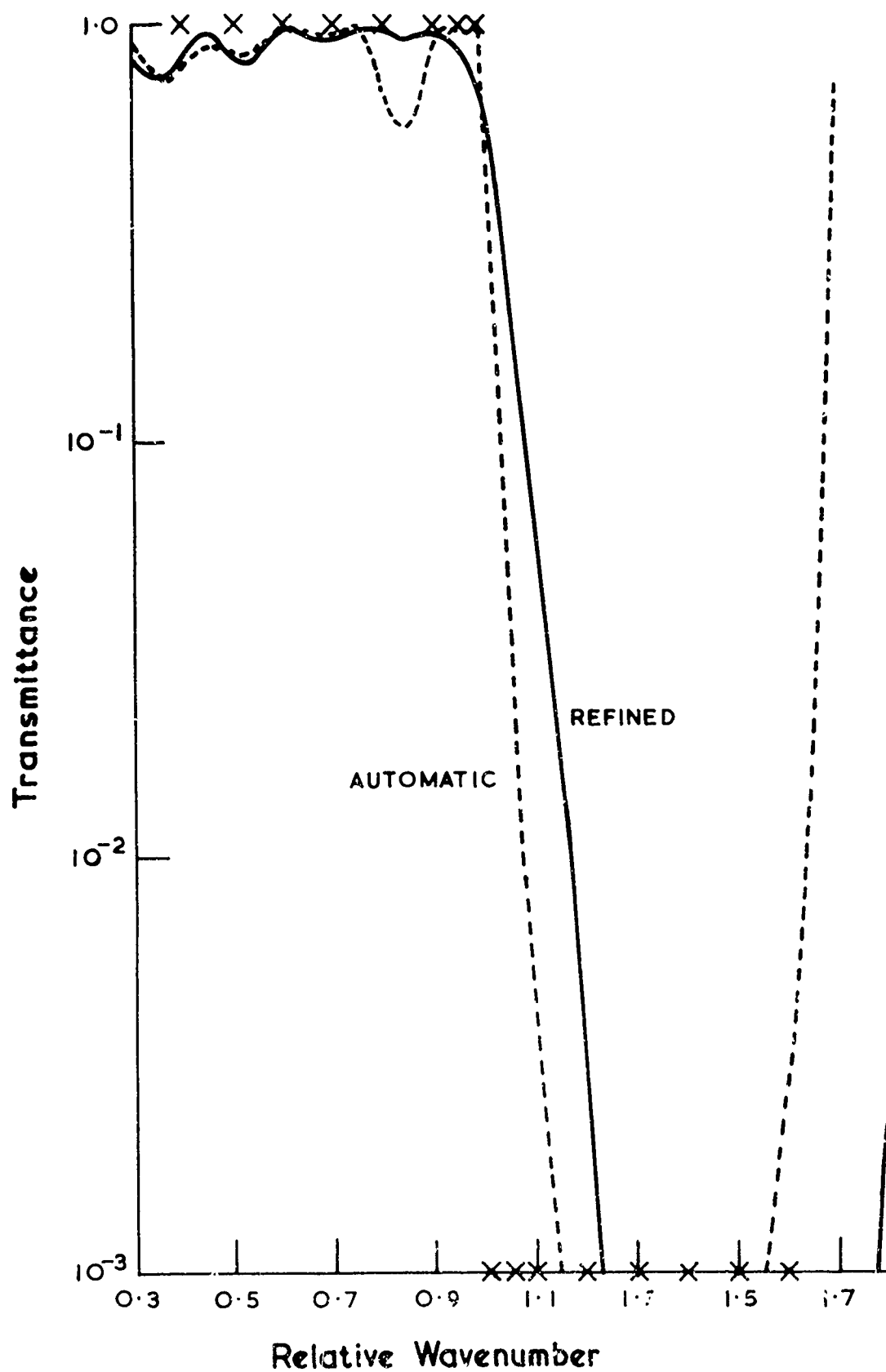
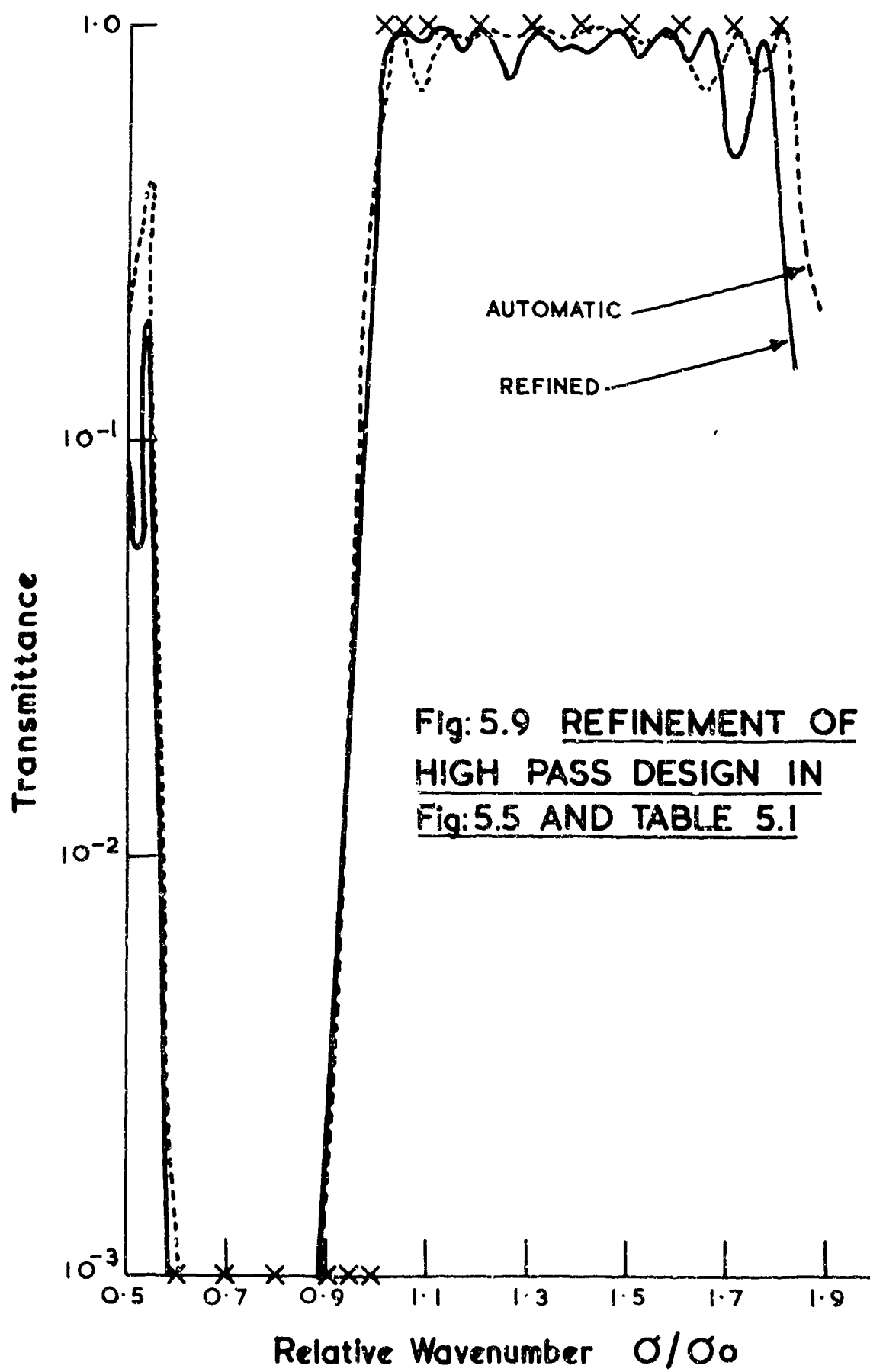


Fig:5.8 REFINEMENT OF LOW PASS
DESIGN IN FIG:5.5 AND TABLE 5.1





10-LAYER FILTER

MONITOR WAVELENGTH* 15.0000 MICRONS

RAIR* 1.0000

RSUB* 4.0000

STANDARD DEVIATION* 2.0000 PER CENT

CASE NO. 1

LAYER INDEX	LAYER THICKNESS
2.3500	0.2567
5.3000	0.2458
2.3500	0.2545
5.3000	0.2530
2.3500	0.2611
5.3000	0.5080
2.3500	0.2515
5.3000	0.2537
2.3500	0.2406
5.3000	0.2522

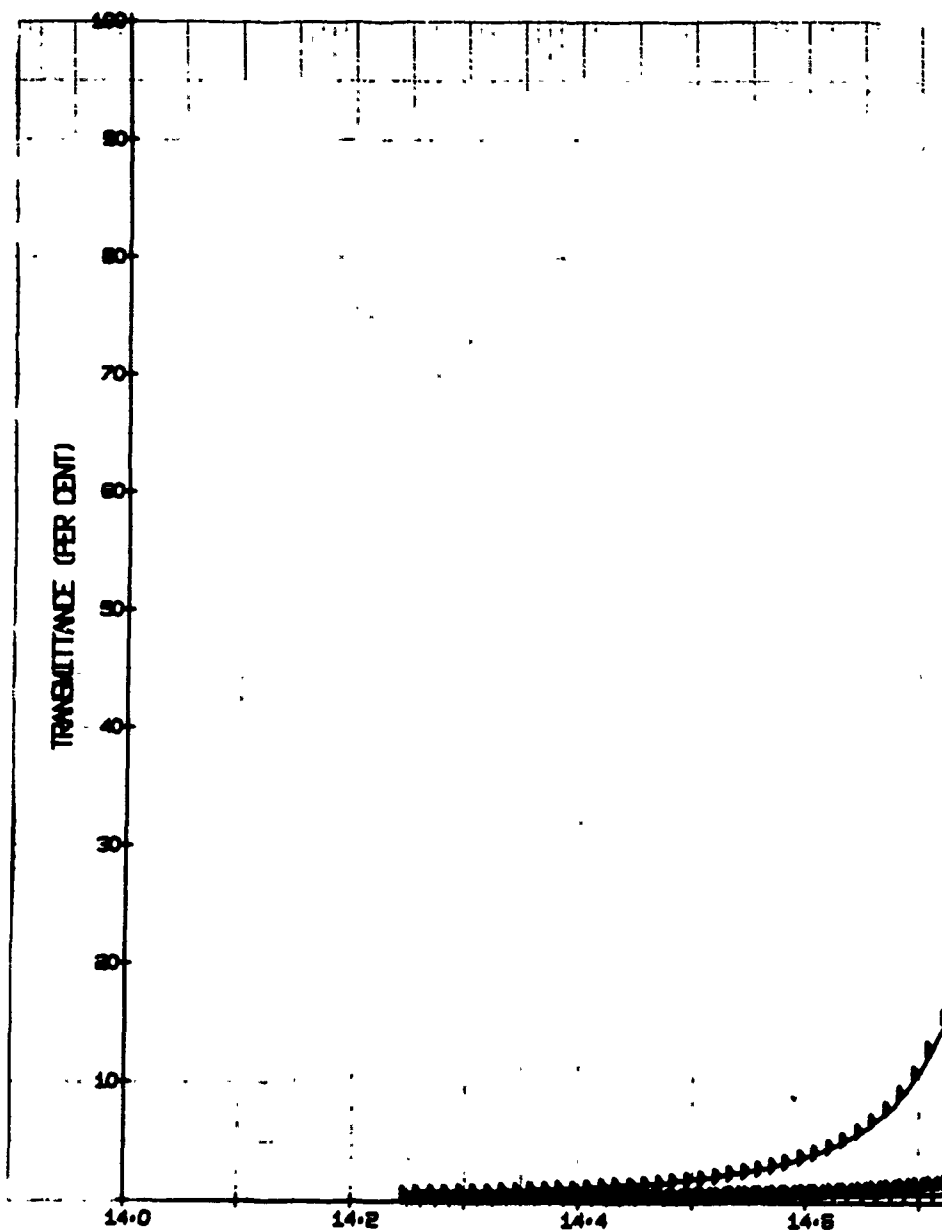
CASE NO. 2

LAYER INDEX	LAYER THICKNESS
2.3500	0.2534
5.3000	0.2444
2.3500	0.2550
5.3000	0.2454
2.3500	0.2554
5.3000	0.5003
2.3500	0.2495
5.3000	0.2586
2.3500	0.2524
5.3000	0.2558

CASE NO. 3

LAYER INDEX	LAYER THICKNESS
2.3500	0.2590
5.3000	0.2468
2.3500	0.2493
5.3000	0.2465
2.3500	0.2534
5.3000	0.4900
2.3500	0.2463
5.3000	0.2522
2.3500	0.2529
5.3000	0.2532

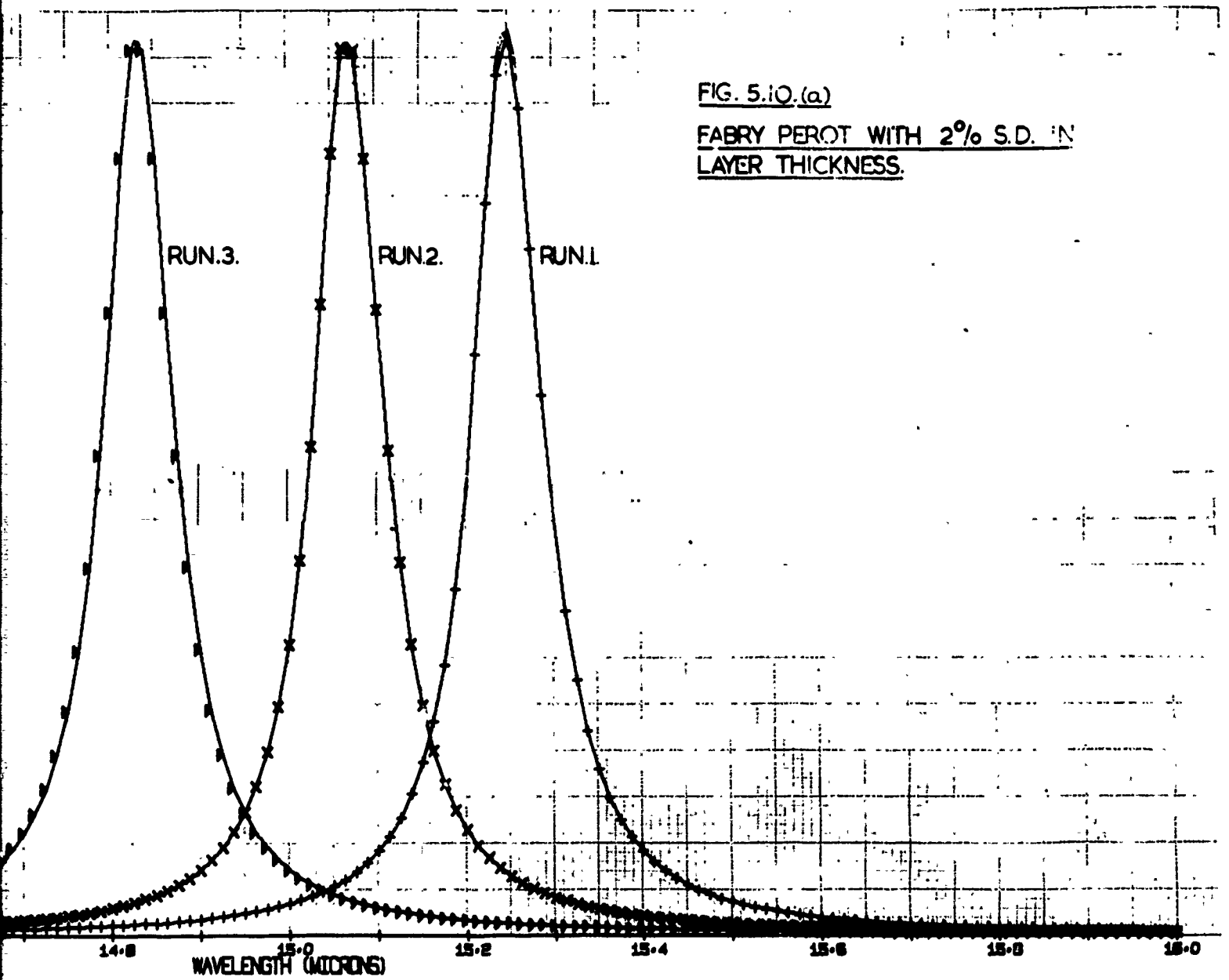
END OF CALCULATIONS



A

FIG. 5.10.(a)

FABRY PEROT WITH 2% S.D. IN
LAYER THICKNESS.



B

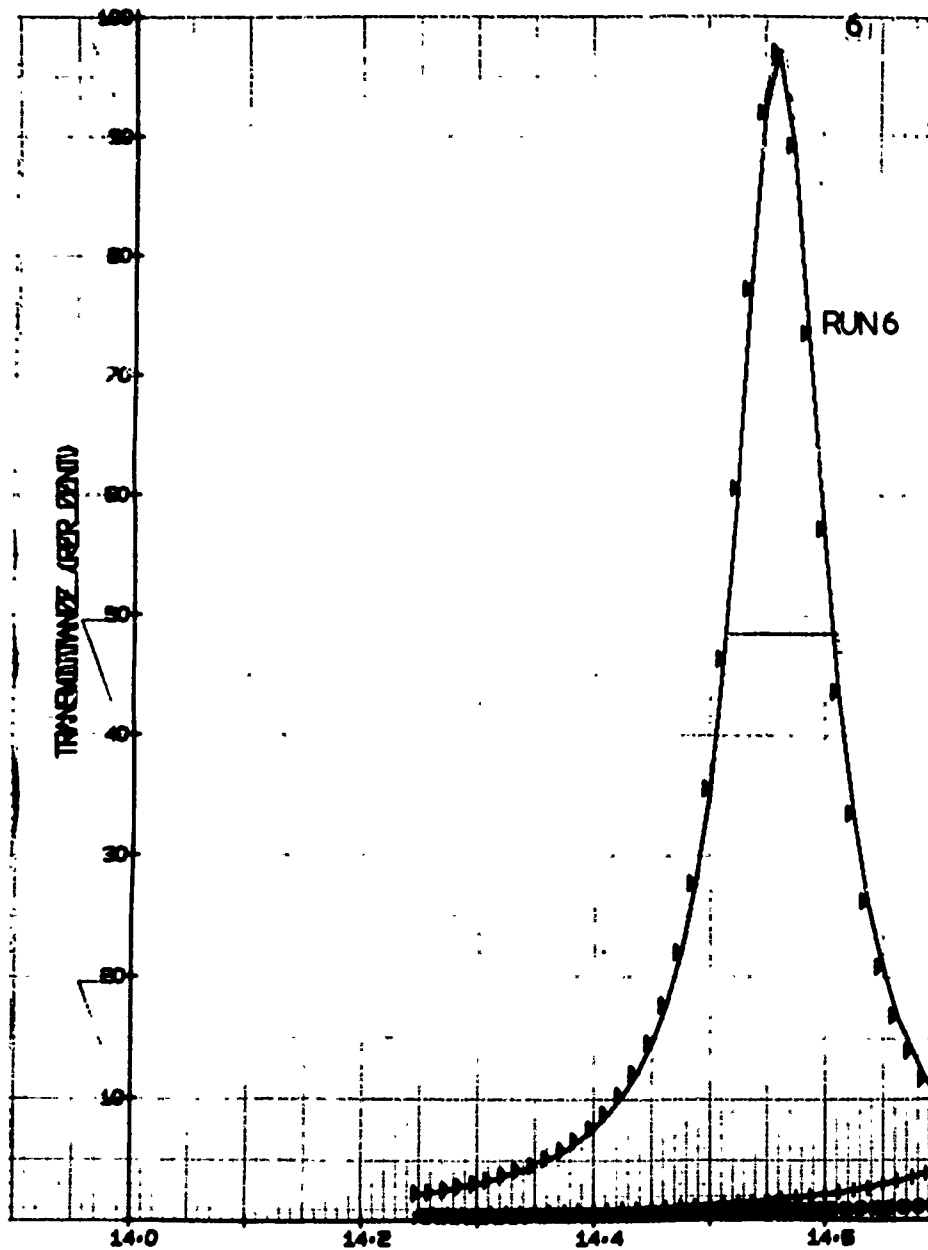
10-LAYER FILTER
 MONITOR WAVELENGTH* 15.0000 MICRONS
 RAIR* 1.0000
 RSUB* 4.0000
 STANDARD DEVIATION* 2.0000 PER CENT

CASE NO. 1	
LAYER INDEX	LAYER THICKNESS
2.3500	0.2493
5.3000	0.2421
2.3500	0.2552
5.3000	0.2487
2.3500	0.2474
5.3000	0.4929
2.3500	0.2558
5.3000	0.2555
2.3500	0.2454
5.3000	0.2507

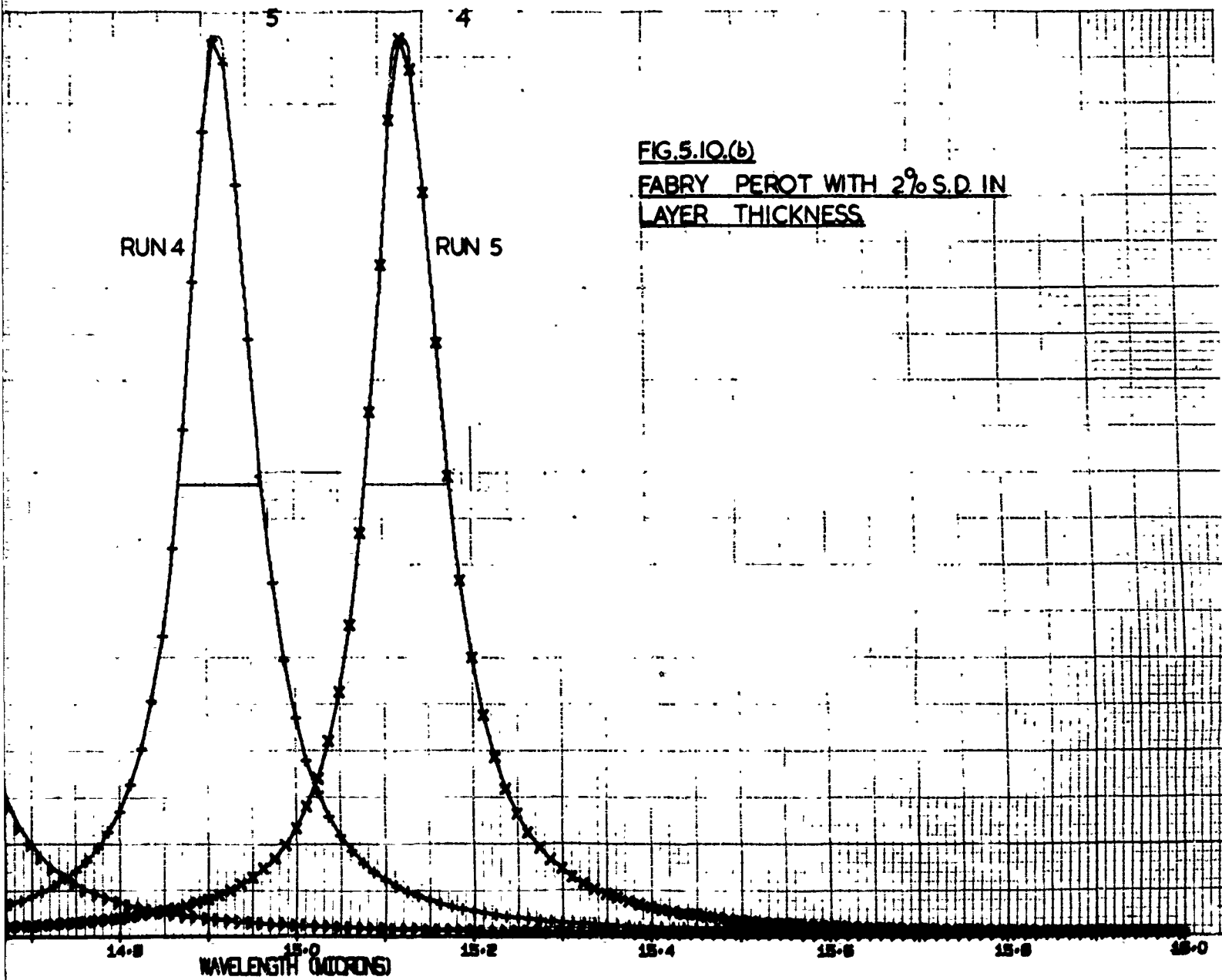
CASE NO. 2	
LAYER INDEX	LAYER THICKNESS
2.3500	0.2513
5.3000	0.2573
2.3500	0.2385
5.3000	0.2450
2.3500	0.2519
5.3000	0.5082
2.3500	0.2515
5.3000	0.2493
2.3500	0.2424
5.3000	0.2559

CASE NO. 3	
LAYER INDEX	LAYER THICKNESS
2.3500	0.2496
5.3000	0.2436
2.3500	0.2580
5.3000	0.2526
2.3500	0.2526
5.3000	0.4759
2.3500	0.2435
5.3000	0.2444
2.3500	0.2457
5.3000	0.2572

END OF CALCULATIONS



A



B

10-LAYER FILTER
 MONITOR WAVELENGTH= 15.0000 MICRONS
 RAIR= 1.0000
 RSUB= 4.0000
 STANDARD DEVIATION= 2.0000 PER CENT

CASE NO. 1
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2448
5.3000	0.2474
2.3500	0.2440
5.3000	0.2597
2.3500	0.2494
5.3000	0.5065
2.3500	0.2511
5.3000	0.2531
2.3500	0.2490
5.3000	0.2491

7

CASE NO. 2
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2482
5.3000	0.2514
2.3500	0.2437
5.3000	0.2500
2.3500	0.2403
5.3000	0.4996
2.3500	0.2483
5.3000	0.2408
2.3500	0.2474
5.3000	0.2581

8

CASE NO. 3
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2579
5.3000	0.2467
2.3500	0.2596
5.3000	0.2465
2.3500	0.2475
5.3000	0.5051
2.3500	0.2517
5.3000	0.2548
2.3500	0.2521
5.3000	0.2534

9

END OF CALCULATIONS

RUN 8

TRANSMITTANCE (PER CENT)

14.0

14.2

14.4

14.6

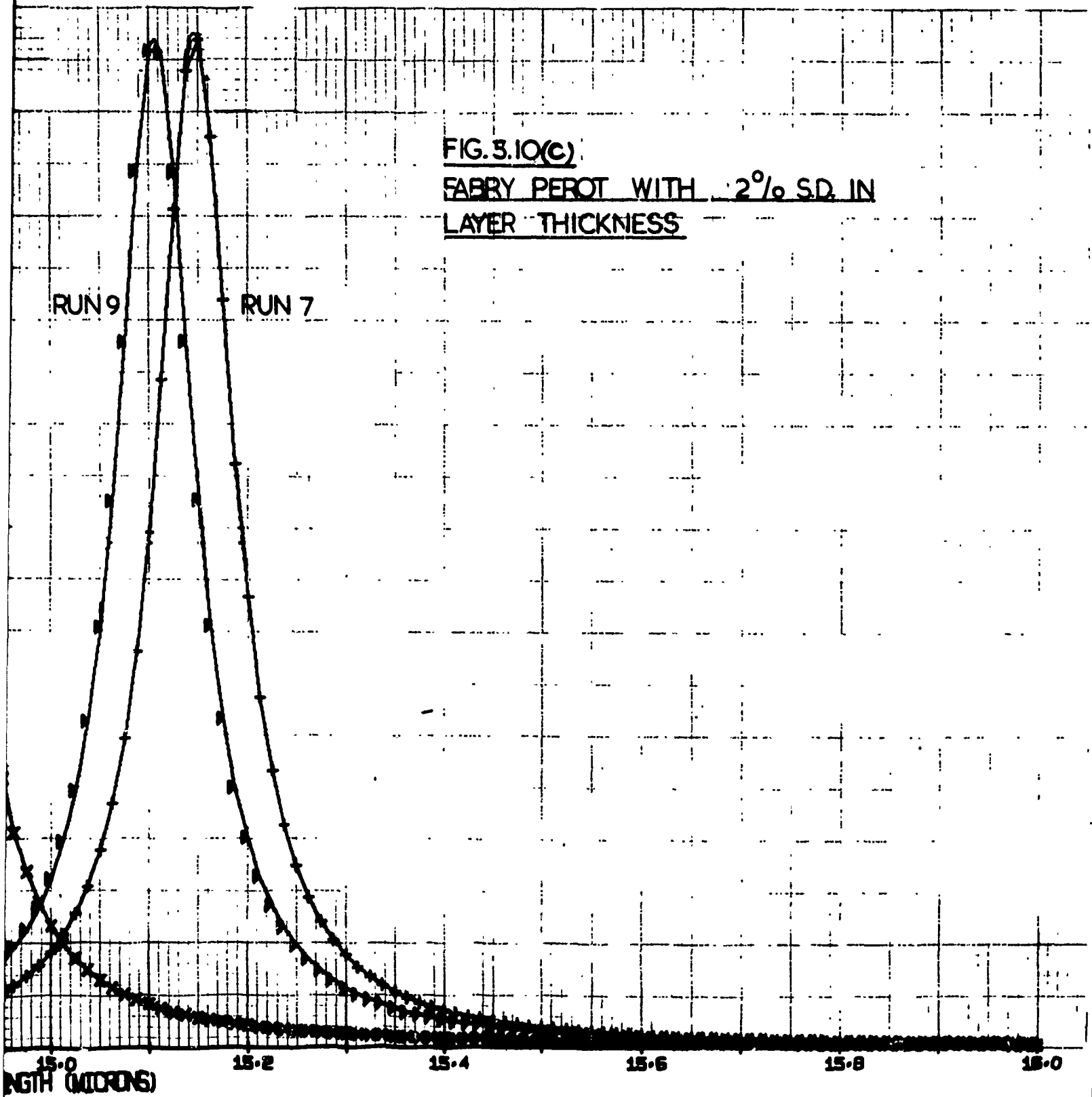
14.8

WAVELENGTH

A

FIG. 3.10(C)

FABRY PEROT WITH 2% SD. IN
LAYER THICKNESS



B

10-LAYER FILTER
 MONITOR WAVELENGTH= 15.0000 MICRONS
 RAIR= 1.0000
 RSUB= 4.0000
 STANDARD DEVIATION= 2.0000 PER CENT

CASE NO. 1
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2436
5.3000	0.2518
2.3500	0.2496
5.3000	0.2521
2.3500	0.2493
5.3000	0.5125
2.3500	0.2528
5.3000	0.2441
2.3500	0.2500
5.3000	0.2507

CASE NO. 2
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2510
5.3000	0.2510
2.3500	0.2507
5.3000	0.2501
2.3500	0.2442
5.3000	0.4960
2.3500	0.2464
5.3000	0.2496
2.3500	0.2524
5.3000	0.2499

CASE NO. 3
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2521
5.3000	0.2540
2.3500	0.2556
5.3000	0.2469
2.3500	0.2528
5.3000	0.5070
2.3500	0.2438
5.3000	0.2538
2.3500	0.2485
5.3000	0.2429

END OF CALCULATIONS

TRANSMITTANCE (PER CENT)

RUN II

14.0

14.2

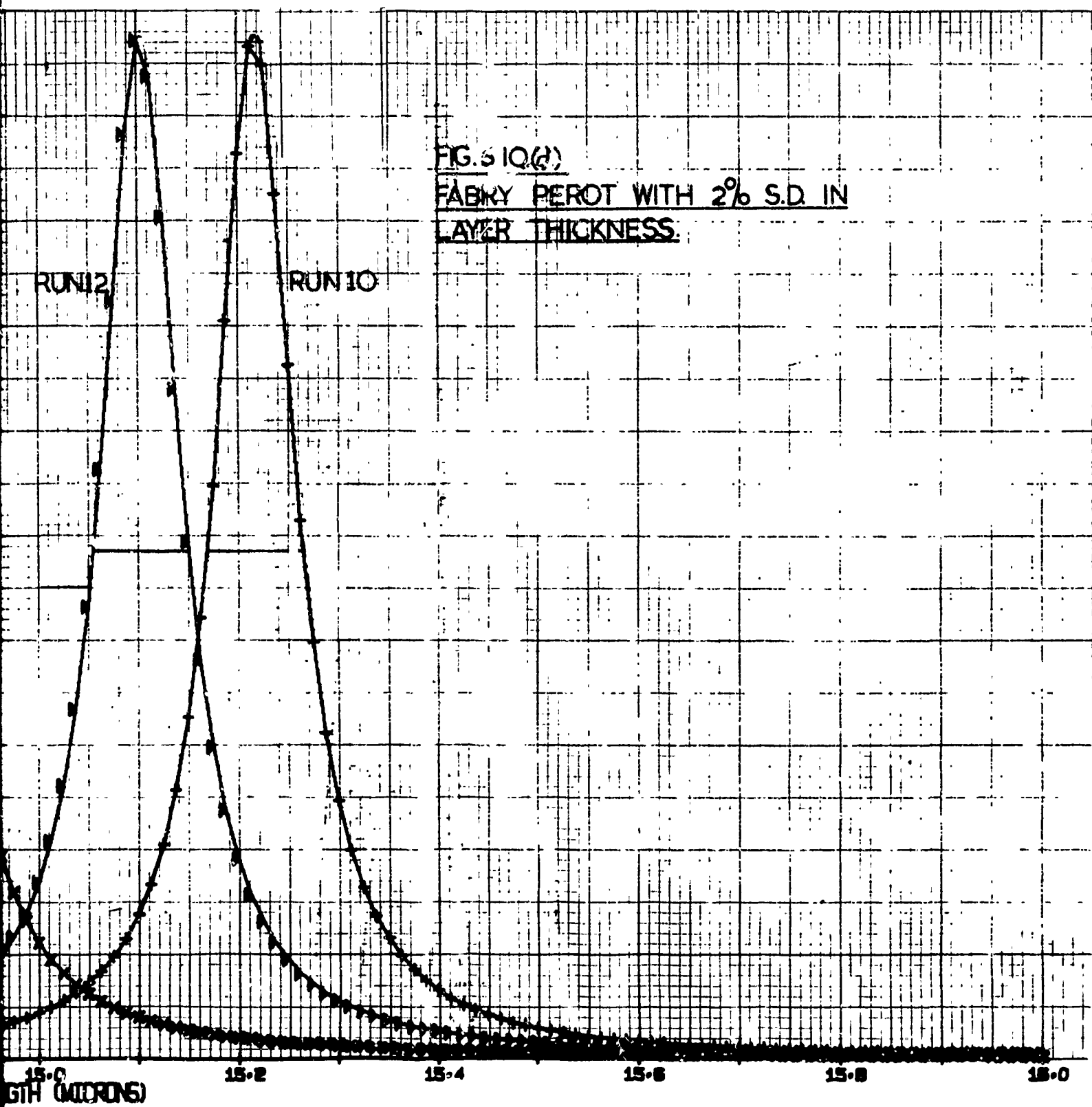
14.4

14.6

14.8

WAVELENGTH

A



14-LAYER FILTER
 MONITOR WAVELENGTH* 15.0000 MICRONS
 RAIR* 1.0000
 RSUB* 4.0000
 STANDARD DEVIATION* 2.0000 PER CENT

CASE NO. 1
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2436
5.3000	0.2518
2.3500	0.2496
5.3000	0.5043
2.3500	0.2493
5.3000	0.2562
2.3500	0.2528
5.3000	0.2441
2.3500	0.2500
5.3000	0.2507
2.3500	0.2510
5.3000	0.5021
2.3500	0.2507
5.3000	0.2501

CASE NO. 2
 LAYER INDEX

LAYER THICKNESS

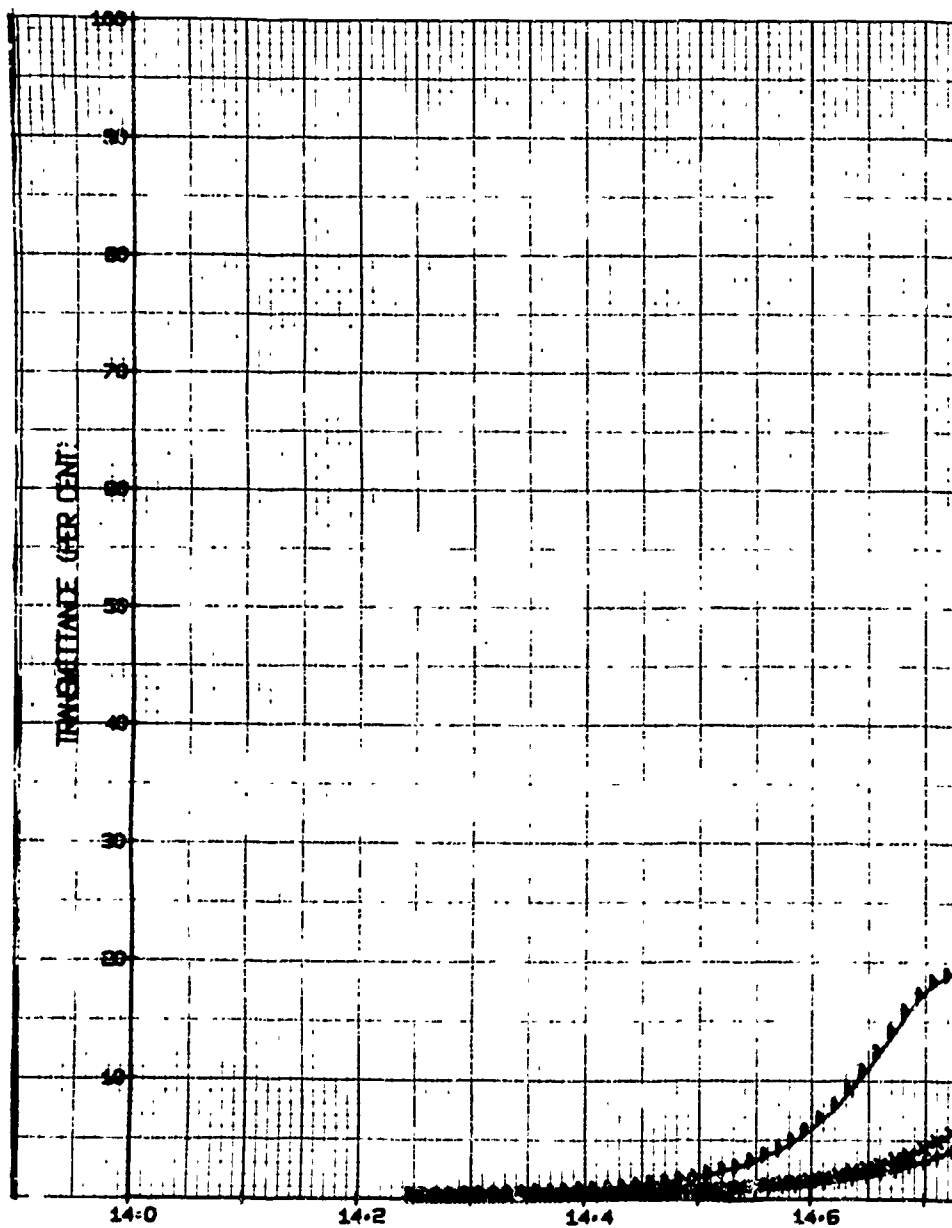
2.3500	0.2442
5.3000	0.2480
2.3500	0.2464
5.3000	0.4992
2.3500	0.2524
5.3000	0.2449
2.3500	0.2521
5.3000	0.2530
2.3500	0.2556
5.3000	0.2469
2.3500	0.2528
5.3000	0.5070
2.3500	0.2438
5.3000	0.2538

CASE NO. 3
 LAYER INDEX

LAYER THICKNESS

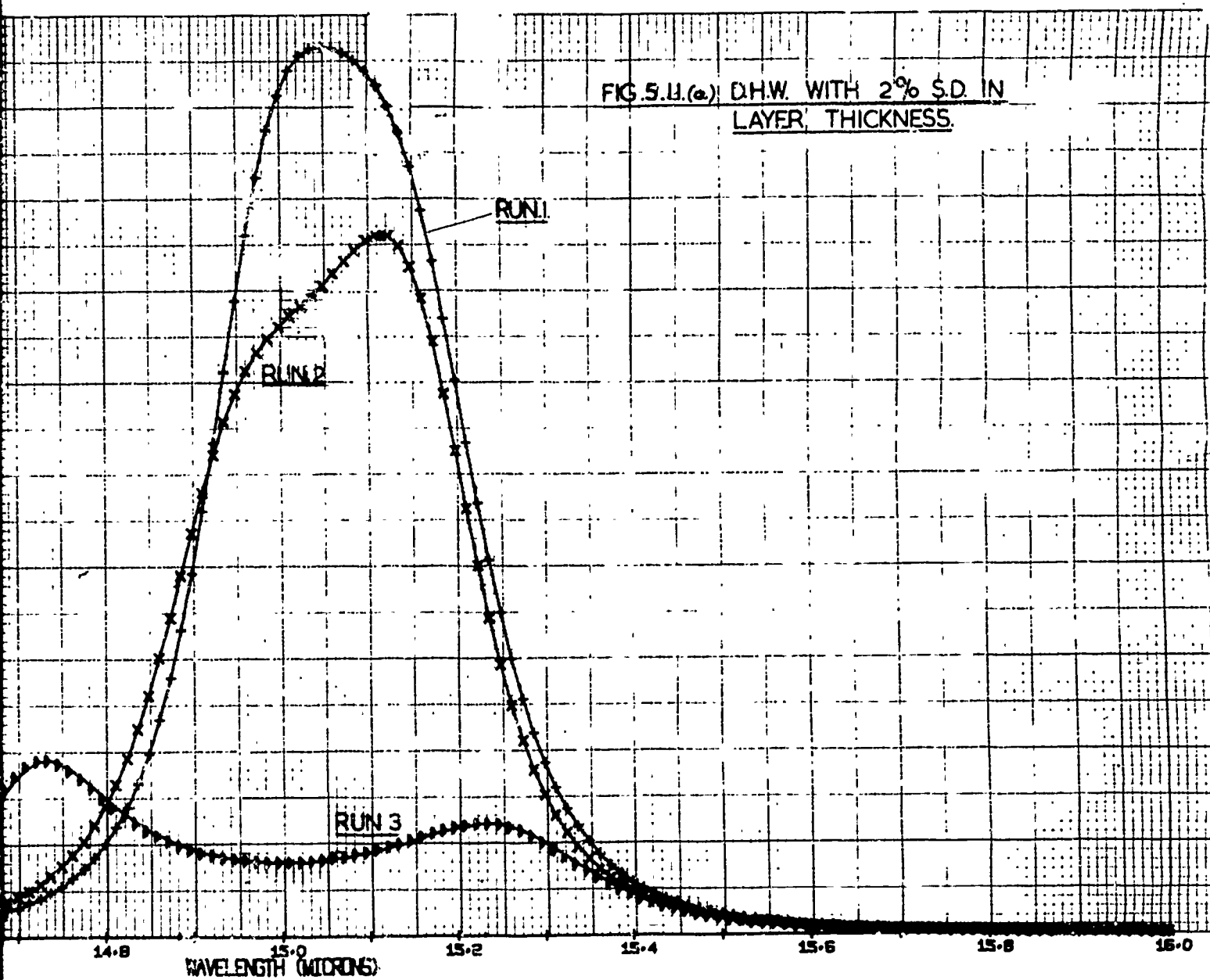
2.3500	0.2485
5.3000	0.2429
2.3500	0.2620
5.3000	0.5116
2.3500	0.2442
5.3000	0.2574
2.3500	0.2502
5.3000	0.2477
2.3500	0.2449
5.3000	0.2518
2.3500	0.2434
5.3000	0.4894
2.3500	0.2457
5.3000	0.2513

END OF CALCULATIONS



A

FIG. 5.11(a) D.H.W. WITH 2% S.D. IN
LAYER THICKNESS.



B

1*-LAYER FILTER
 MONITOR WAVELENGTH 15.0000 MICRONS
 R_{IR} 1.0000
 R_{SUB} 4.0000
 STANDARD DEVIATION 2.0000 PER CENT

CASE NO. 1

LAYER INDEX	LAYER THICKNESS
2.3500	0.2448
5.3000	0.2474
2.3500	0.2440
5.3000	0.5194
2.3500	0.2493
5.3000	0.2532
2.3500	0.2511
5.3000	0.2531
2.3500	0.2490
5.3000	0.2491
2.3500	0.2482
5.3000	0.5029
2.3500	0.2437
5.3000	0.2500

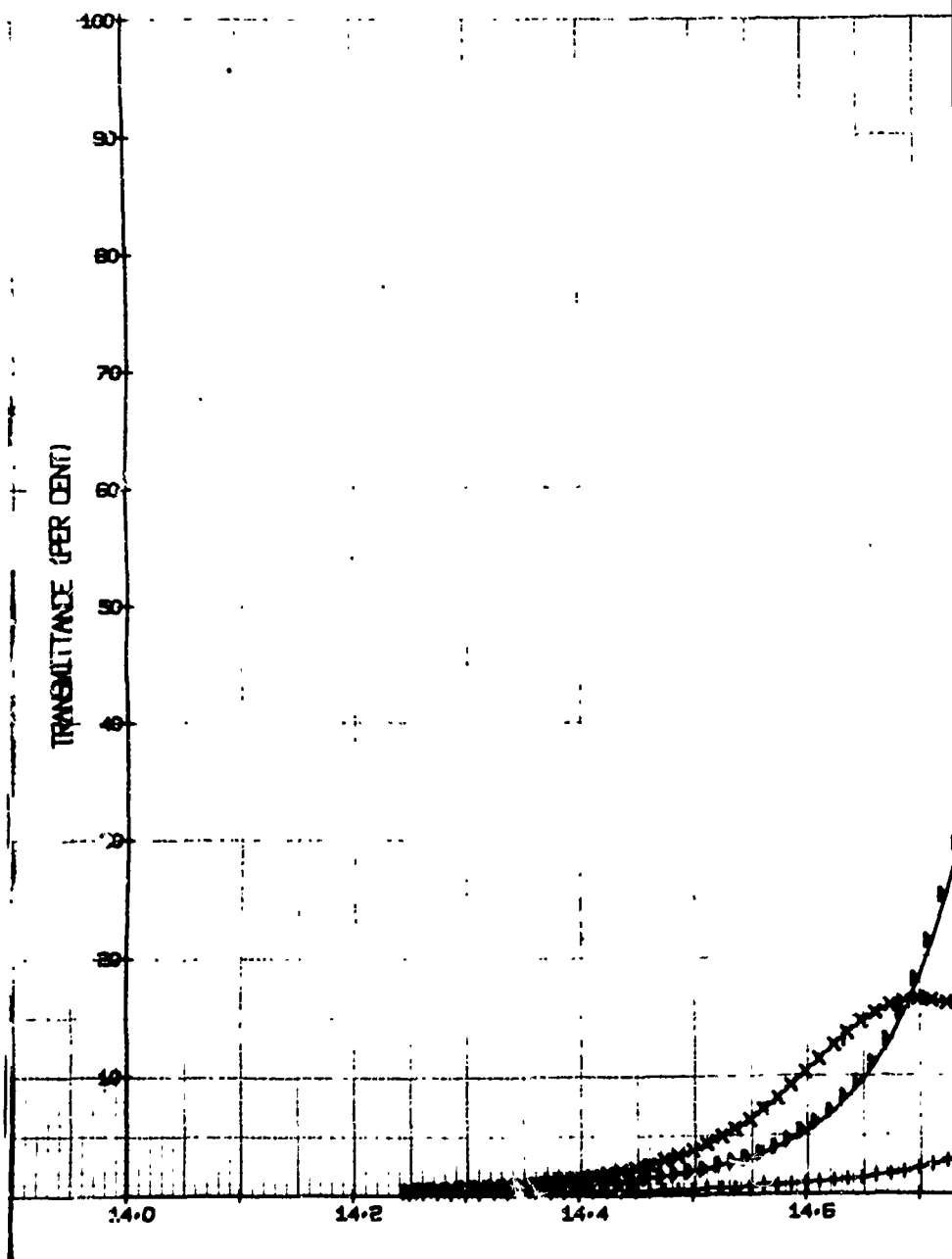
CASE NO. 2

LAYER INDEX	LAYER THICKNESS
2.3500	0.2403
5.3000	0.2498
2.3500	0.2483
5.3000	0.1817
2.3500	0.2474
5.3000	0.2581
2.3500	0.2579
5.3000	0.2467
2.3500	0.2596
5.3000	0.2465
2.3500	0.2475
5.3000	0.5051
2.3500	0.2517
5.3000	0.2548

CASE NO. 3

LAYER INDEX	LAYER THICKNESS
2.3500	0.2521
5.3000	0.2534
2.3500	0.2438
5.3000	0.4965
2.3500	0.2467
5.3000	0.2493
2.3500	0.2559
5.3000	0.2466
2.3500	0.2513
5.3000	0.2501
2.3500	0.2480
5.3000	0.4999
2.3500	0.2459
5.3000	0.2510

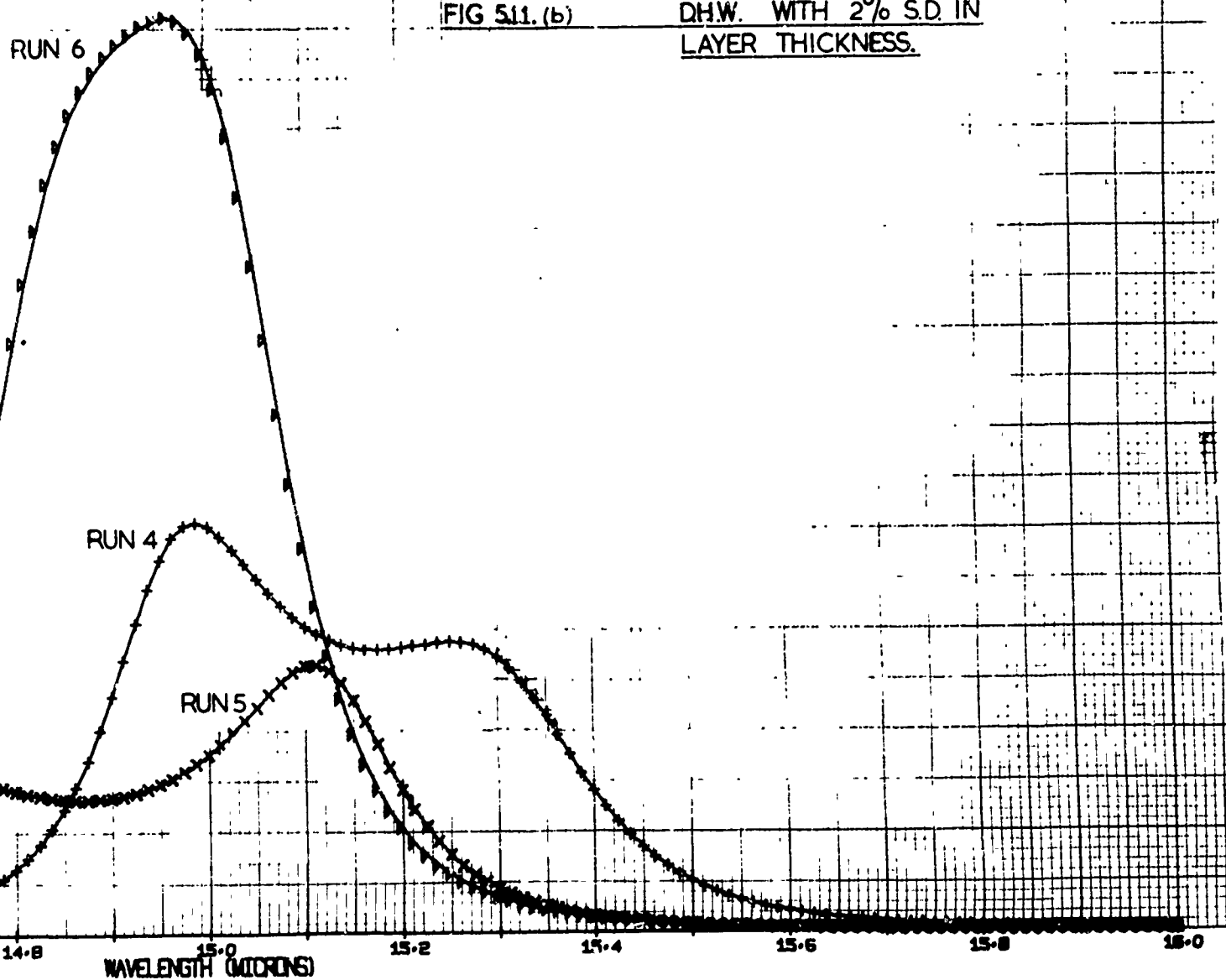
END OF CALCULATIONS



A

FIG 5.11. (b)

DH.W. WITH 2% S.D. IN
LAYER THICKNESS.



B

14-LAYER FILTER
 MONITOR WAVELENGTH* 15.0000 MICRONS
 RAIR* 1.0000
 RSUB* 4.0000
 STANDARD DEVIATION* 2.0000 PER CENT

CASE NO. 1

LAYER INDEX	LAYER THICKNESS
2.3500	0.2493
5.3000	0.2421
2.3500	0.2552
5.3000	0.4974
2.3500	0.2474
5.3000	0.2464
2.3500	0.2558
5.3000	0.2555
2.3500	0.2454
5.3000	0.2507
2.3500	0.2513
5.3000	0.5146
2.3500	0.2385
5.3000	0.2450

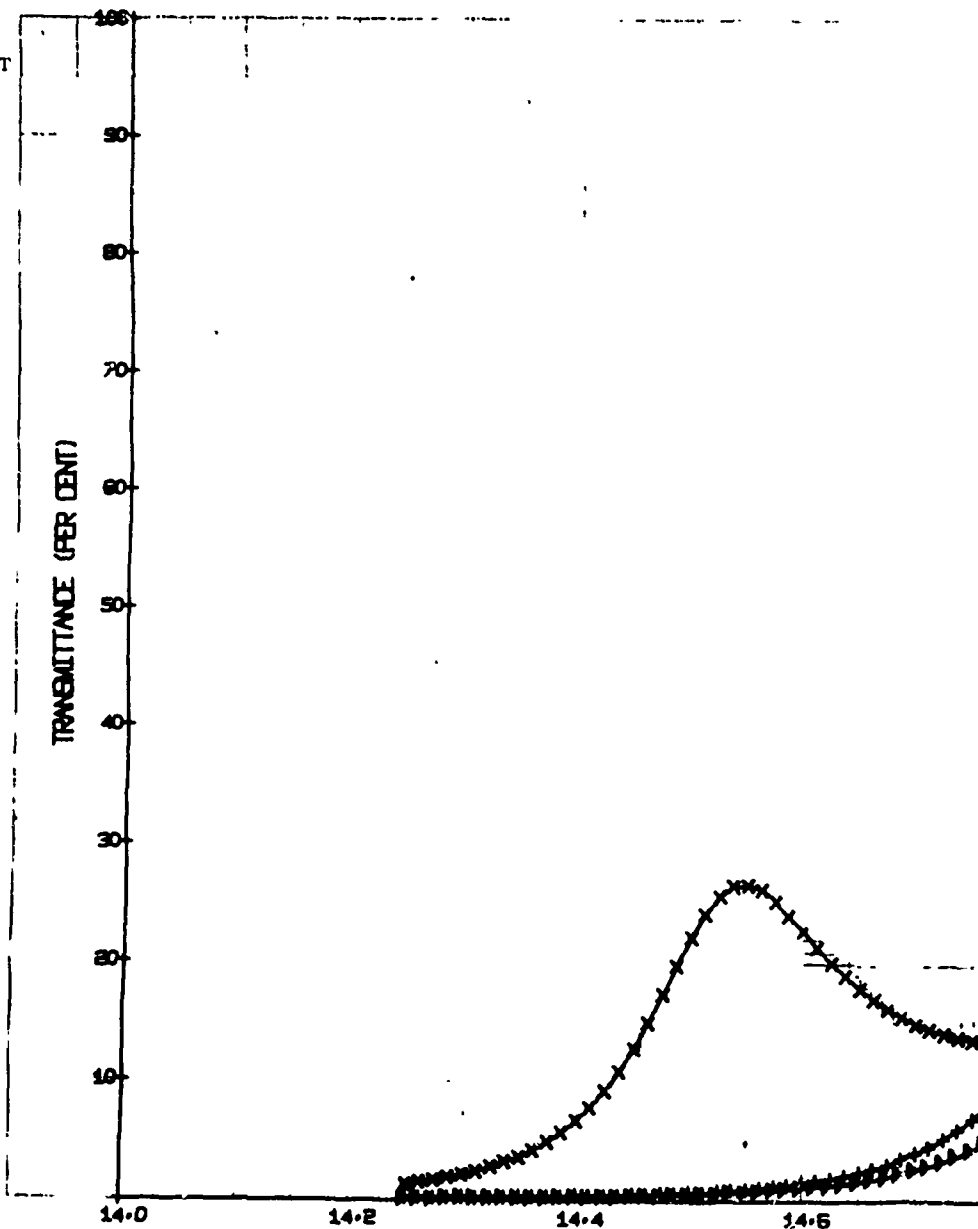
CASE NO. 2

LAYER INDEX	LAYER THICKNESS
2.3500	0.2519
5.3000	0.2541
2.3500	0.2515
5.3000	0.4987
2.3500	0.2424
5.3000	0.2559
2.3500	0.2496
5.3000	0.2436
2.3500	0.2580
5.3000	0.2526
2.3500	0.2526
5.3000	0.4759
2.3500	0.2435
5.3000	0.2444

CASE NO. 3

LAYER INDEX	LAYER THICKNESS
2.3500	0.2457
5.3000	0.2572
2.3500	0.2541
5.3000	0.5025
2.3500	0.2537
5.3000	0.2515
2.3500	0.2546
5.3000	0.2430
2.3500	0.2468
5.3000	0.2458
2.3500	0.2402
5.3000	0.5097
2.3500	0.2498
5.3000	0.2451

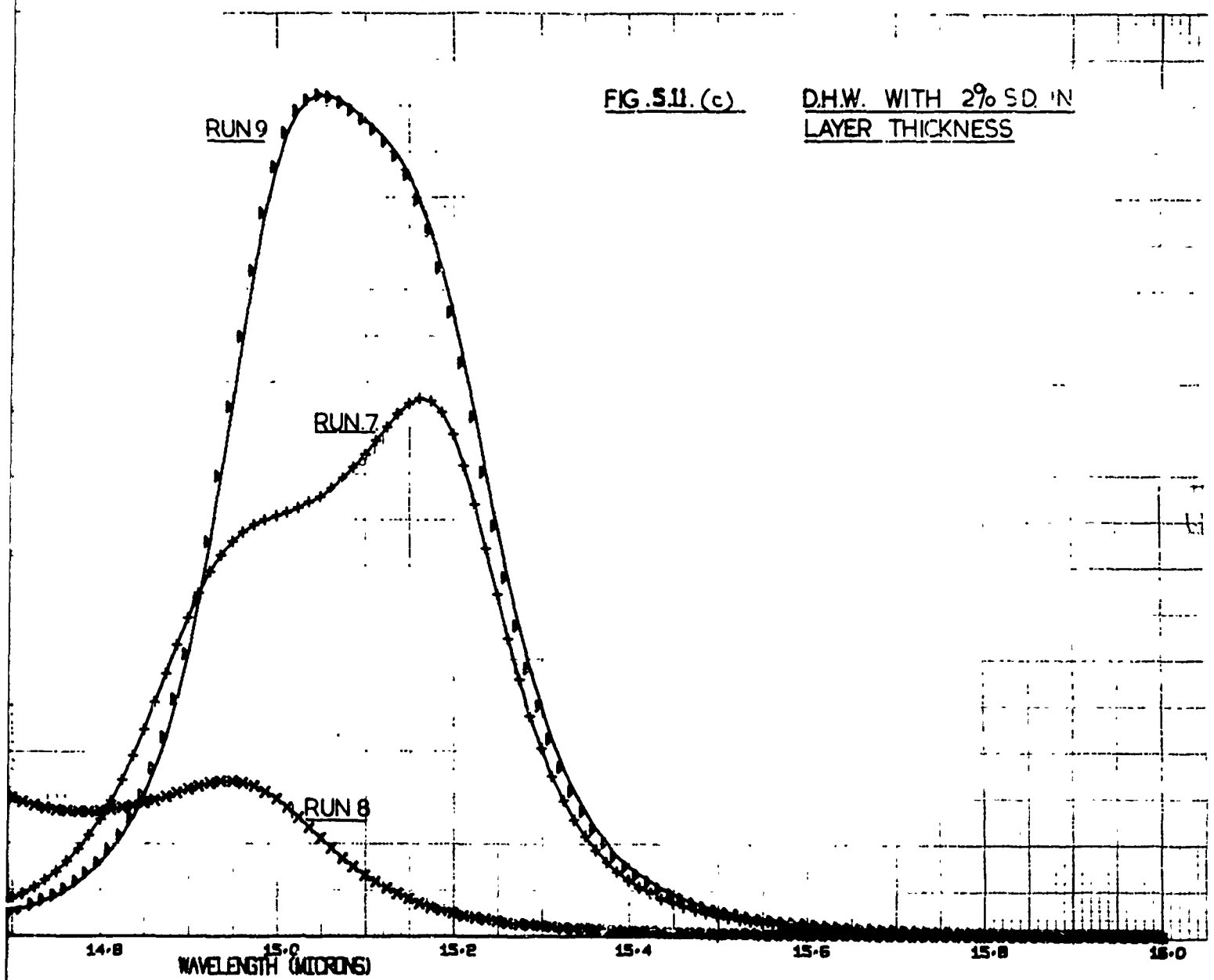
END OF CALCULATIONS



A

FIG. 5.11. (c)

D.H.W. WITH 2% SD IN
LAYER THICKNESS



B

14-LAYER FILTER
 MONITOR WAVELENGTH-
 FAIR- 1.0000
 SUB- 4.0000
 STANDARD DEVIATION-

15.0000 MICRONS
 2.0000 PER CENT

CASE NO. 1
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2567
5.3000	0.2458
2.3500	0.2545
5.3000	0.5060
2.3500	0.2611
5.3000	0.2540
2.3500	0.2515
5.3000	0.2537
2.3500	0.2406
5.3000	0.2522
2.3500	0.2534
5.3000	0.4889
2.3500	0.2550
5.3000	0.2454

10

CASE NO. 2
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2554
5.3000	0.2501
2.3500	0.2495
5.3000	0.5172
2.3500	0.2524
5.3000	0.2558
2.3500	0.2550
5.3000	0.2468
2.3500	0.2493
5.3000	0.2465
2.3500	0.2534
5.3000	0.4900
2.3500	0.2463
5.3000	0.2522

11

CASE NO. 3
 LAYER INDEX

LAYER THICKNESS

2.3500	0.2529
5.3000	0.2532
2.3500	0.2532
5.3000	0.5159
2.3500	0.2473
5.3000	0.2464
2.3500	0.2552
5.3000	0.2536
2.3500	0.2518
5.3000	0.2446
2.3500	0.2521
5.3000	0.4987
2.3500	0.2512
5.3000	0.2528

12

TRANSMITTANCE (PER CENT)

14.0

14.2

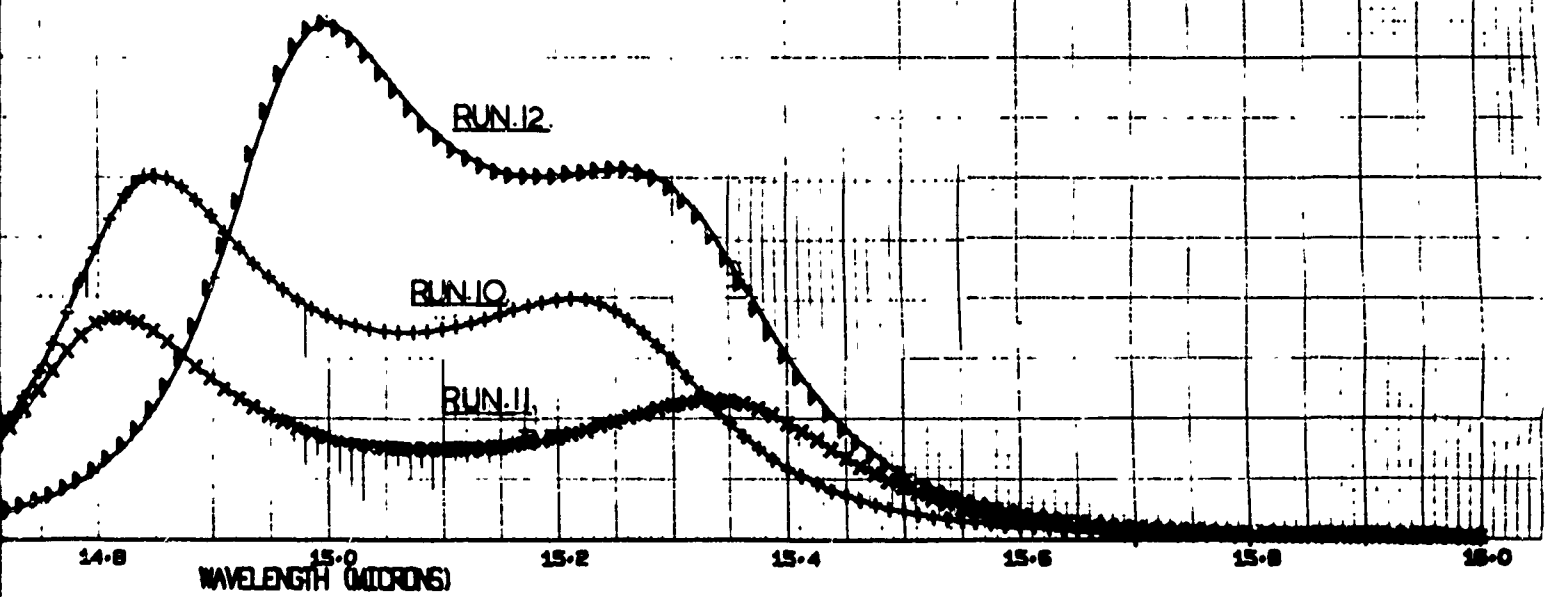
14.4

14.6

END OF CALCULATIONS

A

FIG. 5.12.(d). D.H.W. WITH 2% SD IN
LAYER THICKNESS



B

PEAK TRANSMISSION AS A FUNCTION OF HALF-WIDTH
 FOR THE DHW Ge/ LHL HH LHLHL HH LH FOR 2%
 & 1.4% SD. IN LAYER THICKNESS.

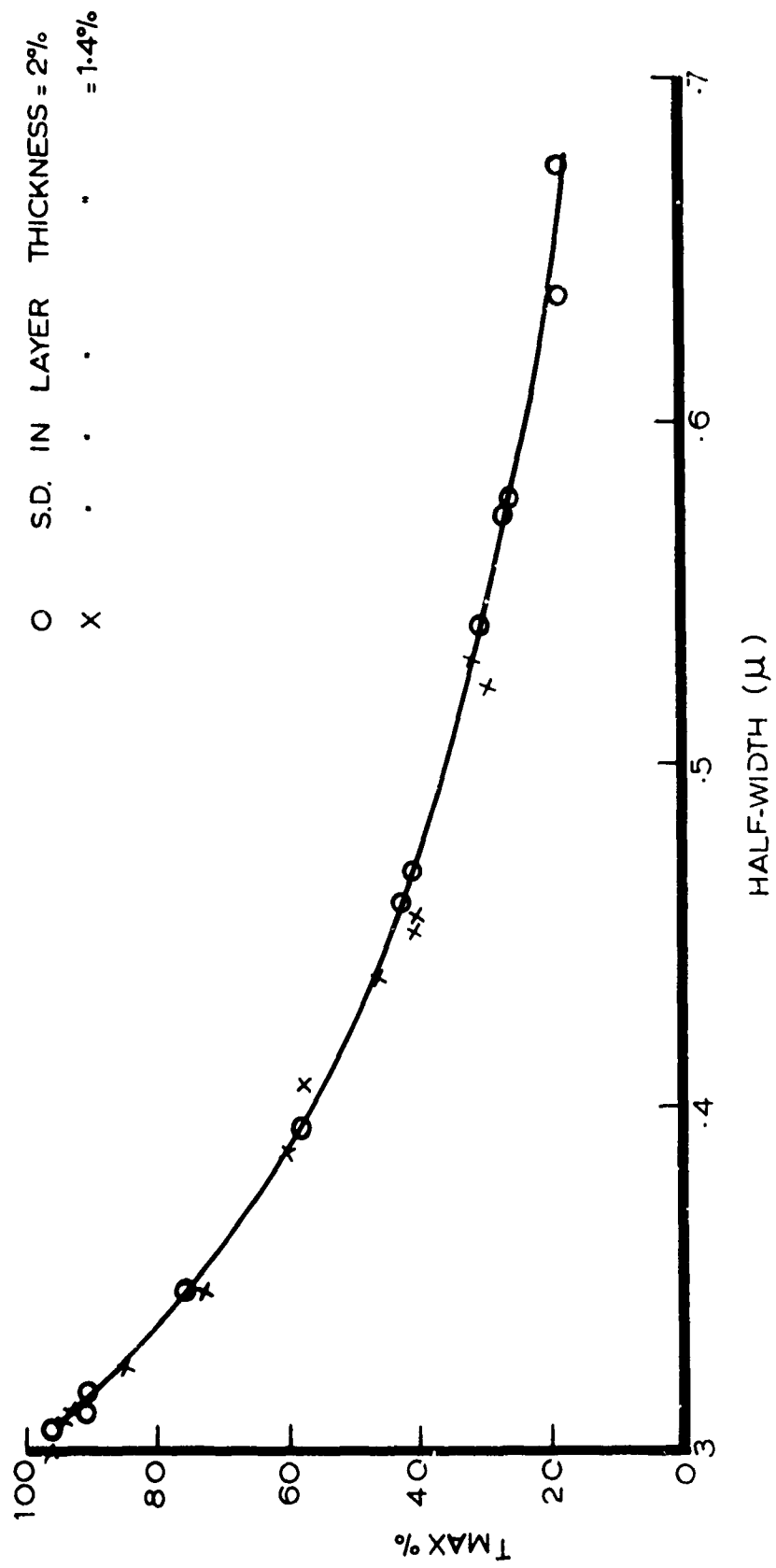


FIG. 5.12.

PEAK TRANSMISSION AND HALF-WIDTH OF THE D.H.W.
 DESIGN $\text{Ge/LHLHH LHLHLH LHLH}$ AS A FUNCTION
 OF $\lambda p - \lambda c /$ FOR 2% AND 1.4% SD IN LAYER THICKNESS.

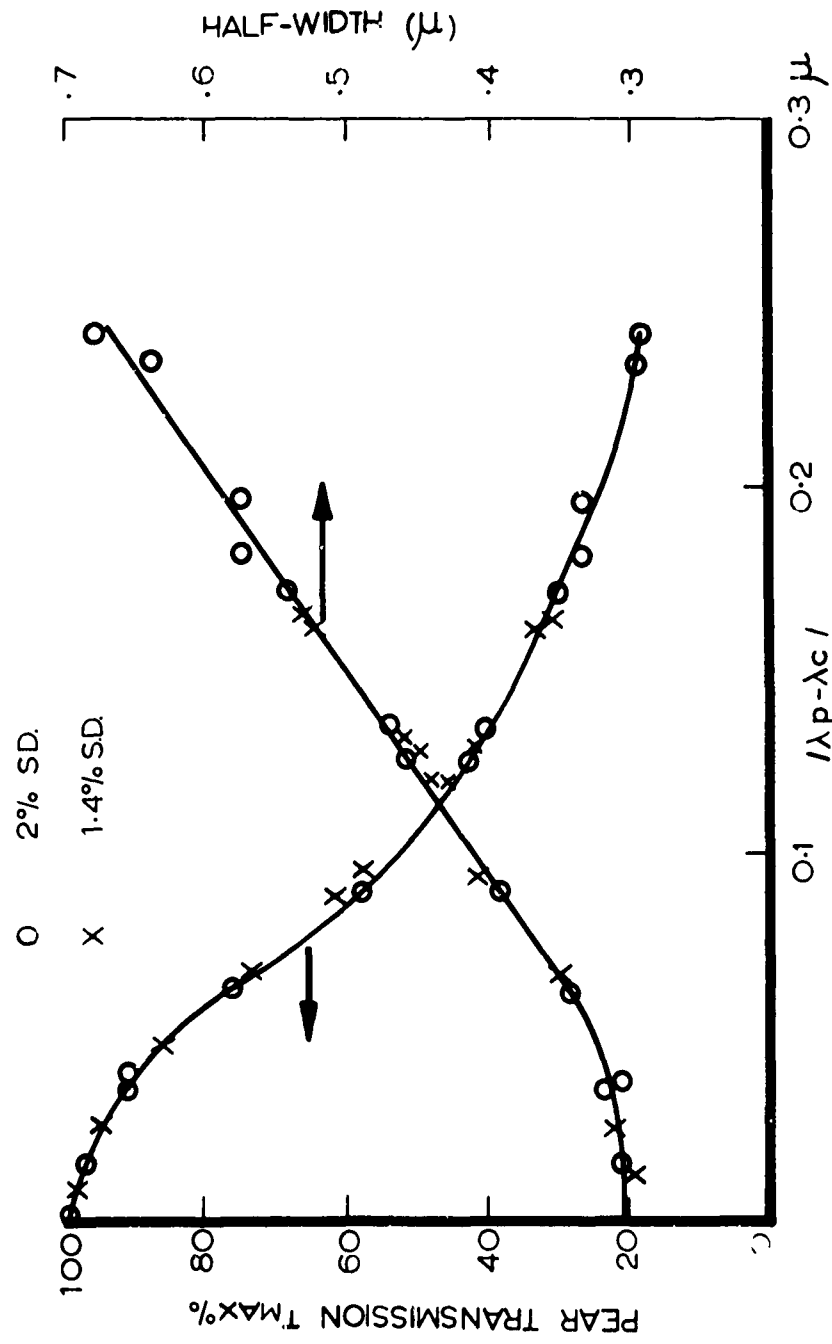


FIG.5.13.

14-LAYER FILTER

MONITOR WAVELENGTH= 15.0000 MICRONS
RAIR= 1.0000
RSUB= 4.0000
STANDARD DEVIATION= 1.4000 PER CENT

CASE NO. 1

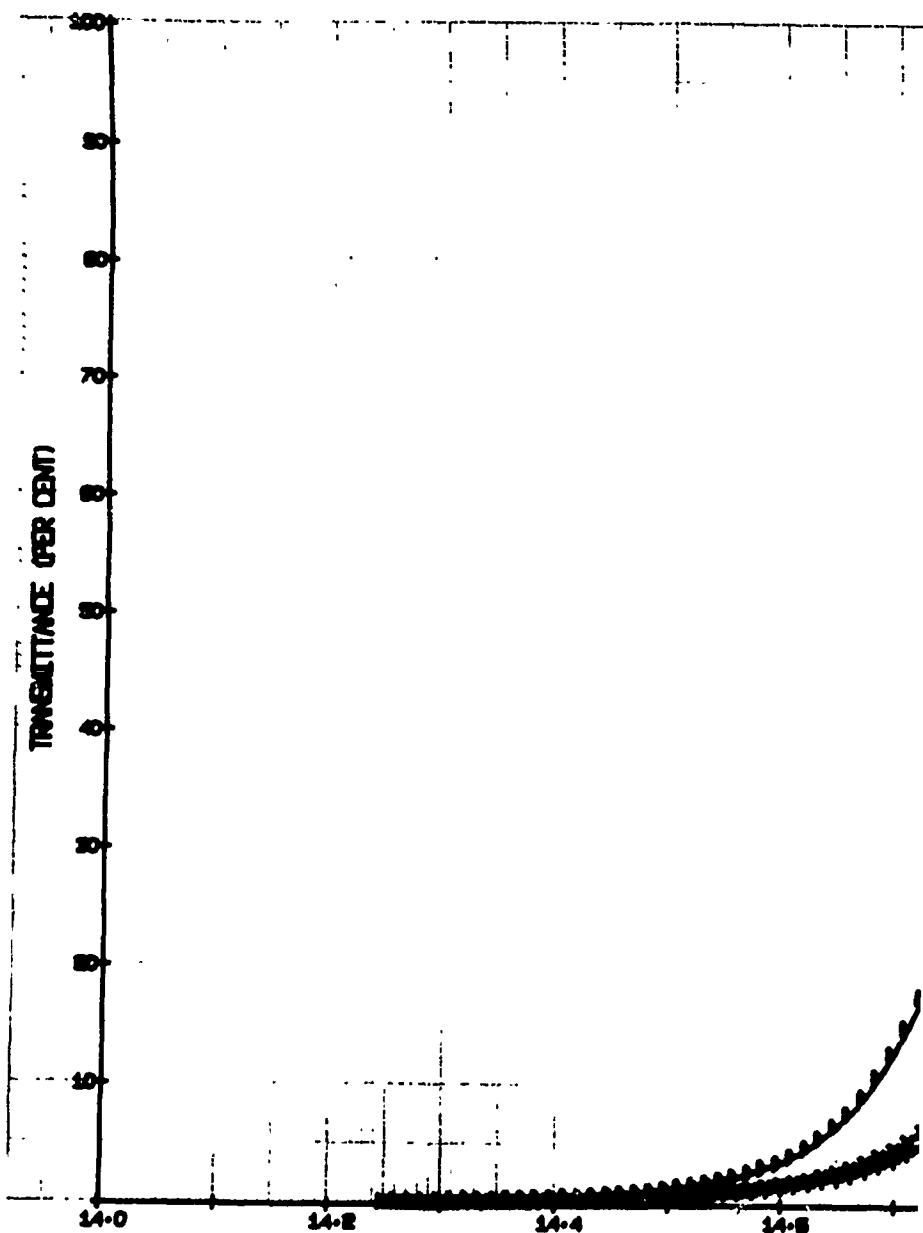
LAYER INDEX	LAYER THICKNESS
2.3500	0.2455
5.3000	0.2512
2.3500	0.2497
5.3000	0.5030
2.3500	0.2495
5.3000	0.2543
2.3500	0.2519
5.3000	0.2458
2.3500	0.2500
5.3000	0.2505
2.3500	0.2507
5.3000	0.5015
2.3500	0.2505
5.3000	0.2501

CASE NO. 2

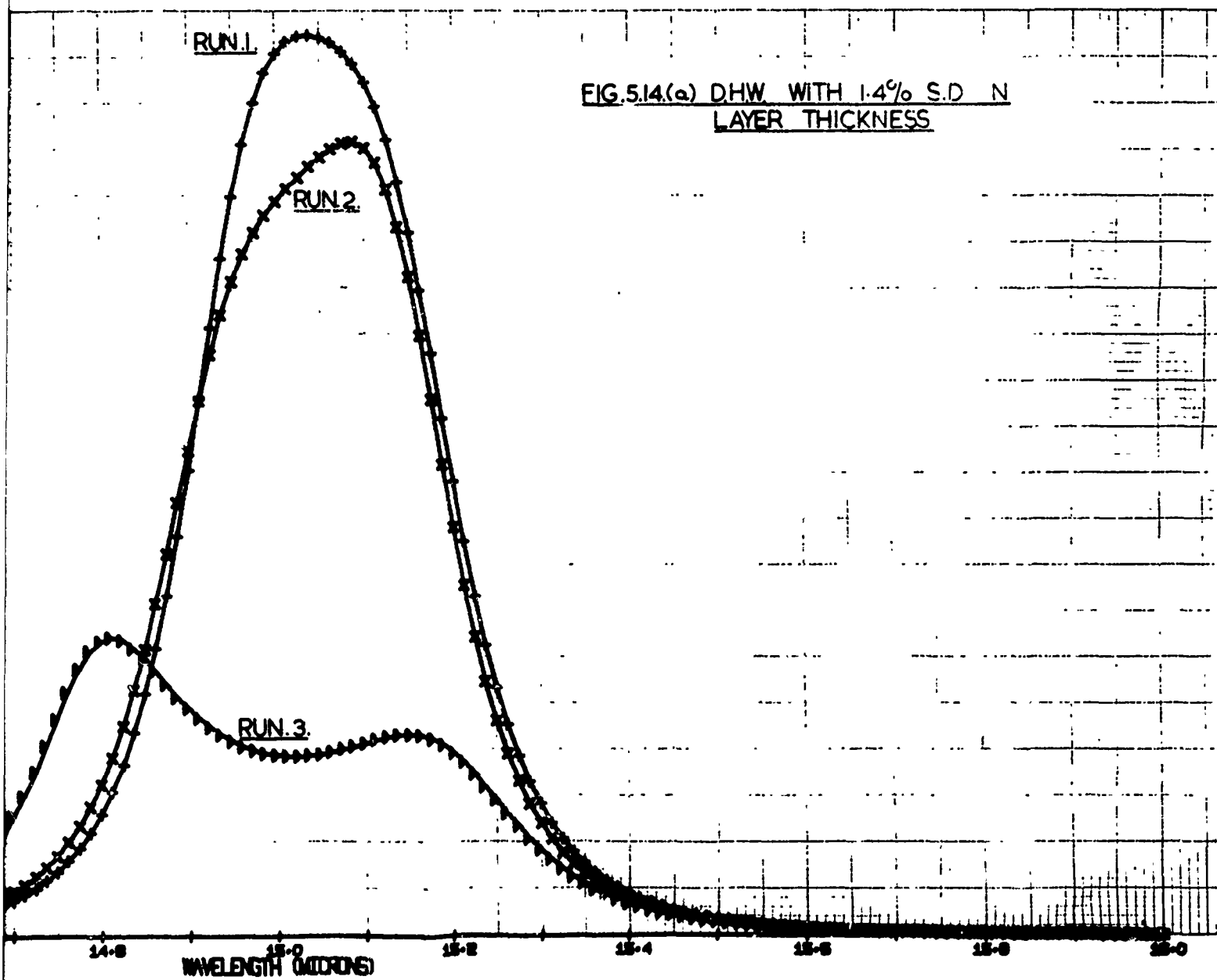
LAYER INDEX	LAYER THICKNESS
2.3500	0.2459
5.3000	0.2486
2.3500	0.2475
5.3000	0.4994
2.3500	0.2517
5.3000	0.2499
2.3500	0.2515
5.3000	0.2528
2.3500	0.2539
5.3000	0.2478
2.3500	0.2520
5.3000	0.5049
2.3500	0.2457
5.3000	0.2527

CASE NO. 3

LAYER INDEX	LAYER THICKNESS
2.3500	0.2490
5.3000	0.2450
2.3500	0.2584
5.3000	0.5081
2.3500	0.2460
5.3000	0.2552
2.3500	0.2501
5.3000	0.2484
2.3500	0.2464
5.3000	0.2513
2.3500	0.2454
5.3000	0.4926
2.3500	0.2469
5.3000	0.2509



A



B

14-LAYER FILTER
 MONITOR WAVELENGTH* 15.0000 MICRONS
 RAIR* 1.0000
 REUB* 4.0000
 STANDARD DEVIATION* 1.4000 PER CENT

CASE NO. 1

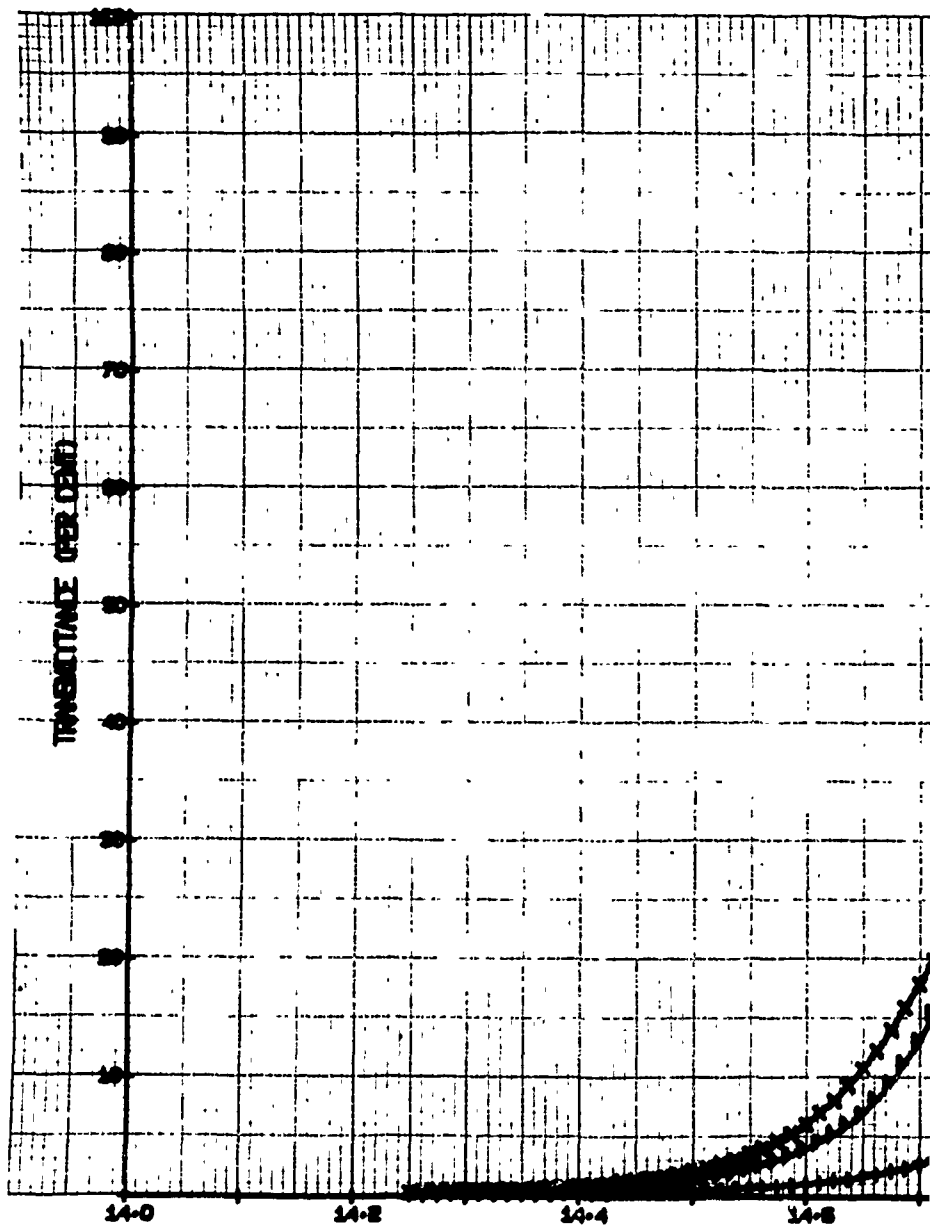
LAYER INDEX	LAYER THICKNESS
2.3500	0.2464
5.3000	0.2482
2.3500	0.2458
5.3000	0.5136
2.3500	0.2496
5.3000	0.2523
2.3500	0.2508
5.3000	0.2521
2.3500	0.2493
5.3000	0.2494
2.3500	0.2487
5.3000	0.5020
2.3500	0.2455
5.3000	0.2500

CASE NO. 2

LAYER INDEX	LAYER THICKNESS
2.3500	0.2432
5.3000	0.2498
2.3500	0.2488
5.3000	0.4872
2.3500	0.2482
5.3000	0.2557
2.3500	0.2555
5.3000	0.2477
2.3500	0.2567
5.3000	0.2475
2.3500	0.2482
5.3000	0.5036
2.3500	0.2512
5.3000	0.2534

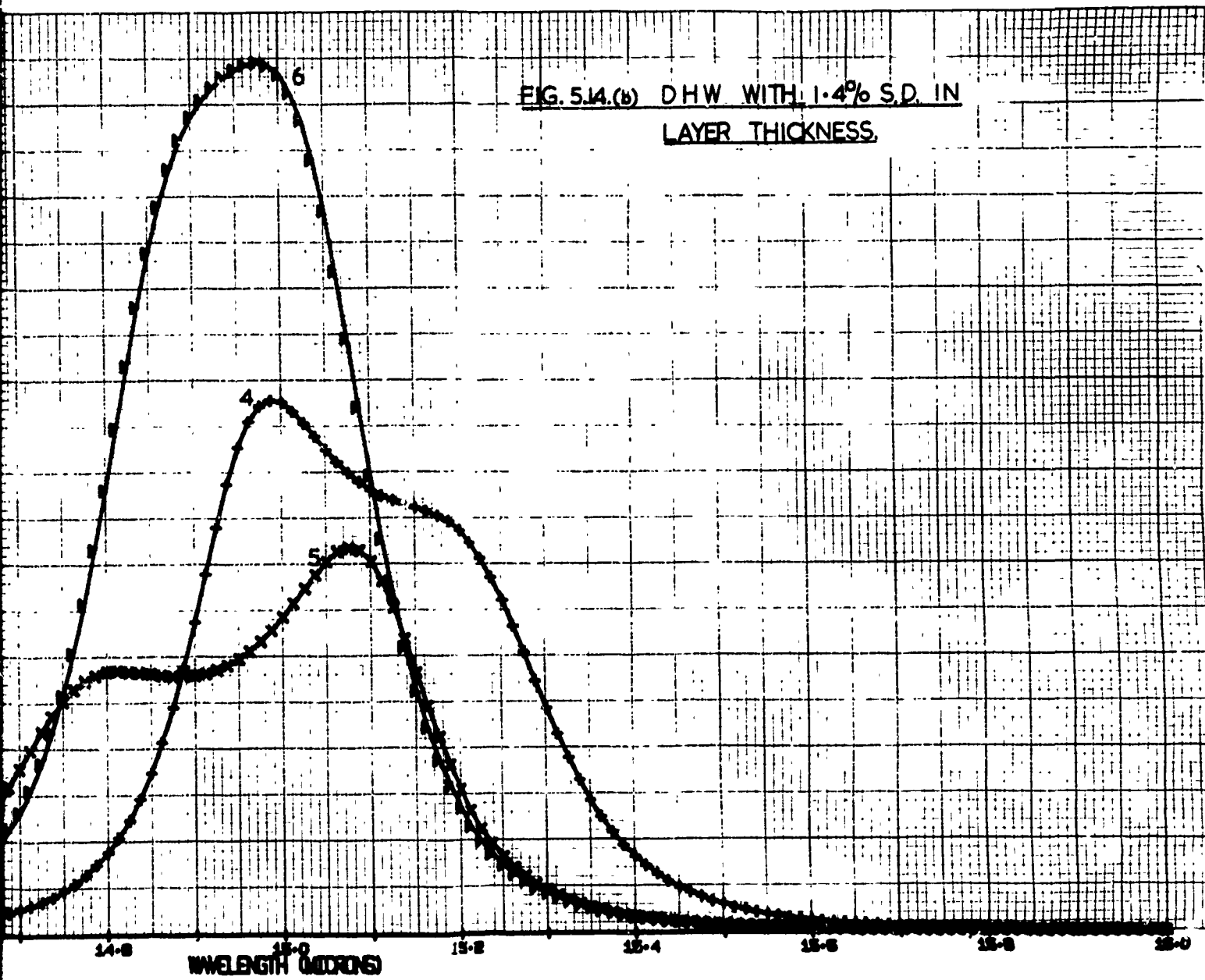
CASE NO. 3

LAYER INDEX	LAYER THICKNESS
2.3500	0.2515
5.3000	0.2524
2.3400	0.2456
5.3000	0.4975
2.3500	0.2477
5.3000	0.2495
2.3500	0.2541
5.3000	0.2476
2.3500	0.2509
5.3000	0.2501
2.3500	0.2486
5.3000	0.4999
2.3500	0.2471
5.3000	0.2507



A

FIG. 5.14.(b) DHW WITH 1.4% S.D. IN
LAYER THICKNESS.



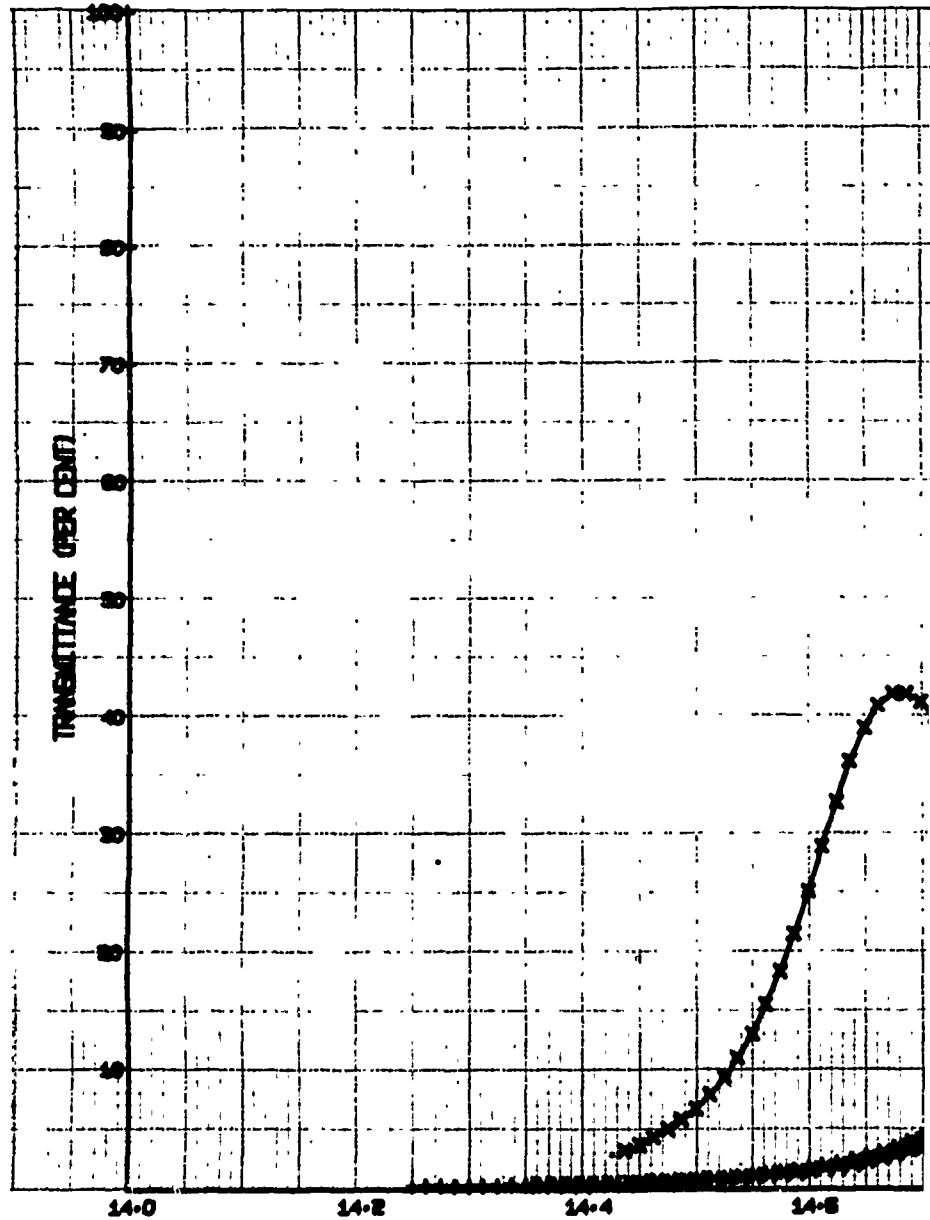
B

14-LAYER FILTER
 MONITOR WAVELENGTH* 15.0000 MICRONS
 RAIR* 1.0000
 RSUB* 4.0000
 STANDARD DEVIATION* 1.4000 PER CENT

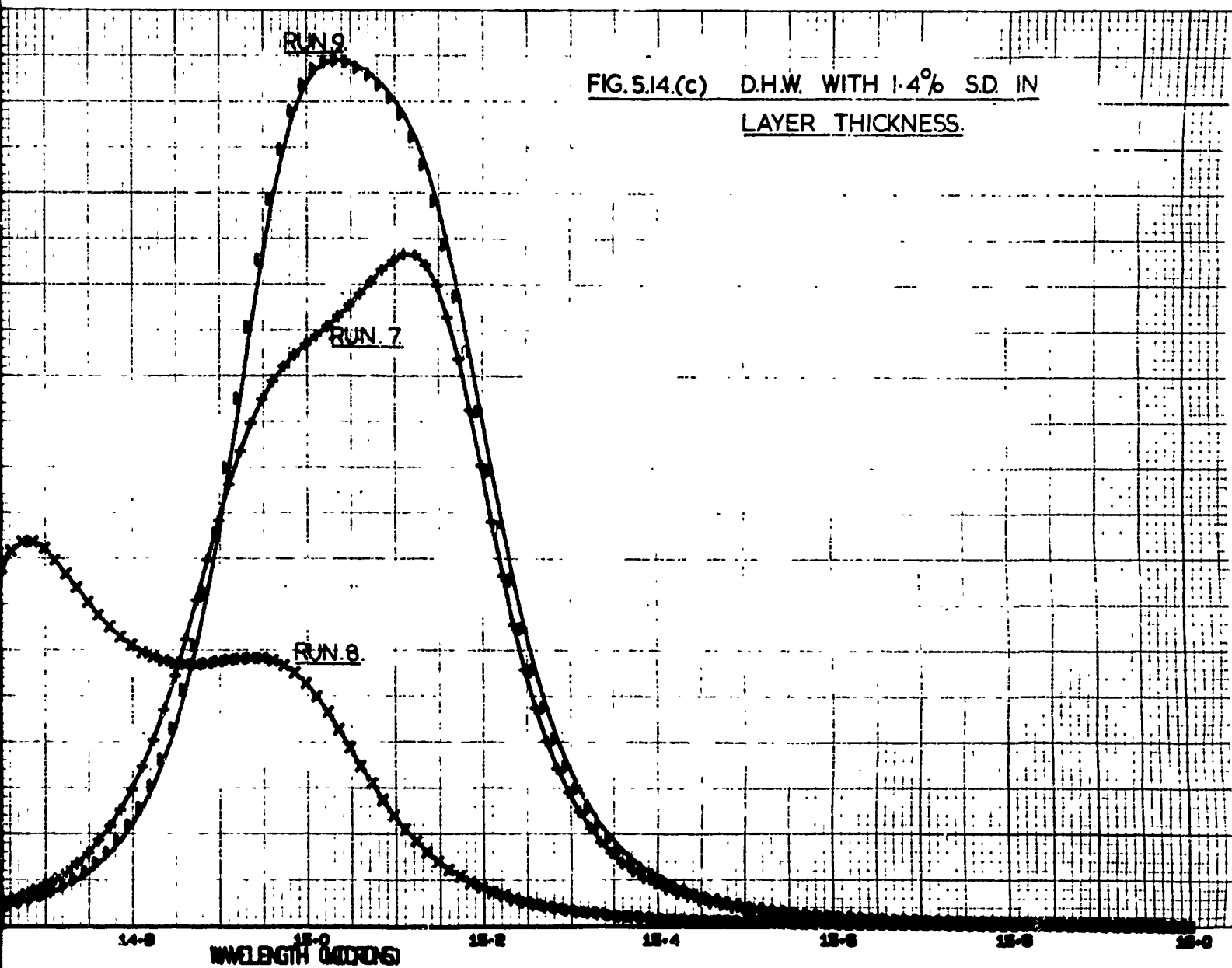
CASE NO. 1	
LAYER INDEX	LAYER THICKNESS
2.3500	0.2495
5.3000	0.2445
2.3500	0.2537
5.3000	0.4981
2.3500	0.2482
5.3000	0.2475
2.3500	0.2540
5.3000	0.2538
2.3500	0.2468
5.3000	0.2505
2.3500	0.2509
5.3000	0.5102
2.3500	0.2419
5.3000	0.2465

CASE NO. 2	
LAYER INDEX	LAYER THICKNESS
2.3500	0.2513
5.3000	0.2528
2.3500	0.2511
5.3000	0.4991
2.3500	0.2447
5.3000	0.2541
2.3500	0.2497
5.3000	0.2455
2.3500	0.2556
5.3000	0.2518
2.3500	0.2518
5.3000	0.4831
2.3500	0.2455
5.3000	0.2461

CASE NO. 3	
LAYER INDEX	LAYER THICKNESS
2.3500	0.2470
5.3000	0.2550
2.3500	0.2528
5.3000	0.5018
2.3500	0.2526
5.3000	0.2510
2.3500	0.2532
5.3000	0.2451
2.3500	0.2477
5.3000	0.2471
2.3500	0.2431
5.3000	0.5068
2.3500	0.2499
5.3000	0.2466



A



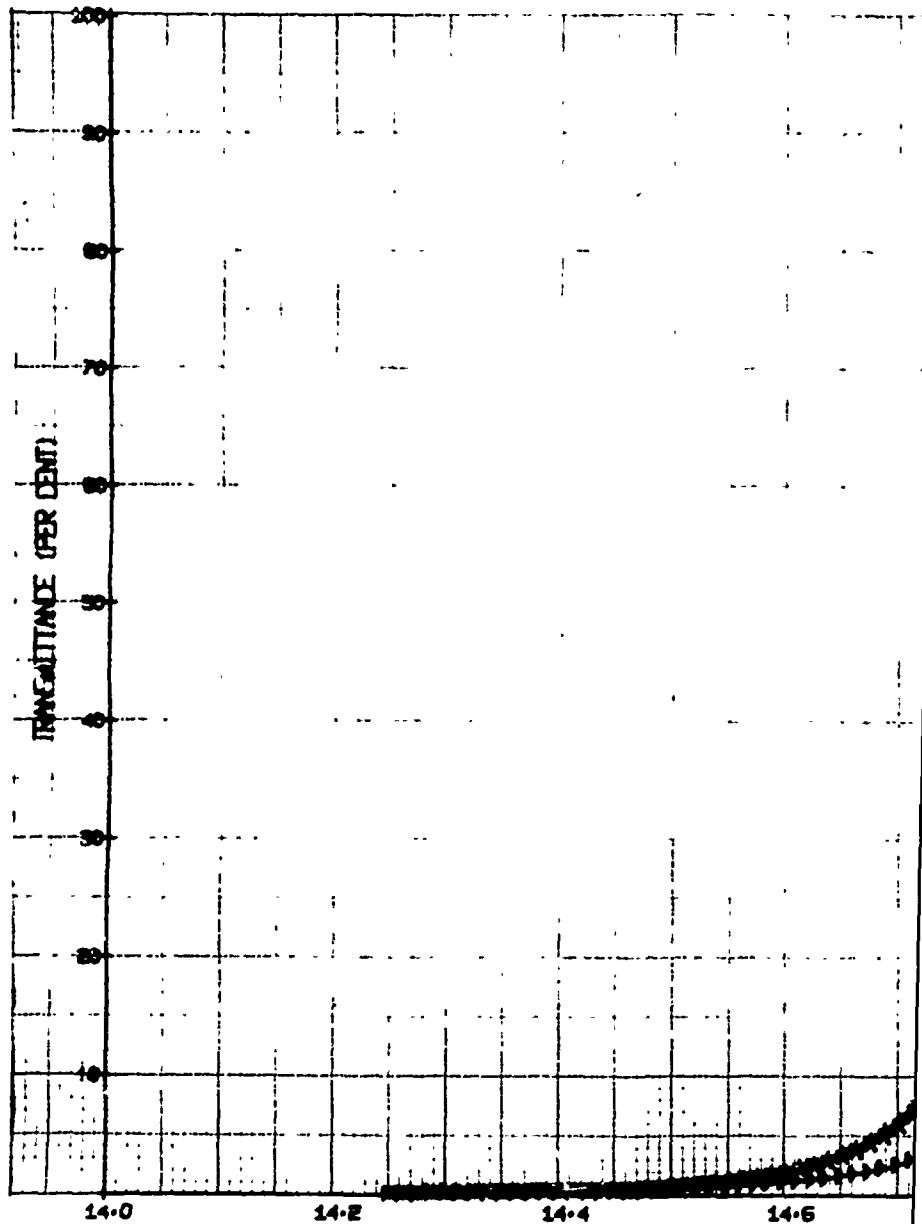
B

14-LAYER FILTER
 MONITOR WAVELENGTH* 15.0000 MICRONS
 RAIR* 1.0000
 RSUB* 4.0000
 STANDARD DEVIATION* 1.4000 PER CENT

CASE NO. 1		
LAYER INDEX	LAYER THICKNESS	
2.3500	0.2547	
5.3000	0.2470	
2.3500	0.2532	
5.3000	0.5042	
2.3500	0.2578	
5.3000	0.2528	
2.3500	0.2510	10
5.3000	0.2526	
2.3500	0.2434	
5.3000	0.2515	
2.3500	0.2524	
5.3000	0.4922	
2.3500	0.2535	
5.3000	0.2468	

CASE NO. 2		
LAYER INDEX	LAYER THICKNESS	
2.3500	0.2538	
5.3000	0.2501	
2.3500	0.2496	
5.3000	0.5120	
2.3500	0.2516	
5.3000	0.2541	
2.3500	0.2563	11
5.3000	0.2477	
2.3500	0.2495	
5.3000	0.2475	
2.3500	0.2524	
5.3000	0.4930	
2.3500	0.2474	
5.3000	0.2515	

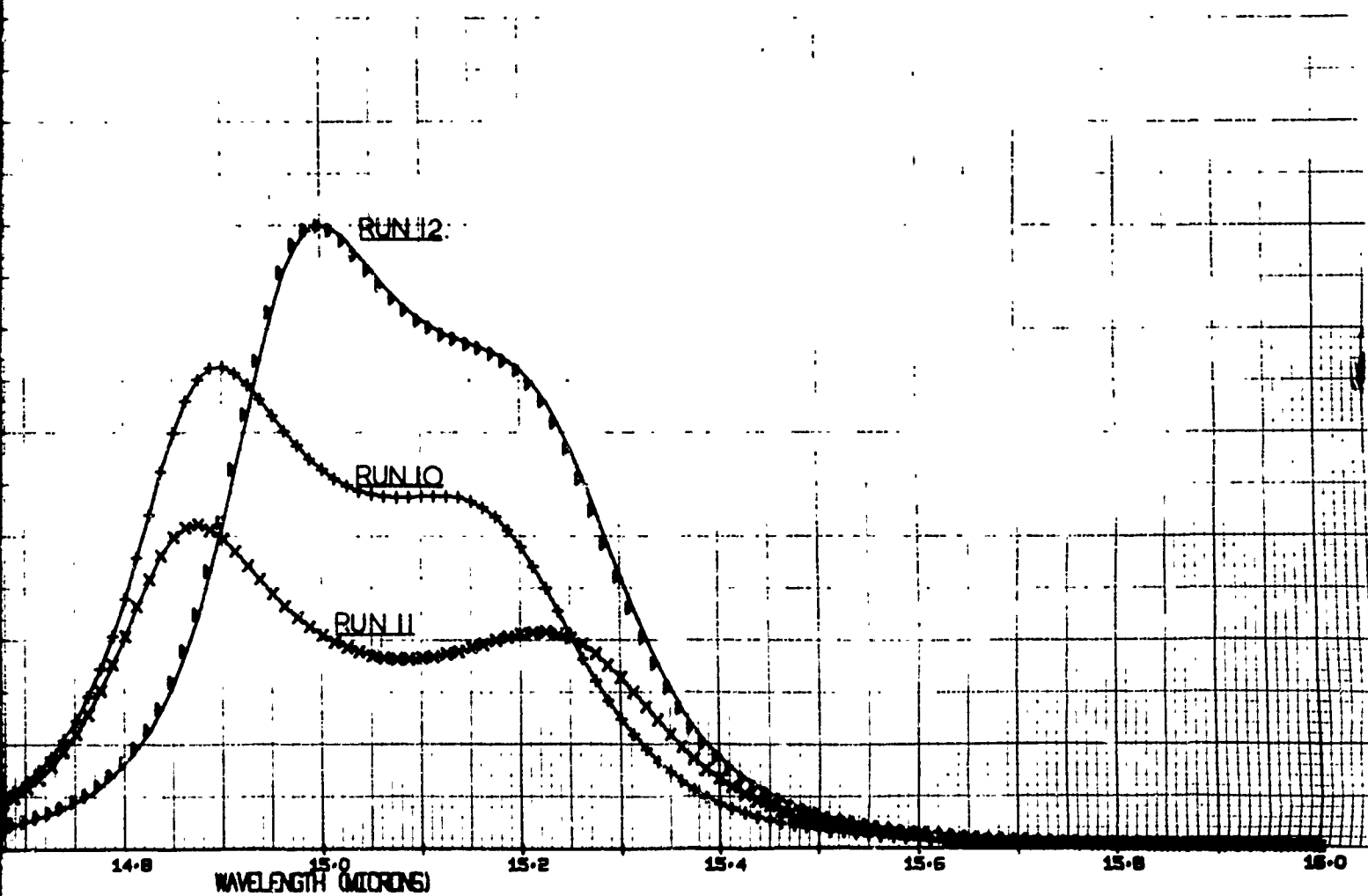
CASE NO. 3		
LAYER INDEX	LAYER THICKNESS	
2.3500	0.2520	
5.3000	0.2522	
2.3500	0.2522	
5.3000	0.5111	
2.3500	0.2481	
5.3000	0.2475	
2.3500	0.2536	12
5.3000	0.2525	
2.3500	0.2512	
5.3000	0.2462	
2.3500	0.2515	
5.3000	0.4991	
2.3500	0.2508	
5.3000	0.2519	



A

FIG. 514(d)

D.H.W. WITH 1.4% S.D. IN
LAYER THICKNESS.

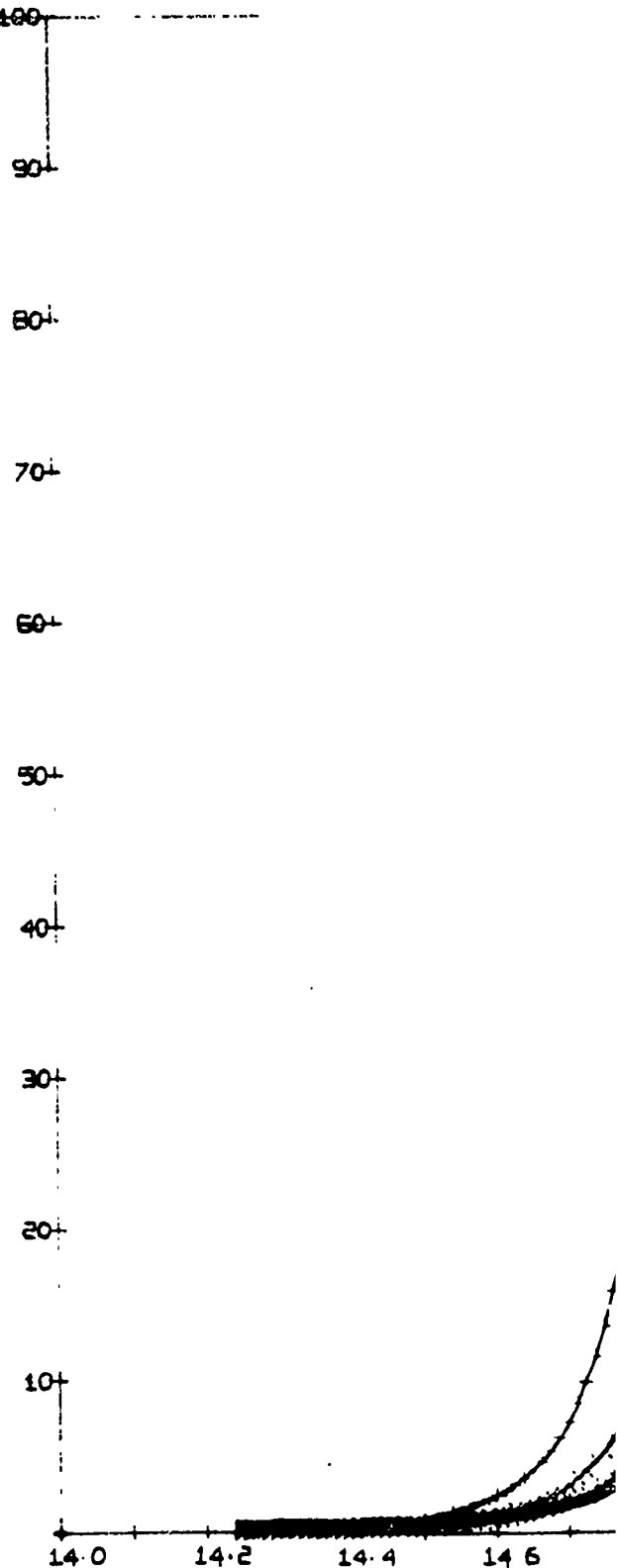


B

14-LAYER FILTER
 MONITOR WAVELENGTH= 14.8200 MICRONS
 RAIR= 1.0000
 RSUB= 4.0000

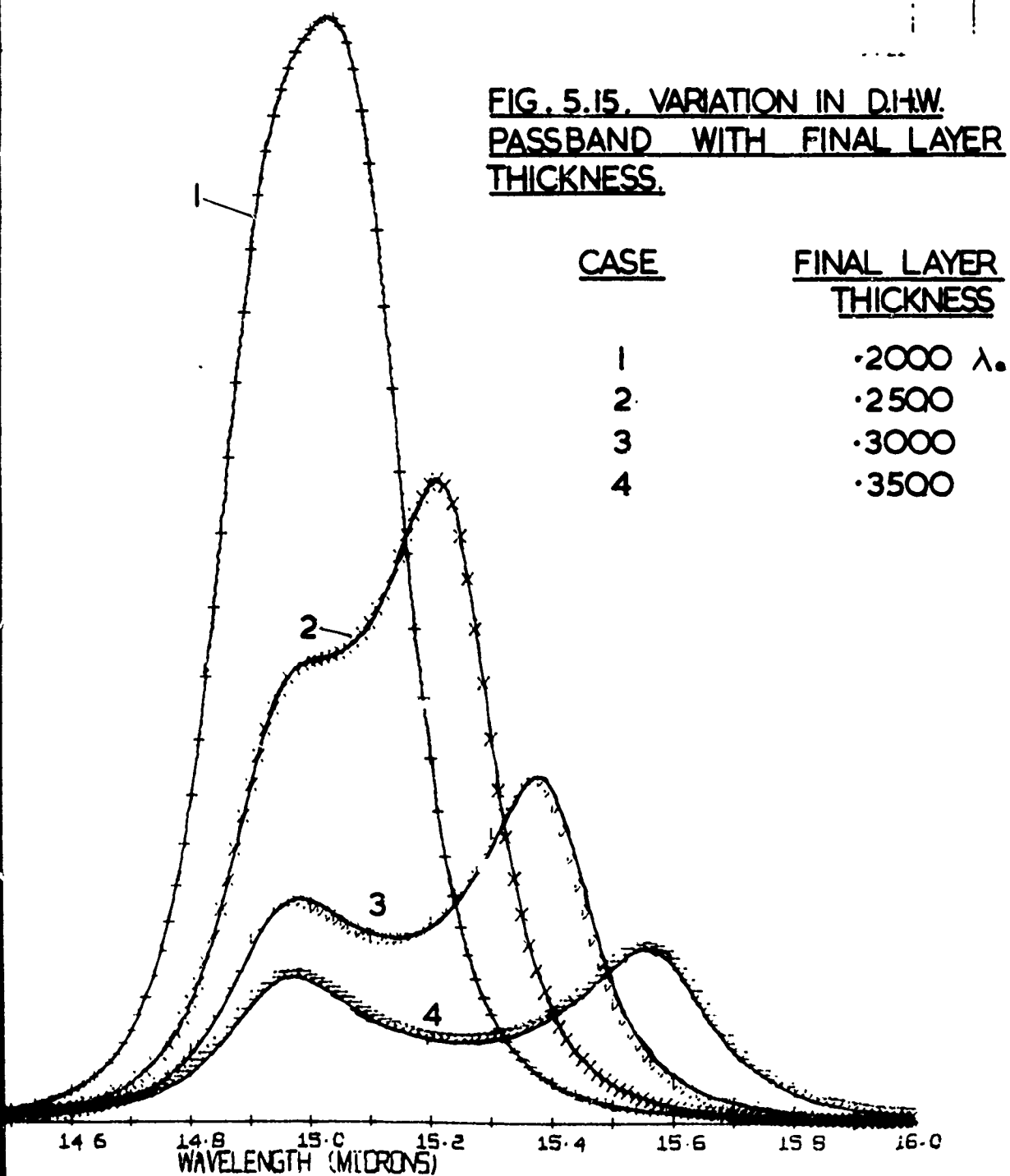
CASE NO. 1		
LAYER INDEX	LAYER THICKNESS	
2.3500	0.2464	
5.3000	0.2566	
2.3500	0.2537	
5.3000	0.5075	
2.3500	0.2467	
5.3000	0.2419	
2.3500	0.2491	
5.3000	0.2492	
2.3500	0.2604	
5.3000	0.2478	
2.3500	0.2518	
5.3000	0.5184	
2.3500	0.2564	
5.3000	0.2000	(1)
	0.2500	(2)
	0.3000	(3)
	0.3500	(4)

TRANSMITTANCE (PER CENT)



f1

FIG. 5.15. VARIATION IN D.H.W. PASSBAND WITH FINAL LAYER THICKNESS.



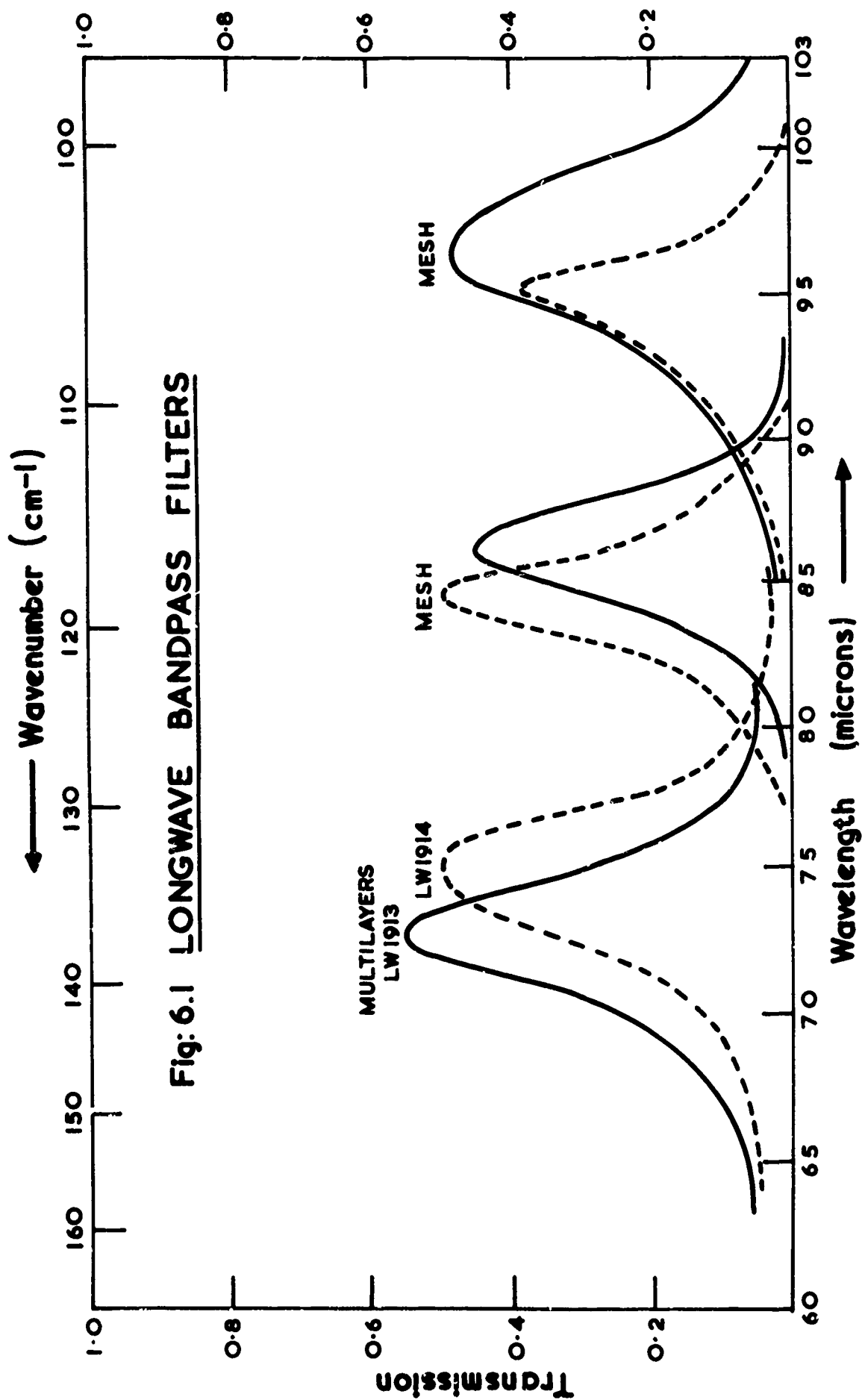
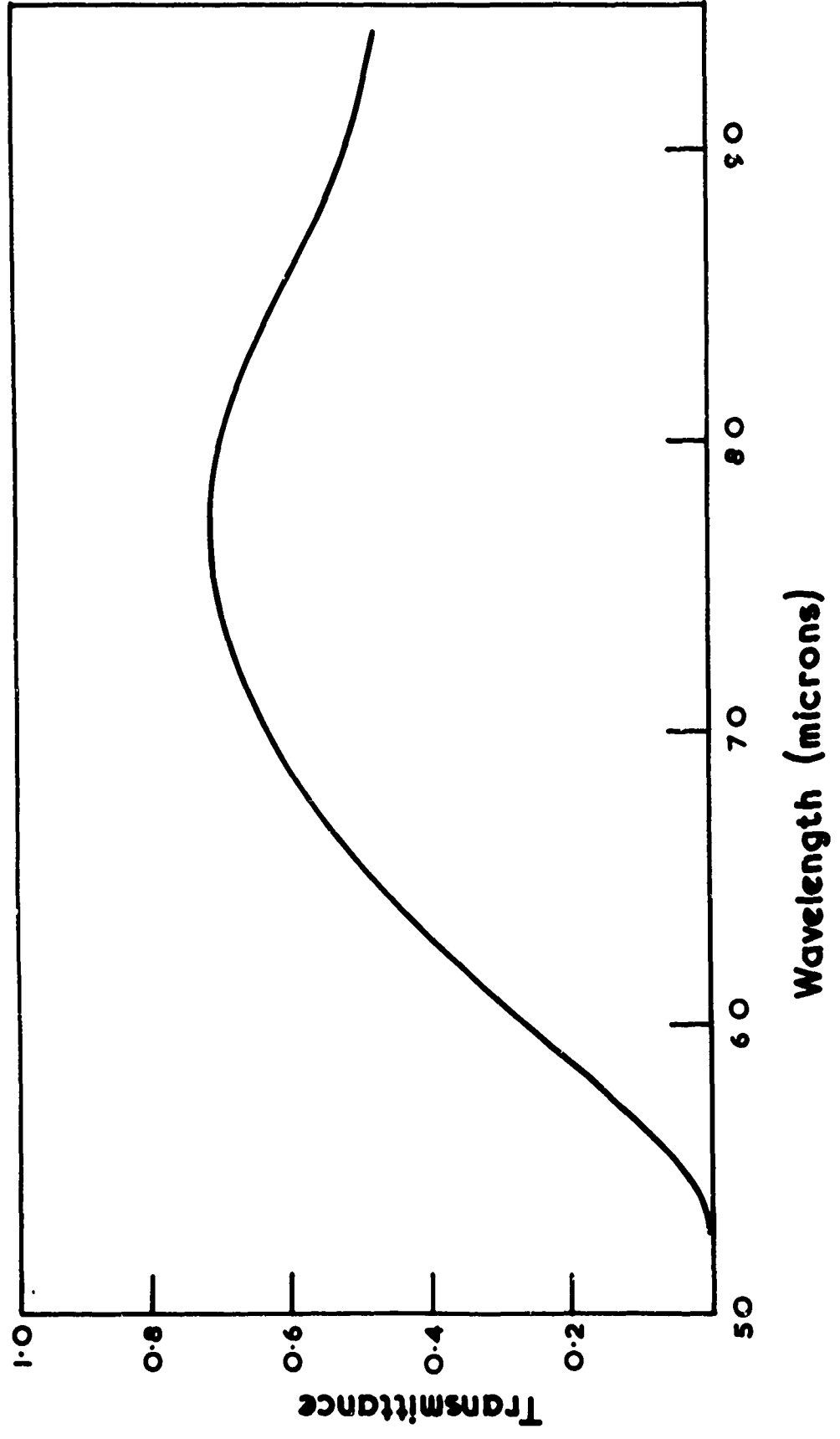


Fig: 6.2 LONGWAVE LOWPASS FILTER



Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Physics Department University of Reading Reading, England		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP	
3. REPORT TITLE "..... Multilayer Filters for the region 0.8 to 100 microns"			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Scientific Final.			
5. AUTHOR(S) (First name, middle initial, last name) S.D. Smith J.S. Seeley			
6. REPORT DATE 7th May 1968		7a. TOTAL NO. OF PAGES 192 in Vol. 1 6 in Vol. 2	7b. NO. OF REFS 28
8a. CONTRACT OR GRANT NO AF61(052)-833		9a. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO 8662			
c. 4730		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) IN TWO VOLUMES: Vol. 1 Text and Tables Vol. 2 Illustrations	
d.			
10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.			
11. SUPPLEMENTARY NOTES TECH, OTHER		12. SPONSORING MILITARY ACTIVITY AIR FORCE CAMBRIDGE RESEARCH LABORATORIES L.G. Hanscom Field Bedford, MASS 01730	
13. ABSTRACT A study of materials for multilayer evaporated film filters for the region 1-100 μ has yielded several successful high index-low index combinations, notably PbTe/ZnS (5 - 25 μ) and Ge/CsI (10 - 80 μ). Filters of $\frac{1}{2}\%$ bandwidth, centred to $\frac{1}{4}\%$ can be produced on a routine basis for the 15 μ region. Band pass filters of 10% bandwidth between 50 μ and 100 μ have been achieved and evaporated film and mesh techniques have overlapped in the 60-70 μ region. Good blocking filters with edges out to 70 μ have also been obtained with performance better than other methods of filtering for this region.			

DD FORM 1 NOV 63 1473

UNCLASSIFIED

Security Classification

14	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
	Multilayer filters, near infra-red, far infra-red, vacuum evaporation, micro-mesh, radiometry, semi-conductors.						