CHAPTER 2

THE GENERAL PRACTICE OF INFRARED PHOTOGRAPHY

2.1 Introduction to Infrared Plates and Films

There is no fundamental difference between the practice of infrared photography and that in which visible light is used. Anyone equipped for photography with ordinary, orthochromatic, or panchromatic plates or films can make infrared photographs without investing in any extra equipment other than a filter for use on the lens of his camera. However, a variety of infrared--sensitive plates and films, is now available from several manufacturers. The selection of the material will be made according to requirements of speed, contrast, and region of sensitivity.

The materials[1] which are in most common use for general infrared photography by amateurs and by professional and commercial photographers are:-

Sheet film:

Kodak Infrared Sheet Film

Roll and miniature films:

Kodak Infrared Film (Miniature and Roll)

Kodak High Speed Infrared Film

Plates:

Kodak Infrared-- Sensitive Plates

Kodak (England) I.R.E.R. Extra Rapid Infrared Plates

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[1] - Clark W., Infrared Photography, p. 12.

N.B.: No other products are available, except special order.

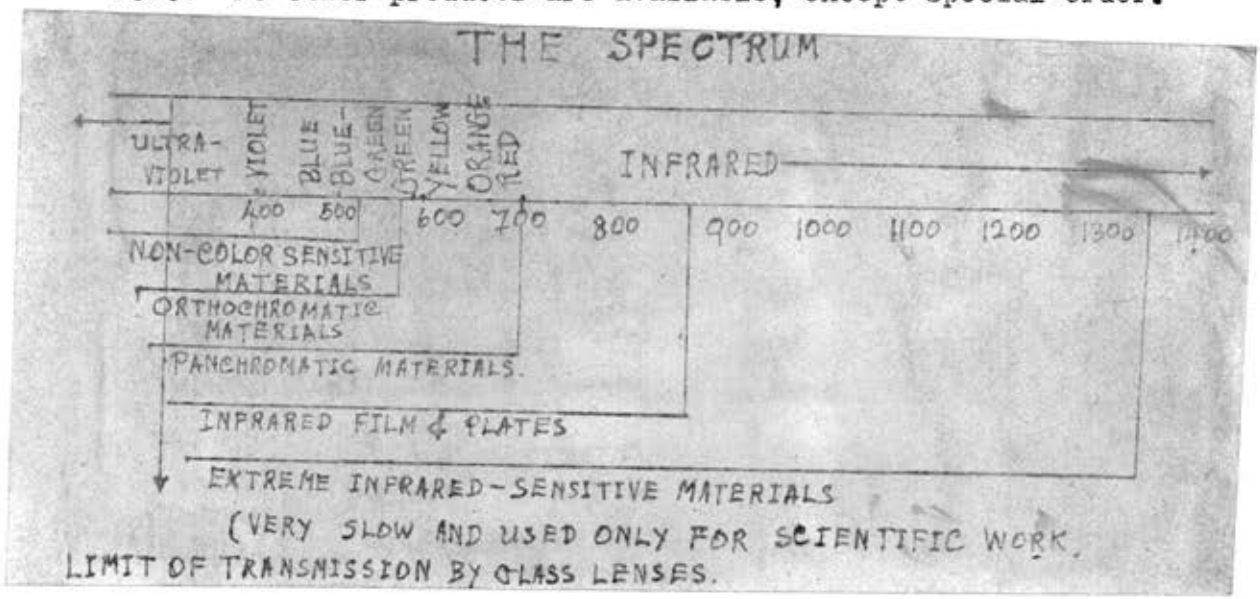

Fig. 2.1: Showing the spectral range of photographic sensitivity (from Kodak Advanced Data Book, M - 3 pp. 3).

2.2 Infrared--sensitive Emulsions

These emulsions are made by treating the ordinary emulsion with special dyes, see TABLE 2.1.*

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* - Kenneth Mees, C.E.; The Theory of The Photographic Process, pp. 357-370

- Clark, W., op.cit., pp. 72-87

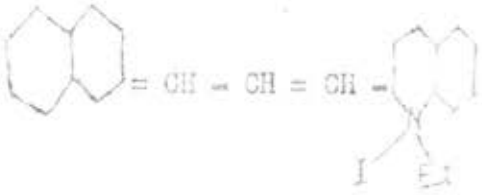
- Simon, Ivan, Infrared Radiation, pp. 111-113

TABLE 2.1

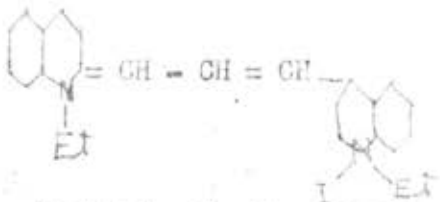
SPECIAL EMULSION DYES

Name	Discoverer (preparer)	Discovered year	Absorption Maximum in A	Sensitising Maximum in A
Pinacyanol	Homolka	1904	5,600 and 6,100	5,700 and 6,600
Dicyanines	Hoechst Dye Works	1903	5,800 and 6,600	6,250 and 7,100
Kryptocyanines	Adams and Haller	1919	7,100	7,500
Neocyanines	H.T. Clarke	1925	7,750	8,200
Pinacyanol + Auramine	Bloch and Renwick	1920	-	-
Merocyanines	Kendall and Brooker	1932	-	-
		1950	-	-
Dicarbocyanines	W. König	1942	7,100	7,500
Xenocyanines (tricarbocyanines from lepidine)	Brooker	1931	8,300 and 9,300	8,500 and 9,800
Tetracarbocyanines	Brooker and Keyes	-	8,500	9,400
Pentacarbocyanines		1948	7,800 and 9,950	10,500

The structural formulas[1] of the chief Infrared Sensitizing Dyes are shown in the followings:

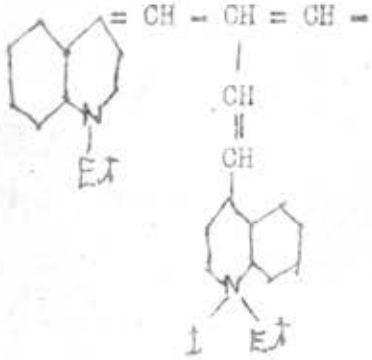


Pinacyanol (1,1' - diethyl - 2, 2' - carbocyanine iodide)



Dicyanine (1,1' - diethyl - 2, 4' - carbocyanine iodide)

Kryptocyanine (1, 1' - diethyl - 4, 4' - carbocyanine iodide)



Neocyanine

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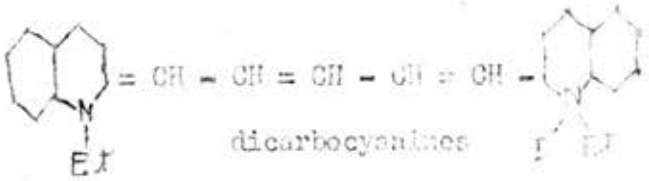
1 - Kenneth Mees, C.E., op. cit.

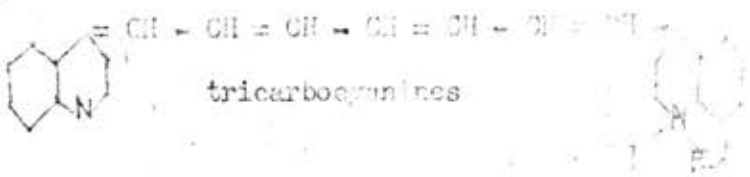
- Clark, W., opcit, pp, 72 - 99

From above formulas Pinacyanol, dicyanines, cryptocyanines and neocyanines have the same group,

$$= CH - CH = CH - \quad ;$$



dicarbocyanines



tricarbocyanines

$$(- CH = CH)_2 - C\ (OA_c)\ (= CH - CH)_2 =$$

tetracarbocyanines Chain

$$(- CH = CH)_2 - C\ (OA_c)(= CH - CH)_2 =$$

pentacarbocyanines Chain.

The fo ng figures are the wedge emulsions.

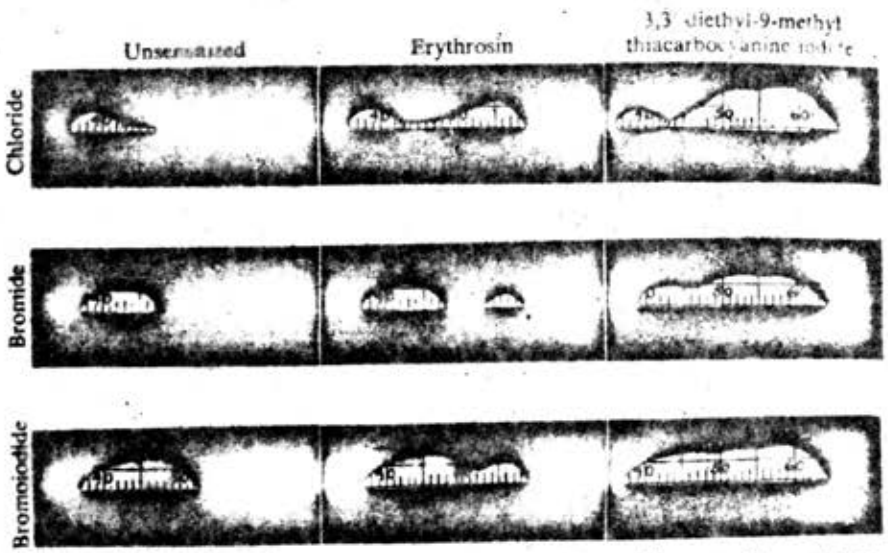


Fig. 2[illegible] Wedge spectrograms of chloride, bromide, and bromoiodide emulsions. First column, unsensitized; second column, sensitized with erythrosin (5); third column, sensitized with 3,3'-diethyl-9-methylthiacarbocyanine bromide.

1. - Kenneth Mees, C.E., op.cit., pp.[illegible].

(1) [illegible]-diethyl-4,5,4',5'-dibenzothiacyanine chloride.

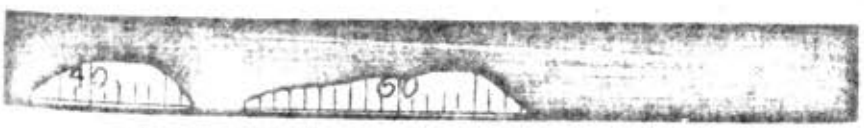
(2) 1,1'-diethyl-2,2'-cyanine iodide (21).

(3) 1,1'-diethyl-2,4'-cyanine iodide (ethyl red) (22).

(4) 1,1'-diethyl-6,6'-dimethyl-2,4'-cyanine bromide (orthochrome T) (38).

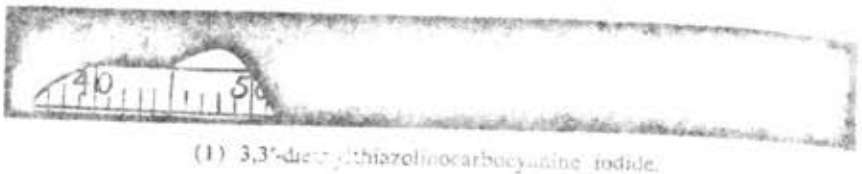
(5) 1,1'-diethyl-6,6'-diethoxy-2,4'-cyanine bromide (pinachrome) (39).

(6) 1,1'-diethyl-4,4'-cyanine iodide.



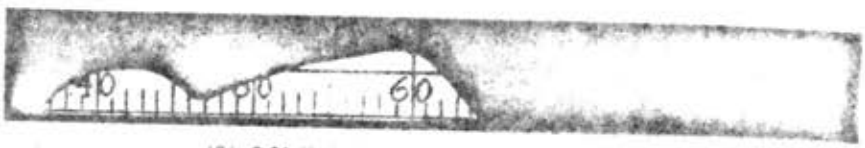
(7) 1,1'-diethyl-2,2'-carbocyanine iodide (pinacyanol) (24).

Fig. 8 Wedge spectrograms of a chlorobromide emulsion sensitized with various cyanine dyes.

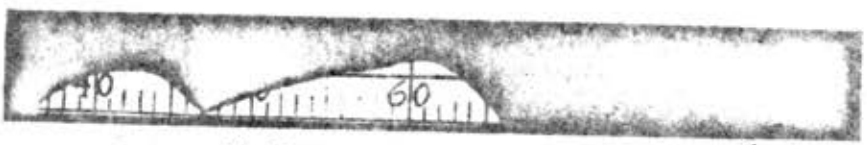


(1) 3,3'-diethylthiazolinocarbocyanine iodide.

(2) 3,3'-diethloxacarbocyanine iodide.

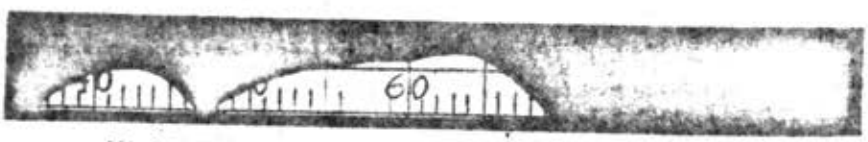


(3) 3,3'-diethylthiacarbocyanine iodide (30).



(4) 3,3'-diethylselenacarbocyanine iodide.

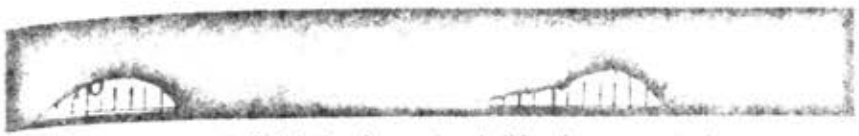
(5) 3,3'-diethyl-9-methylthiacarbocyanine bromide (45).



(6) 3,3'-diethyl-4,5,4',5'-dibenzothiacarbocyanine bromide (43).

(7) 1,1'-diethyl-2,4'-carbocyanine iodide (dicyanine).

Fig. 200. Wedge spectrograms of a chlorobromide emulsion sensitized with carbocyanine dyes.



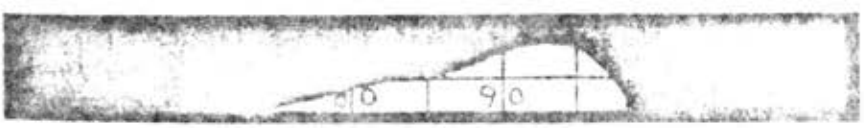
(1) 1,1'-diethyl-4,4'-carbocyanine iodide (kryptocyanine).

(2) 3,3'-diethylthiadicarbocyanine iodide.

(3) 3,3'-diethylthiatricarbocyanine iodide (69).

(4) Neocyanine (82).

(5) 1,1'-diethyl-4,4'-tricarbocyanine iodide (xenocyanine).



(6) 12-acetoxy-3,3'diethylthiatetracarbocyanine perchlorate.

(7) 12-acetoxy-3,3'diethylthiapentacarbocyanine perchlorate.

Fig. 2 to 5 Wedge spectrograms of a chlorobromide emulsion sensitized with infrared sensitizers.

Although the emulsion obtained with the addition of special dyes rays, it is still much more sensitive to blue rays. When these special emulsions are used for taking photographs by infrared, therefore, the unwanted blue rays must be held back by a filter. Suitable filters are made of deep red or black glass which transmits only red and infrared radiation. Infrared sensitive plates and films are comparatively slow (about 24 B.S. Log. Index or lower) when they are used for infrared photography.

The sensitivity range of these emulsions depend upon the sensitizing dyes employed, as shown in TABLE 2.1.

2.2.1 Characteristics of Kodak Infrared Plates and Films.[1]

The following figures are the spectrogram and characteristic curves of Kodak Infrared Sensitive materials.[2]

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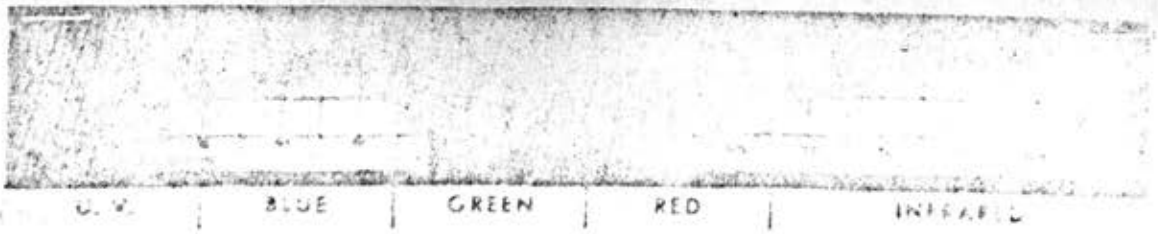
[1] - Purves, Frederick, Loc.cit., pp. 1093-1095.

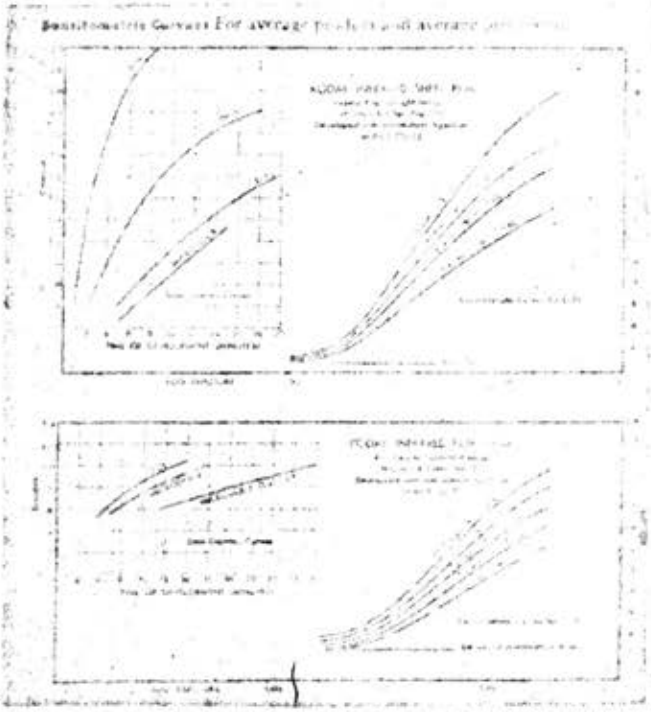
- Walls, H.J. Photo-Technique, pp. 172-179.

[2] - Kodak Co., Kodak Advanced Data Book p - 9, pp. 14d-15d.

- Ibid, Infrared and Ultraviolet Photography, pp. 30-32.



Spectral sensitivity of Kodak infrared materials, namely, Kodak Infrared Film and Kodak Infrared Film (in magazines).



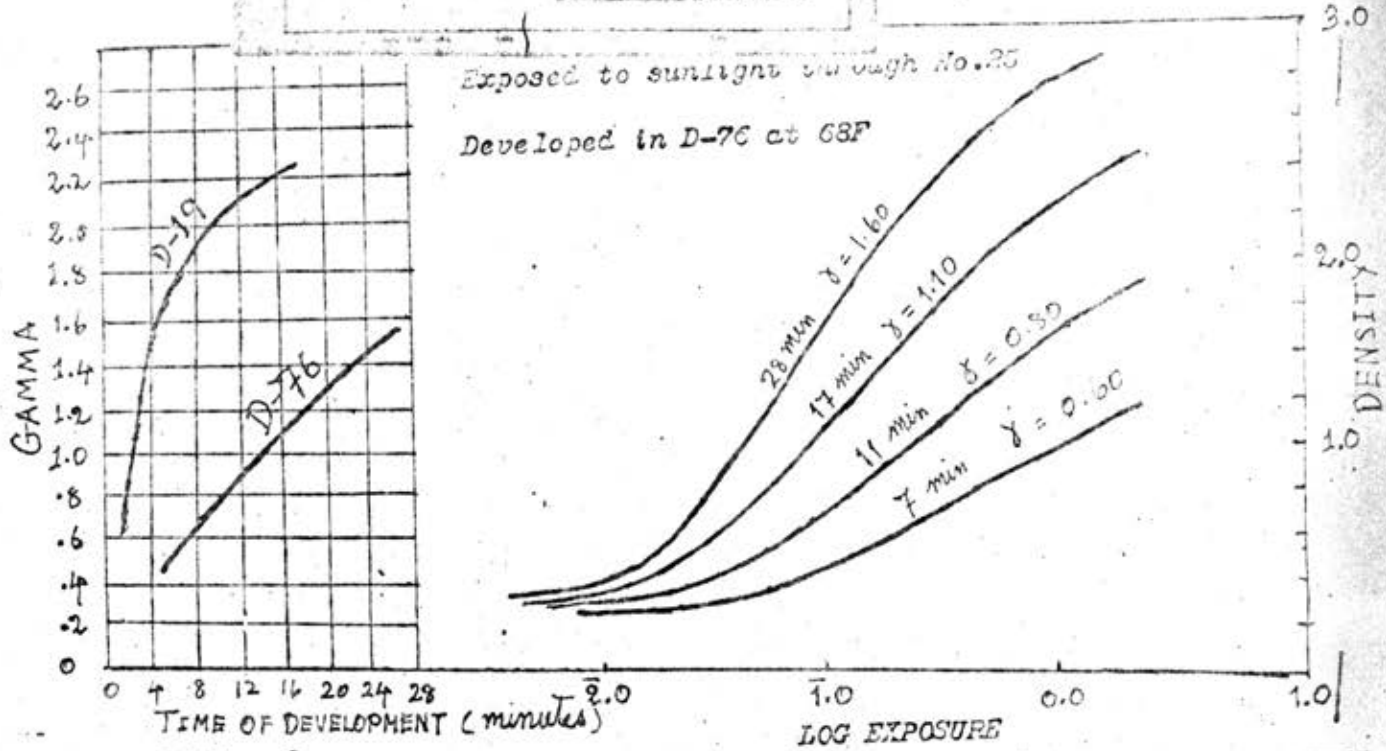


Fig 2.6 (a) The spectrogram of the Kodak infrared films,

(b) The Characterisnc curves of Kodak infrared sheet film

(c) " " " " " film 35 mm.

(d) " " " Kodak High speed infrared film

2.2.2 Storage and Handling

Plates and films for general infrared photography require no greater care in storage than do panchromatic materials, they should be kept cool and dry. Certain types of the plates which are used only for spectrographic studies and are sensitive in the far infrared should be kept in an icebox or refrigerator at about 50°F (10°C). If plates and films are kept cool in this manner, they should be removed about 15 hours to come to room temperature before the box is unsealed. Otherwise, moisture condensation could causesmears and mottle.

For the exposed films, if it is not possible to develop the film right away, the holders should be stored overnight or longer in a refrigerator. They must not be opened until they have had about an hour to warm up.

Kodak infrared films and plates must be handled and developed in total darkness or only with the aid of a Kodak Safelight Filter, Wratten-Series 7 (infrared), used in a suitable safelight lamp with a 15-watt bulb, at a distance of not less than 4 feet from the film of plate. Other Kodak Safelight filters cannot be used with infrared--sensitive materials, because they transmit infrared radiation which rapidly fogs the film or plate.

No safelight can be used with Kodak High Speed Infrared Film because the film may be fogged by such radiation.

2.3 Cameras

Cameras for infrared photography by infrared do not differ in any essential principle from those for ordinary photography. There are a few precautions which must be observed to ensure satisfactory operation. They are concerned with the bellows, the dark slides, the shutter and the lens.

The camera bellow must not transmit any radiation to which the film responds; otherwise the negative will be fogged when the draw slide is withdrawn. The bellows used on most cameras made at present are quite opaque to the infrared. The leak of infrared radiation may be checked by uncovering a film in the camera cover, and then the lens with a metal cap moves a strong tungsten light around the bellow for about a minute. Any density that occurs on the developed film is due to an unsafe bellows, or camera body provided the shutter and film holder which have been ruled out.

If the shutter and film holder are also suspected, remove the lens cap, then place the strong tungsten light over the lens about a minute, the density of the developed film is due to the unsafe shutter. The film holder can be tested by the same method.

Material holders and slides made of metal are perfectly safe for use with infrared films, and the metal shutter blades are also entirely satisfactory.

2.3.1 Lenses and Focussing[1]

In the early days of photography the materials used were sensitive only in the blue, violet, and ultraviolet, and photographic lenses were so designed that, when they were focussed visually, they were also in focus for black-and-white photography. When panchromatic plates and films became available, a different correction was necessary, because the sensitivity was no longer confined to the short wavelengths. This correction is of minor importance for ordinary photography, but is of significance for cinematography where it is important to have exceedingly sharp focus, and particularly in cases where materials

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[1] - Massopust, Leo C., Infrared Photography in medicine, p.p88.
Clark, W., Loc.cit., pp. 14-18.

are used which are very sensitive to the red, as described on CHAPTER I.

As the wavelength departs from that for which the lens is corrected, the focus for it deviates further from the correct focus. In the case of the infrared, this difference of focus may be considerable enough to give out-of-focus pictures, when sharp results would be obtained with panchromatic plates and films. Lenses differ in their infrared focus, and it is not possible to draw any general conclusions as to the change in the bellows extension which must be made after focusing visually on the ground glass or by scale. In all cases where a correction is required for the infrared, the lens must racked[1] out for a distance slightly longer than that necessary for good panchromatic. This is equivalent to focussing on a nearer object. The correction is usually small, in most cases much less than one per cent of the focal length, for example, ½ per cent.[2] In fact, in a large series of modern lenses tested, the maximum correction was one half of one per cent and in most cases it did not exceed 0.35 per cent.

For the modern cameras with high optical quality, usually have the infrared focussing mark, such as, the Ektar group for the Ektar camera, ASAHI PENTAX SPOTMATIC, RICOH SINGLEX, OLYMPUS PEN FT, etc.

The "Data Book on Kodak Lenses"[3] gives the infrared focus corrections for a large group of lenses, as shown in the following table:-

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1 - Clark, W., op.cit., pp. 14-15.

2 - Kodak Co., Medical Infrared Photography, pp. 31-32.

3 - Clark, W., op.cit., pp. 15-16

TABLE 2.2

Infrared Focusing

(From "Data Book on Kodak Lenses")

No.	Camera type.	Focussing Correction.
1	Kodak Anastigmat Special f/13.5, 50 mm. (as used on Kodak 35)	Turn focusingscale counter clockwise by 0.25 in*
2	Kodak Anastigmat f/14.5, 51 mm., and f/15.6, 50 mm. (as used and Kodak 35)	" " " 0.17 in*
3	Kodak Anastigmat Special f/14.5 47 mm. (as used on Kodak Bantam)	" " " 0.15 in*
4	Kodak Anastigmat Special f/14.5, 100 mm., 101 mm., and 127 mm.	" " " 0.16 in*
5	Eastman Ektars f/16.3, 8.5 in	Extend lens after visual focus by 0.008 in (0.2mm.)
	" " f/16.3, 10 in	" " " 0.012 in (0.3 mm.)
	" " f/16.3, 12 in	" " " 0.016 in (0.4 mm.)
	" " f/16.3, 14 in	" " " o.031 in (0.8 mm.)
6 and etc.	No. 70 Kodak Anastigmat f/17.7,8 in	" " " 0.016 in

* This correction from the visual focus represents a working average for all

These corrections were derived by taking series of photographs and judging the setting for best focus on infrared and panchromatic film.

If critical work is being done and the shift of focus in the infrared is not know, it is best to calibrate the lens by actually making photographs. Series of exposures should be made of objects at various distances, starting with the position of correct visual focus, or that indicated by the focussing scale. The other photographs in each series should be made by increasing the bellows extension slightly beyond that necessary for correct visual focus.

Some help is obtained if the picture is focussed on the ground glass with a red filter on the lens. This reduces the brightness of the image on the glass, and so focussing is very difficult. This method is quite satisfactory for occasions when the films used are sensitive only in the near infrared, as is usually the case for landscapes and medical infrared photography, and when the lenses are of relatively short focus.

For the most exacting work, ions especially designed to give sharp focus in the infrared when they are in sharp visual focus are used. These are available from a number of manufacturers from whom information concerning them may be obtained.

Apochromatic[1] lenses should perform better in infrared photography than any other type, if the exposure is to be made at the visual focus with out correction. They are usually of low aperture and of long focus and so they are of little interest for the ordinary photographer. They should be satisfactory for photo-engraving work, however, since low apertures are generally employed for this.

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1 - Purves, Federick, op.cit., p. 40.

2.4 Filters[1]

Filters are used in photogr phy to modify the light falling on the subject or passing through the camera lens. Thus we have camera filters which are colored discs of glass or gelatin placed on the lens, and lamp filters which are placed in front of light source. Filters actually stop some of the light falling on them, so that the color or nature of the light which pass through is changed. There are many classes[2] of filters, the writer should like to exclude the classification.

2.4.1 Filters for Infrared sensitive materials

The sensitivity of Kodak infrared--sensitive materials are shown in Fig. 2.2. It should be noted that these materials are sensitive not only in the extremely red and the infrared regions of the spectrum but also in the blue region. With infrared--sensitive materials; it is, therefore, necessary to use over the lens a deep orange or red filter to absorb blue light and thus allow the picture to be made entirely by infrared radiation. The following filters is recommended:-

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1 - Purves, Frederick, op.cit., pp. 454-455.

- Boucher, Paul E., op.cit., pp. 150-170.

- Walls, H.J., op.cit., pp. 145-166.

2 - Newcombe, H.S., 35 mm., op.cit., pp. 94-108.

- Kodak Co., Kodak Plates And Films, p. 340.

TABLE 2.2*

Filters for Infrared Photography

Manufacturer	Name and Number of Filter	Wavelength beyond which Filter Transmits (in Å)
Eastman Kodak Co.	Wratten 23 A	5,400
Kodak, Ltd.	" 25	6,000
(Wratten filters)	29	6,200
	70	6,700
	89	6,800
	89 A	7,000
	88	7,200
	88 A	7,400
	87	7,700
	Special, Eaten 5233	about 9,200
Agfa Co.	Agfa 42	6,000
	" 83	7,250
	" 84	7,500
	" 85	8,300
	" 87	8,400
	" 89	about 9,300
Ilford, Ltd.	201	5,600
	202	5,800
	204	6,000
	205	6,300
	206	6,600
	207	7,600
	207 + 212	7,800

Manufacturer	Name and Number of Filter	Wavelength beyond which Filter Transmits (in A)
Carl Zeiss	Infrared (Combina - tion of Schott glasses RG 5 and BG 3)	7,500

* W. Clark, Photography by infrared p. 20

The following figures are the wedge spectrograms of the infrared filters.

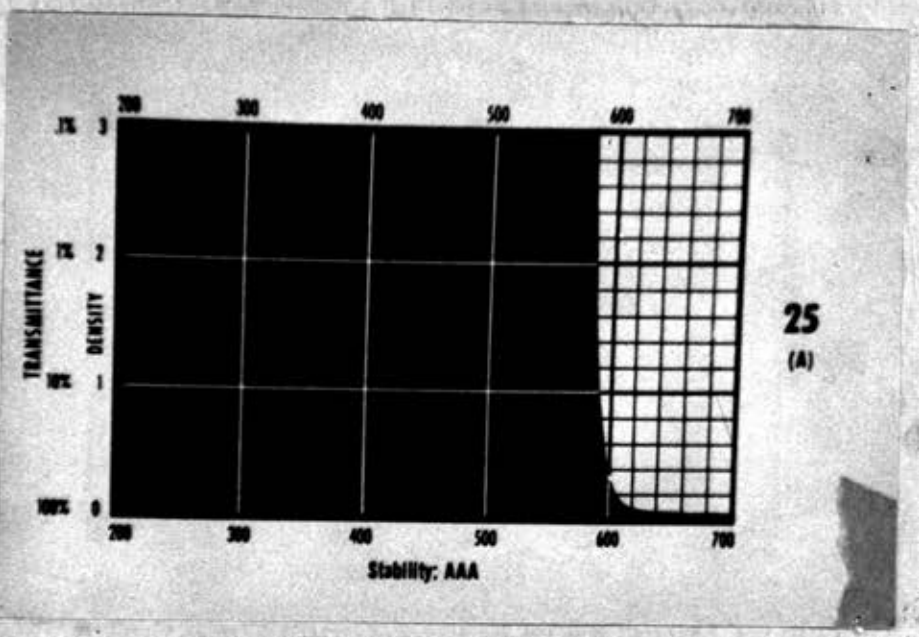

Fig 2.7 Spectrogram of Kodak filter No.25 (A)

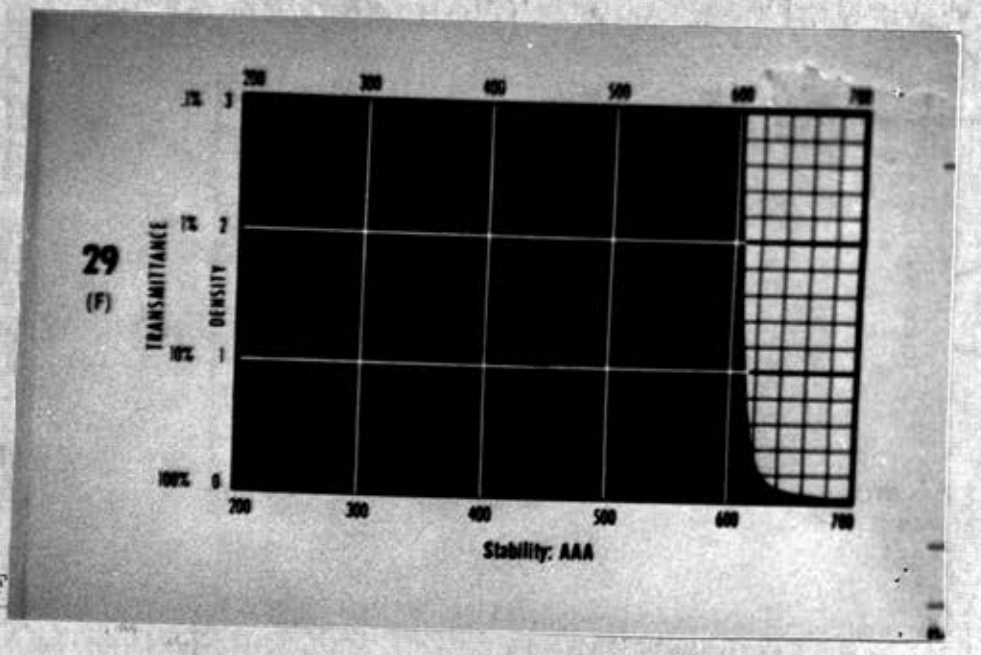

Fig 2.8 Spectrogram of Kodak Filter No.29 (F)

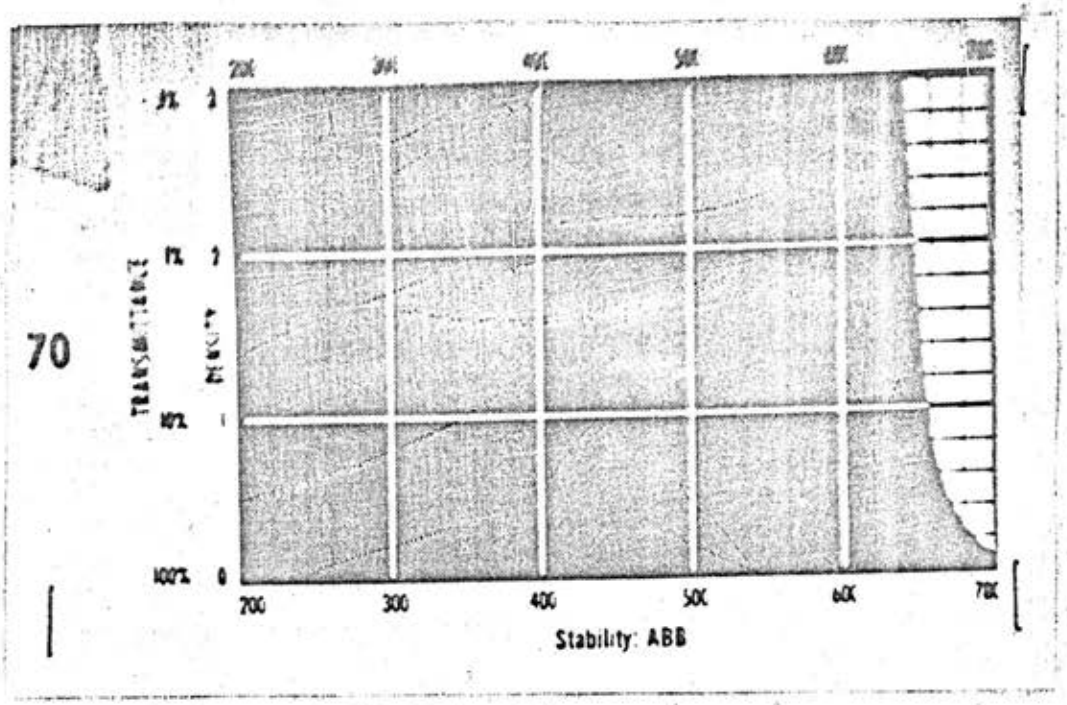

Fig.2.9 Spectrogram of Kodak Filter No.70

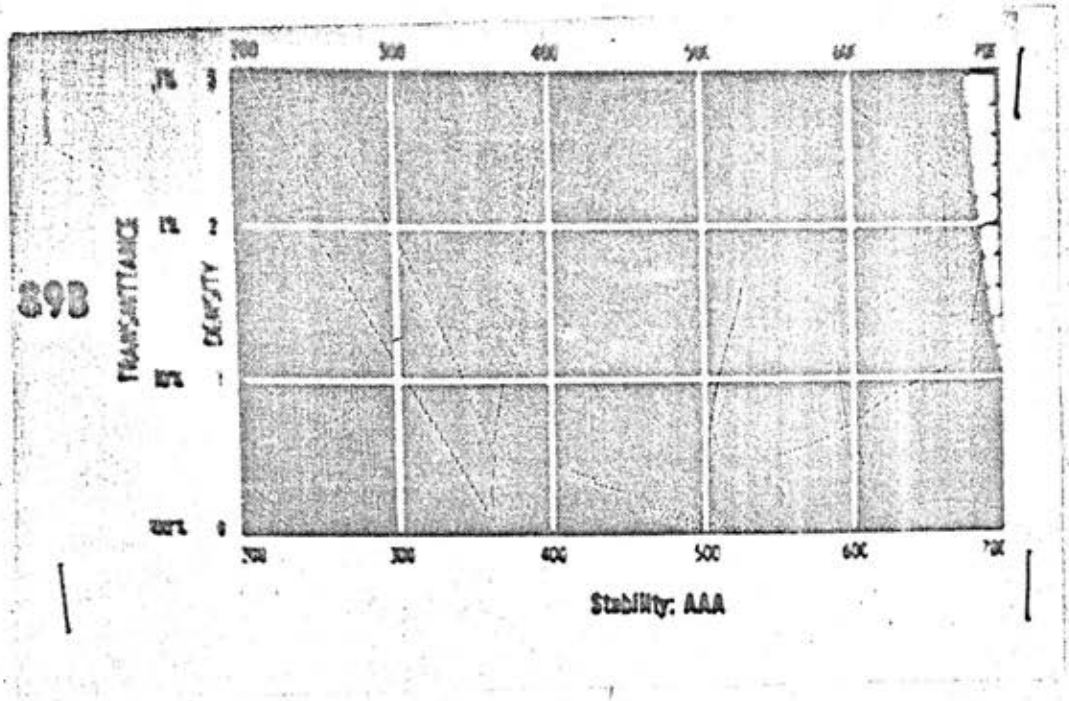

Fig.2.10 Spectrogram of Kodak Filter No.89B

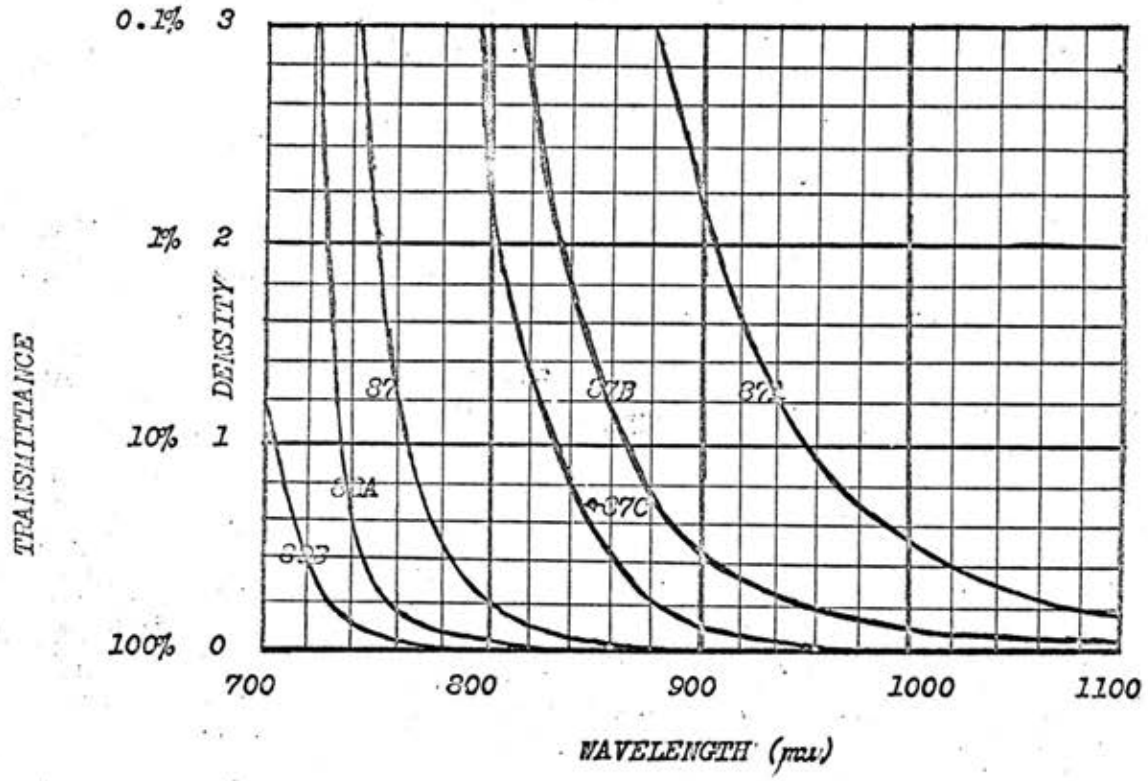

Fig 2.* The Infrared Absorption Curves of the Kodak Wratten Filter No. 89 B, No.88A, No.87, No.87 C., No.87 B and No.87 A

* From the Kodak Wratten Filters, B - 3 pp. 31 - 71

TABLE 2.4*

WAVE LENGTH	PERCENT TRANSMITTANCE No.87	No.87A	No.87B	No.87C	No.88A	No.89B
700	-	-	-	-	-	11.2
10	-	-	-	-	-	32.4
20	-	-	-	-	-	57.6
30	-	-	-	-	3.16	69.1
40	0.10	-	-	-	19.0	77.6
50	2.37	-	-	-	37.8	83.1
60	8.82	-	-	-	55.2	85.0
70	21.0	-	-	-	69.5	86.1
80	36.2	-	-	-	78.4	87.0
90	52.0	-	-	-	81.5	87.7
800	63.8	-	-	0.32	82.6	88.1
10	72.2	-	-	3.20	83.0	88.4
20	78.0	-	0.10	8.90	83.8	88.6
30	82.2	-	0.60	17.8	84.5	88.8
40	84.5	-	1.86	28.2	85.0	89.0
50	86.2	-	4.07	41.0	85.4	89.2
60	87.7	-	7.58	53.8	85.8	89.4
70	88.7	-	12.7	61.6	86.2	89.6
80	89.5	0.10	18.0	69.2	86.5	89.8
90	90.0	0.28	24.5	74.1	86.8	89.9
900	90.4	0.73	31.2	78.5	87.0	90.0
10	90.6	1.55	38.0	81.5	87.2	90.1
20	90.8	2.95	44.1	83.6	87.4	90.2
30	91.0	4.89	49.5	85.1	87.5	90.3
40	91.1	7.33	53.7	86.0	87.6	90.4
50	91.2	10.2	58.2	87.0	87.7	90.5
60	-	14.0	61.7	-	-	-
70	-	17.8	64.6	-	-	-
80	-	21.8	67.6	-	-	-
90	-	26.3	70.0	-	-	-
1000	-	30.2	73.3	-	-	-
10	-	33.8	75.8	-	-	-
20	-	38.0	78.5	-	-	-
30	-	42.1	80.2	-	-	-
40	-	46.7	82.2	-	-	-
50	-	50.6	84.1	-	-	-
60	-	54.3	87.2	-	-	-
70	-	58.3	88.1	-	-	-
80	-	60.9	88.2	-	-	-
90	-	63.1	89.1	-	-	-
1100	-	64.5	89.1	-	-	-

* From the Kodak Wratten Filtess Data Sheet, B-3, pp.70

2.5 Practical Selection of Sources for Infrared Photography

The Selection of infrared sources depend on the purpose of recording. Some applications, must record the reflected infrared radiation or the transmitted infrared radiation. Therefore, the photographer must be careful about selection of infrared sources.

As a convenience for the practical photographer, the following TABLE 2.5 is the types of infrared source most suited to the various applications of infrared photography.

TABLE 2.5

INFRARED SOURCES[1]

1. General Photography:-

.Sunlight,

Tungsten--filament lamps of high efficiency:- lamps of 500 watts and higher, Photoflood and movieflood lamps; projector type lamps; all of tungsten-filament studio lamps.

Carbon arcs: flame, neutral--cored, and plain arcs, all types of studio and projection arc.

Photoflash and superflash types of lamps.

Kodatron Speedlamp.

2. Cinematography:-

Sunlight,

All types of tungsten---filament and arc lamps normally used for studio work.

3. Medical Photography:-

All the sources grouped under "General Photography".

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[1] - Clark, W., loc.cit., pp. 172-173.

4. Photomicrography:-

Tungsten--filament lamps as used in normal photomicrography, especially the ribbon-filament lamps.

Carbon-arc lamps,

Enclosed metallic arcs, especially the Pointolite and tungs-arc type of tungsten arc,

Mercury capillary lamps.

5. Documentary, Graphic Art, Criminology, Scientific Record Photography:

All the sources grouped under "General Photography".

6. Spectrography, Radiation Measurement:-

Any source of continuous or discontinuous radiation selected according to the purpose.