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CONTENTS:

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PRICE FIVE SHILLINGS NET

Television at the 1933 Berlin Radio Exhibition

By ERNEST H. TRAUB (Fellow)

SUMMARY

The exhibits of Fernseh, A.G., Tekade, Telefunken, Loewe, Mihaly, German Post Office, Heinrich Hertz Institute, and von Ardenne, are reviewed. A new intermediate film type of large screen projector receiver is described, in which the television image is photographed on to a film which is quickly developed and printed, and the film copy passed through a standard cinema projector, and thus thrown on to a large screen. Details are also given of a new type of spot light transmitter in which the subject is totally enclosed in a tube of which the walls are painted zinc white, having a high reflecting factor, and thus giving improved efficiency over the standard type of transmitter. A new light valve of Okolicsanyi is described which is considered to be the greatest advance in light valves for many years.

Mention is furthermore made of 3 cathode ray systems, that of Fernseh A. G., Telefunken, and Loewe. The results on the last named were excellent, although the physical and electrical dimensions of these receivers make them unsuitable for home use. An interesting multi-channel system was shown by Professor Karolus in which the picture impulses are transmitted by four separate channels. A remarkable feature of this system is that at the receiver a quadruple Kerr cell is used with only a single arc lamp.

A new mechanical receiver, invented by Mihaly, and employing a stationary scanning unit, namely, a mirror drum in conjunction with one single tiny rotating mirror, is described. The advantage of this system is the extremely low power needed for the synchronisation of the receiver, only a small fraction of a watt being necessary, thus synchronism is fully automatic.

The German Post Office illustrated Cathode Ray Tube reception of television, the results of which were somewhat inferior to the commercial systems. Manfred von Ardenne demonstrated the variable velocity system of Cathode Ray television, in which the modulation of the image is effected by varying the scanning speed. In this system the intensity of the image is about ten times that of ordinary Cathode Ray Systems.

A picture standard is being set up of 180 lines and 25 pictures per second, using ultra-short-waves of the order of 7 metres. The range of the German transmitter is about 100 miles.

The German Government are highly interested in aiding Television development, and will do their utmost to persuade manufacturers to place sets on the market as soon as technically possible.

Concluding, it is stated that although one particular Cathode Ray Receiver gave very admirable results, mechanical receivers are at the present moment the only ones simple and cheap enought to introduce into the home.

FIG. 1

I WILL first of all give a short retrospection of television development in Germany during the last five years.

1928.

The first appearance of Television in 1928 caused somewhat of a sensation. Mihaly showed a simple disc receiver and Karolus a more ambitious mirror drum projector. The results were disappointing for experts and public alike, as the standard of reproduction was extremely poor.

1929.

Considerable progress was evident on the previous year. 30-line radio transmissions had been started. The State (represented by the Post Office) joined in the research work, as well as the then newly-formed Fernseh A.G. Thus the number of television exhibitors was increased to four. Most stands showed 30-line images, but Karolus showed 48. An interesting feature, which has unfortunately not been further developed, was a two-way television telephone.

1930.

Karolus-Telefunken dropped out. Progress was not very remarkable. Fernseh A.G. showed a receiver for 67 lines and a small mirror drum receiver for home use.

TRANSMITTERS.

Firms.	FERNSEH, A.G.			TEKADE.		TELEFUNKEN.		LOEWE.	MIHALY	R.P.Z.			H.H.I.	v.ARDENNE
Exhibit No.	*a*	*b*	*c*	*a*	*b*	*a*	*b*	*a*	*a*	*a*	*b*	*c*	*a*	*a*
Type ...	Tele. Talkie	Tele. Talkie	Spot Light	Tele. Talkie		Tele. Talkie	Tele. Talkie	Tele. Talkie	7 Metre U.S.W. Transmission	7 Metre U.S.W. Transmission.	Tele. Talkie	Tele. Talkie	7 Metre U.S.W. Transmission and TEKADE Transmission.	Tele. ciné
Scanner ...	disc	disc	disc	disc		disc	Drum Mirror	disc			disc	disc		Cathode Ray Tube
Lines ...	120	180	90	90		180	96	180			180	180		80
Points ...	19200	43,200	6000	10800		43,200	12000	43,200			43,200	43,200		8750
Images/p./sec.	25	25	25	25		25	25	25			25	25		20—25
Ratio ...	3 : 4	3 : 4	4 : 3	3 : 4		3 : 4	3 : 4	3 : 4			3 : 4	3 : 4		3 : 4
$F_{max.}$ cycles	240,000	540,000	76,000	135,000		540,000	150,000	540,000			540,000	540,000		109,000
Amplifier ...	S.L.F.	8.L.F.	L.F.	7 L.F.		H.F.	H.F.	4 direct			—	H.F.		L.F.
Trans. Channel	wire	wire	wire	wire		wire	4 wires	wire	radio	radio	wire	wire		wire
				Also 7 Metre Transmission.	Also 7 Metre Transmission.									

RECEIVERS.

	FERNSEH, A.G. a	FERNSEH, A.G. b	FERNSEH, A.G. c	TEKADE. a	TEKADE. b	TELEFUNKEN. a	TELEFUNKEN. b	LOEWE. a	MIHALY a	R.P.Z. a	R.P.Z. b	R.P.Z. c	H.H.I. a	v.ARDENNE a
Scanner ...	disc	Cathode Ray Tube	Mirror Screw	Mirror Screw	Mirror Screw	Cathode Ray Tube	Mirror Drum	Cathode Ray Tube	Mirror Ring	Cathode Ray Tube	Cathode Ray Tube	Cathode Ray Tube	Mirror Screw	Cathode Ray Tube
Light Source	Kerr Cell		Sodium Lamp	Neon Lamp	Neon Lamp		Karolus Cell		Neon Argon L.				Mercury Lamp	
Lines ...	120	180	90	90	90	180	96	180	90	90	180	180	90	80
Points ...	19200	43,200	6000	10800	10800	43,200	12000	43,200	10,800	10,800	43,200	43,200	10,800	8750
Images/p./sec.	25	25	25	25	25	25	25	25	25	25	25	25	25	20—25
Ratio ...	3 : 4	3 : 4	4 : 3	3 : 4	3 : 4	3 : 4	3 : 4	3 : 4	3 : 4	3 : 4	3 : 4	3 : 4	3 : 4	3 : 4
Image Size	6ft. x 8ft.	4½ x 6in.	6in. x 4½	4½ x 6in.	7½ x 10in.	5in. x 7in.	3ft. x 4ft.	6in. x 8in.	4½in. x 6in.	3in. x 4in.	3in. x 4in.	6in. x 8in.	4½in. x 6in.	up to 12x16in.
Colour ...	white	white	pale yellow	pink	pink	yellowish green	white	white	strong pink	pale green	yellow green	yellow	pale blue	pale blue
Detail ...	fair	excellent	excellent	v. good	v. good	v. good	v. good	excellent	good	good	v. good	good	v. good	good
Intensity ...	v. bright	v. bright	v. bright	bright	bright	v. bright	good	v. bright	fair	bright	bright	bright	extremely bright	extremely bright
Flicker ...	none	none	none	none	none	slight	none	none	none	none	none	none	slight	considerable
Synchronising	mains	wire	mains	mains	mains	wire	mains	wire	picture impulse	generated impulses	wire	wire	mains	wire

1931.

This show was one of the most important from the point of view of television progress from the following angles:—

(1) It had been recognised that an increase in image detail and brightness was essential. The receiver of the Fernseh A.G., using a sodium lamp and giving a 90-line picture, represented an important step in this direction. This was by far the best television image that had yet been shown in public.

(2) It had been realised that an image giving reasonable entertainment value (90 lines or more) could only be transmitted on ultra-short waves. Telefunken showed a small ultra short wave 7-metre transmitter and receiver.

(3) That year, von Ardenne gave the first public demonstration of cathode ray television.

(4) First public appearance of the mirror screw.

1932.

Last year's show is probably still fresh in the minds of most members. It marked a further step forward, mainly due to the inauguration of the 7-metre television transmitter working on the new 90-line standard. The number of exhibitors increased from four to six. Progress showed that a basis for commercial television had been attained.

1933.

GENERAL.

As you are aware, the political situation in Germany has changed very drastically during the last year. The new political regime has had a very marked influence on the show in general, as well as the television section. One may well speak of "Television in the sign of the Swastika." (*Fig. 1*). We are, however, here not concerned with the political side of television, but with technical progress. I shall, therefore, submit for your consideration a detailed technical description, and refer you to the table of exhibits in conjunction with the description.

FERNSEH, A.G.

The intermediate film transmitter described last year has been further developed. The latest model was *not* actually shown at the Show, but I think a description would nevertheless be of interest.

It will be recalled that the ordinary intermediate film transmitter described last year worked on the lines of *Fig. 2*. The film contained in the spool (1) is exposed to the scene by a camera (2). Thence it is passed through a quick developing and fixing bath (3), passed through a television transmitter (4), and rolled up on spool (5). The time taken between the photographing of the scene and the televising of the film was about 15 seconds. It has been found that this type of

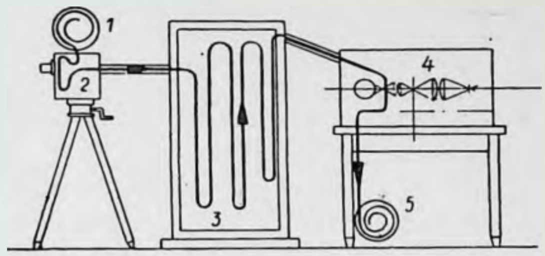


FIG. 2—Intermediate film transmitter.
[*By courtesy of Fernsehen und Tonfilm*

transmitter is too expensive in running costs. The film costs about £45 per hour. In order to reduce these high running costs a new system was developed wherein a continuous loop of blank film is used. Referring to *Fig. 3*, the blank film is passed through a chamber (1), in which the emulsion is automatically poured on to the film, and is then hardened and dried in tank (2). Now the film is exposed as before, quickly developed and fixed in hypo in tank (4), and televised in transmitter (5). From here, instead of being rolled on to a spool, the film is washed and the emulsion removed in tank (6). Thence the film is dried in hot air in tank (7), and is now ready again to receive a new emulsion. Thus, using a short continuous loop of film, the film costs per hour are reduced to about £2. The results are just as good as when using the ordinary system, and the time lag is no greater than before.

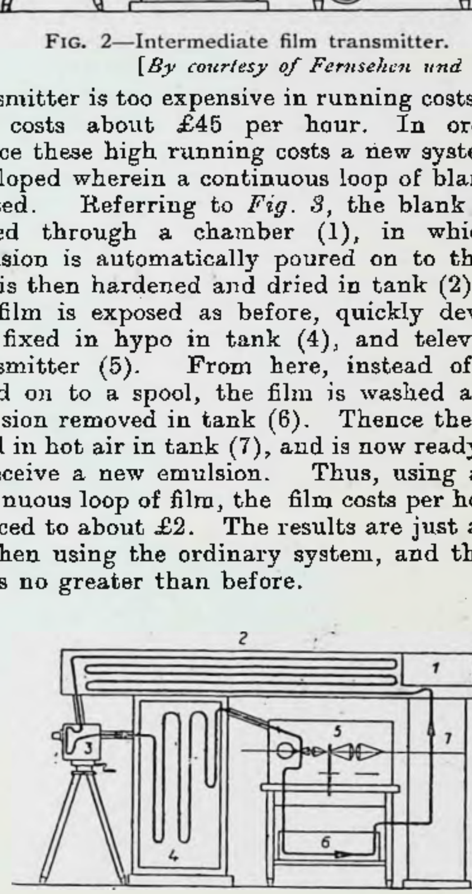


FIG. 3—Continuous intermediate film transmitter
[*By courtesy of Fernsehen und Tonfilm*

Lack of sufficient space made it impossible to show this type of transmitter at the exhibition, but a new type of large screen projection receiver using the same principle was demonstrated. The television impulses are received by an amplifier giving negative image output. The impulses are fed to a Kerr cell of special construction. A 120 hole disc is used for picture composition. The resultant 120-line image is photographed on to a continuous loop of film. The film is developed and fixed in negative, thus giving a positive copy. The positive is passed through a standard cinema projector and thrown on to a screen about 6 feet by 8 feet. After projection, the film is passed through a bath in which the emulsion is removed, then through an electrically heated drying tank, and then re-emulsioned. The film is now ready to photograph a new television image, and the process begins anew. The complete receiver equipment is shown in *Fig. 4*. Mechanically it is one of the most interesting examples of television engineering I have ever seen. The system is technically highly interesting, but the results were photographically "thin," denoting under-exposure or under-development of the film. The time of exposure per element using 120 lines is only one five hundred thousandth ($\frac{1}{500000}$) of a second. Unfortunately splashes and bubbles sometimes appeared on the film, due to insufficient wiping. The defects of the system at present are, therefore, mainly chemical. It should be pointed out that only three months' research work had been done on it, and with more time I feel sure that the results should become well-nigh perfect. For big screen projection, the system is well nigh ideal, as the usual light inefficiency is entirely overcome.

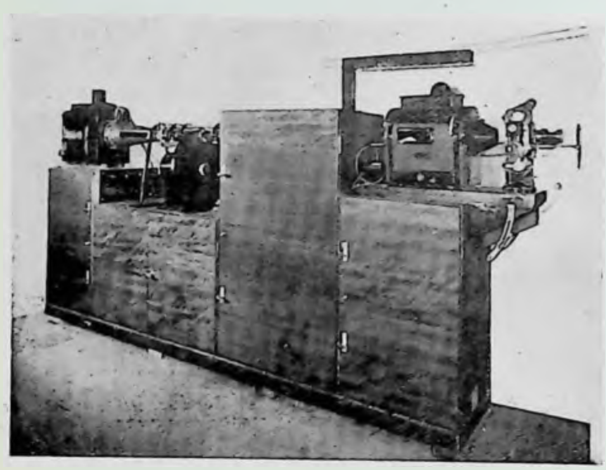


FIG. 4—Fernseh, A.G. continuous intermediate film receiver.

On an adjacent stand, a 180-line cathode ray receiver was shown working off a film transmitter behind the scenes. The 180-line transmitter (*Fig. 5*) used a 45-hole disc running at 6,000 r.p.m. in vacuum, a pump being permanently attached to maintain the vacuum. The synchronising impulses were generated by slits in the same disc.

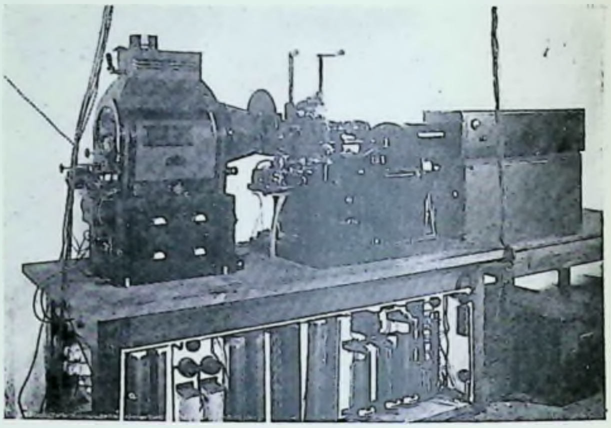


FIG. 5.—Fernseh, A.G. 180 line cinema transmitter

The cathode ray receiver itself gave a very pleasing black and white image, but due to slight overlapping of scanning strips, did not give the amount of detail one might expect from 180 lines. The image size was a little too small for a home receiver, but the length of the tube was almost three feet. No details of the tube are available.

This firm also showed an improved type of mirror screw, which gave an image from an adjacent spot-light transmitter.

The transmitter was a new type, in which the object to be transmitted is placed in a totally enclosed cube, the inner walls of which are painted zinc-white, having a high reflecting factor. With this novel arrangement, the light reflected on to the photo-cells is about three times the amount in an ordinary spot-light transmitter. Moreover, three-dimensial and shadow effects are accurately rendered.

The mirror screw was of the so-called concave mirror-type. That is, the reflecting edges of the laminations were each filed at a slightly staggered angle at each end of the screw, thus giving the same optical effect as if a concave cylindrical lens were used. The new arrangement dispenses with that lens, and permits a much shorter light source. A sodium lamp was used, and the images were very bright and the details excellent.

TEKADE.

Two 90-line mirror screw receivers (*Fig. 6*) were shown working off the same transmitter. At times the 7-metre transmissions were also picked up. Although the same number of lines was used as last year, improvement in picture quality was very noticeable. This improvement is due to several factors:—

1. The pictures were clearer, due to a new method of adjusting the laminations.
2. Images visible from all directions, due to improved optical system.
3. Light source built in casing, which is attached to the wall of the room.
4. The receiver is ready for operation in 10 seconds, due to multi-point switch.
5. Easy phase adjustment by a knob.
6. Quick change of mirror screws to higher numbers of lines, as the axis of the motor is conical.
7. No motor noise, due to triple damping.

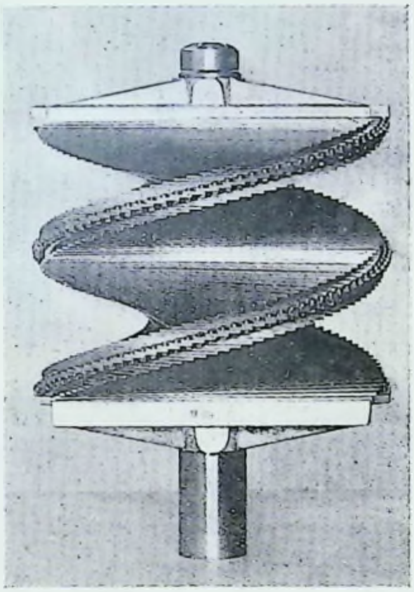


FIG. 6—Latest type 90 line mirror screw

As regards image detail, these images were the best 90-line images I have ever seen. Even small sub-titles on films were legible, which was not the case with several cathode-ray tubes using 180 lines. This is due to the unavoidable fact that the picture spot on the cathode ray tube is round, instead of square. Thus a mechnical receiver will always give about 30 per cent. better definition than a cathode ray one, when both are using the same number of lines.

The Tekade also showed but did not publicly demonstrate an entirely new type of light valve. This new invention is of very considerable importance, and I think it is worth while to describe it in detail.

Among the hitherto known light sources, the neon lamp is the commonest. Whilst it has the undoubted advantage that it is easy to modulate, the light efficiency is inadequate for modern television receivers where only a small fraction of the light can be used. Mercury and sodium lamps are brighter and give a more pleasing colour, but the latter fails to follow frequencies over 50,000 cycles. The Kerr cell, on the other hand, gives quite good light although the actual efficiency is poor. It is, moreover, difficult to modulate with ordinary output voltages, and its characteristic is not linear. Thus one never finds true black and white gradation.

The ideal form of light source should have high efficiency, be easy to modulate, give pure white light and have a true linear characteristic. Further it must have absolutely no lag, even at frequencies running into six figures. The prospects for further research in gas discharge lamps seem rather poor, as practically all combinations of gases using both the negative

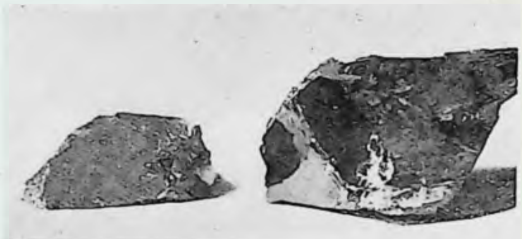


FIG. 7—Natural zinc sulphide crystals

plate and the positive column, have been tried without further success. The more hopeful path lies along the lines of a light valve, such as the Kerr cell, but without the latter's shortcomings.

Working systematically on the lines suggested above, von Okolicsanyi, the well-known Hungarian television inventor, who is also the inventor of the mirror screw scanner, searched for a light valve that would, in addition to the aforementioned properties, fulfil the following demands: namely that it be cheap to produce, easy to handle and needless of attention. This brings us to the conclusion that the substance needed should be a solid with a high Kerr constant and of great durability, in order to avoid the inconvenience and smell of liquids such as nitro-benzol. The solid must be sufficiently hard, but yet be easy to cut and polish. Lastly, the substance must be as clear as water and perfectly transparent.

Okolicsanyi, therefore, continued his search among *inorganic crystals*, and tested many of these for electrical double refraction. This is known to occur to some degree in quartz, tourmalin

FIG. 8—Cut plate of zinc sulphide crystal

and sodium chloride crystals. Electrical double refraction is a secondary effect in which the light is influenced indirectly by the electric field, i.e., through a dielectric. The static field directs the molecules of the crystal, according to the field strength, increasing or decreasing the angle of rotation in the polarized plane in proportion. It

FIG. 9—Multi-plate crystal cell

was found that such an effect was confined to cubic crystals, which could in turn be divided into two groups: the regular rock salt type and the acentric group, in which the final solution of the problem was found, namely the *Zinc Sulphide Crystal*. (*Fig. 7*).

For experimental purposes, a small plate of crystal such as shown in *Fig. 8* was cut and filed. The dimensions of each plate are about 6 by 10 mm., and 1 mm. thick. Several crystal plates

FIG. 10—Complete crystal light valve

were then placed between foils and the tension applied to the two ends. (*Fig. 9*). The crystal was now placed between two crossed Nicol prisms, and set up in a television receiver. To the great joy of the inventor, a perfectly good and bright image appeared, which fulfilled all the demands of an ideal light valve.

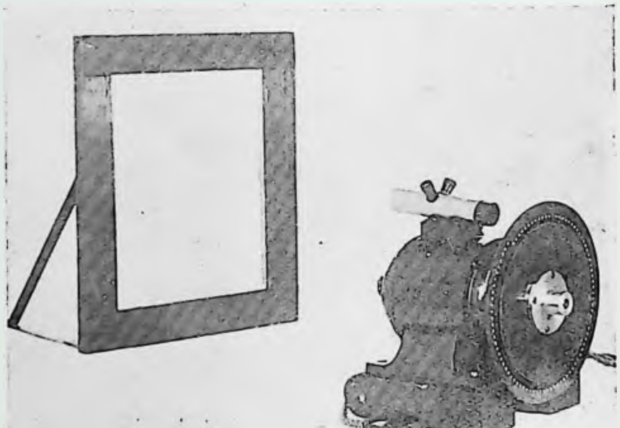


FIG. 11—90 line Nipkow disc projection receiver using crystal cell light valve

For commercial use, the whole light valve is set up in a metal tube about four inches long, which contains the crystal, the two Nicol prisms and two concentrating lenses. (*Fig. 10*). To prove the absolute superiority of the crystal cell, a receiver was constructed using a 90-hole Nipkow disc, which is optically the least efficient of all scanners. (*Fig. 11*). The disc is of only 10 inches diameter, the holes being only one-tenth of a millimetre square. Using only a small 30 watt lamp as light source, an image was *projected* on to a ground glass screen, the size being about *one foot square*.

The advantages of the crystal cell over the ordinary nitro-benzol Kerr cell are as follows:—

1. Solid, therefore no smell.
2. Smaller, thus allowing the whole electro-optical system to be built into a single unit.
3. Better light efficiency due to closer spacing of Nicols and crystal. Efficiency about 35 per cent., compared with 10 per cent.
4. Infinite durability.
5. Perfectly linear characteristic.
6. *Ten times smaller capacity*, therefore only *one-tenth of the power* needed, compared with the nitro-benzol cell. As the cell can be placed directly in the anode circuit of the output valve, only a resistance of 30,000 ohms. is required. (*Fig. 12*). The tension is about 400 volts, thus the power needed can be calculated at about 5 watts. This figure can be obtained with any powerful mains receiver.

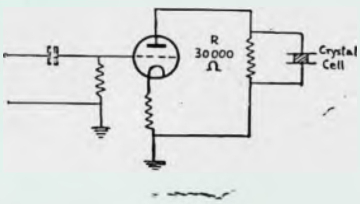


FIG. 12—Circuit of crystal cell output stage

Okolicsanyi has therefore succeeded in finding a light valve that is suitable for any mechanical television receiver where a concentrated source of modulated light is required. This light source is more efficient than any other previously known. It is moreover absolutely without lag. Measurements have been made and it was found that the frequency curve shows no sign of falling off even at 350,000 cycles.

Even if the new cell is ideal for home television receivers from a technical point of view, the price factor still plays an important part. It is, therefore, assuring to know that the price of the complete electro-optical unit is estimated by the inventor to be under £5.

A 180-line mirror screw receiver using the new light valve is at present being constructed, and promises to be the most important development in television for many years.

FIG. 13—Franz von Okolicsany
The inventor of the mirror screw and the crystal cell.

Before closing my description of Tekade, I should like to pay some tribute to the inventor. Okolicsanyi is one of the most brilliant and not less charming men engaged in television research. From his fertile brain we have first had one of the neatest mechanical scanners that have yet appeared. And now a new light valve of hitherto unheard of efficiency. (*Fig. 13*).

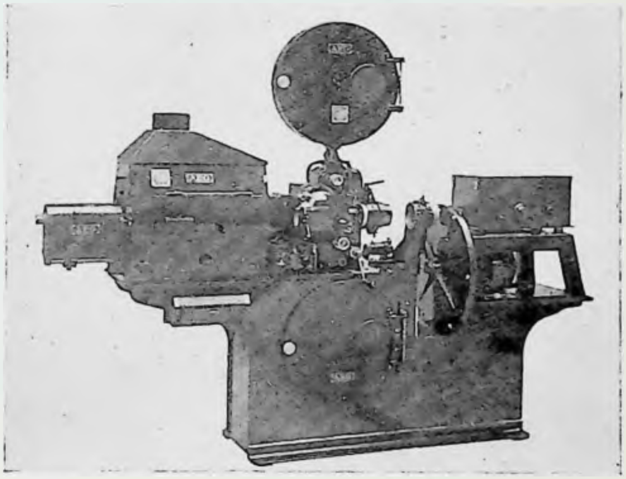


FIG. 14—Telefunken 180 line film transmitter unit

TELEFUNKEN.

180-line demonstrations were given on this stand.

The transmitter (*Fig. 14*) is a particularly fine example of engineering skill. It consists of three portions, all built into a single unit of sturdy construction:—

1. An A.E.G. sound film projector.
2. A 90-hole disc running at 3,000 r.p.m.
3. Photo-cell and associated amplifier stage.

Telefunken favour the carrier-wave type of photo-cell amplifier. An oscillator is coupled with the photo-cell in a bridge circuit (*Fig. 15*), which is so adjusted that no carrier frequency can reach the grid of the first amplifying stage when no light falls on to the photo-cell. When light falls on to the photo-cell, the carrier-wave of the oscillator acts on the grid of the first amplifier valve in proportion to the amount of light falling on to the photo-cell. The advantage of this method is that amplification takes place on a predetermined

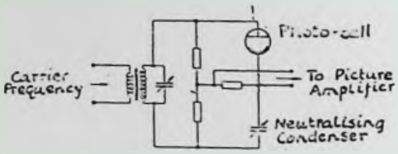


FIG. 15—Amplifier circuits
[*By courtesy of Fernsehen und Tonfilm*

frequency band and thus equal amplification of all frequencies is possible. After the amplifying stages, the carrier-wave is removed by a rectifying stage. (*Fig. 16*).

The 180-line cathode ray receiver gave a bright and fairly well defined image. Considering the high number of lines used, the detail was not quite as good as one might expect. Modulation was good, but strip-effect rather noticeable. The images had, nevertheless, good entertainment value.

The Telefunken cathode ray tube (*Fig. 17*) is remarkable for the wide angle of deflection that is used. The tube is of the gas-filled type and uses an anode voltage of 2,000. Only 20 volts swing is needed on the deflecting plates. The spot concentration is effected by a round metal cylinder which can be seen surrounding the electrodes in the neck of the tube. The screen material, which is of great brightness, though not yet possessing the desired colour, is a phosphor material being developed by Prof. Schleede.

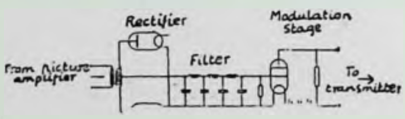


FIG. 16—Amplifier circuits
[*By courtesy of Fernsehen und Tonfilm*

Telefunken have also developed a 5-valve superhet for television and a 7-metre converter. In the complete receiver 12 valves are used in all.

This firm has also developed an improved synchronising method invented by Dr. Schriever, who is Telefunken's chief television engineer. In this new method, the aerial current of the transmitter, when unmodulated, is adjusted to a value about one quarter of the maximum aplitude. The picture impulses are modulated upwards, but the synchronising signals at the end of each line and each image are modulated down to zero as shown in *Fig. 18*. At the receiver, a special discharge circuit is used. This system works absolutely automatically and is independent of the mains supply.

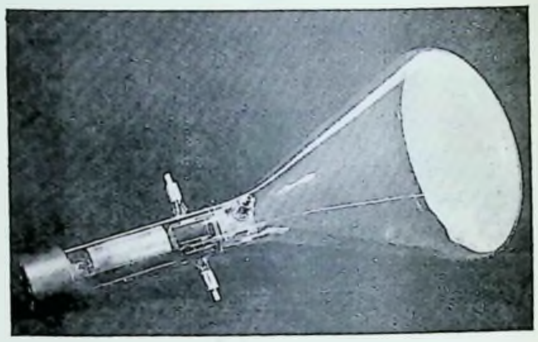


FIG. 17—Telefunken Cathode ray tube

On another stand, the system developed by Prof. Karolus, who works in conjunction with Telefunken, was shown. Whilst the main television laboratory is concerned with producing a television receiver for the home, Prof. Karolus is concentrating on big screen work.

A very interesting new multi-channel system was shown. Four channels, each carrying a 24-line picture signal, were used, thus giving a 96-line image. The Karolus multi-channel system differs from the Baird Zone System in so much that each transmission channel takes care of consecutive picture lines. That is, the first channel transmits the impulses of line Nos. 1, 5,

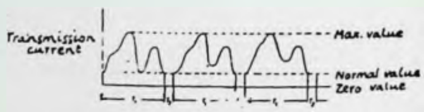


FIG. 18 - Diagram of synchronising signal
[*By courtesy of Fernsehen und Tonfilm*

9, 13, etc., and the second channel Nos. 2, 6, 10, 14, etc. Strangely enough, a mirror drum is used in the film transmitter. The light from the mirror drum is reflected through an optical system on to four photo-cells.

At the receiver, a *single* arc lamp is used in conjunction with a special Karolus multi-cell. (*Fig. 19*). Thus even illumination is obtained throughout the image. Although only a 15

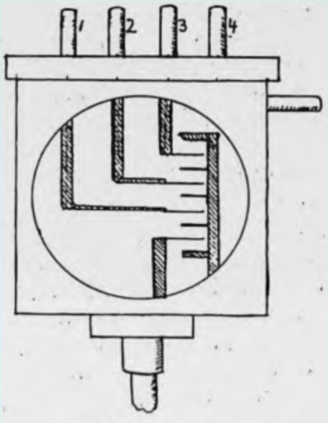


FIG. 19—Karolus multi-cell

ampêre arc lamp was used, the picture brightness was good. Detail and modulation were also very pleasing. The system is capable of further

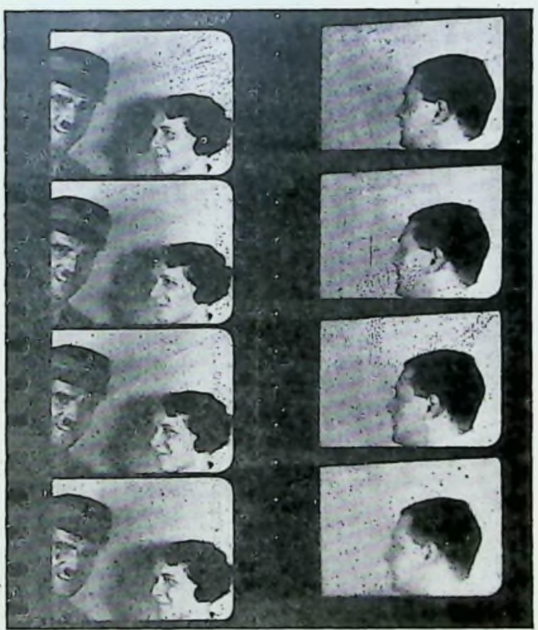


FIG. 20—Strip of intermediate film (positive)

improvement in all directions, the limit having not nearly yet been attained. Prof. Karolus tells me that he intends to show a very much bigger, brighter and still more detailed image next year.

An intermediate film transmitter was also demonstrated. This has been developed by the Agfa concern in conjunction with Prof. Karolus. This transmitter is not of the continuous type, but the film is used for re-showing at later times, if desired. The Fernseh A.G. used special film and special highly poisonous developers in their transmitter last year, but this one uses standard films and standard developers and fixers. The acceleration is obtained by heating the developer to about 65° centigrade.

The transmitter worked extremely well and reliably. The accompanying reproduction of a strip of intermediate film (*Fig. 20*) shows the depth and intensity obtained in 15 seconds. The quality of the film is in no way inferior to ordinary film.

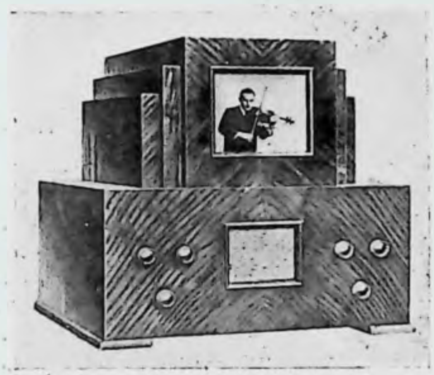


FIG. 21—Leowe 180 line cathode ray and ultra short wave sound receiver

RADIO A.G.D.S. LOEWE.

Loewe demonstrated a 180-line system, using a mechanical transmitter and a cathode ray receiver. I should like to emphasise at once that the Loewe receiver is *far in advance* of anything yet shown in any country, and that this is the only cathode ray receiver that has definitely reached the commercial stage. The transmitter uses a 90-hole disc running at 2,000 r.p.m. in conjunction with a combined chopper disc to generate the synchronising impulses. The amplifier is remarkable for its simplicity and small size. It contains only four valves and makes use of steep sloped high frequency pentodes.

Fig. 21 shows the complete cathode ray receiver containing a superhet for vision, an U.S.W. sound receiver and synchronising and mains units. Loewe have developed a special transmission system, details of which are not available, but the idea seems to be to transmit vision and sound from two transmitters using very close wave lengths. These two signals are tuned in at the receiver by a single receiver and then separated by two detectors. Thus only one tuning control is required for sound and vision. The six control knobs on the panel have the following functions: left side, combined tuning control, volume, and on-off switch; right side, picture brightness, spot sharpness, and framing. Synchronism is fully automatic.

FIG. 22—Loewe cathode ray tube

I am afraid that very few technical details of this system are available. *Fig. 22* shows the cathode ray tube. I cannot give any details beyond the fact that a novel "electrode-optical system" is used for spot concentration, and that spots of only 0·1 mm. have been achieved. The screen material is of very pleasant colour, being almost black and white. Both gas filled and vacuum tubes are used, and it has not yet been decided which type will finally be adopted. The Loewe images were the best in the exhibition, in fact *the nearest approach to a perfect television image that I have yet had the privilege of seeing*! Dr. Schlesinger, who is in charge of Loewe's television laboratory, must be congratulated on having achieved such wonderful results in the short time of only 16 months that he has been with Loewe. Still further improvements, both at the transmitter and at the receiver are at present being conducted. The price of the complete receiver, when finally placed on the market, is said to be *under 400 marks.*

MIHALY (INTERNATIONAL TELEVISION CORPORATION).

An entirely new mechanical system was shown for the first time.

The scanning apparatus is a stationary mirror drum, whose mirrors are attached to the inside instead of on the outside. The modulated beam of light, coming from the modulated light source, is made to pass over the ring of stationary mirrors by a single tiny rotating mirror.

The diagram (*Fig. 23*) shows how the modulated television impulses coming from the transmitter are fed to the neon lamp *AB*, whose modulated light beam is in turn thrown through the lens *C* on to the small, double-sided, rotating mirror *D*. From here the beam is turned on to each of the small mirrors on the inside of the mirror drum. Each of these mirrors is set a little more towards the vertical plane than its predecessor. The beam is now reflected back on to the rotating mirror, and through another lens, *M*, is projected on to the screen *P*, on which the image is built up. The advantages of this extremely simple system are obvious.

The tiny rotating mirror only needs a very small and weak motor, which is no bigger than those used in synchronous electric clocks. As a result of this, the driving and synchronising energy is extremely small, being only *a fraction of a watt* in the case of the latter. The energy can, therefore, be taken from the receiver itself, and thus the television transmitter controls the synchronism of the receiver.

As already mentioned, the mirror drum is stationary and its different mirrors, when once adjusted in the factory, need no further attention. The images thrown on the screen are sufficiently big to be viewed by a number of people from almost any position of the room. Apart from the technical advantages are the constructional ones, as the manufacturing price of this receiver is low.

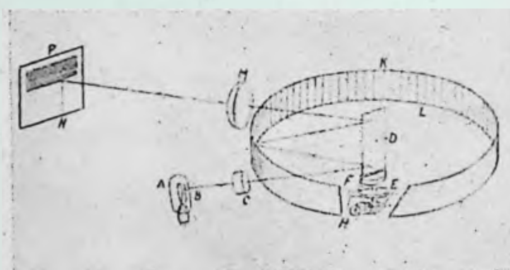


FIG. 23—Diagram of new Mihaly system

At the Berlin Radio Exhibition, this receiver was shown working off the 7-metre television transmitter. The image consisted of 90 lines (10,000 elements), there being 90 mirrors on the drum. In this receiver, the small rotating mirror was silvered on both sides, so that the rotating speed need only be half of the picture speed. The results on the 90-line receiver were pleasing, the detail being about equal to a 9 mm. home cinema outfit. The image size was anything up to about 6 by 8 inches. Synchronism was perfect, the

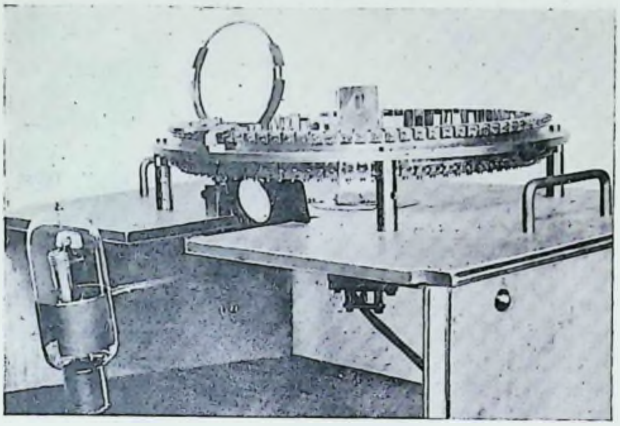


FIG. 24—Chassis of Mihaly receiver

picture being rock steady. This receiver was the only one at the show which relied solely on the picture impulse for synchronism. The internal construction of the receiver can be clearly seen in

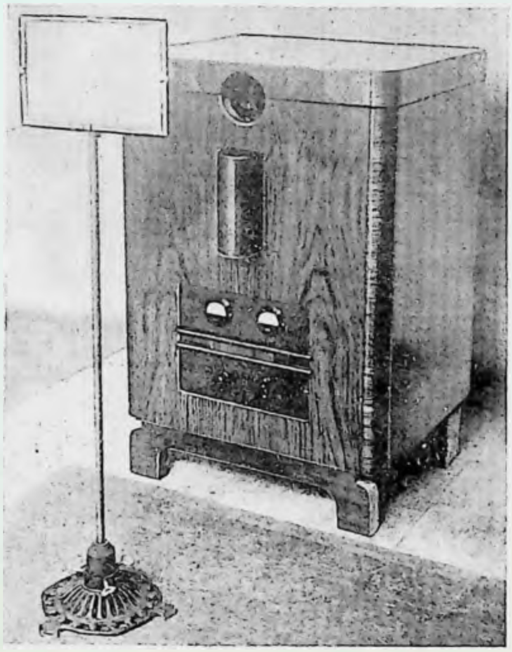


FIG. 25—Complete Mihaly receiver

the illustration. (*Fig. 24*). The complete set contains the actual television portion, together with a 3-valve ultra-short wave receiver for A.C. mains.

A receiver for the new German standard of 180 lines will shortly be put into production. A view of the complete receiver fitted in a radiogram cabinet is shown in *Fig. 25*.

This system has been financed and developed with the aid of an English syndicate, who hope to make this type of receiver available to the British public in due course.

Among the official institutions exhibiting were:—

GERMAN POST OFFICE (R.P.Z.).

Two 180-line cathode ray receivers were shown working. A view of the transmitter is shown in *Fig. 26*. The separate chopper disc can be seen in the front on the left. A new type of amplifier, which is the subject of a patent of Dr. Krawinkel, is used in one transmitter. The electrode construction is new, inasmuch as one deflecting

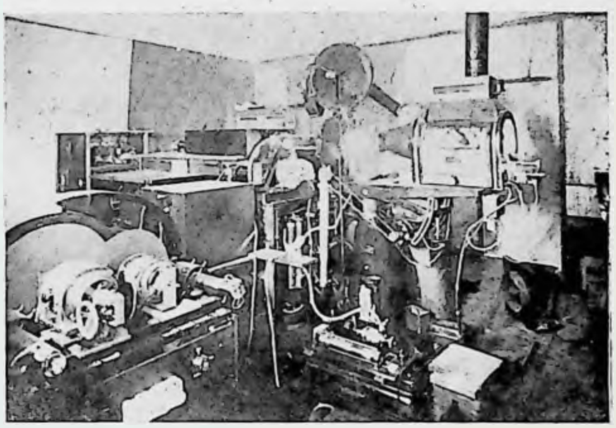


FIG. 26—R.P.Z. 180-line transmitter

plate is split, and the neck of the tube is distorted in such a way that the " ion-cross " falls outside the image. (*Fig. 27*). The results were quite good, but inferior to the commercial systems. The 7-metre transmissions were picked up daily on another cathode ray receiver giving a 90-line image, which, though too small for commercial use, gave quite pleasing and recognisable results.

HEINRICH HERTZ INSTITUTE.

A 90-line mirror screw was shown using a mercury lamp. The lamp has been further improved and simplified since last year and is no longer fed with high frequency. The receiver, which picked up the 7-metre transmission, gave an extremely bright image, but these were not consistent in quality. Modulation was not always good, and the frequency characteristic of the mercury lamp is not perfect, as the images were not so sharp as those obtained by Tekade, using the same mirror screw with a neon lamp. The radio receiver used was a 6-valve superhet.

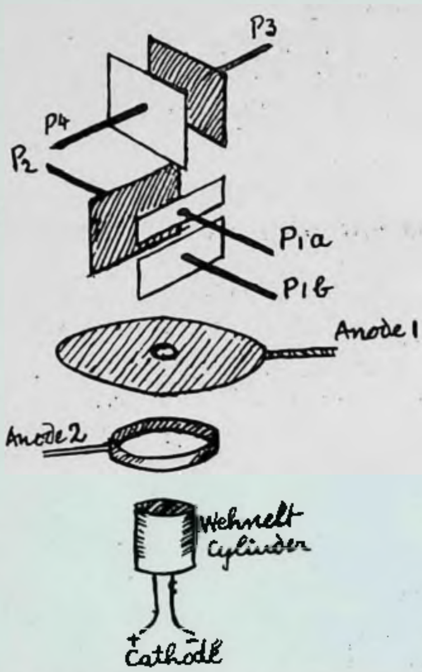


FIG. 27—Electrode construction of R.P.Z. cathode ray tube

MANFRED VON ARDENNE (PRIVATE LABORATORY).

The variable speed system of cathode ray television was demonstrated to the public for the first time. The system has been very fully described in a previous paper of mine,* and I shall not deal with the theoretical side again here.

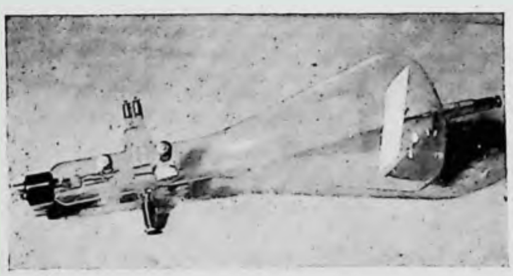


FIG. 28—Von Ardenne's latest cathode ray tube for variable speed television

Von Ardenne has developed some very interesting new tubes (*Fig. 28*) giving three times greater light than before. The fluorescent screen is set at an angle and is viewed from the inside. The tube is of the gas filled type and has a guaranteed life of 500 hours. In practice, considerably longer life is maintained. It is interesting to note here the life estimate of different makes of tubes. Telefunken say "several hundred hours," Loewe guarantee 1,000 hours, though 1,700 hours have been attained. Fernseh A.G. go still further and claim "almost indefinite life."

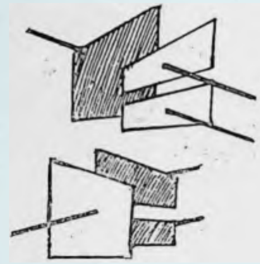


FIG. 29—Split deflecting plates in Von Ardenne's latest tubes

In the Ardenne tube, a second electron acceleration takes place at the actual screen.

A special deflecting system is used (*Fig. 29*), in which, firstly spade-shaped plates correct the distortion due to the angularly placed screen, and secondly split plates correct line distortion when the deflecting current falls below zero.

The images were visible on the screen of the *transmitting tube*, and were also projected on to a silvered screen at the receiver, a lens of F 1 : 1 being used. The images were remarkable for

FIG. 30—Untouched photo of television image

their enormous intensity, but as only 80 lines were used, the detail left much to be desired. Baron von Ardenne pointed out that these demonstrations represented experiments made in his laboratory two years ago, and "for industrial reasons" he could not show the present state of his work. *Fig. 30* shows a photo of the actual image as seen on the transmitting tube.

* "New Television System," E. H. Traub—*Journal of Television Society*, Vol. I., Part VI., Dec., 1932, pp. 177-182.

GERMAN TELEVISION SOCIETY.

A very ambitious amateur built universal 30-line disc receiver was shown consisting of two separate cabinets and costing 1,000 marks. Details of an interesting competition for members of that society have been arranged. Prizes of 600, 250 and 50 marks are offered for the best design of a cathode ray time-base unit consisting of not more than four valves.

CONCLUSION.

The German plans for television during the following year are to standardise *180 lines*, as soon as certain alterations have been made to the transmitter, in order to handle the increased frequency band. A second ultra-short wave transmitter will be built for the sound part of the programme. The new Government are interested in aiding television development and will do their utmost to persuade manufacturers to place sets on the market as soon as they can.

I believe that the limit of picture detail required has been reached at 180 lines. There is absolutely no need to go any further; in fact, any further increase might lead to deterioration in quality. Although cathode ray receivers were dominating in numbers, mechanical receivers are still simpler and cheaper. Also mechanical receivers are capable of giving better detail than the cathode ray ones, when both are working on the same standard.

In conclusion, I have no hesitation in saying that Germany is ahead of all other countries as regards television.

DISCUSSION.

Mr. T. M. C. Lance stated that it was interesting to note that although a 7-metre transmitter is situated close to the Exhibition grounds, only two receivers utilised the television's transmissions radiated from this transmitter. All other Exhibitors had their own transmitters connected to the receivers by wire. Also he queried the price of the Loewe Cathode Ray Receiver, which, in his opinion, could not be sold below £50.

Dr. Rosenfeld has drawn attention to the fact that although Mr. Traub mentioned the names of Okolicsanyi and Wikkenhauser, as inventors of the mirror screw, in his opinion the first patent was issued to Herr Hans Hatzinger of Frankfurt, Patent No. 358411, the patent being assigned to Nationale Telephon and Telegraphenwerke, G.m.b.H.

Mr. Hankey required information as to the number of amateur television workers in Germany, as compared with the number in England.

Mr. Semper: With reference to the notices in the press about linking up U.S.W. transmitters in Germany, could Mr. Traub give some information as to how the land lines are designed to deal with the very wide frequency band involved.

Dr. Hughes asked if the German Show gave some information as to whether (1) direct scanning, or (2) scanning of film processes are gaining ground. In his opinion the scanning of films is more promising, as the whole subject of television is akin to films, and therefore requires similar settings and editing. He also mentioned the new Cathode Ray system being developed in this Country, similar to M. von Ardenne's variable speed scanning, which, in his opinion, gives remarkable results.

Mr. Sherring: With reference to the German Post Office method of split deflecting plates of the Cathode Ray tubes, he asked for more information of the functioning of same. What purpose have the split cathode plates?

Mr. Bridgewater asked for more information about the method of placing one photo cell in specially shaped (parabolic) studios. Mr. Bridgewater wanted some more details about this system, especially about the designing of the studio. Could this system be used for more than 60 lines of scanning?

In reply to Mr. Lance, Mr. Traub stated that it is evident from the table in this report that not two but four receivers picked up the television transmissions from the 7m. transmitter. Most of the exhibitors who preferred to use their own transmitters did so purely because they wished to transmit 180 line transmission, while the ultra wave transmissions were only working on 90 lines.

With regard to the Loewe Cathode Ray Receiver, Mr. Traub said his information was based purely on a figure given by Loewe, although he, personally, is inclined to agree with Mr. Lance that such a set, at any rate in this country, could not be sold below £50.

In reply to Dr. Rosenfeld, Mr. Traub said he was aware of the Hatzinger patent, but the matter was still *sub judice*. (The situation has since been cleared, and it would appear that Hatzinger has no longer any claim on the mirror screws).

Mr. Traub, replying to Mr. Hankey, said that the number of amateur television workers in Germany was practically negligible.

In reply to Mr. Semper, Mr. Traub said that it was not proposed to link up various towns with ultra-short wave transmitters, but at first to start with a regular service from Berlin only, connecting the transmitter with the aerial by a specially screened low capacity cable.

Replying to Dr. Hughes, Mr. Traub stated that direct scanning was only shown by the Fernseh A.G., using a 90 line spot light transmitter. Direct scanning for higher than 90 lines had not yet been transmitted. For very high definition transmissions, the order of 180 lines seemed at the moment that programmes would consist of film transmissions or a studio transmission using an intermediate film.

Mr. Sherring's question was answered to the effect that the splitting of the deflecting spot in the Post Office Cathode Ray tubes was for the purpose of avoiding threshold effect.

In reply to Mr. Bridgewater, Mr. Traub said that the Photo cell in a total enclosed parabolic studio could be placed either in a spot where the light from the object is directly reflected on to it, or it could be placed behind the screen situated behind the object being transmitted, in which case the light falling on the cell would be indirectly and diffusely reflected from the specially treated walls of the studio. In theory, the studio should be of perfectly spherical shape, but in practice the cubic studio will give almost as good results.

What the limit of the area for such a studio is cannot be estimated at present, but it seems that if the area is increased the distance from the walls to the photo cell will be increased and light losses will occur.

The system has, so far, been successfully demonstrated for 90 lines, and it can possibly be used satisfactorily even with 120 lines.

*Ultra Short Waves and their Application to Television**

by R. W. CORKLING, F.P.S (Fellow)

In introducing the subject of ultra short waves as applied to Television, I propose dealing with the subject in a general way, which will, I trust, enable those of you less acquainted with the technique of ultra short wave radio to more readily appreciate the subsequent speakers who will deal specifically with the problems of generating and receiving ultra short waves.

For some time past it has been realised that use would ultimately be made of ultra short waves in order to achieve high definition Television.

Realising that these ultra short waves must be investigated, the subject of their nature and the study of the available technique therefore becomes one of the many stepping stones that ultimately will lead to the final production of unrestricted television.

I know that most of you are fully aware of the reason why we must adopt these ultra short waves, therefore suffice it to say that in order to obtain sufficient detail, the image must be transmitted and received in as many picture elements as possible.

Let us briefly consider the frequency requirements of television as compared with those required for the transmission of sound.

We may presume that the requisite frequency range for sound be 25–10,000, whereas the range for television for the present conditions, transmitted on the normal wave-length, is approx. $12\frac{1}{2}$–13,000.

Now it has been agreed that good Television can be provided with perhaps 180 lines and 25 frames per second, requiring a theoretical maximum frequency of about 450,000 cycles/sec. This theoretical maximum frequency considers the image under the very worst conditions ever met with in practice; that is, the image is of checker-board pattern with the picture element the same size as the light spot. Nevertheless it should be seen that the normal wave-band with a 9 Kc. separation is entirely unsuitable for accommodating higher frequencies of the order that I have quoted as being necessary.

* A Paper presented at a meeting of the Society held on Wed., Nov. 8th, 1933, at University College, London. The subject introduced was "Short Wave Television," and the principal speakers were R. W. Corking, F.P.S., E. C. S. Megaw, B.Sc., D.I.C., E. L. Gardiner, B.Sc. and L. B. Friedman, Grad.I.E.E. (who opened the discussion).

Keeping these frequency requirements in mind, let us consider what the ultra short waves have to offer. I would strongly urge those of you unacquainted with their technique to consider the question in terms of frequencies.

For instance we have—

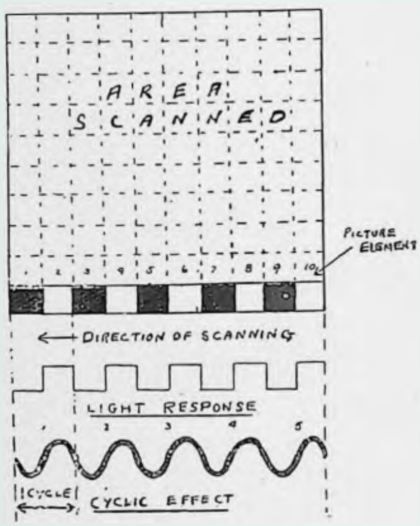
	Metres.		kc/s
London National	261·5	=	1147
London Regional	355·9	=	843
Midland Regional	398·9	=	752
National Daventry	1554·4	=	193

But to appreciate the question of side-band limitation we must also remember kc/s equivalent.

Let us now consider the situation on the medium wave-band say—

200 metres to 500 metres
1500 kc/s to 600 kc/s

giving a frequency range of 900 kc/s and accommodating about 100 stations and providing



1 cycle covers 2 Picture Elements
∴ Total number of cycles = $\frac{1}{2}$ total number of Elements.
Theoretical maximum frequency = $\frac{1}{2}$ Picture ratio × (number of pictures per second) × number of lines)^2

that these stations each remain on their allotted wave-length there should be no interference for the broadcasting of sound. I am, of course, ignoring the question of heterodyning. It is only when we begin to encroach upon the higher frequencies such as those that I have mentioned as being necessary for good Television that the trouble begins.

Let us compare the situation on the ultra short wave-band, say—

3 metres to 8 metres
100,000 kc/s to 37,500 kc/s

giving a frequency range of 62,500 kc/s, over which we could accommodate nearly 7,000 sound broadcasting stations.

Now for Television purposes, if we allocate 100 kc/s, we could accommodate 625 stations without interference, and we can thus see the great advantage of these ultra short waves with regard to the question of frequency congestion.

There are other important advantages to be gained by the utilisation of ultra short waves, but time will not allow me to go further unto this frequency question, but no doubt the subsequent speakers will add to what I have said.

Before leaving the question of frequency in respect to wave-length, there is one more item that I would like to point out to those of you who are just about to get familiar with ultra short waves.

During the evening no doubt you will hear mentioned the term megacycle, *m.c.*, representing a million cycles/sec. thus,

$$8 \text{ metres} = 37{,}500\ kc/s$$

which in terms of $m/c = 37{\cdot}5\ m/c$

Those of you who have up to the present been thinking in terms of wave-lengths and metres will no doubt at first be somewhat confused, hence I have endeavoured to make this point clear.

If any of you are ambitious enough to consider at some later date applying for a transmitting licence, you will learn that certain frequency bands exist for amateur transmissions.

m/c.		*kc/s.*		*metres.*
1·7	...	1730—1985	...	173·4 —151·1
3·5	...	3520—3730	...	85·23— 80·43
7·9	...	7025—7275	...	42·7 — 41·24
14·0	...	14030—14370	...	21·38— 20·88
28·0	...	28050—29950	...	10·7 — 10·02
56·6	...	56070—59930	...	5·35— 5·0

Now having satisfied ourselves of the advantage of using these ultra short waves for Television, let us now briefly consider their nature compared with the longer waves.

Firstly, we must remember that the shorter these waves, the nearer do they resemble light waves, being known as quasi-optical wave-lengths. Thus, when very short waves are used it is essential to have the receiver in sight of the transmitter, and reception is affected by the screening of high buildings, hills, etc.

It is generally considered that this is definitely the case with waves below 5 metres, between 5 and 10 metres this is only partially true.

Having considered the utility and the nature of ultra short waves, we will now briefly consider the design of apparatus necessary for their operation.

It was not very long ago, in the absence of sufficient information as to the correct values of components and other essential information, that it was considered necessary to design an ultra short wave receiver with control knobs mounted on very long spindles well away from the remainder of the set and carefully screened, de-capped valves, and no wire, with the result that early ultra short wave receivers consisted of nothing more than components directly soldered to one another.

Such precautions may still be an advantage for very short waves of only a few centimetres, but we can now construct an ultra short wave receiver for 5 metres on more or less orthodox lines. It is desirable to keep the tuning range low, to a few metres perhaps, but we must realise that the value of components is very critical. There is the possibility of obtaining inconsistent results when slight changes are made to the set even by the replacement of components such as the changing of a valve.

The slight variation in the characteristics of a valve would pass un-noticed in normal radio; but this slight variation in ultra short wave work might easily change the condition from successful reception to no results at all.

I would like to offer the suggestion in passing that the latest Catkin valves, owing to their special construction, are made to much finer limits of variation, hence their suitability for ultra short wave work.

Too much attention cannot be paid to the aerial system. I think a whole evening could be easily devoted to this subject alone. Doubtless much useful work is lost through lack of attention to this very important link in ultra short wave work. In conclusion, I would like to add a word or two of explanation in connection with the ultra short wave demonstration of Television last April at the Television Society Exhibition, which I had the privilege of arranging in co-operation with Mr. Baird.

I have been asked why more detail was not obtained, seeing that ultra short waves were used. It was the original intention, when arranging for ultra short waves transmissions from the B.B.C., to increase the number of lines to 90, but owing to certain technical reasons at that time it was only possible to utilise a 30-line transmitter.

Although this was undoubtedly the first public demonstration in this country of Television on ultra short waves, unfortunately it was not possible to take full advantage of them.

Short Wave Oscillators

Report of a paper contributed by E. C. S. MEGAW, B.SC., D.I.C.
(G.E.C. Research Laboratories)

Mr. Megaw, of the G.E.C. Laboratories, spoke about "Short Wave Oscillators," on which subject he is a leading authority; and concluded with a most interesting demonstration. He explained that his object was to describe briefly the latest developments in valves designed to produce oscillations of very high frequency for use in ultra-short wave transmitting and receiving circuits, especially in the former.

The chief difficulty, he explained, in obtaining very high frequency oscillations is due to the inter-electrode capacity and inductance of the valves used; for example, with normal valves the internal capacity may be of the same order as the total capacity required in the tuned circuit. This difficulty may be called the "circuit problem" and its solution lies in the reduction of valve capacity.

Mr. Megaw showed an Osram *DEQ* valve, which type has been used for about ten years in commercial short wave work, and can normally be operated down to 1 or 2 metres. The leads from all the electrodes are brought out to separate terminals round the envelope in order to minimise capacity between leads. He also showed a small French transmitting valve of more conventional appearance and capable of giving 1 watt of high frequency power at a wavelength of 1 metre. This valve had a standard base, but again the grid and anode leads were taken by the shortest possible routes to separate terminals on the glass envelope.

In developing higher powered short-wave transmitting valves, Mr. Megaw continued, the water-cooled type soon attracted attention, because the efficient cooling allowed the anode to be relatively small for a given dissipation, with a consequent reduction of the internal capacity. A typical example of this type of valve would have the following characteristics: Approx. size of anode, 2in. × 1½in. diameter; anode voltage, 5000–6000 v.; high frequency output, 2 K.W. at 7 metres or 1 K.W. at 3 metres.

In the case of lower powered valves, the performance has been greatly improved by using hard glass and small anodes, both of which are capable of withstanding much higher temperatures than their predecessors. The anodes are usually made of molybdenum, and a valve of this type can handle an anode dissipation two to five times greater than a normal valve with a lead glass envelope.

In passing from a consideration of modern valves to the circuits in which they are used, Mr. Megaw said he would not describe the common varieties of the reaction circuit, but would deal with the less well-known arrangements. The Barkhausen, or electronic method, he said, can be used to provide oscillations of very short wave-length, not by a normal method of coupling the anode and grid, or cathode circuits, but by affecting the actual paths and behaviour of the electrons emitted from the cathode, and consequently the method only becomes efficient at very low wave-lengths where the period of the oscillation is comparable with the time taken for an electron to travel from the cathode to the grid or anode.

A triode can be made to oscillate in this way by applying a small negative bias to the anode relative to the cathode, and a high positive potential to the grid, the grid and anode being connected across the external parallel tuned circuit. The theory of this effect is not yet agreed upon universally, but the generally accepted explanation is as follows: Electrons emitted from the cathode are accelerated by the high potential of the grid through the meshes of which they pass towards the anode, which they reach if they arrive at a part of the cycle when the potential of the anode side of the resonant circuit is positive relative to the grid, thereby reducing the effect of the negative bias on the plate; an electron reaching the anode in this manner absorbs power from the tuned circuit, whereas one which arrives at a part of the cycle when the negative anode bias is augmented by the voltage across the tuned circuit, is repelled towards the cathode only to be re-attracted by the grid about which it oscillates, and on which it finally comes to rest, having given up energy to the tuned circuit in the process of oscillation. Thus the phenomenon is more easily understood by considering it as an electro-static effect rather than as a flow of current.

At this point, a slide was shown of a small transmitter which operated on the Barkhausen principle at 90 cm. It was constructed in one compact unit, in which the tuned circuit consisted of two parallel rods coupled directly to the valve terminals and located parallel to the axis of a parabolic reflector through which they projected, thus forming a directive aerial.

Similar oscillations can be obtained by operating a cylindrical diode in a magnetic field, and valves used in this way are commonly known as magnetrons. In the special case, however, where the axis of the anodes is parallel with the magnetic field, oscillations are produced by a process which is entirely independent of the Barkhausen effect. In this case, the tuned circuit is connected across the two anodes, which obtain a positive anode voltage through a centre tap in the circuit; thus at an instant when one anode is above and the other below the mean anode voltage, electrons are attracted from the cathode towards the positive anode, but instead of following a straight path they are continuously deflected by the magnetic field so that they follow a curved path in a plane normal to the anode axis, and the majority of the electrons eventually arrive at the negative anode, which results in an unstable condition leading to oscillation.

There are two factors however which limit the highest frequency that can be generated by electronic means; the first is the minimum value to which unwanted capacity and inductance can be reduced and the second is the electron inertia, which limits the acceleration of electrons along a given voltage gradient. In the modern magnetron, the first limitation is negligible, and the second is minimised by using the highest possible anode voltage.

With a magnetron, an efficiency of 50 % can be obtained at 2 metres, but with a triode 30 % is about the highest obtainable, and these high efficiencies are due to increasing secondary cathode emission as the wave-length approaches the minimum possible for a given value. This secondary emission may comprise as much as a third of the total emission and is due to additional electrons being dislodged from the cathode by a bombardment of returning electrons, which have failed to reach either of the two anodes. This results in a decrease of the valve impedance and a rise in efficiency.

A magnetron valve type, *E*-396, made by the M.O. Valve Co., was presented for inspection, and a slide of the same valve was projected on the screen. The capacity was only 1 *MMF* between the two semi-cylindrical anodes, which were enclosed in a hard glass envelope and designed for an anode voltage of 1,200 volts. At 1 metre this valve will give a high frequency A.C. output of 5–10 watts, increasing to 35 and 40 watts at 2 and 3 metres respectively. Above 4 metres, however, the efficiency falls, due to reduced secondary cathode emission.

Mr. Megaw then demonstrated a magnetron oscillator in operation, having first described the apparatus with the aid of a slide. It consisted of an *E*–396 Valve in an adjustable mount, arranged so that the anode axis was parallel with the poles of a large electro-magnet located at each side, and attached to the two anode terminals were two parallel rods each about 1 metre long and 5 centimetres apart. These rods, which formed the tuned circuit, were bridged at the end remote from the valve and supplied with 1,000 v. from dry batteries through a milliameter. The filament and maget coils were supplied from low tension batteries through meters and variable rheostats.

The valve was first made to oscillate at a wave-length of 4 metres, and by means of a long tube containing neon gas, which glows in a high frequency field, it was possible by the varying brightness to observe the increase in alternating voltages between the two rods, increasing from zero at the bridged ends to a maximum at the valve terminals. Then by altering the filament current, which affects the valve impedance, an oscillation of 1·4 metres was produced and the neon tube showed a point of zero voltage about thirty centimetres from the valve terminals, as well as the point where the rods were connected. During the demonstration the anode dissipation of the valve was approximately 30 watts and an interesting effect was demonstrated by placing the neon tube on insulated supports, so that it rested above and approximately parallel to the two rods. Under these conditions the whole tube glowed when the power in the tuned circuit was large, but as it was decreased, the glow gradually split up into separate globules, which disappeared one at a time as the emission was reduced, until finally none were left. Some amusement was caused also by the fact that the globules were either attracted or repelled from a finger placed near the tube, their exact behaviour depending on the prevailing conditions in the tuned circuit.

It was obvious throughout that the meeting took the keenest interest in Mr. Megaw's remarks and convincing demonstration, which were presented by an expert in a way that all could understand and appreciate.

DISCUSSION.

Mr. L. B. Friedman, Grad.I.E.E. (Fellow), in opening the discussion remarked that a very comprehensive paper, entitled "A Magnetron Oscillator for ultra short wave-lengths," by Mr. Megaw, had been published in *The Wireless Engineer*, Vol. 10, No. 115, April, 1933. He stated that high definition television, using a short length of wire as a link between transmitter and receiver, is already technically solved. But this link is not satisfactory for a television service, and it seems that the only one adaptable for the purpose is the ultra short wave link. In the speaker's opinion, a large amount of research will have to be done before a satisfactory system can be established. For future public television service, it seems that the chief problems to be solved are:—

(a) The uniform amplification of the wide frequency band involved.
(b) Satisfactory transmission on ultra short waves using comparatively high power.
(c) The design of receivers which can be handled easily.
(d) Problems of chain transmitters.

Experiments have been carried out in connection with transmission over sea water, especially as this enables the U.S.W. signals to be studied under specific and known conditions, and it has been found that the increase of signal with elevation was much greater on the high frequency than on the lower frequency. Also, when considering transmissions over land, in general, the highest frequency showed the smallest attenuation.

Generally speaking, the signals received were very steady, but some evidence of slow fading was obtained in certain cases.

Variations in strength were observed, and this may be due to variable atmospheric refraction, on the other hand it may have been due to reflection from the clouds.

It has also been observed that longer ranges of transmission were obtained than can be assumed from the optical and geographical survey of the service areas.

According to some reports, U.S.W. propagation is also greatly affected by the Seasons. Some definite changes have been observed, and I hope that some Members will be able to give more details of this.

Before bringing my few remarks to close, I would like to state that although it is generally known that U.S.W. do not suffer to any great extent from atmospherics, on the other hand, interference from motor cars is very pronounced, at least as far as my experience extends.

Satisfactory television service on U.S.W. would be entirely out of the question if the nuisance of ignition interference is not stopped in time. The advent of motor car wireless will bring relief to some extent, as necessarily, a motor car fitted with a wireless must have anti-interference units fitted. To my mind, it is now the appropriate time for this Society, and perhaps the B.B.C., the G.P.O., and the I.E.E. to co-operate with a view to obtaining some definite legislation regarding the fitting of anti-interference units to motor cars, more especially as it could be done very cheaply.

I would also like to ask Mr. Megaw if the stability of the frequency of the oscillators described is sufficiently satisfactory when dealing with short wave transmissions, and I would like also to ask Mr. E. L. Gardiner if he can give us some more information as to whether there are any advantages in having specialised antenna types when dealing with U.S.W., and also if any frequency drift has been observed whilst switching on the receiver, especially in cases where indirectly heated valves are used.

Mr. Megaw, in replying to Mr. Friedman's question as to range and efficiency of valves, said that ordinary triode oscillator valves might work down to a wave-length of 5 metres; other types such as the L.S.5 and the Catkin had a minimum working wave-length of about 2 metres and were reasonably satisfactory on U.S.W. Oscillators and Receivers, except that possibly the Catkin would be better if used without its metal case. As to interference, this would be most serious on 5 metres, unless specially guarded against. He understood that the Post Office had instituted enquiries and research on the matter of interference on these very short wave-lengths. The speaker thought that motor-car systems caused a maximum interference on wave-lengths between 4 metres and 20 metres. He would here like to mention some experiments made by the French, using receivers within 20 yards of a running aeroplane engine, from which no interference was experienced.

Mr. E. H. Traub (Fellow) answered a question as to range and said that the Berlin U.S.W. transmitter worked on 6·985 metres, using 15 Kw, and sometimes only 6¼ Kw, and occasionally covered the distance from Berlin to Leipzig, a distance of about 100 miles.

Mr. Megaw mentioned that he had heard that U.S.W. reception had been accomplished in America between New York and a station near Washington, a distance of some 284 miles.

Mr. E. Phillips (Fellow) confirmed that the Post Office were carrying out research to overcome interference on U.S.W.

Mr. Semper felt that to increase range, a chain of U.S.W. radio links would be necessary to give service, and with chain stations, defects would be cumulative. He asked whether anyone had had experience of "pea nut valves" in U.S.W. work? (Mr. Megaw was understood to say in reply to the last question that they would not be very efficient generally as the clearance between anode and grid was only of the order of 1/1,000 in.)

Mr. R. J. P. Jeffcock, A.C.G.I. (Fellow), in thanking the various speakers for their helpful and illuminating papers, said that they were very interested to hear how the effect of "The ten little nigger boys" was achieved, and he hoped Mr. Megaw would find time to repeat this experiment. This Mr. Megaw kindly did to an appreciative audience.

Optimum Colour Combinations for the Television Stage*

by DR. E. B. KURTZ,
Head of the Electrical Engineering Department
and PROF. R. R. WHIPPLE,
Assistant Professor of Electrical Engineering,
State University of Iowa.

OBJECT

The experimental study on which this paper is based was undertaken to determine the most effective combinations of colour or shading to be used on objects to be scanned for television transmission. Photographic evidence was secured to corroborate and render more permanent the visual decisions.

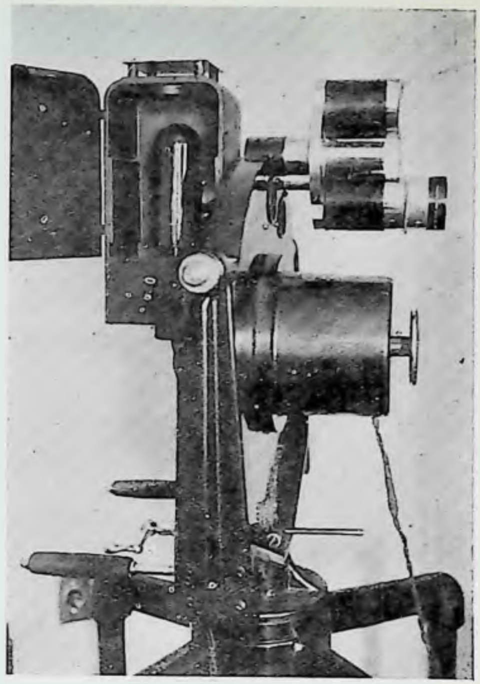


FIG. 1—Portable scanner showing lamp house and lenses.

Equipment.—The project was carried out in the Television Laboratory of the Electrical Engineering Department of the State University of Iowa in conjunction with the University Experimental Television Station *W9XK*. This station employs a disc scanner (*Fig. 1*) using 45 holes arranged in three spirals. The rotating speed of 900 r.p.m. gives the equivalent of fifteen pictures per second. A bank of ten 8-inch potassium hydride photo-electric cells (*Fig. 2*) is used to pick up the reflected light from the object, and the customary multi-stage vacuum tube amplifier is used to step up the photo-cell currents. A monitor on the amplifier panel (*Fig. 3*) was available to observe the picture quality. Most of the visual observations were made directly on the monitor screen to exclude the variable factors introduced by broadcasting and reception. The photographic results were taken on a receiver identical with the monitor and connected to the same terminals. This separate receiver (*Fig. 4*) was necessary to make it possible to work in photographic darkness, as well as to provide guides for holding the camera.

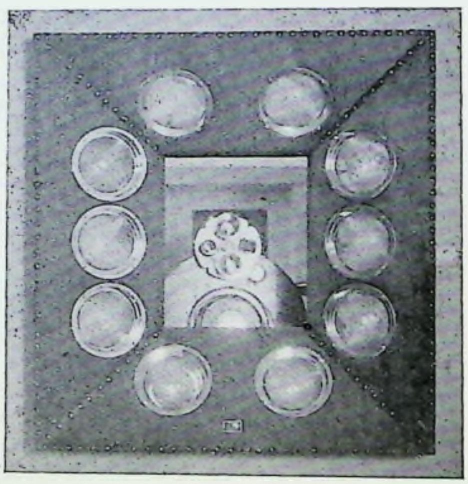


FIG. 2—Photo-cell bank.

Sensitivity Curves.—*Figure 5* shows curves of relative sensitivity to various wave lengths of light for the potassium photo-electric cells used and for the human eye. The fact that these curves are plotted with the same maximum value is of no significance. The disparity between these two curves makes it clear that colour effects for television scanning will be unnatural when viewed directly. It will be shown that the actual results may be predicted with considerable accuracy by examination of these curves. The first test was a visual test, which illustrates the effect of the sensitivity curve of the photo-electric cells upon the distortion of apparent intensities in the received picture. The second test consisted in obtaining photographic verification of the visual observations.

* Manuscript received by the Editor, Nov. 20th, 1933.

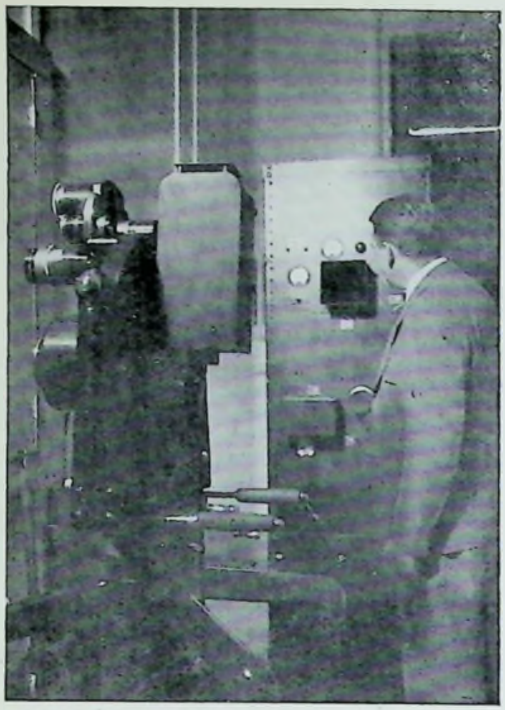


FIG. 3—Scanner, amplifier panel and monitor.

Visual Decision with Variable Amplifier Gain.—This test was performed by scanning squares of six different colours mounted alterately on solid backgrounds of the same six colours. Squares were used because they offer a fixed shape to the scanning beam. With each specimen, the amplifier gain was gradually increased until the coloured square was rendered visible in the monitor. This gave a semblance of quantitative values. The recorded data were as follows:—

Back-ground.	Gain.	Colours showing and whether (L)ight or (D)ark.
White	1	Yellow (D), red (D), black (D), green (D)
,,	2	Above plus blue (D)
Blue	1	Red (D), white (L)
,,	2	Above plus yellow (D), black (D), green (D)
Green	1	White (L)
,,	2	Above plus blue (L)
,,	4	Above plus red (D)
,,	5	Above plus black (D)
,,	6	Above plus yellow (D)
Yellow	1	White (L)
,,	2	Above plus blue (L)
,,	5	Above plus red (D)
,,	8	Above plus black (D)
,,	9	Above plus green (L)
Red	1	White (L), blue (L)
,,	7	Above plus green (L), yellow (L)
,,	20	Above plus black (D) faintly
Black	1	White (L), blue (L)
,,	4	Above plus green (L)
,,	6	Above plus yellow (L)
,,	12	Above plus red (L)

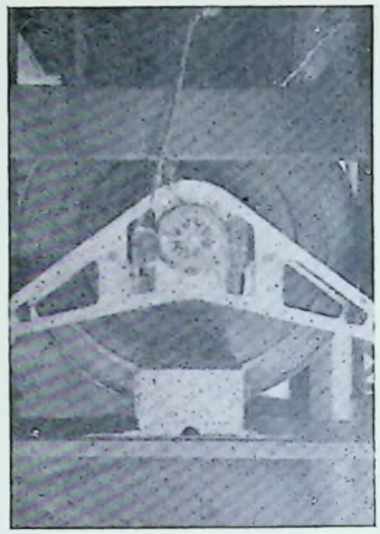
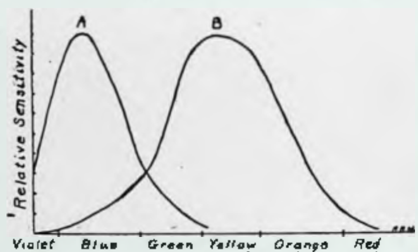


FIG. 4.—Special monitor arranged for obtaining photographs of received image. Picture shows camera in place.

The data from this test may be used to plot curves of the reciprocal of gain setting against colour. The curve will approximate the curve of relative sensitivity of the photo-electric cells if the data for the black background are used. This curve is plotted in *Fig. 6*. The similarity of this curve to Curve *A*. of *Fig. 5* will be apparent. It thus follows that the choice of best colours may be determined in advance if the original sensitivity curve is available.



A. Potassium hydride photo-electric cell
B. Human vision.

Figure 5

Photographic Check.—A second station monitor placed in a dark room was arranged with metal guides to hold a small box camera with its open back close to the scanning disc. Verichrome film was placed reversed in the camera, so the sensitive side was towards the disc. Exposure was made by means of a switch in the neon lamp circuit. The exposure time for successful pictures was between 5 and 20 seconds. Neither ordinary film nor supersensitive film showed as good results.

The neon lamp was coated with tinfoil, except for an opening the size of the picture, to increase intensity and cut down stray light. The lamp was moved away from the disc beyond its normal position to decrease dispersion through the holes. Photographs were then taken of the materials used in the preceding test. The pictures shown in *Fig. 7* bear out the results obtained in the visual tests.

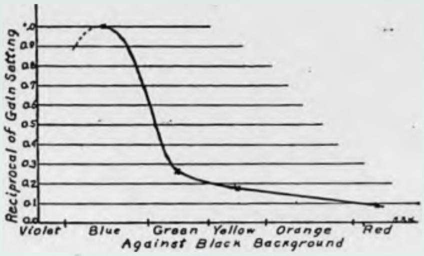
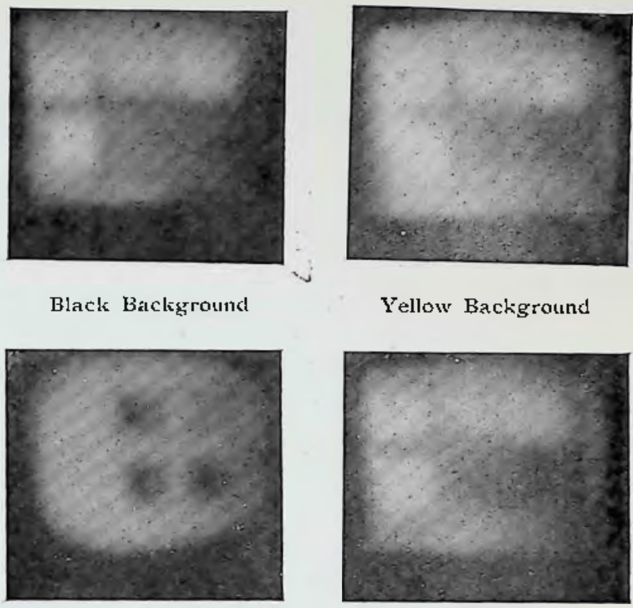


Figure 6

The photographs of *Fig. 7* show overshooting when the light pencil strikes a block of different colour rather than under reaction, which would be expected due to aperture distortion. This effect was not apparent to the eye even after the camera had pointed it out, but it is thought that the appearance of the picture might be improved if this effect were removed. This could be done by proper shading of a drawing, by avoiding sharp changes in facial make-up and by careful choice of background.

Facial Make-up.—Tests on facial make-up showed that great care must be exercised in the use of expression lines which are close to the horizontal to avoid what has been termed "fluttering eye-brow." This is the result of a narrow horizontal line being covered by only one scanning spot in certain parts of its extent and by two spots at other points. Slight movement of the subject may cause a large apparent shift in the position of the horizontal line, thus making the result grotesque. Red paint for cheeks and lips must be avoided, as it shows as black. Red may be used conveniently in place of black for expression lines, eyebrows and beards. Cheeks and lips may be emphasised by the use of the proper shade of green. From the foregoing it is clear that a person made up to televise effectively may look astonishing to the eye.

Observations on Objects.—Tests with coloured prints, black and white photographic reproductions and sepias, showed no definite advantage in any type. Nevertheless, in pictures made up particularly for television transmission by a non-artist, success was greater when using colour according to the specifications of this report than when trying to produce the same effect by light and shade alone.



Black Background — Yellow Background

Blue Background — Red Background

FIG. 7—Photographs showing colour contrasts with various backgrounds.

Order of colours on each photograph.

White	Yellow	Green
Blue	Red	Black

Certain less formal tests gave additional information of interest. It was found that solids of white drawing paper in the form of cubes or cones could not be identified as solids in the received picture. The appearance of a cone is simply that of a plane triangle. This difficulty might not hold for single cell pick-up, as it is undoubtedly caused by the embracing bank used in these tests. It is suggested that a solid should be properly shaded or coloured to give the desired effect.

Conclusions.—It should be remembered that the detailed results given here apply only to a particular type of photo-electric cell. The method outlined herein, however, is perfectly general and can be used with any type of cell. It was interesting to learn that satisfactory predictions of colour combinations may be made directly from the cell sensitivity curve without the trouble of formal tests. The method of obtaining photographic records is thought to be original, as well as simple and effective. Furthermore, the sensitivity curve of an unknown photo-electric cell may be fairly closely approximated by visual tests using the black background.

The authors wish to acknowledge the assistance of Mr. H. J. Monk in the experimental work.

Electro-optics and Television*

By L. M. MYERS (Fellow)

SUMMARY

1. Retardation in anistropic media.
2. Modification of optical properties of media by mechanical stress:—
   a. Isotropic media.
   b. Uniaxial crystals.
   c. Biaxial crystals.
   d. Isometric crystals.
3. Optical effects in vibrating media; the Biot effect.
4. Electrostriction.
5. Electrostatic induction of crystal deformation:—
   a. In liquids; particularly nitrobenzene.
   b. In solids; particularly piezo-electric quartz.
6. Form of polariscope for television work.

1. *Retardation in anistropic media.*—The whole science of polarized light deals with retardation in media, whether natural as in birefrigent crystals, or artificially induced by means of mechanical, magnetic or electrostatic stress. Therefore it might be well to open this paper with a brief description as to what is meant by this phenomenon.

When light travels through a stressed medium it does so by splitting into two separate rays, each of which vibrate in mutually perpendicular directions. Owing to the slight difference of elasticity for these two directions, the light is said to possess two eases of vibration, the maximum and the minimum corresponding to these two directions. Of course, these two directions of vibration are both at right angles to the direction of propagation of the light through the crystal. We know that the ripple of water on the surface of a lake travels at right angles to the direction of vibration of the particles themselves. As we have spoken of a maximum and minimum ease of vibration, it follows that the two rays of light have different velocities; the ray which has the greater velocity is that vibrating in the direction of greatest ease. It follows too that, providing there is no path difference when the light enters the crystal, there will be a path difference between the emerging rays. Now this linear path difference, measured generally in Ångstrom units (10^{-8} cms) is termed the relative retardation. It is measured in such units so as to be readily comparable with the wave length of light.

If such retardation occurred between two rays vibrating in the same direction, then matters would be very simple indeed, but unfortunately, as we have already pointed out, the direction of vibration of the one ray is perpendicular to that of the other. We proceed, then, to consider that the two rays entering the crystal have just been split up into two components and that when these two components leave the crystal the resulting light will be a combination of the two components having regard to the important fact that retardation has been set up between them. For this purpose the retardation is considered in terms

* Revised Manuscript received by the Society Dec. 30th, 1933, being a paper read before the Society on Dec. 13th, 1933, at University College, London.

of angular phase difference. Thus for a linear retardation of half a wave-length a phase difference of π has been introduced. For a retardation of 1/nth of a wave-length, then obviously the phase difference will be $2\pi/n$. We then advance the faster component by the phase difference and add them together geometrically. We shall consider one simple case to illustrate this point. Suppose that we introduce a quarter wave plate in a beam of polarized light. Then we resolve the incident vibration of amplitude a in the two vibration directions of the crystal. We shall suppose, *Fig. 1*, that the " fast " direction,

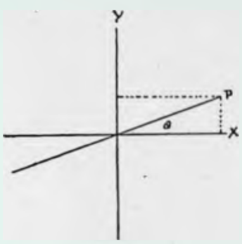


Fig. 1.

or the direction of greatest ease of vibration in the crystal makes an angle θ with the direction of vibration of the incident light. Then resolving the incident vibration in the two directions of the crystal, we have for the amplitude of vibration in the crystal for the two directions—

$$x = a \cos\theta \quad \text{for the fast ray,}$$

$$y = a \sin\theta \quad \text{for the slow ray,}$$

in which x and y are taken as the fast and the slow directions respectively. Now when the two rays emerge from the crystal, the fast ray will have advanced a quarter of a wave length, there its phase difference will be $\pi/2$, so that the emerging components will be—

$$x = a \cos(\theta + \pi/2)$$

$$\text{and } y = a \sin\theta$$

which reduces to $x^2 + y^2 = 2a^2/\sin^2\theta$ when the two components are re-combined. In particular, when $\theta = 45°$, the expression for the combined rays reduces further to that of a circle. Therefore we find that a retardation of a quarter of a wave-length results in a circular vibration. It is easy to show that all possible forms of vibration of light, whose components have been subjected in this manner to relative retardation in the crystal, reduce to that of an ellipse. When the retardation is a quarter of a wave-length, the axes of the ellipse are equal and we have a circular vibration as above. When one of the axes vanishes, which is the case when the retardation is half a wave-length, the vibration becomes rectilinear and for this particular case of half a wave length retardation, the vibration direction of the emerging ray is perpendicular to that of the incident ray.

Now if we take the velocity of light in *vacuo* as unity, then the retardation, which is the path difference of the two rays travelling for respective times t_1 and t_2 in the crystal, will be the difference between these times. Hence,

$$r = t_1 - t_2$$

r being the linear retardation. If V_1 and V_2 are the velocities of the two components corresponding to the times t_1 and t_2, then $t_1 = l/V_1$ and $t_2 = l/V_2$, in which l is the distance which the light travels through the crystal. Therefore we can put.

$$r = l\,(1/V_1 - 1/V_2)$$

But as we have taken the velocity of light in *vacuo* as being unity, then $1/V_1 = \mu_1$ and $1/V_2 = \mu_2$, so that our expression takes the form—

$$r = l\,(\mu_1 - \mu_2)$$

in which μ_1 and μ_2 are the indices of refraction of the two components. This difference of the refractive indices for the two components is termed the birefringence β of the crystal, so that we arrive finally at the expression

$$r = l\beta$$

For practical purposes if l is reduced to Angstrom

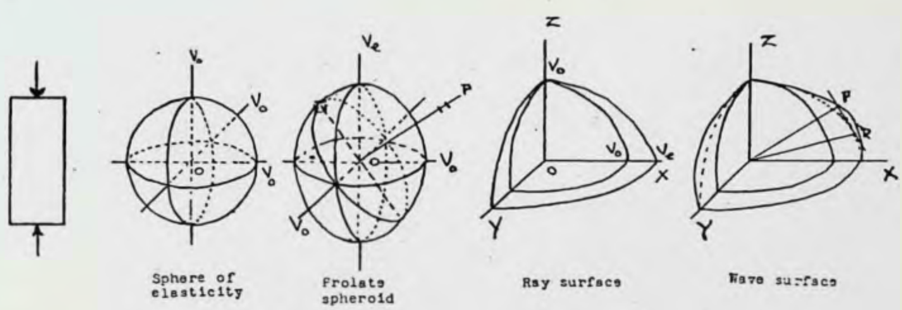


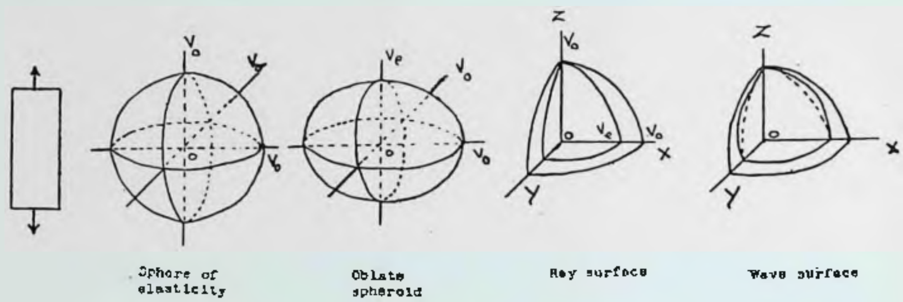
FIG. 2—Conversion of isotropic medium (glass) into negative uniaxial crystal by compression

units, the retardation will also be determined in Ångstrom units.

2. *Modification of optical properties of media by mechanical stress.* (*a*) *Isotropic media.*—Brewster discovered that if a piece of glass was stressed, it became doubly refracting and that if the stress was compressive, the glass acted as a negative crystal; if the stress was tensile, the glass assumed the properties of a positive crystal. He assumed that the crystal thus formed was of a uniaxial nature, for he compared the stressed glass with calcite and quartz, the former negative and the latter positive. His assumption was correct and confirmed later. We shall see how this transition takes place.

normal to OP. This plane will intersect the prolate spheroid in an ellipse and the major and minor axes of the ellipse of intersection will be the vibration directions for the two rays within the medium and the velocities of these two rays will be proportional to the lengths of the two axes. Therefore along OP we must mark off two distances, one of which, proportional to the one axis of the elliptical section, will give the velocity of the one ray and the other distance, proportional to the other axis, will give the velocity of the second ray. Now this procedure must be gone through for every possible direction through the origin, which may be regarded as the source of disturbance from which the light is being sent out.

FIG. 3—Conversion of isotropic medium (glass) into positive uniaxial crystal by tension



An isotropic medium is that for which its physical properties are the same for all directions, and particularly its elasticity or ease of vibration for the passage of light through the medium. If we were to draw a surface which would be the locus of points for which the magnitude of elasticity in all possible directions would be represented by the distance of the locus from a given centre or origin, then obviously our surface would be that of a sphere. We might term this sphere the sphere of elasticity; it is shown in *Fig. 2*. If now the glass is stressed in the direction of the arrows so that it is compressed—this direction is shown vertical in *Fig. 2*—then we must alter the value of elasticity for this vertical direction. If a material is compressed, then its elasticity is increased in the direction of compression; the elasticity is decreased if the stress is purely tensile. Therefore, owing to this stress, the vertical axis of elasticity is lengthened so that our sphere of elasticity has become a prolate spheroid. The next stage is to enquire into the passage of light through this stressed medium. Bearing in mind that the direction of propagation of light through a medium is at right angles to the direction of vibration, we take any direction OP for the light and find the magnitude of its velocity by constructing a plane through the origin and

This construction will result in the derivation of two surfaces and these two surfaces evidently represent the velocities of the two rays for any direction in the medium. They are, therefore, termed ray surfaces. Their trace in any plane is called the ray front.

We have yet another stage before our construction is complete. The wave surface; that is, the surface representing the velocity of the wave within the medium must now be determined. If we take the ray OR, in *Fig. 2*, then the wave is the tangent at R to the ray surface. The distance OP of this tangent from the origin is obviously the velocity of the wave. So that whereas R lies on the ray surface, P lies on the corresponding wave surface. The locus of P gives the wave surface. It is, in this case, the wave surface for the extraordinary ray. The wave surface of the ordinary ray coincides, of course, with its ray surface as the latter is a sphere.

We can now see quite clearly by following these diagrams how it comes about that the stressed glass takes the form of a uniaxial crystal. We notice with particular interest that the velocity of the extraordinary for the OX axis, is greater than that of the ordinary ray. This defines the character of the negative crystal. For the sake of clarity, only one quadrant of the ray and wave surfaces is shown. The direction OZ for which no relative retardation occurs, that is for which there is no double refraction, is the axis of single wave velocity or, simply, the optic axis. This, it will be observed, coincides with the direction of original stress in the glass.

If we take the velocity of light in vacuo as unity, and if V_o and V_e represent the velocity of the ordinary and extraordinary ray respectively, then we can write down the expressions for the various surfaces which we have just discussed. They are—

$$\frac{x^2}{V_o^2}+\frac{y^2}{V_o^2}+\frac{z^2}{V_o^2}=1 \quad \text{sphere of elasticity}$$

$$\frac{x^2}{V_o^2}+\frac{y^2}{V_o^2}+\frac{z^2}{V_e^2}=1 \quad \text{ellipsoid of elasticity}$$

$$\left.\begin{aligned}\frac{x^2}{V_o^2}+\frac{y^2}{V_o^2}+\frac{z^2}{V_o^2}&=1 \quad \text{ordinary ray surface}\\ \frac{x^2}{V_e^2}+\frac{y^2}{V_e^2}+\frac{z^2}{V_o^2}&=1 \quad \text{extraordinary ray surface}\end{aligned}\right\}$$

$$\left.\begin{aligned}\frac{x^2}{V_o^2}+\frac{y^2}{V_o^2}+\frac{z^2}{V_o^2}&=1 \quad \text{ordinary wave surface}\\ V_e^2x^2+V_e^2y^2+V_o^2z^2 &=(x^2+y^2+z^2)^2 \quad \text{extraordinary wave surface}\end{aligned}\right\}$$

For the second case, that of tensile stress, we must follow the construction of *Fig. 3*. We begin with the isotropic glass with the sphere of elasticity and stress the medium in the direction of the arrows, then the velocity of the light vibrating in this direction will be decreased, because the value of the elasticity has been decreased. Therefore our ellipsoid of elasticity assumes the form of an oblate spheroid. From this oblate spheroid we obtain the ray surface and finally the wave surface in exactly the same manner as before. We notice, that for the direction OX for which double refraction now occurs, the velocity of the extraordinary ray is less than that of the ordinary ray. This, by definition, is the character of the positive crystal.

It may be concluded, then, that when isotropic non-crystalline media are stressed they become positive or negative uniaxial crystals in accordance with the sign of the stress—positive for tension and negative for compression. We have purposely added the term " non-crystalline " because, as we shall see later, there are crystals of the isometric class which are, with exceptions, definitely isotropic. When these crystals are stressed they do not always become optically uniaxial.

It is possible even to stress liquids mechanically, but, with the exception of an extremely viscous liquid—Canada balsam—the means for so doing are somewhat complicated. Clerk Maxwell observed that, if Canada balsam was disturbed with the sides of a flat spatula, the liquid would become birefringent. The writer has not found that undisturbed Canada balsam is perfectly isotropic, so that it is difficult to observe whether the disturbed liquid becomes uniaxial or biaxial.

In order to demonstrate the change of character in glass when it is stressed, a most convincing method is to bend a strip transversely in the polariscope against a quartz wedge. When the glass is unstressed, the retardation bands of the wedge are perpendicular to the length of the wedge, but as soon as the glass is bent the retardation band becomes oriented round a centre. This centre determines the position in the glass for which there is no stress. But where the bands advance, as the wedge itself is a positive crystal, the stress in the glass must have converted it into a positive crystal. This is the portion of the glass which is in tension. But on the other side of the neutral line the bands recede so that here the glass has become a negative crystal. *Fig. 4* will make

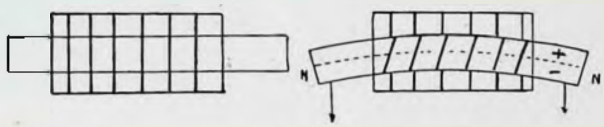


Fig. 4—Bending a strip of glass against a quartz wedge in the polariscope

this clearer. NN is the neutral line or line of zero stress. The upper portion of the bent glass is in tension and the lower in compression.

(*b*) *Uniaxial Crystals.*—We have now to consider the behaviour of uniaxial crystals when they are stressed normal to the optic axis. When the stress is parallel to the optic axis, it will be evident that the crystal becomes more or less birefrigent in accordance with the intensity and the sign of the stress, but when the crystal is stressed normal to this axis it reacts somewhat differently. We begin by considering the first diagram of *Fig. 5*. This is the oblate spheroid of elasticity which appeared in *Fig. 3* of the positive crystal. The optic axis of this crystal is vertical. Therefore we shall first compress the crystal, which may be quartz, for example, in the direction of the arrows. At once the axis OX of our oblate spheroid becomes elongated, because the elasticity has been increased. This results in a triaxial ellipsoid; an ellipsoid having all three axes unequal. From this triaxial ellipsoid we have to construct the ray surface. As before, we take any direction OP and mark off two distances proportional to the major and minor axes of the elliptical intersection by the plane through O and normal to OP. When the whole construction is carried out, we find that in the xy plane the two ray surfaces intersect at I and we note that the resulting surfaces are those of a biaxial crystal.

We should find a similar state of affairs if a negative uniaxial crystal was stressed compressively, but this time the axial plane would be formed normal to the direction of stress.

We now proceed to consider the effect of tension instead of compression. It will be seen on following *Fig. 6* that the elasticity in the OX direction will have been decreased owing to the

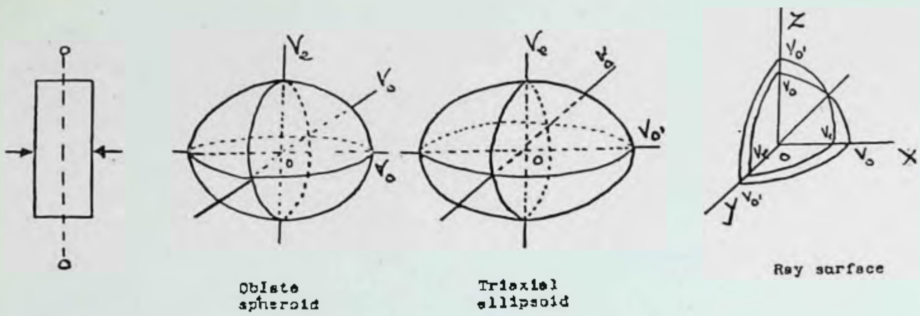
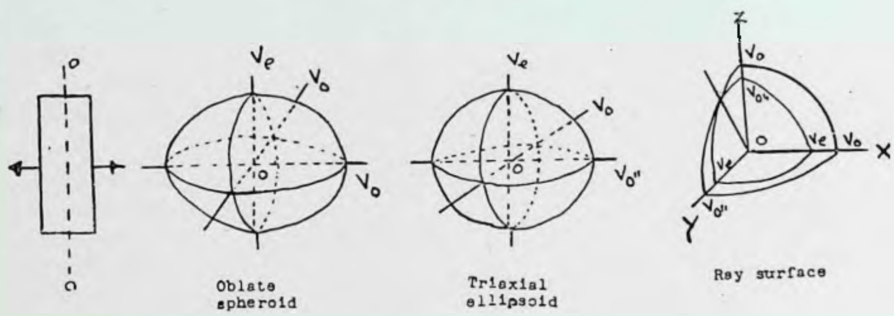


Fig. 5—Conversion of positive uniaxial crystal into positive biaxial crystal by compression

Finally we should construct the wave surfaces, but we shall omit it here as being not altogether relevant. The intersection of the wave surfaces, however, determine the axes of single wave velocity or the optic axes. The intersection of the ray surfaces determine, on the other hand, the axes of single ray velocity and these are therefore not the true optic axes of the crystal.

tension, thus the corresponding velocity will have decreased. On constructing the ray surface in this case, it will be seen that the new optic axes emerge in the yz plane, and that this plane is normal to the direction of the stress. We conclude, therefore, that a tension renders the positive uniaxial crystal biaxial with the newly formed axial plane normal to the direction of tension.

Fig. 6—Conversion of positive uniaxial crystal into positive biaxial crystal by tension.



Thus we have produced a positive biaxial crystal from a positive uniaxial crystal by compressing the latter normal to the direction of the old optic axis. It is of particular interest to note that the newly formed axial plane, that is, the plane containing the two new axes, also contains the direction of the compression. This newly formed crystal has, then, the same character as topaz, selenite and sulphur.

For the negative crystal of the opposite effect takes place. The newly formed axial plane for tension is parallel to, and thus contains, the direction of the tension. But the biaxial crystal still remains negative in sign. In *Fig. 7* we see the ray surface for the negative biaxial crystal. For the OX axis only the rays V_o and V_o^1 appear; along OY, V_o^1 and V_e appear; and for the OZ axis both V_e and V_o are present. V_o is that ray having the same refractive index in the medium when unstressed. It appears in two directions in the biaxial crystal and in all directions in the uniaxial crystal. For the negative uniaxial crystal the fast ray vibrates parallel to the optic axis, this is also the case for the negative biaxial crystal. These vibration directions are indicated by short lines in the *Fig. 7*.

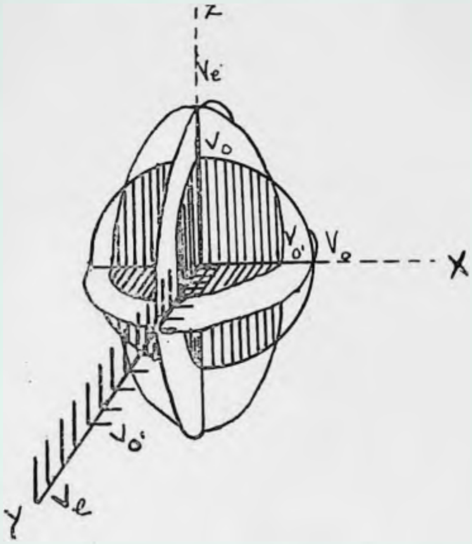


FIG. 7—Ray surface of negative biaxial crystal showing the vibration directions of rays

We can now tabulate our results as follows:—

Medium.	Stress.	Type of crystal.	Sign.	Axial plane.
Isotropic	Comp.	Uniaxial	Neg.	
Isotropic	Tens.	Uniaxial	Pos.	
Uniax. Neg.	Comp.	Biaxial	Neg.	Normal to stress
Uniax. Neg.	Tens.	Biaxial	Neg.	Parallel to stress
Uniax. Pos.	Comp.	Biaxial	Pos.	Parallel to stress
Uniax. Pos.	Tens.	Biaxial	Pos.	Normal to stress

We shall now see how the conversion of the uniaxial into the biaxial crystal can be observed, and thus confirm the tabulations above. For this purpose we have to view the conoscope image of the uniaxial crystal to be stressed. Now this conoscopic image is the intersection in a plane of a series of surfaces known as the isochromatic surfaces. If we trace out the locus of a point which moves such that its distance from a given origin is a path of constant retardation in the crystal, then this locus is the surface of equal retardation or an isochromatic surface. It will be the surface given by the expression—

$$r = l\ (1/V^1 - 1/V^2) = \text{constant}$$

For the uniaxial crystal the surface is fairly simple, but it is more complicated for the biaxial crystal. In *Fig. 8*, we see a number of surfaces for the uniaxial and the biaxial crystal. Such a series of surfaces can be observed only if the light passing through the crystal is highly convergent. If we look down on to the crystal in the direction of the optic axis then the trace of these surfaces for uniaxial and biaxial crystals will be similar to

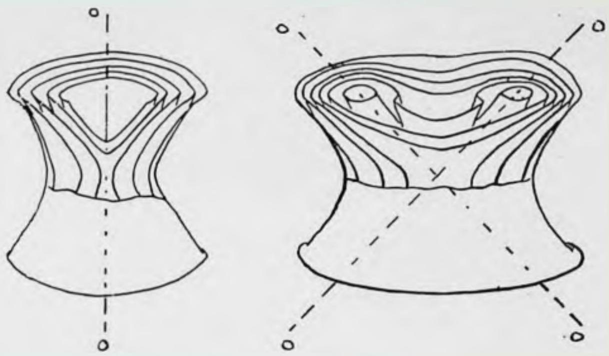


FIG. 8—Isochromatic surfaces for the uniaxial and the biaxial crystal—OO is the optic axis

Figs. 9 and *10*. But if the crystal is observed by light travelling through it normal to the optic axis, or normal to the bisector of the axes in the case of the biaxial crystal, then the trace of the surfaces will be similar to the curves shown in *Figs. 11* and *12*.

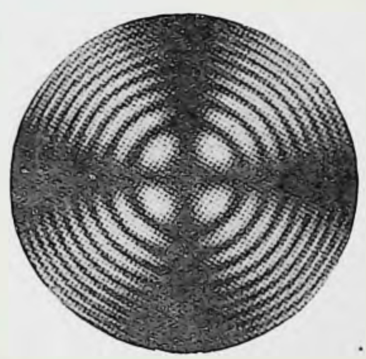


FIG. 9—Conoscopic image of uniaxial crystal cut normal to optic axis

Now when the uniaxial crystal is stressed, we should expect that when the one axis splits into two the first thing that would happen would be that the rings would become ellipses. Then these ellipses would become elongated and form two loops. Finally the loops would close and the

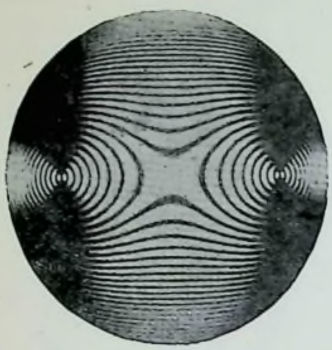


FIG. 10—Conoscopic image of biaxial crystal cut normal to bisectrix

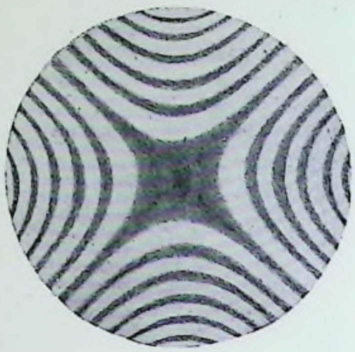


FIG. 11—Conoscopic image of uniaxial crystal cut parallel to axis

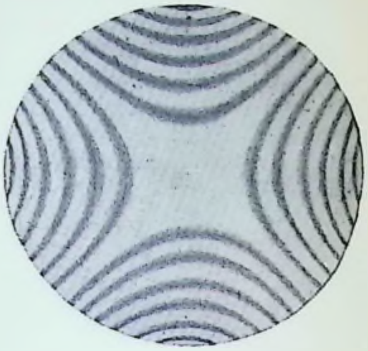


FIG. 12—Conoscopic image of biaxial crystal cut parallel to axis plane

conoscopic image of the biaxial crystal would come into being. By stressing quartz in the petrographic microscope, such a change can actually be observed. The rings of the uniaxial crystal become ellipses and the major axes of the ellipses are in the direction of (compressive) stress.

By compensating the rotation in quartz, the actual separation of the axes can be seen.

An even more convincing method is to observe the crystal in a direction parallel to the optic axis, so that the hyperbola of *Fig. 11* are seen. Now when the crystal is stressed these opposite hyperbola fall apart, showing that the crystal has become biaxial.

(*c*). *Biaxial Crystals.*—For our purpose we need not study the modifications in the biaxial crystal when subjected to mechanical stress. It is sufficient to state, therefore, that the effect of stress is to change the optic axial angle together with the ray and wave velocities. This alters the birefringence of the crystal. It is thus possible to convert a biaxial crystal into one of uniaxial character by applying equal and opposite stress to that necessary for the reverse process.

(*d*). *Isometric Crystals.*—These crystals, with exceptions, are not birefringent, but it has been shown that for particular directions of stress isometric crystal becomes at once biaxial. The crystal of zinc sulphide, ZnS, with which experimental work is being conducted in Germany, belongs to this class.

3. *Optical effects in vibrating media; the Biot Effect.*—Biot discovered that when a glass strip was in a state of vibration, retardation would be set up in the strip where the stress was appreciable. This experiment, shown to a large audience, is generally known as Tyndall's experiment. A six foot glass strip is held in a clamp at its centre and the strip is set into vibration by stroking with a resined cloth. Then the portion of the strip in the immediate vicinity of the centre clamp will be the node of a fundamental longitudinal vibration. Here, then, will be the greatest stresses in the glass and this is the portion through which the light of the polariscope should be passed. If this is done, the field is at once illuminated when the glass is set into vibration. If the vibration of the glass strip is transverse, however, the state of affairs is far more complicated. At the nodes there will be the greatest shear stress and at the antinodes there will be the greatest bending stress. It was found by Koenig that the double refraction at the nodes was very weak, the illumination of the field in the polariscope rarely exceeding the dull grey of about one-eighth of a wave length retardation. But at the antinodes the retardation was much greater, amounting to as much as three wave-lengths. Such a glass strip performing transverse vibrations when observed in the polariscope forms a very interesting experiment. Matters are even more complicated in the case of transverse vibrations of a glass plate.

4. *Electrostriction.*—As far back as 1831, Fontana made the discovery that when a Leyden jar become charged, the volume of the jar became appreciably modified. A quantitative experiment was carried out much later and the actual change in volume was measured. The experiment by which electrostriction in glass can be observed is as follows. A large glass bulb should be filled with acidulated water and connected by a short rubber tube to a capillary in which the level of the water can be conveniently observed. The glass bulb is then introduced into a tank of acidulated water so that the water inside and outside of the glass bulb

acts as electrodes to the condenser, of which the glass of the bulb is the dielectric. Wires are connected to the water electrodes and the condenser is charged. As soon as this happens, the level of the water in the capillary tube falls, indicating that the glass has become stretched and the volume of the bulb has therefore become greater.

The longitudinal expansion of a glass strip coated both sides with tinfoil has also been investigated and the expression for the expansion is—

$$S = p\,(E^2/d^2)$$

in which S is the expansion per unit length, or the strain; E is the electric field; d is the thickness of the glass strip; and p is a constant.

Now the retardation set up in stressed glass is given by—

$$r = CTl$$

in which l is the length of the path of light and T is the stress, C is a constant which is termed the stress-optical co-efficient. This strain brought about by electrostriction may be interpreted as a stress in the glass by multiplying it by the modulus of elasticity, E. Therefore in the expression we can put $T = ES$ and thus—

$$r = (CEp)lF^2$$

Collecting the constant under one term and substituting the potential difference for the electrostatic field for which $F^2 = V^2/d^2$, d being the distance between the electrodes, we have—

$$r = C^1 l(V^2/d^2)$$

In this expression, C^1 stands for a new constant.

The above formula, at which we have arrived, gives us the retardation for the case of electrostriction. It is the retardation set up indirectly by the electrostatic field.

Electrostriction in liquids has been studied by those two pioneers in Electro-optics, Rœntgen and Quincke, but the results of their investigations do not correspond in all details. The former reported that he had found volume expansion for all liquids, but the latter maintained that a number of liquids suffered volume contraction when under the influence of the field.

Quincke made the interesting discovery that a globule of gas enclosed in a liquid changed its shape from that of a sphere to that of an ellipsoid when the electrostatic field was applied.

The study of electrostriction has not been a very far reaching one, for no practical use has been made of the phenomenon. But for our purpose it is very instructive and may give the clue to the theory of stressed liquids which gives rise to the Kerr effect. We shall see later that the expression developed above is similar to that developed by Kerr for the mathematical theory of his effect.

5. *Electrostatic induction of crystal deformation.* (*a*) *In liquids, particularly nitrobenzene.*—We now approach the most interesting field of research when we come to the study of the Kerr effect. This may be briefly defined as the modification of the optical properties of a medium when subjected to an electrostatic field. The effect is observable in solids, liquids and gases. But in the gases, the effect is so feeble as to warrant no application to Television. Kerr first discovered the effect in glass and later in liquids. To-day the effect in

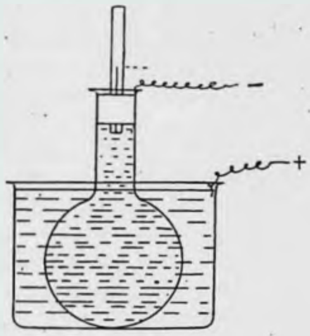


FIG. 13—Electrostriction experiment

liquids, particularly nitrobenzene is best known in the Television field, but the modern tendency is to give more attention to the work on crystals. It has been found that the retardation in media subjected to the electrostatic field is proportional to the square of the field and, of course, to the length of the path by which the light travels through the stressed medium, we can therefore put

$$r = clF^2,$$

in which l is the light path and F is the field. But, as before, we can express the field in terms of the potential difference between the two electrodes, so that our formula becomes

$$r = cl(V^2/d^2)$$

The field is now expressed in volts per cm. Now if r is to be expressed in Ångstrom units, the constant c must be so chosen that the equation is satisfied. The constant c is termed the Kerr constant and for carbon bisulphide, which is generally taken as a standard with which the electro-optic power of other liquids can be compared, the constant is equal to $3{\cdot}2 \times 10^{-7}$.

Taking the value of the constant for carbon bisulphide as 100, it is of interest to compare with it a number of well-known organic liquids. We have chosen organic liquids because, owing to their crystalline structure, the constant has for them the highest values.

Optically Negative Liquids.

Paraffin alcohols having the form of $C_nH_{2n+1}OH$.

Methylalcohol	n 1	CH_3OH	15
Ethylalcohol	n 2	C_2H_5OH	20
Propylalcohol	n 3	C_3H_7OH	65
Butylalcohol	n 4	C_4H_9OH	
Amylalcohol	n 5	$C_5H_{11}OH$	89
etc.			

The benzene group having the radical C_6H_5

Benzene	C_6H_5H	12
Toluene	$C_6H_5CH_3$	24
Zylene	$C_6H_5C_2H_5$	25
Cumene	$C_6H_5(CH_3)_2CH$	31
Chlorobenzene	C_6H_5Cl	363
Bromobenzene	C_6H_5Br	363
Iodobenzene	C_6H_5I	272
Nitrobenzene	$C_6H_5NO_2$	6000
Nitrotoluene	$C_6H_5CH_3NO_2$	5400
etc.		
Water	H_2O	100
Carbon bisulphide	CS_2	100

Optically Positive Liquids.

Halogen derivatives of the paraffin group.

Amylchloride	$C_5H_{11}Cl$	114
Amylbromide	$C_5H_{11}Br$	175
Chloroform	$CH\,Cl_3$	100
Bromoform	$CH\,Br_3$	88
Iodoform	$CH\,I_3$	
etc.		

Acids having the form $C_nH_{2n}O_2$

Formic acid	n 1	$H\,COOH$	value of constant increases with n
Acetic acid	n 2	CH_3COOH	
Propionic acid	n 3	C_2H_5COOH	
Valeric acid	n 5	C_4H_9COOH	
Caproic acid	n 6	$C_5H11COOH$	
Aniline		$C_6H_5NH_2$	38

It is of interest to note that those compounds having the formula, $C_nH_{2n+1}OH$ of the alcohol class, are, as a rule, optically negative. There is not sufficient information for all liquids to determine whether the negative crystal is uniaxial or biaxial. Kerr assumed that the character of the stressed liquid was uniaxial. At the same time the acids, having the form $C_nH_{2n}O_2$, of which formic acid is an example, are optically positive. In both groups the electro-optic power increased with n. The same in the case of the halogen derivatives of C_nH_{2n+1}. The electro-optic power decreases in the order, chlorides, bromides and iodides. It appears that if the combination NH_2 is present, the effect is optically positive and for these substances it is found that the electro-optic power increases the more unsymmetrical the arrangement within the molecule. For the benzene group, the liquids are optically negative with the exception of aniline, in which NH_2 appears. For this benzene group it is clear that the electro-optic power increases with the complexity of the molecule and we note with interest that nitrobenzene and nitrotoluene head the list with constants 60 times that of carbon bisulphide. This information is an excellent guide to the liquid to be used for a desired effect. It is remarkable that water has the same electro-optic power as carbon bisulphide.

We can now compare the electrostriction expression with that for the Kerr effect. The former was

$$r = c_1 l \ (V^2/d^2)$$

and the latter

$$r = cl \ (V^2/d^2)$$

We may easily draw the conclusion that the expressions are identical, but this is by no means the case. The constant c_1 of the first expression is of the order 10^{-10}, and that of the Kerr effect of the order 10^{-7}. The voltage is in ordinary units, not electrostatic units. Thus apparently the Kerr effect is quite different from the phenomenon of electrostriction.

For the purpose of calculating the voltages required to operate a cell of given linear dimensions, the expression:—

r (Ångstrom units) $= cl$ (cms) V^2 (volts)$/d^2$ (cms)

must be employed. We shall suppose, for example, that it is required to determine the voltage to produce half-wave retardation with a cell in which the light path is 4 cms., the electrodes being 0·5 cms apart using nitrobenzene. We shall determine this voltage for sodium light (λ 5890 Å). For a half-wave length retardation we have $r = 2945$ Å) and for the cell dimensions we are given $l = 4$ and $d = 0{\cdot}5$, therefore we have

$$2945 = 4 \ (3{\cdot}2 \times 10^{-7} \times 60) \ (V^2/0{\cdot}5^2)$$

or

$$V^2 = (2945 \times 0{\cdot}5^2 \times 10^7)/(3{\cdot}2 \times 60)$$

which gives a potential difference of roughly 6,500 volts. This is rather a high voltage for practical and commercial purposes, so that it is usual to adopt the arrangement due to Karolus and dispose the liquid in a multicellular or multiplate container. If the light beam through the cell is parallel, then the electrodes of the cell should be parallel, but if the light beam is converging through the cell, then the plates of the cell should be so disposed as to converge to a point; the apex of the light cone.

For all cells we can deduce a simple formula for their design. We take the retardation as being half a wave-length, or rather half an order in the Newton colour scale. As the first order of the scale covers a wave-length of 5,500 Ångstrom units, we put $r = 2{,}750$. Taking the Kerr constant for nitrobenzene as $3{\cdot}2 \times 10^{-7} \times 60$, the expression reduces to

$$V^2 = 14{\cdot}32 \times 10^7 \, (d^2/l)$$

This is the most convenient form.

We can also consider the expression for the effect in terms of the intensity of light, which leaves the polariscope. It is shown in text books on the subject that the intensity of the light emerging from the analyser of a plane polariscope with crossed nicols and vibration direction of

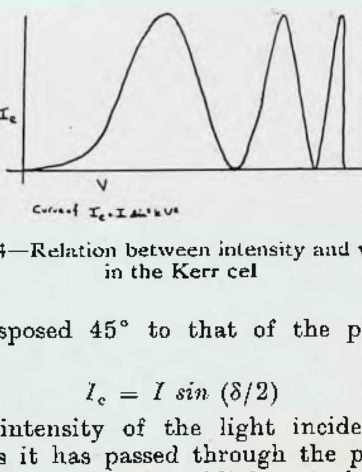


FIG. 14—Relation between intensity and voltage in the Kerr cel

crystal disposed 45° to that of the polarizer is given by

$$I_c = I \, sin \, (\delta/2)$$

I is the intensity of the light incident of the crystal; as it has passed through the polarizer it will be half the intensity of light entering the first nicol. The angular retardation is represented by δ. Now the angular retardation 'bears the same relation to the complete rotation 2π as the linear retardation to the wave-length. Thus

$$r/\lambda = \delta/2\pi$$

on substitution for r we have

$$I_c = I \, sin^2(\pi c l/\lambda d^2) V^2$$

For a given cell, the only variable will be the potential difference, so that we can put

$$I_e = I sin^2 k V^2$$

in which k stands for the square of the product of the other terms. This expression is, of course, not linear but a simple periodically repeating curve as shown in *Fig. 14*. In particular it is to be noticed that the loops of the curve become steeper as the value of the potential difference increases. A number of investigators have suggested working on a subsequent slope of the curve as less voltage is required to bring about half-wave retardation. In ordinary circumstances it will not be possible to work on a subsequent slope because only for the first slope does a transition from extinction to white light become obtainable. By means of judicious compensation, however, this difficulty can be surmounted. We shall suppose, in order to illustrate this point, that it is required to work on the third slope. Then the compensation of two orders will be essential. This can be effected with mica or preferably cellophane of such thickness that retardation of exactly two orders is brought about. The mica or cellophane is now disposed in the polariscope, so that their slow direction coincides with the fast direction in the nitrobenzene. The fast direction for nitrobenzene, as we shall see later, is parallel to the electrostatic field. By this means it is possible to work from extinction to maximum white illumination on the third slope of the curve.

A word now as to the behaviour of nitrobenzene when it is electrostatically stressed. Kerr assumed that it adopted the character of a negative uniaxial crystal, for he compared it with Iceland spar. In this he was under a misapprehension, for it was discovered later that the behaviour of the liquid was unique in that one component was accelerated and the other retardated. Now for all uniaxial crystals one component, the ordinary ray, remains undisturbed and as this component does not appear in the stressed nitrobenzene, we conclude that the stressed liquid cannot be compared with a uniaxial crystal.

By allowing two beams of light to interfere in the Michelson interferometer, it is possible to observe by the shift of interference fringes whether the one component is in advance of or behind the other when the both have reached the plane of interference—in other words, whether the components have been accelerated or retarded. Aeckerlein found and McComb confirmed by the method outlined above, that if light was first polarized and if one beam passed through stressed nitrobenzene and the other through unstressed nitrobenzene, then when the light in the stressed liquid was vibrating parallel to the field, this component was accelerated. When the light was vibrating perpendicular to the field, this component was retarded. That is, the former travelled faster and the latter slower than the light in the unstressed nitrobenzene. Comparison was made between the components in the stressed liquid and the beam passing through the unstressed liquid. The arrangement is shown in *Fig. 15*. By orientating the nicol it is possible to ensure the direction of vibration of the light passing through the stressed nitrobenzene. The vibration direction

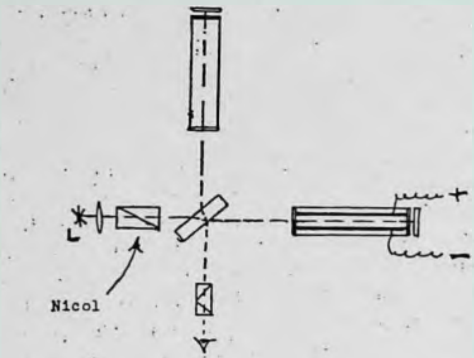


FIG. 15—Arrangement for investigating optical effect in stressed nitrobenzene

of the extraordinary ray is in the principal plane and is therefore parallel to the lines of force, for we have already shown that the optic axis of a crystal produced by stress lies in the direction of the stress, and, of course, the principal plane is that plane containing both optic axis and the ray itself. Therefore it appears that the extraordinary ray is accelerated and the other ray—we cannot call this ray the ordinary ray—is retarded. Now in *Fig. 7* we saw that for the OY axis of the negative biaxial crystal V_e is accelerated and $V_o{}'$ is retarded, therefore on first thoughts we might regard stressed nitrobenzene as a negative biaxial crystal.

Unfortunately there is one great drawback. For stressed nitrobenzene, this state of affairs is the same for all directions normal to the lines of force, but such is not the case in a true biaxial crystal. For in the OX direction the ordinary ray appears. No solution to this curious problem appears to have been offered. We have shown that the stressed liquid does not behave as a uniaxial crystal and not as a normal biaxial crystal. In *Fig. 16*, the ray surface of the liquid is shown. The dotted line represents the sphere of the ordinary ray, which does not appear when the liquid is stressed. The surfaces are a prolate within an oblate ellipsoid, their common axes being the direction of the lines of force.

(*b*) *In solids; particularly piezo-electric quartz.*—The first serious work on the Kerr effect in quartz was carried out by Rœntgen, and he made the interesting discovery that the fringes seen in convergent light were modified when the field was applied. This modification of the ring system is identical with that which we witnessed in the mechanical stressing of the quartz. The effect was of such magnitude to preclude any possibility of it

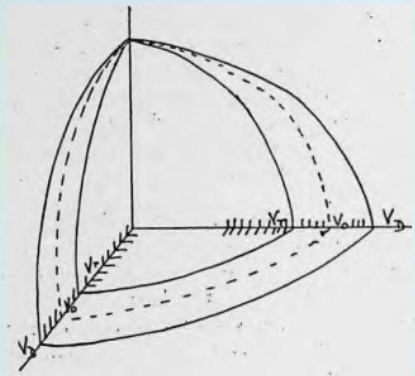


FIG. 16--Ray surfaces of direct and transverse components in stressed nitrobenzene—V_o is the ordinary ray

being due to electrostriction. The first dark ring for which the retardation is two wave-lengths is converted into an ellipse.

Now for a particular kind of quartz there occurs an actual dilatation much greater than that brought about by electrostriction. This is the converse piezo-electric effect. The dilatation is different for different directions in the quartz. The expression for the piezo-electric dilatation is

$$S = KV^1/d$$

in which S is the strain, or dilatation per unit length, measured in cms., V^1 is the voltage across the crystal in electrostatic units and d is the distance between the electrodes. The constant K is termed the piezo-electric constant and its value in quartz is $6{\cdot}48 \times 10^{-8}$ along and perpendicular to any diagonal axis of the quartz crystal. This axis is also called the electric axis, because when the quartz is cut so as to give the greatest converse effect the lines of force of the electrostatic field are parallel to this axis. In *Fig. 17*, showing the crystal as cut from the piece of quartz, the optic axis is normal to the plane of the paper and the electric axis is parallel to EE. The axis perpendicular to both optic and electric axes is called the third axis, TT. The value of the piezo-electric constant for the optic axis is negligibly small. For extremely accurate work it is necessary to add the electrostriction dilatation, but this is too small an amount to warrant addition in this case.

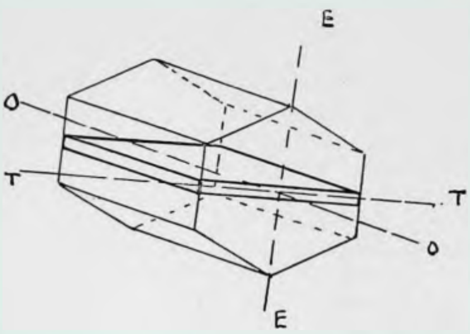


FIG. 17—Plate of piezo-electric quartz—
OO is the optic axis
EE is the electric axis
TT is the third axis

If the quartz is strained by an electrostatic field, applied so as to produce the greatest dilatation, then retardation should be set up and the field of the polariscope should be accordingly illuminated. It is of interest, then, to calculate the voltage required to give maximum illumination, that is, to set up a retardation of 2,750 Ångstrom units. We have first to calculate the stress set up in the quartz as a result of the strain. The stress T will be ES, in which E is the modulus of elasticity; for the direction of the third axis we can take this to be roughly 10^{12} dynes per cm^2. We can therefore put $T = ES = EK(V^1/d)$ dynes per cm^2, and the retardation set up in the quartz will be

$$r = cTd$$

under which C is the stress-optical co-efficient, which we may take as 5 for quartz in this direction. T must be expressed in megadynes per cm^2. On substitution for T we have, dividing by 10^6 to reduce to megadynes per cm^2,

$$r = cTd = CKV^1E/10^6$$

as V^1 is in electrostatic units we have to divide by 300 to reduce to volts, therefore we have finally

$$r = (CKVE)/(3 \times 10^8)$$

Giving the various constants their proper values, we have

$$2750 = (5 \times 6{\cdot}4 \times 10^{-8} \times V \times 10^{12})/(3 \times 10^8)$$

from which V is computed to be 258 kilovolts. This will be required to set up a retardation of half a wave-length, thereby fully illuminating the field. It is to be noted that the expression does not contain either the length or the thickness of the crystal and this is so because the light is passing in the direction of the electric axis and therefore through the electrodes, which must be supplied with holes for this purpose. If the light is to pass through in the direction of the third axis, then our expression takes the modified form—

$$r = [(CKVE)/(3 \times 10^8)] \times l/d$$

in which l is the length of the light path and d is the distance between the electrodes. Suppose that l was 10 cms., and that d was 0·1 cm., then the above voltage for the same retardation would be reduced by 100, and would become 2·58 kilovolts, which is not so seriously high a voltage. Pockels actually produced retardation by this method, but as it is necessary to employ a compensator, the light path is very long and narrow, so that but little light can be made to pass through the combination.

The piezo-electric constant of Rochelle salt for a particular axis is 1000 $\times$ 10^8 and is thus about 16 times that of quartz. The formula of the salt is $KNaC_4H_40_64H_2O$; it is a positive biaxial crystal with indices $\alpha = 1{\cdot}492$, $\beta = 1{\cdot}493$ and $\gamma = 1{\cdot}496$. The angle between the optic axes is 117°. Unfortunately, however, as the writer has ascertained, the stress-optical co-efficient is extremely low so that the retardation due to mechanical pressure even up to the breaking point of the crystal is negligible. In the experiment, the crystal was cut so that the acute bisectrix of the optic axes lay in the plane of the surface. The axis normal to the axial plane of the crystal is that for which the piezo-electric constant is a maximum. The field was therefore applied by electrodes disposed normally to the obtuse bisectrix. This is shown in *Fig. 18*.

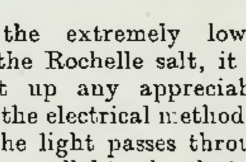


FIG. 18—Experiment to examine the retardation in Rochelle salt.—OO is the obtuse bisectrix of the crystal and also the direction of the light.

Owing to the extremely low stress-optical co-efficient of the Rochelle salt, it was not found possible to set up any appreciable amount of retardation by the electrical method just described. Of course, if the light passes through the crystal in between and parallel to the electrodes, then, the light path being fairly long, if the voltage is high enough it is possible to set up a small amount of retardation. This has actually been achieved by

Pockels. For Television work this method is unsatisfactory, owing to the long and narrow light path.

There remains, however, one method by which to produce the desired retardation and that is by setting the crystal of piezo-electric quartz into vibration. A number of investigators have suggested this method. They arrange that the light shall travel through the crystal in the direction of the optic axis so that when the vibration is induced there will be a modification in the amount by which the plane of polarization of the light will be rotated. Kerr Grant exhibited this method in 1927. But it is found that, if such a method is employed, owing to the large dimensions of the crystal it is difficult, if not impossible, to modulate the natural frequency of the crystal. In other words to modulate the amplitude of vibration of the crystal when this is vibrating at its natural frequency.

If the electrodes of the crystal are so disposed that the electrostatic field is parallel to the electric axis, the best results with regard to amplitude of vibration are obtainable and the natural fundamental vibration frequency of the quartz crystal is given by the expressions—

$\frac{272}{e}$ kilocycles per second for vibration along the e axis,

$\frac{272}{t}$ kilocycles per second for vibration along the t axis,

$\frac{312}{o}$ kilocycles per second for vibration along the o axis,

in which e, t, and o are the electric, the third and the optic axis respectively. It will be obvious that for the highest natural frequency we should have the crystal vibrating along the electric axis, which is simply the distance between the electrodes. We can reduce this distance as we please. For instance, if the crystal were 0·5 mm. in thickness, the natural frequency would be 5·4 megacycles. Now if two such crystals are arranged in the polariscope so that the fast direction of the one coincides with the slow direction of the other, then the retardation would be nil; but if now the crystals are set into resonant vibration, retardation will be set up in both of them so that the field of the polariscope will become illuminated. Such an experiment has been performed with success by Tawil and Ny Tsi Ze, the reference to whose work is given in the biography at the end of this paper. The writer has confirmed their results and has attempted to produce a form of light relay for Television work by choosing crystals of such dimensions as to allow of an extremely high natural vibration. The higher the natural vibration the higher the frequency to which modulation can be carried out. *Fig. 19* shows the state of the crystal at rest and in vibration. The photograph is due to the late Dr. Dye and is obtained by observing stroboscopically the shift of interference bands when the crystal is in motion. A fairly thick specimen is taken in which the shift of bands is appreciable. With the crystals obtained by the writer, such a large mechnical vibration is not to be anticipated, but the internal stress in the vibrating specimen is enough to afford adequate retardation. The crystals are set into vibration by connecting their electrodes across an oscillating circuit or simply across the anode and grid of an oscillating valve. This is sufficient to obtain the requisite retardation.

FIG. 19 - (on left) Quartz plate at rest (on right) in vibration

When the crystals are freely vibrating, their frequency-amplitude characteristic is very peaked and but little modulation in an undamped crystal can be expected. But if the crystal is successfully damped, the range of modulation is, of course, increased. At the same time the power needed to drive the crystal is increased. This is shown in *Fig. 20*. Up to the present it has been found possible to modulate the crystal up to 20 kilocycles without appreciable attenuation at the higher frequencies, but such a device cannot be claimed as perfectly successful until it can be modulated up to, at least, 200 kilocycles. The writer used 50—100 metre crystals 15 mm. diam.

There is indeed an entirely new avenue of research open in this direction and no small amount of attention should be given to it. The great advantage of such a device lies in the shortness of path through which the light has to

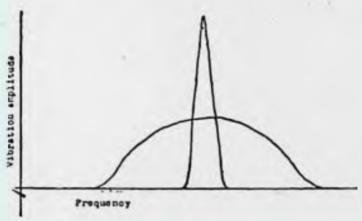


FIG. 20 Damping of the quartz crystal

travel in traversing the crossed crystals and secondly the comparatively large area offered normal to the direction of travel of the light. It is possible to excite the crystal by means of a fine mesh and thus the area normal to the light beam is practically as great as that of the face of the crystal. It would be possible, no doubt, to employ a transparent colloidal form of electrode, in which case this area would be greater still. The two crystals disposed in the polariscope are shown in *Fig. 22*.

6. *Form of Polariscope for Television Work.*—If we are to employ as much of the available light as possible, then we must certainly use both the ordinary and the extraordinary rays of the polarizer, whatever form this may take. We have the choice of a plain block of calcite, a Rochon prism, a Wollaston prism or a De Senarmont prism. We shall discuss first the Rochon prism form of double image polariscope as advocated by the writer. In this form of prism the ordinary ray passes through undeviated, and the extraordinary ray suffers the deviation. This deviation δ is given by the simple expression—

$$Sin\ \delta = \beta tan A \text{ (see Preston " Light ")}$$

in which β is the birefringence of the material in respect of the direction of the ordinary ray. A is the angle of the prism. Thus the prism must be cut so that this direction is that for which the birefrigence is a maximum. Therefore the optic axis of the prism must be in the surface of incidence. Needless to say, one prism of the combination can be made of glass of refractive index equal to that of the ordinary ray in the

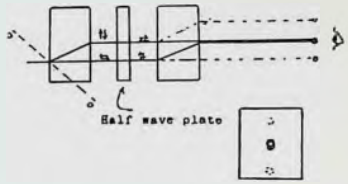


FIG. 21—The double image polariscope
Two simple blocks of calcite

calcite. This will ensure that the ordinary ray will remain undeviated when passing through the combination. For calcite $\beta = 0{\cdot}172$, so that with a convenient angle A of the prism, say 30°, the deviation of the extraordinary ray will be roughly 5°40′.

On looking through one prism, the image of a point will appear double, but if a second prism is introduced, the image will be quadrupled, at least for particular relative orientations. If the principal planes of the two double image prisms are parallel, then two images only will appear and

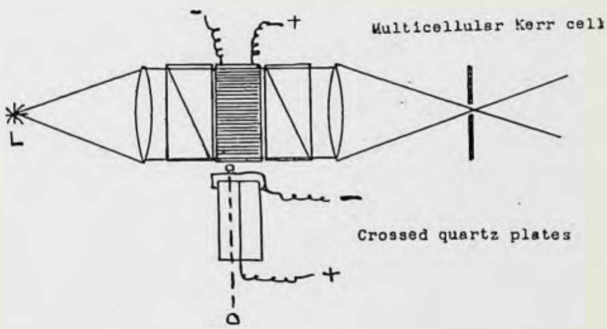


FIG. 22—Arrangement of double image polariscope

the separation between these two images will be twice as great as that when only the first prism is used. If one prism is now orientated through two right angles, then these two images will be extinguished and only one image will appear. This one image will not occupy the position of either of the two former images. Its position will be exactly in the centre of the line joining the first two images. The single image is in reality two images which coincide. Now by introducing a half wave plate in the double image polariscope, consisting of two parallel double image prisms, the same effect can be brought about. That is, the two images become extinguished and two further coinciding images appear half-way between them.

We can follow the action of the half wave plate better if we consider the double image polariscope consisting of simply two blocks of calcite cut in a manner which we shall describe later. A ray of light incident on the first calcite block, which we shall call the polarizer, is split up into two rays in the usual manner, one of which passes through the polarizer undeviated and the other becoming bent away from the normal within the polarizer, and thus following the course of the extraordinary ray. When it leaves the polarizer, it travels parallel with the ordinary ray. But after emerging from the polariser, the ordinary ray is vibrating normal to and the extraordinary ray parallel to the principal plane. This principal plane is the plane of the paper in *Fig. 21*. Therefore we can draw short lines representing the vibration directions. For the ordinary ray, which is vibrating normal to the plane of the paper, we have, for convenience sake drawn the vibration direction as shown. Now when the two rays reach the analyser, which is a similar block of calcite, the ordinary ray pursues its course undeviated as before. The extraordinary ray again becomes deviated and its parallel shift with regard to the ordinary ray is increased. Their paths through the analyser are shown in dotted lines.

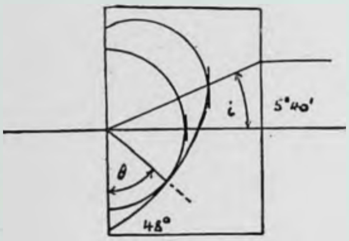


Fig. 23 The polariser

But when the half wave plate is introduced, the state of affairs will have altered somewhat. The half wave plate will have rotated the vibration directions of both rays through a right angle. This means that the extraordinary ray of the polarizer will become the ordinary ray of the analyser, because it is now vibrating normal to the principal plane. Therefore it passes undeviated through the analyser. On the other hand, the ordinary ray of the polarizer becomes the extraordinary ray of the analyser, because it is now vibrating in the principal plane. Therefore it suffers a shift parallel to itself as in the case of the extraordinary ray. The new paths of the two rays are drawn in full lines. On examination of the *Fig.*, it will be seen how the centre image has replaced the two outer images.

It follows from this experiment that the Kerr cell or the crossed quartz plates might take the place of the half wave plate. If the Kerr cell is inserted between the polarizer and the analyser, then it should be of the Karolus multicellular type, because the light passing through it will be nearly parallel. When the cell is stressed to give half wave retardation, with a proper optical system, the two original images can be intercepted by a conveniently disposed screen. The central image formed when the medium within the polariscope is stressed should fall opposite an aperture in the screen and thus the light can pass through and reach the scanning system.

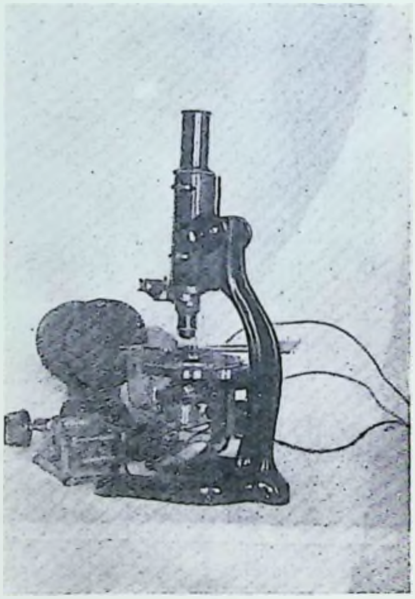


FIG. 24—Retardation in crystal observed in petrological microscope

The question at once arises as to how to cut the calcite for the polariscope just discussed, in order that the separation of the two rays may be a maximum. On referring to *Fig. 23*, we see the block in which the optic axis makes an angle θ with the surface of separation. The deviation within the block of the extraordinary ray is i. The relation between θ and i is given by the expression—

$$tan\ i = \frac{\mu_o^2 - \mu_e^2}{\mu_o^2\ Cot\ \theta + \mu_e^2\ tan\ \theta}$$

which is taken from Shuster's "Theory of Optics" (Arnold). Now to find the value of θ which will give a maximum for i, we have to differentiate the right hand side of the equation with respect to θ and then equate the result of the differentiation to zero. When this operation is performed it will give—

$$tan\ \theta = \frac{\mu_o}{\mu_e} = \frac{1{\cdot}658}{1{\cdot}486}\ or\ \theta = 48^\circ\ 8'$$

which is the value of θ for i to be a maximum. From this i can be calculated and it will be found to be 5° 40′. This gives the method of cutting the calcite.

The above is, of course, only a rough outline of a method that should be employed in this connection, and there are many ways of carrying out this principle.

It would appear, therefore, that there is much serious work to be done on the lines indicated above and particular attention should be paid to the method of light modulation by vibrating quartz plates or discs. Also to the form of double image polariscope to be used in conjunction with this device and even in conjunction with the Kerr cell.

In conclusion, the writer wishes to place on record his indebtedness to all those who have assisted him in his investigations and in particular to Messrs. Adam Hilger for the preparation of crystals and for the loan of two crystals for demonstration; to Messrs. E. Leitz for the loan of Petrological Microscope; to Mrs. R. Suttill for loan of Specimen Microscope; and to Messrs. Scophony Ltd.

SHORT BIBLIOGRAPHY.

SECTION 1.

Preston, *Light* (Macmillan).
Johannsen, *Manual of Petrographic Methods* (McGraw Hill).

SECTION 2.

Coker and Filon, *Photo Elasticity* (Cambridge). A valuable bibliography will be found at the end of this book.
Brewster, *Roy. Soc. Edin. Trans.*, 8, 1818, p. 281.
Beaulard, *Comptes Rendus*, 112, 1891, 1503. This paper deals with the conversion of uniaxial quartz into a biaxial crystal by compression.

SECTION 3.

Koenig, *Ann. der Physik*, 4, 1901, 1.
Mach, *Ann. der Physik*, 146, 1872, 313.

SECTION 4.

Fontana, *Letre inedite di Volta Pesaro*, 15, 1831.
Duter, *Comptes Rendus*, 87, 1878, 838, 960, 1036.
Duter, *Comptes Rendus*, 88, 1879, 1260.
Duter, *Journ. de Phys.*, 8, 1879, 82.
Kemble, *Physical Review*, 7, 1916, 614.

SECTION 5.

Kerr, *Phil. Mag.*, 50, 1875, 337, 446.
Kerr, *Phil. Mag.*, 8, 1879, 85, 229.
Kerr, *Phil. Mag.*, 9, 1880, 159.
Schmidt, *Ann. der Physik*, 7, 1902, 142.
Aeckerlein, *Phys. Zeitschrift*, 7, 1906, 594.
McComb, *Physical Review*, 27, 1908, 336.
McComb, *Physical Review*, 29, 1909, 525.
McComb, *Physical Review*, 6, 1915, 180.
Vigoureux, *Quartz Resonator and Oscillators*, (H.M. Stationery Office). An excellent bibliography is given at the end of this work.
Rœntgen, *Ann. der Phys.*, 19, 1883, 319.
Valasek, *Physical Review*, 19, 1922, 478.
Tawil, *Comptes Rendus*, 185, 1927, 114.
Ny Tsi Ze, *Journal de Phys.*, 9, 1928, 13.

SECTION 6.

Same as for Section 1.
A comprehensive survey of the best known polarizing devices is given by S. P. Thompson in the *Proceedings of the Optical Convention* for 1905.
Rochon, *Ann. der Physik*, 40, 1783, 141.
Wollaston, *Phil. Trans.*, 1802, 381.
Jellet, *Brit. Assoc. Reports*, 186, Vol. 2, 13.

DISCUSSION.

Dr. Tierney the chairman, opened the discussion and congratulated Mr. Myers on his paper, which he said was of particular interest because such information had not previously been very plentiful and was essential for the efficient design of a television system. He quoted from his experience the case of a manufacturer who supplied certain apparatus which embodied a block of quartz through which ultra violet radiation was to pass. The maker provided a fine specimen of quartz but it was a type which became fluorescent under the action of ultra violet radiation and was thus useless. A proper knowledge of every phase of his work would have saved the manufacturer from making such a mistake, and similarly in television the highest efficiency can only be obtained by a fundamental knowledge of every factor from the light source onwards. The paper, he said, would be especially valuable in the *Journal* for reference.

Mr. Hankey asked whether the dark area which had appeared on the screen when polarized light was transmitted through a resonating quartz plate, could be avoided, and Mr. Myers replied that in practice a clear field would be obtained by using two resonating plates.

Mr. Gilbert asked for information on the method of using zinc sulphide crystal as a light valve, and Mr. Myers explained that such modulation was obtained purely by the Kerr effect and not by stressing the crystal mechanically as in the case of quartz, which was made to vibrate mechanically by the application of an oscillating voltage. In order to obtain the necessary retardation the light passes endways through a thin plate of zinc sulphide about an inch long and metal coated on each side. A polarizing voltage of 500 or 600 volts is applied between the metal coats, together with the modulating voltage, and in order to improve the optical efficiency several of these units are clamped together side by side, thus providing a number of parallel paths.

Mr. Phillips asked whether the modulation curve of the zinc sulphide cell was straight or whether it flattended out at the bottom, as was the case with the Kerr cell, and Mr. Myers replied that from what he knew and had read about the cell, he believed that the curve was straight.

Mr. Bridgewater expressed his interest in the paper, and particularly in the proposed scheme of modulating a freely vibrating quartz crystal up to 4 kilocycles or a damped crystal up to 200 kilocycles per second, but he said that in his opinion the 120 or 180 line pictures of the near future would require a working frequency band approaching one million cycles per second, and he asked whether modulation with such a high frequency would be possible. Mr. Myers replied that normally he would consider 500 kilocycles to be the highest modulation frequency that could be successfully applied, but he thought that by damping over a suitable series of peaks a wider response might be obtained.

Mr. Kingstone asked for information on the effect of magnetic fields on the optical characteristics of crystals, and Mr. Myers pointed out that the subject was not really within the scope of the paper. However, he described the Faraday effect by which the plane of polarization can be rotated by passing light axially through a cylinder of dense lead glass which is coaxial with a strong magnetic field, and the Rœntgen effect in which the plane of polarization is rotated when light is passed through a magnetised steel plate which it sufficiently thin to be transparent, but neither of these arrangements, he said, would cover a wide enough frequency band to be of use in television.

Another speaker asked whether the width of the frequency band covered by a vibrating quartz crystal was proportional to the fundamental frequency of vibration, and Mr. Myers replied that this was the case. It was, therefore, important to use the highest possible fundamental frequency and the author had so far succeeded in working at frequencies up to 10 megacycles.

Mr. Walters said he believed that tourmaline could be made to vibrate at 50 or 60 megacycles, and he asked whether it would not therefore offer advantages over quartz. Mr. Myers agreed that the higher fundamental frequency would be an advantage but it would have to be considered in conjunction with the light absorbtion and the stress optical co-efficients of the two crystals.

NOTES and NOTICES.

THE SOCIETY'S INDEX OF LITERATURE.

With the intention that the production of abstracts of current Television literature should be of a permanent character, it is important to consolidate the foundations upon which future work will rest. The Research Committee has received some helpful criticisms of the suggested terms published in the last issue of *The Journal.*

TELEVISION ABSTRACTS.

Mr. Barnard hopes shortly to call upon those members who have promised to assist in the actual work of abstracting, and for their information, and possibly others who may feel able to help with this important work, the following is now printed :—

SECTION A.—Notice to Abstractors.

1. Coloured forms headed Index of Literature are to be issued for abstracts.
2. The abstractor is requested to sign his name on the line marked " Referred to."
3. Each abstract should begin with the Author's name with initials only, and no titles.
4. The title of the paper, given on the next line in English, should be short, and need not be a literal translation. It should not begin with " The," " On the," " Research on the," etc.; but should clearly designate the subject of the paper.
5. On the line marked " Publication," the recognised abbreviation of the publication concerned should be given; this should be followed by the volume number, the year of publication, and the page numbers for the paper abstracted.
6. Abstractors are particularly requested to see that the information given on lines 1, 2 and 3 is correct, since generally it will not be possible to check these references; the responsibility for their correctness will therefore rest with the abstractor.
7. The abstract should be as concise as is consistent with clearness; in general, the abstract should not occupy more than 250 words. When the value of an abstract is much increased by including curves and diagrams, these may be reproduced. Such figures should be drawn upon white " Bristol " board.
8. In all cases, papers of an historical character, and those dealing with matter which is already well known should not be abstracted. But if such a paper is of exceptional merit, it is advisable to state briefly the scope and character of the work, so that attention may be drawn to original.
9. The abstract should be in the present tense when describing experimental results.
10. Any note by the abstractor should be in square brackets. Criticism by an abstractor cannot be permitted in an abstract.
11. The abstractor is relied upon to read papers critically, and to reject them if they are not sufficiently important to be abstracted. Matter of which the correctness appears doubtful should not be reproduced. When papers are found to be unsuitable, the abstractor is requested to say so, stating author, title, and publication.

12. A mathematical or complicated paper, which cannot well be abstracted, should have the references for lines 1, 2 and 3, and a few words if possible, merely to say what it is about, so that a reader interested in the subject may know that the paper has been written. In mathematical works the solidus, $d\beta/d\gamma$ instead of $\frac{d\beta}{d\gamma}$ saves room and expense in printing, and should be adopted as far as possible; but care must be taken not to introduce ambiguity in extending this principle. For example, $\frac{\alpha + \delta}{\pi - \delta}$ must be written $(\alpha + \delta)/(\pi - \delta)$ with brackets.
13. If a paper appears in several parts, a separate abstract should not be made for each part; but the whole series should generally be combined in a single abstract, which should include a reference to each part in the heading.
14. Initials of speakers in discussions should in all cases be given when their remarks are abstracted.
15. When the description of an invention is anonymous, the name of the inventor should not be given as the author of the description.
16. Decimals should be written thus, 0·07, not ·07; words in 'ize' and 'ization' with a 'z' where this is possible. Use should be made of the list of standard symbols and abbreviations for Television.

    (*Note.*—The List of Standard Symbols is now being revised in accordance with suggestions received.—Editor.)
17. It is important that abstractors should send in copy not later than one month after publication of the paper. If an abstractor is unable to deal with a paper, he should notify the Editor without delay, since prompt publication of the abstract is most desirable.
18. The Editor reserves to himself the right to revise or to reject any abstract.
19. It will be a great help if abstractors make suggestions and criticisms, and call attention to misprints and other slips, so that they can be corrected at the end of the year.

SECTION B.—Subject Matter.

The Committee has decided to omit entirely the subjects of Talking-Films and Photo-telegraphy. The abstractor should remember that in so far as he is concerned with the abstracting of papers on Television and its associated subjects, he should give particular prominence to technical papers; that is to say, applied science and not pure science is his concern. Only for very special reasons should a paper dealing with a research into pure science be considered for abstracting.

Index of Subjects.

1. Amplifiers, valve, Design and operation of.
2. Exploring devices at transmitter and receiver, Synchronization of.
3. Illumination, Problems of, at transmitter.
4. Light-Sensitive cells—
   Photo-conducting,
   Photo-electric,
   Photo-electrolytic,
   Photo-voltaic.
5. Light tubes for receivers.
6. Studio arrangements for television broadcasts.
7. Systems, Complete.
8. Terminology.
9. Theory, Abstract.
10. Transmission and Reception by wireless of television signals.

Abstractors are requested to notify the Editor of those subjects with which they feel most competent to deal.

SECTION C.—List of Standard Abbreviations.

Abbreviation.	*Full Title.*
Abh.	Abhandlungen.
Acad., Accad., Akad. ...	Academy, Académie, Accademia, Akademie.
Am.	America(n).
Ann.	Annals, Annales, Annalen, Annali, etc.
Ass.	Association.
Ber.	Berichte.
Brit.	Britain, British.
Bull.	Bulletin.
C.R.	Comptes Rendus.
D.	Deutsche.
Ecl.	Eclairage.
El.	Electric(al), Electro-, etc., Electrique.
Elektrot.	Elektrotechnische, Elektrotechnik.
Eng.	Engineer(s), Engineering.
Franc.	Française.
Ges.	Gesammte, or Gesellschaft.
Ind.	Industry, Industrie, Industrial, etc.
Ing.	Ingénieur.
Inst., Ist.	Institution, Institute, Istituto.
Ital.	Italiana.
J.	Journal.
Mem.	Memoirs, Mémoires, Memorie.
Nachr.	Nachrichten.
Opt.	Optical, Optique, Optik.
Phil.	Philosophical.
Phys.	Physics, Physica, Physique. Physik, Physical, etc.
Proc.	Proceedings.
Pub.	Publications.
R.	Reale.
Rend.	Rendiconti.
Rep.	Repertorium, or Report.
Rev.	Review, Revue.
Roy.	Royal(e).
Sci.	Science(s), Scientific, etc.
Soc.	Society, Société, Società.
Techn.	Technology, Technological, Technische, etc.
Trans.	Transactions.
Ver.	Verhandlungen.
Wiss.	Wissenschaft (liche).
Z.	Zeitschrift.
Ztg.	Zeitung.

ACTIVITIES OF THE RESEARCH COMMITTEE DURING 1933.

During the year, the Committee has concentrated on providing members and others interested in Television with opportunities of inspecting actual Television apparatus. To this end they have assisted lecturers with apparatus so that demonstrations at our meetings and papers have become rather an attractive feature of the year's work. Lantern slides and large scale drawings are also available for those who desire to borrow them for the purpose of giving lectures on Television to other societies. The members of the Research Committee have actually organised and given many such lectures during the year in various parts of the country.

They have provided exhibits of Television apparatus under the name of the Society at the following Exhibitions :—

January—

The Physical Society's Exhibition. Mr. R. W. Corkling showed a combined sound and vision receiver.

Lecture on Television, with demonstration, to the Wembley Society.

February—

Exhibition of Television apparatus at the Mercer's School.

Exhibition of Television apparatus at the Royal Institution.

April—

Television Society's Fourth Exhibition at Imperial College, London.

May—

Lecture by Mr. R. W. Corkling to the South London Transmitters' Association.

Opening of three months Exhibition of photo-electric cell applications at the Science Museum, South Kensington. The Television Society was invited to exhibit and provided a working piece of apparatus to illustrate the application of photo-electric cells to scanning a subject. This invitation was a signal honour to the Society and the apparatus attracted considerable attention from the visiting public.

October—

The International Inventions Exhibition.

Mr. R. W. Corkling had a very comprehensive exhibit of Television, occupying a stand some 30 feet long.

The exhibit was divided into 10 Groups, the main object being to demonstrate the gradual development of the art, commencing with Selenium and finishing up with the latest application of Cathode Rays.

Chiefly the exhibits shown consisted of a collection of apparatus which Mr. Corkling has designed from time to time during his investigations and experiments on Television during the last nine years.

The grouped exhibits were made up as follows :—

1. Selenium.
2. Light Modulators.
3. Photo Electric Cells.
4. The problems of exploring.
5. Disc Receiver.
6. "Televidascope."
7. Mirror Drums.
8. Projected Television.
9. A Complete Home Receiver Embodying Vision and Radiogram.
10. Cathode Rays.

Throughout the Exhibition, demonstrations were given showing the working of the Cathode Ray Tube complete with time base unit, producing an image of 30 lines, 12½ times per second.

Mr. Corkling subsequently gave a lecture to the Institute of Patentees. The chair was taken by Lord Askwith and excellent demonstrations were given on two Baird "Televisors" and a Cathode Ray Receiver kindly provided by Mr. T. W. Price, of Messrs. Ediswan's.

November—

Lectures by Mr. T. M. C. Lance to the Birmingham General Electric Co. Apprentices and the Brickett Wood Ratepayers' Association.

T.M.C.L.

THE TELEVISION SOCIETY.

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Editorial Notice.

The Papers Committee of the Council will give careful consideration to contributions of a scientific nature submitted by Member and Non-Member contributors for publication. Contributors should prepare their manuscript as concisely as possible, special care being given to the legibility of mathematical formulæ. A short summary should accompany the paper.

The Society does not necessarily endorse the views and opinions expressed by individual writers in the JOURNAL. The right to reprint limited portions or abstracts of the papers, discussions and notes appearing in the JOURNAL is granted subject to the usual courtesy recognition. Diagrams or photographs published in the JOURNAL may not be reproduced without special permission.

All contributions and Editorial communications should be sent to W. G. W. MITCHELL, B.Sc., "Lynton," Newbury, Berkshire, England.

Forms of proposal for Membership, and further information regarding the Society, may be obtained on application to the Business Secretary, J. J. Denton, 25, Lisburne Road, Hampstead, London, N.W.3.

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