

## PATENT SPECIFICATION

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### PROVISIONAL SPECIFICATION.

#### Process for Altering the Energy Content of Dipolar Substances.

I, JAMES YATE JOHNSON, a British Subject, of 47, Lincoln's Inn Fields, in the County of London, Gentleman, do hereby declare the nature of this invention (which has been communicated to me from abroad by Ternion Aktiengesellschaft, of Glarus, Switzerland, a Joint Stock Company organized under the Laws of Switzerland), to be as follows:—

Among the properties of substances there are several which are dependent on the frequency of the electromagnetic oscillations used for observation. Among such properties may be mentioned for example speed of transmission, absorption, rotation of the plane of polarisation and dielectric constant. The term used in these cases is dispersion of the properties concerned. In order to explain this phenomenon, Sellmeier (1871) and later Helmholtz, Ketteler and others developed the theory that with respect to the period of oscillation employed the substances can no longer be regarded as continual, but rather they must be regarded as more or less rigidly coupled aggregates of oscillators. As oscillators according to modern conceptions of the construction of materials may be mentioned the combined electrons, the combined atoms and the dipolar molecules. Since these particles are carriers of electric charges, they are set in oscillation under the influence of external electrical alternating fields, as for example the electromagnetic radiation field. They absorb energy from the applied alternating field. The excitation is especially strong and the absorption of energy therefore especially great in the case of resonance. Simultaneously with this there takes place a sudden change in all those properties which are connected with the energetic alternating action between oscillator and external oscillation, for example the abovementioned properties. A typical resonance curve is shewn in Figure 1 of the accompanying drawing. The oscillation frequencies are given as abscissæ and the ordinates are the corresponding strengths of the absorption of energy (dotted) and the values of any one of the dispersion properties, as for example the dielectric

constant (full line). The region of the sudden change is termed the anomalous dispersion region, in contrast to the regions of normal dispersion on the branches of the curve lying further to the outside.

In many cases, for example when it is desired especially to emphasise the electrical nature of the alternating action the term polarisation of the substance is also used, in order to express the polar structure of the oscillators.

In order to be able to state into which forms the absorbed energy is converted, it is necessary to bring the conception of polarisation into a somewhat more precise form. It is preferably subdivided into:

1. an electron polarisation, i.e. an influencing of the electron shells which build up and hold together the atoms;
2. An atomic polarisation, i.e. a displacement of the position of the atoms which build up the molecule, and
3. an orientation polarisation, i.e. a change in the relative positions of the molecules themselves.

The energies to be employed for the different polarisations are of quite different orders of size. The greatest energy for polarisation is required by the electrons, the least by the molecules. Now according to the quantum theory the following equation holds good;

$$\text{energy} = h \cdot \nu$$

in which  $h$  represents the Planck elementary quantum and  $\nu$  represents the frequency of oscillations of the electromagnetic rays. Thus the greater the energy to be introduced into the particles of material, the greater must be the frequency of oscillation of the rays, and the shorter therefore must be their wavelength. Accordingly the resonance positions of electron polarisation lie in the region of the Röntgen, ultra-violet and light rays, the resonance positions of atomic polarisation lie in the region of the infra-red spectrum and the resonance positions of orientation polarisation lie still further beyond in the region of the radio short and ultra-short waves. Those which

have been best investigated are the absorption spectra in the region of visible light. It is known therefrom that the absorbed light causes no appreciable physical or chemical changes in the irradiated substance. It is to the greater part radiated again as such. A part is converted into heat, another part may serve, with a change in its wave-length, to excite atomic oscillations (Raman effect) and in comparatively rare cases the rays of light passing into the substance give rise to chemical changes (photochemical reaction). The rareness of photochemical reactions is especially prominent. The behaviour in the infra-red region and in the ultra-violet region is very similar.

Only a little is known of the behaviour of substances with respect to waves having a wave-length of from the infra-red to several metres. The anomalous dispersion bands, especially, have still scarcely been exactly investigated. The region of waves which has hitherto been well investigated lies above about 2 metres, which is, generally speaking, outside the anomalous dispersion bands. The dielectric polarisation is only slightly noticeable therein. Energy is only absorbed slightly and since it is moreover almost completely converted into heat, is generally unsatisfactory, so that dielectric losses are spoken of. Only in a few special cases can this polarisation be usefully employed (diathermy, Kerr cells).

My foreign correspondents have now found that dipolar substances and substances containing the same behave in a thoroughly new and unforeseen manner when they are subjected to the action of an electro-magnetic radiation field which oscillates mainly or wholly in one or more frequencies which are the same as the natural frequencies of the said substances in the region of waves of from the infra-red to several metres in wavelength. The term "natural frequency" is intended to mean the range of frequency of the anomalous dispersion. Especially profound influences take place by the action of alternating fields which correspond to the natural frequencies of the substance which lie below 2 metres. By this action, an alteration in the energy content of the dipolar substance takes place which becomes strikingly noticeable in an increased reactivity and an orientation of the molecules. The orientation of the molecules renders the substances double refractive. This double refraction also effects a rotation of the plane of a ray of polarised light passed therethrough.

Before entering into details of this phenomenon, some observations may be made on the determination of the natural

frequencies. From the previously described connection between resonance frequency and anomalous dispersion position it results that the latter is a suitable indicator for the resonance frequency. It is only necessary to follow the frequency dependence of a constant of a substance suitable for the range of waves concerned up to the anomalous position. The dielectric constants are especially suitable for this purpose. My foreign correspondents have found that there are two sharply separated kinds of anomalous dispersion which may be differentiated as friction dispersion and resonance dispersion. Friction dispersion appears in all non-conducting dielectrics. With water for example it is as shewn in Figure 2, wherein the curve shews the course of the dielectric constant when using varying wave lengths for observation, and exhibiting a band of anomalous dispersion at a wave length of about 1.5 centimetres.

The course of such functions has already been theoretically explained by Debye and brought into mathematical form. In the description, the time lag appears as a substantial constituent of the conception, i.e. the time which the molecules require in order to come into equilibrium with an external electric field. The time lag is, inter alia, dependent on the internal friction constant and the temperature. In order to tune the irradiating alternating field and the natural frequency of the substance to be treated to each other, the external frequency may be altered while keeping the time lag constant until resonance is attained, or the time lag may be altered while keeping the external frequency constant. The latter may be conveniently attained by altering the internal friction, i.e. by alteration of the concentration and/or temperature.

Resonance dispersion appears in all conducting dielectrics, i.e. in electrolytes. It is of special importance for the processes in living organisms. Its curve differs very clearly from that of the friction dispersion, as may be seen from Figure 3 of the accompanying drawing. The band of anomalous dispersion is very small and sharply pronounced, frequently scarcely wider than  $\Delta\lambda = \frac{2}{100}\lambda$ . It can consequently be very readily overlooked. This hitherto unknown dispersion anomaly is connected with the alternating action of the ions.

In order to determine the natural frequency of dipolar substances and to alter the energy content of these substances, thereby allowing the technical effects hereinafter described to be

obtained, electromagnetic fields in part of relatively small field strength but also in part of great field strength are necessary. For the production of fields of the necessary wavelength there may be employed in the transmitter ordinary commercial short wave tubes which are operated with waves of wave lengths of more than about 80 centimetres in back coupling circuit and with waves of wave lengths of less than 80 centimetres in the oscillating circuit according to Barkhausen, Kurz and Hollmann. The tuning of the transmitter to the dipole resonance is effected in known manner by alteration of the self-induction and/or capacity of the circuit and by alteration of the grid and/or anode potential of the tube. Waves having a wave length of down to 3 centimetres can be produced with sufficient power with the aid of electron tubes. In the case of still shorter waves, it is at present still necessary to resort to the oscillation energy of known spark transmitters. Also with suitable spark transmitters, small wave bands may be produced by appropriate technical high frequency arrangements.

In order to strengthen the action of the electromagnetic fields thus produced they may be directed and concentrated by known means. This is especially of importance in cases when it is desired to carry out the action only in certain zones. A direction of the field may be effected by reflectors and a concentration may be effected between Hertz parabolic mirrors. Extremely concentrated fields may be produced by a new apparatus which is the object of the co-pending application No. 11,628/34, (Serial No. 417,564). This describes a plate oscillator which resembles a condenser in its external form, but not in its electric behaviour. In one of the modes of execution which are adequate for use in practice, it consists of two plates oppositely arranged. By reason of the distributed self-induction and distributed capacity the plate oscillator has electric resonances which appear at very high frequencies.

In order to bring into action the electromagnetic alternating fields corresponding to one or more natural frequencies of the dipolar substance, the dipolar substance is brought, according to the desired intensity of the action, into the electromagnetic alternating field of corresponding frequency which may be undirected, or directed (e.g. by reflectors) or concentrated (e.g. by Hertz mirrors), or, if a specially intense action is necessary, the dipolar substance is exposed to the stationary alternating field in thin

layers between the electrodes of the plate-oscillator.

In cases when a substance has several natural frequencies in the range concerned, such as is the case mainly in electrolyte mixtures, a tuning may also be effected with the aid of means known in high frequency technique. Such work has already been done by working upon curved characteristics and also by coupling further transmitters tuned to the higher harmonics.

The energy supplied by resonance excitation varies either the intermolecular or intra-molecular equilibrium of the substance depending on the radiated natural frequency or on the intensity thereof. In the case of colloids for example the influencing of the intermolecular fields of force results in a change in the size of particles (conversion from the sol into the gel conditions or vice versa, flocculation, change in the viscosity or conductivity and the like) or in a change in the degree of hydration (influencing of the ageing phenomena of colloids, as for example silica gel, albumens, pectins and similar colloids).

In order to illustrate the effects taking place in colloidal solutions by irradiation with electromagnetic alternating fields having a frequency which corresponds with a natural frequency of the irradiated solution, an experiment carried out with a colloidal solution of gold is given below. The solution shewed a maximum resonance with a wavelength of 18.6 centimetres and at about 20° Centigrade. The solution was interposed in a layer 1 millimetre in thickness between the circular plates of a plate-oscillator the said plates being 1 centimetre apart. In this arrangement the natural oscillation of the plate oscillator with a plate diameter of about 6.2 centimetres was at a wavelength of 18.6 centimetres. In the transmitter a French short wave special tube "Metal Type E.4.M" was used. After acting on the solution for an hour, the original red colour of the solution changed to orange, a change in colour which as is well known indicates a diminution in the size of the colloid particles. By intensive irradiation for longer periods an opposite effect is observed, a flocculation taking place.

For further illustration an experiment carried out with agar-agar solution the resonance position of which lay at a wavelength of 116 centimetres may be referred to. These longer waves require plates of considerably greater diameter for the purpose of tuning the plate-oscillator. With the plates 1 centimetre apart, plates having a diameter of nearly 39 centimetres are necessary, as determined by

- calculation and confirmed by experiment in order that the fundamental wave of the oscillator has a wavelength of 116 centimetres. In order to avoid these somewhat
- 5 troublesome dimensions, the experiment was carried out in a plate-oscillator in which the distance between the plates was reduced from 1 centimetre to about 0.5
- 10 centimetre, whereby it was possible to employ circular plates having a diameter of 20 centimetres. The fine tuning of the oscillator system to the dipolar layer (having a thickness of 1 millimetre and a natural frequency of 116 centimetres)
- 15 interposed between the plates was effected by regulating the distance between the plates. The oscillatory energy in this experiment was produced with a tube "Metal Type T.M.C." After a short
- 20 time the solution became more mobile, and after irradiation for several hours the opposite effect occurred and the solution became more viscous.
- 25 The effects in the case of colloids of living organisms are especially striking, where they are equivalent to a preservation. For example by suitable dosing of the intensity of radiation, the natural decomposition processes, which always
- 30 commence with a decrease in the energy content and a change in the colloidal state, may be suspended. For example if fruit of all kinds be irradiated with the natural frequency of their expressed
- 35 juices (on an average 40 centimetres with slight deviations) or animal products with the natural frequency of their serums (on an average from 85 to 95 centimetres), a preservation for weeks at ordinary temperature is obtained, whereas the same
- 40 products without irradiation are spoilt within a few days under otherwise identical conditions. It is remarkable that the natural aroma is completely retained
- 45 in the case of radiation-preservation. If the intensity of radiation exceeds the degree necessary for preservation, profound chemical changes take place.
- 50 By the action of electromagnetic alternating fields of frequencies which correspond to one or more of the natural frequencies of the blood serum, profound effects may be produced in men and animals.
- 55 Serums are thoroughly complex liquids in which is present a large number of dipolar substances in more or less great dilution. The solvent is water. The position and strength of the anomalous
- 60 dispersion bands varies according to the nature and concentration of the dipolar substances. Experiments have shewn that differences in the position of the resonance positions occur not only in
- 65 different serums but also in serums taken from different individuals. In fact even with one and the same individual, the strength and number of the absorption bands differ according to the prevailing condition of change-of-matter. Since the
- 70 absorption bands, especially in the case of dipolar substances which are only present in small concentration, are in part extremely sharp (half value widths of less than 5 per cent) they readily escape
- 75 observation when normal pure electrical methods are employed. The position of the resonance points herein described has been found for example by observing the alteration of the intensity of a beam of
- 80 polarised light penetrating the influenced substances.
- In the said manner the serum of a test person was investigated. At a temperature of 37° Centigrade an especially strongly
- 85 pronounced resonance position was established at a wavelength of about 90 centimetres. Between this wavelength and the shortest dipolar resonance bands occurring in the serum, that of chemically
- 90 pure water which lies at a wavelength of about 1.28 centimetre there are a large number of characteristic resonance positions the accurate knowledge of which might give a comprehensive conception of
- 95 the state of health of the person concerned. Resonance positions above a wavelength of about 1 metre are according to observations made up to the present rather wide.
- 100 The supply of oscillatory energy from these long ranges of waves leads chiefly to increases in temperature, but not to the quite specific influences which are characteristic for most of the resonance
- 105 positions below a wavelength of 1 metre. By irradiation with frequencies corresponding to the sharply pronounced resonance positions, it is possible, as experiments have proved, to cause quite definite
- 110 reproduceable effects. The alterations of energy in the body lead to advantageous effects or also to marked injury.
- If it is intended specifically to act on foreign bodies in the serum, as for
- 115 example bacteria, there are two possibilities; either the irradiation is effected in the frequency which corresponds to a strongly pronounced absorption position owing to the presence of
- 120 foreign bodies in the serum and thus the nutrient medium and therefore, for example, the living conditions of the bacteria are altered, or the irradiation is effected in frequencies which correspond to the natural frequencies of the dipolar
- 125 substance from which the bacteria are built up.
- Purely chemical reactions can also be enforced which otherwise only proceed under the influence of heat or of catalysts.
- 130

For example isoprene is converted into a rubberlike polymerisation product, rubber solutions are vulcanised in the presence of sulphur, Bakelite A and B are converted into Bakelite C, varnishes and lacquers dry more quickly, acetylene combines with water to form acetaldehyde which in the presence of oxidising agents, as for example ozone, is immediately converted into acetic acid, and so forth.

A further effect to be observed by the action of resonant electromagnetic alternating fields is that the dipolar molecules are orientated. Such orientation of dipolar molecules which in general are in the disordered thermal equilibrium, could hitherto only be produced by the action of an external electrostatic field which due to the smallness of the dimensions of the molecules must be very strong, in order to exert an appreciable torque on the molecules and thereby orientate them. For the orientation of dipolar molecules by means of electrostatic fields voltages are necessary which nearly reach the disruptive strength of the dielectrics and thus are of the order of about between 100,000 and 200,000 volts. Consequently an orientation of conductive dielectrics by means of electrostatic fields is not possible since in such dielectrics the fields break down.

In contradistinction thereto, conductive as well as non-conductive dipolar substances can easily be orientated by means of resonant electromagnetic alternating fields. At first glance this appears to be improbable since it is to be assumed that the molecules will change periodically their direction in phase with the alternating field or rotate in the same phase and not arrange in a preferred position. This assumption would be correct, if the molecules did not exert directed forces on each other. Such directed forces, however, are existent as results from the fact that without any external influences the single molecules orientate themselves to some extent on their neighbouring molecules while passing through the sphere of influence of the latter, as can be observed in X-ray spectrograms. The same forces are also the cause of the formation of associates of molecules as can be observed in many cases, for example of pairs of molecules, as in the case of acetic acid, shoals of molecules as with azoxyanisol, or the accumulation of dipolar molecules around an ion as is the case with hydrated ions. Such associates are liable to form groups by interlocking.

The formation of such associates essentially depends on the frequency of collisions of two molecules, the greatness of the intermolecular forces and the

probability of the collision of two molecules in a position favourable for the formation of associates. By setting the molecules in uniform oscillation by means of a resonant electromagnetic alternating field the probability of the molecules colliding with each other in a position favourable for the formation of associates and the formation of such associates and groups of interlocked associates is essentially increased. Such associates and groups are no longer capable of following the phase of the applied alternating field, but can only exert tilting oscillations about a position determined by the applied alternating field. This, however, is equal to an orientation of the molecules throughout the whole mass. An electrostatic field acting simultaneously with the alternating field and in parallel therewith has no great influence on the orientation process for the reason already stated. It may, however, help to increase the percentage of orientated molecules and to keep a body of molecules which have once been orientated, in the ordered condition, even when the alternating field is withdrawn, since it is no longer necessary to orientate a body of disordered molecules requiring a high voltage, but prevent a body of orientated molecules substantially supporting itself to fall back into the disordered condition. For this purpose an electrostatic field is sufficient, the voltage of which is from 10 to 20 times smaller than is necessary to produce such orientation by means of an electrostatic field alone.

After withdrawing the applied resonant alternating field by which the orientation is produced, the disordered thermal equilibrium is produced again. The orientation may be maintained however, if the dipolar substance, while being orientated, be converted into the solid state the orientation being thus "frozen in", so to speak. This may be attained by solidifying an orientated gelatinisable dipolar substance or a gelatinisable liquid in which an orientated dipolar substance is dissolved, or by cooling an orientated dipolar substance below its melting point, or by evaporating the solvent in which an orientated solid dipolar substance has been dissolved. Such "freezing in" of an orientated substance in the said manner can only be effected while maintaining the resonant electromagnetic alternating field alone, if the solidification takes place without change of temperature or concentration, that is to say if during the solidification the alternating field and molecules do not come out of phase by change of the time lag. This is the case if the solidification be

5 effected by gelatinisation at constant temperature. When producing solidification by cooling or evaporating of a solvent the orientation must be maintained by means of an electrostatic field since during the solidifying process the time lag of the molecules is changed. In the latter case the electromagnetic alternating field by which the orientation is produced may be withdrawn. The maintenance of an orientation proceeds especially well when particularly long-chained molecules (great time lag) are embedded in an amorphously solidifying melt. Mixtures of paraffin and wax or glycerine with wax or colophony or ethoxy-benzene-amino-methylcinnamic acid were investigated in this way. The value of the mean surface density of the permanent orientation charge amounted for example to 0.5 to  $2.0 \times 10^{-9}$  coulombs per square centimetre positive.

15 A substance having a "frozen-in"

orientation of its molecules is more rich in energy than the same substance in natural thermal equilibrium. When "thawed" it gives up again this excess of energy, and, indeed, in the form of radiations of the same wavelength as those with which it was originally orientated. This behaviour may be used in order to supply to animal bodies dosed amounts of energy of a natural frequency which is active in the organism, as for example by allowing an aqueous gelatine the natural frequency of which is the same as the natural frequency of the serum to solidify while orientated and then to incorporate it into the body in this form.

Dated this 17th day of November, 1932.

J. Y. & G. W. JOHNSON,  
47, Lincoln's Inn Fields, London, W.C. 2,  
Agents.

#### COMPLETE SPECIFICATION.

#### Process for Altering the Energy Content of Dipolar Substances.

I, JAMES YATE JOHNSON, a British Subject, of 47, Lincoln's Inn Fields, in the County of London, Gentleman, do hereby declare the nature of this invention (which has been communicated to me from abroad by Ternion Aktiengesellschaft, of Glarus, Switzerland, a Joint Stock Company, organized under the Laws of Switzerland), and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

50 This invention relates to a process for altering permanently as well as temporarily the energy content of dipolar substances by exposing them to rapidly oscillating electromagnetic fields.

55 By dipolar substances are meant, not only those that contain dipoles in the absence of an electric field, but also those in which dipoles are induced when the substance is exposed to a suitable electric field. "Dipole" is used in the sense familiar in connection with the well known work of Debye, as expounded (for example) in his book entitled "Polar Molecules" published in 1929 in New York by the Chemical Catalogue Co.

60 It is known that the dielectric constant and certain associated properties of a dipolar substance are changed when it is placed in an electric field. But such changes hitherto produced by electric fields have been transitory and have vanished

with the field. This invention is not concerned with them except in so far as they are necessarily associated with permanent alterations; by a permanent alteration is meant one that endures for an appreciable period after the substance has ceased to be exposed to the electromagnetic field.

65 By an alteration in the energy content of a substance is meant one that does not consist solely in a change in the temperature of the substance or in a change inevitably consequent on change of temperature. On the other hand in the process known as diathermy the temperature of a substance which may be dipolar, is raised permanently (in the above sense) by exposure to a rapidly oscillating electromagnetic field. The object of the present invention, however, is not to produce a rise of temperature, although it may happen in certain instances that the characteristic period or frequency of a dipolar substance may be such that a rise of temperature of the medium in which it is immersed will inevitably occur in the course of the application of the process of the invention.

70 The process with which this invention is concerned depends on the fact that a dipolar substance is characterised by one or more definite periods and frequencies, which will be termed its characteristic periods and frequencies. The chief of

these characteristic periods and frequencies, as explained more fully below, are,

- 1.—the relaxation time of the orientation of the dipoles when exposed to a varying electric field;
- 2.—the period of natural oscillation relative to each other of the charges constituting a dipole;
- 3.—differences of the terms (in the spectroscopic sense) characteristic of the atomic and molecular structure.

It has been found that permanent alteration of the energy content of a dipolar substance can be produced by exposing it to an electromagnetic field of sufficient intensity varying with a period or frequency substantially equal to one of these characteristic periods or frequencies.

The characteristic periods or frequencies most important for the invention lie in the region of the spectrum corresponding (in the conventional sense) to wave lengths between 3 millimetres and 6 metres, but the use of periods of frequencies lying slightly outside these limits is not outside the invention. The region of the spectrum within which these periods or frequencies lie will be hereinafter termed quasi optical. Special methods are necessary to obtain electromagnetic fields of sufficient intensity oscillating with these frequencies. They cannot be obtained by setting into oscillation combinations of discrete condensers and self-inductances; for the dimensions of the condenser or coil required are so small, and consequently the volume in which a strong field is established is so small, that no sufficient amount of the substance can be introduced into it. On the other hand two methods have been found of obtaining the necessary fields over the necessary volume.

In one method conductors bounding the space in which the substance is contained are set into natural oscillations in virtue of their distributed capacity and inductance, so that standing waves are set up within the space. Suitable conductors for the purpose are a pair of concentric tubes or a plate-resonator, as described in the co-pending application No. 11,628 A.D. 1934 (Serial No. 417,564) consisting of opposed plates excited into their modes of natural vibration. A field produced by this method will be termed hereafter a "standing field".

In another method radiation of the appropriate frequency is concentrated into the space containing the substance by means of reflectors. A field produced by this method will be termed hereafter a

"radiating field".

The term "concentrated field" will mean a field produced by either of these methods or by any other method which can produce fields of the same frequency and intensity.

According to the invention a process for altering permanently the energy content of dipolar substances comprises the step of exposing the substance to a concentrated electromagnetic field oscillating with a quasi-optical period or frequency, such period or frequency being substantially equal to one of the characteristic periods or frequencies of the substance. It is to be understood that the oscillation of the field need not be sinusoidal, so that it has only a single period or frequency; it may be of any wave form so long as it contains at least one main component whose period or frequency is substantially equal to one of the said characteristic periods or frequencies.

The nature of the invention and the means for carrying it into effect will now be described in greater detail.

#### THE CHARACTERISTIC PERIODS AND FREQUENCIES.

The first step towards a better understanding of the nature and scope of the invention is a discussion of the characteristic periods and frequencies. Those denoted above by (1), (2), (3) will be discussed in order.

(1) The orientation of dipoles exposed to a varying electric field is discussed at length in Chapters V and VI of Debye's book on "Polar Molecules" above-mentioned. The following statement is in principle a brief summary of his exposition.

The orientation of dipoles along the lines of force of an electrostatic field is opposed by irregular motion arising from random thermal agitation. If the field is steady, the perfection of the orientation finally attained, and therefore the value of the dielectric constant of the material, depends only on the temperature, the nature of the dipoles, and the intensity of the field. But if the field is varying rapidly, the dipoles will not follow its variations accurately, their motions being hindered by the mutual actions which give rise to the viscosity of the substance. The dielectric constant depends therefore on the relaxation time  $\tau$ , which measures roughly the time that completely orientated dipoles take to return to the completely unorientated state, under their thermal agitation, when the field is removed. The relaxation constant is given by

$$\tau = \frac{4\pi a^3 \eta}{KT} \quad (1)$$

where  $a$  is the effective radius of the dipoles,  $\eta$  the viscosity,  $T$  the absolute temperature and  $K$  Boltzmann's constant.

The dependency of the relaxation time on the temperature  $T$  may already be pointed out now as, among others, it offers the possibility of transferring the place of anomalous dispersion into other ranges of wave-length.

The forces on which viscosity depends are dissipative and accordingly orientation under a rapidly varying field is accompanied by absorption of energy; the dielectric constant  $\epsilon$  for a field of frequency  $\nu$  is therefore given by the formula:

$$\epsilon = n^2(i - j\kappa)^2 \quad (2)$$

where  $n$  is the refractive index and  $\kappa$  the absorption coefficient of the medium for electromagnetic waves of frequency  $\nu$ , and  $j = \sqrt{-1}$

In Figure A of the accompanying drawings,  $n^2$  and  $\kappa$  are plotted against  $\nu$ ,  $n^2$  being given by the full line and  $\kappa$  by the dotted line ( $\kappa$  is here represented by  $\kappa_s$ ). As  $\nu$  increases,  $n^2$  decreases regularly and  $\kappa$  passes through a maximum; consequently the real part of  $\epsilon$  decreases as  $\nu$  increases, the decrease being particularly rapid in the neighbourhood of the maximum of  $\kappa$  between the limits  $\nu_1 \nu_2$ .

This decrease of dielectric constant (and of refraction index) with increasing  $\nu$  is generally known as anomalous dispersion.

The shape of the curves in Figure A depend, of course, on the properties of the dipolar substance. In particular the scale along the axis of  $\nu$  depends on the relaxation time  $\tau$ . For, as Debye shows, both  $n^2$  and  $\kappa$ , in so far as they vary with the frequency owing to the cause considered here, are functions of  $\nu\tau$ . Accordingly the value of  $\nu$  at which the maximum of  $\kappa$  occurs is inversely proportional or reciprocal to  $\tau$  and  $\tau$  is therefore a characteristic period, of the substance giving rise to a maximum of absorption for oscillations having a corresponding period.

(2) The periods of natural oscillation of the charges of a dipole give rise to a second kind of anomalous dispersion which is completely analogous to that familiar in optics. It arises of course from resonance. Figure B shows the course of  $n^2$  and  $\kappa$  which arises from a natural oscillation of frequency  $\nu_0$  ( $\kappa$  is here represented by  $\kappa(\omega)$ ). Figure C shows the course when there are several natural frequencies  $\nu_1, \nu_2, \nu_3$ . Figure D shows the course when a single natural frequency  $\nu_0$  falls in the range of anomalous dispersion of the kind shown in Figure A between the limits

$\nu_1, \nu_2$ .

The natural oscillations concerned here are of two main origins. (a) Oscillations in electronic polarisation, that is to say, the displacement of electrons within the atom; (b) oscillations in atomic polarisation, that is to say, the displacement of whole atoms within molecules or other permanent groups of atoms. As well-known, the frequencies of oscillation (a) are almost all in the optical region; they are important for the refractive index for visible and ultra-violet light, but have hardly any effect in determining the variation of the dielectric constant at the quasi-optical frequencies with which this invention is concerned. The characteristic frequencies of the kind in the quasi-optical range are those of the atomic oscillations (b). These frequencies also determine maxima of absorption important for the present invention.

It will be observed that the region of anomalous dispersion is much narrower when a characteristic period of type (2) is involved than when a characteristic frequency of type (1) is involved. This may be one reason why type (2) has so far received less attention.

(3) The third kind of characteristic frequency cannot, like the two considered so far, be explained in terms of "classical" conceptions; it demands quantum conceptions. It is well known that the discrete energy states in which alone any system can exist are each associated with a "term"; that the transition from a state of higher energy to one of lower energy is accompanied by the emission of radiation whose frequency is the difference between these terms; and that, conversely, the system can be raised from a state of lower energy to one of higher energy by radiation having that frequency, the radiation being absorbed in the process. Accordingly a difference between terms is a frequency determining absorption and, if it lies in the quasi-optical region, is a characteristic frequency for the purpose of the invention,

#### DETECTION AND ADJUSTMENT OF CHARACTERISTIC PERIODS OR FREQUENCIES.

The process according to the invention consists in exposing a substance to a field of its characteristic period; and the efficiency of the process depends greatly on the exact adjustment of the period of the field to the characteristic period. Accordingly means of making this adjustment are very important.

One useful means consists in examining the substance with polarised light (or other known means) and so determining the extent of its double-refraction when



exposed to the field. Outside the range of anomalous dispersion associated with characteristic periods or frequencies of types (1) and (2), the double-refraction depends on the intensity of the field, but is almost independent of its frequency; but inside that range it varies with the frequency. Accordingly by varying the frequency of the field and observing where a variation of the double-refraction occurs, the position of a characteristic period or frequency of types (1) and (2) can be determined with great accuracy. The variations of the dielectric constant with the frequency can, of course, be used for the same purpose as indicated in Figures A and B.

When the characteristic periods or frequencies have been determined, the frequency of the field may be adjusted to them. In place of making an exact adjustment, the field may be roughly adjusted and then modulated with a lower frequency, so that the frequency of the field oscillates to and fro across the characteristic frequency.

Instead of adjusting the period or frequency of the field to the characteristic period or frequency of the substance, the latter may be adjusted to the former. Thus, according to (1) the relaxation time depends on the temperature; this characteristic period can therefore be adjusted to that of the field by varying the temperature. Changes in characteristic periods and frequencies can also be produced by altering the relative concentration of two components of a solution, or (particularly in the case of gases) by altering their pressure.

#### SUBSIDIARY PROCESSES.

Many of the effects produced by a process according to the invention are probably due to the polarisation of the dipoles, originally existing or induced, whereby they arrange themselves with their axis parallel to the field. Such polarisation can also be produced by constant fields. But the constant fields required to produce those effects are often too large to be practicable. On the other hand, it has been found that there is often an advantage in superimposing a constant field on the field varying with the characteristic period or frequency. The presence of the varying field greatly reduces (e.g. by a factor of 10 to 20) the constant field required to produce a given effect; and the constant field, if maintained after the varying field has been removed, will maintain the state of polarisation set up by the combined field.

The state of polarisation can be preserved in another way. If, after it has been set up, the viscosity of the medium

is increased greatly, the dipoles will be unable to return to the disordered state by thermal agitation. Thus a liquid which has been polarised may be frozen, or a solvent containing the polarised substance may be gelatinised or removed by evaporation. This method of preserving a state of polarisation will be termed generally "freezing". When a freezing operation is reversed, the state of polarisation is destroyed and the energy characteristic of it liberated.

It must be understood that the process according to the invention includes exposing a substance to two or more fields each varying with a different characteristic period or frequency; the exposure to these fields may be simultaneous or successive. If it is successive, the time of exposure to the different fields may be controlled by time relays.

Again exposure to the varying field may be a continuous process, in which the substance is caused to flow, or otherwise to pass, through the field; in this way it may be exposed to fields of different strength at different points in its passage.

#### APPLICATION OF THE PROCESS.

##### A. COLLOIDS.

One of the most important applications of the process according to the invention is to the dispersion and coagulation of colloidal solutions. The effect of the polarisation due to the field in promoting these changes is in most cases connected with hydration of the dispersed particles and/or with changes of the hydrogen-ion concentration. The first effect of exposure to the field is usually an increase in dispersion; but a prolonged exposure may reverse this effect and produce coagulation.

Thus a certain colloidal solution of gold was found by the method described to have a characteristic period corresponding to a wave-length of 18.5 cm. A layer 1 mm. thick was exposed at a temperature of 20° C. to a standing field fed by valves giving an output of 0.1 watt. After one hour the original red colour had changed to orange, indicating an increased dispersion; after 2 hours the effect had been reversed and further exposure produced coagulation.

Again an agar-agar gel with a characteristic period corresponding to a wave-length of 116 cm. was exposed to a field supplied by a generator yielding 10 watts. After 10 minutes the mobility of the gel had increased; but after several hours the effect was reversed and the gel had become more viscous.

##### B. PRESERVATION OF ORGANIC MATERIALS.

The first stage in the ageing of an organic material is usually a coagulation

of a colloid. Accordingly by the process according to the invention ageing may be prevented or even reversed, so that the product is preserved. For the reason just explained, it is necessary to adjust the time of exposure suitably; it has been found that a discontinuous process, in which the substance is alternately exposed and not exposed, is generally more effective than continuous exposure to a field of lesser intensity.

Thus, 2 litres of cow's milk, 3 hours old, was exposed for 2 minutes to fields of each of five frequencies. The wave lengths  $\lambda$  and the power  $N$  of these fields were:— $\lambda_1=455$  cm,  $N_1=230$  watts;  $\lambda_2=283$ ,  $N_2=160$ ;  $\lambda_3=355$ ,  $N_3=160$ ;  $\lambda_4=163$ ,  $N_4=23$ ;  $\lambda_5=27.5$ ;  $N_5=0.6$ . The temperature was originally  $20^\circ$  C. and rose to  $23^\circ$  C. The milk so treated kept fresh for 28 days and could be preserved still longer by exposing it for 5 minutes in each hour to a field of the above wave-length with a total energy of 3.2 watts.

Again 2.5 Kg of veal, 36 hours old, was treated for 3 minutes with a field given (as above by:— $\lambda_1=468$  cm.,  $N_1=250$  watts,  $\lambda_2=362$ ,  $N_2=150$ ,  $\lambda_3=184$ ,  $N_3=10$ ,  $\lambda_4=92.5$ ,  $N_4=3$ . The temperature rose from  $20^\circ$  C. to  $24.5^\circ$  C. The meat remained fresh for 2 weeks and could be kept still longer by exposing it for 5 minutes in each hour to these wave-lengths with a total power of 3 watts.

Again, 2 litres of juice of apples was exposed for  $1\frac{1}{2}$  minutes to a field given by:— $\lambda_1=475$  cm,  $N_1=200$  watts,  $\lambda_2=354$ ,  $N_2=150$ ;  $\lambda_3=145$ ,  $N_3=15$ ;  $\lambda_4=45$ ,  $N_4=1.2$ . The temperature rose from  $22^\circ$  C. to  $24.5^\circ$  C. The juice showed no sign of fermenting after being kept 4 months in a covered jar.

#### C. ACTIONS ON LIVING ORGANISMS.

The process according to the invention can also be applied to organic materials while they still form part of the living organism. Thus animal sera possess characteristic periods and frequencies, which vary with the nature and source of the sera. One of these corresponds approximately to a wave-length of 90 cm; between this frequency and the highest (which is characteristic of water and corresponds to 1.28 cms.) are a large number of characteristic frequencies which vary even in the same serum with the state of the animals. The determination of these characteristic frequencies may therefore have a high value in diagnosis or other examination of the state of the animal. In determining them too great an exposure to the field must be avoided; for grave injury may thereby be inflicted.

But if the exposure is suitably regulated,

beneficial effects may result from the field, especially in the direction of increased vitality, such as stimulation of cell-division. Thus growth may be promoted. Bean seeds, previously swollen, were exposed for 30 secs. at a temperature of  $35^\circ$  C. to fields with frequencies corresponding to 28 cm. and 87 cm., the total output of the generator being 1.5 watts. After four weeks such seeds have grown twice as much as similar untreated seeds.

Fermentation and other processes due to bacteria can also be promoted. The frequencies of the field used may be those characteristic either of the bacteria themselves or of substances in the medium containing the bacteria which effect their activity.

The growth of crystals, as well as of organisms, can be stimulated by the process according to the invention, if the mother liquid is exposed to a varying field of suitable frequency during crystallisation. Of course it is not implied that the cause which promotes inorganic growth is precisely the same as that which promotes the organic growth.

#### D. STORAGE OF ENERGY.

Electrets, that is to say, permanently polarised dielectrics (the electrical analogues of permanent magnets) can be made by subjecting a melted dielectric to the process according to the invention and then allowing it to solidify. Electrets produced by other processes are, of course, already known. Thus a mixture of 100 gm. glycerine, 50 gm. beeswax, 550 gm. montan wax and 400 gms. pine-resin was melted at  $110^\circ$  C. and a layer 8 mm. thick exposed for 10 minutes to a varying field fed by a generator giving 22.5 watts at a frequency corresponding to a wave-length of from 145 to 185 cm. on which was superimposed a constant field arising from a potential difference of 12,000 volts between plates 10—20 mm. distant. The temperature was lowered to  $20^\circ$  C. within 3 minutes. Permanent surface charges of the resulting plate up to  $2 \times 10^{-9}$  coulomb/cm<sup>2</sup> were obtained.

Substances thus endowed with energy from polarisation can be used to supply animals with energy in an effective form. For when the substances are melted or otherwise "unfrozen" in or on the body of the animal, the energy stored is liberated. Medicaments already known may thus be rendered more effective.

Thus a medical plaster was made by adding 6 gm. of euphorbium powder to a melt containing 64 gm. of pine-resin, 24 gm. of yellow wax, 24 gm. of turpentine, and spreading the mixture on a silk cloth. While the mixture was melted at  $85^\circ$  C. it was exposed for 5 minutes to a field of

frequency corresponding to a wave-length of 235 cm. on which was superimposed a constant field arising from a potential difference of 8500 volts. It was then

5 cooled within 2 minutes to 15° C. The resulting surface charge was  $0.7 \times 10^{-9}$  coulomb/cm<sup>2</sup>.

Medicaments for internal use can be prepared in the same way. Thus disinfecting pastilles consisting of beeswax and gums together with the usual drugs were exposed for 10 minutes in layers 5 mm. thick at a temperature of 55° C. to a field given (as above) by  $\lambda_1 = 312$  cm.,  $N_1 = 150$  watts;  $\lambda_2 = 145$ ,  $N_2 = 25$  watts, on which was superimposed a constant field arising from a potential difference of 12,000 volts. After cooling to 15° C. within two minutes the resulting surface charge was about  $10^{-9}$  coulomb/cm<sup>2</sup>.

Again photographic plates, endowed with permanent polarisation by subjecting them to a process according to the invention during preparation, may have an increased sensitivity, especially in the red and infra-red.

Dielectrics with permanent polarisation charge have a greater dielectric strength in consequence of their anisotropic inner structure if stressed in the direction of the dipole axes subjected to orientation.

#### E. CHEMICAL REACTIONS.

The changes considered so far might be classed as physical rather than chemical; but, if sufficiently strong fields are employed, the process according to the invention can induce definite chemical reactions.

Thus the process can produce changes in the mutual relations of the atoms in a molecule of the kind known as tautomeric. It can promote reactions which are of the nature of polymerisation. Thus the process will accelerate the drying of lacquers and varnishes, the consolidation of styrol, the change of Bakelite A and B into Bakelite C, and of isoprene into rubber. Rubber can be vulcanised with no more than a trace of sulphur. In the manufacture of artificial silk the increase of viscosity that occurs as the material leaves the spinning nozzle can be stabilised so as to make the finished product highly resistant to wear.

The process can produce other reactions that usually require a catalyst; for instance acetylene and steam in the presence of ozone react to form acetic acid, with acetaldehyde as an intermediate product. For such reactions the most effective frequencies usually lie in the range corresponding to wave-lengths of 2.5—3.5, 8.6—9.5, 26.5—30.5 cm. These characteristic frequencies are probably of type (3), being term differences.

If, while a reaction of the kind last mentioned is proceeding under the influence of a varying field having a characteristic frequency, a strong constant field is superimposed on the varying field, the energy set free in the reaction may appear in the form of radiation having a characteristic frequency of type (3). A chemical reaction can thereby be used to generate quasi-optical radiation, which can be detected and used in any suitable manner. Reactions between substances having great mutual affinity, e.g. hydrogen, chlorine, phosphorus, arsenic, are favourable to this phenomenon; the radiation emitted may be that associated with the term differences of hydrogen, which correspond to wave-lengths of 2.74, 9.25 and 27.75 cm. If there are two or more adjacent term-differences characteristic of the substances, a band spectrum may be emitted. Also, in accordance with known principles, radiation of lower frequency than that corresponding to the term difference may appear.

In the examples given above the particular figures stated in respect of the various quantities such as wave length are believed to be optimum values for the individual cases. Clearly the beneficial results obtained must at least to a certain extent vary with the initial conditions of the substances, particularly biological substances, which are treated.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A process for altering permanently, as hereinbefore defined, the energy content, as hereinbefore defined, of dipolar substances comprising the step of exposing the substance to a concentrated electromagnetic field oscillating with a quasi-optical period or frequency, such period or frequency being substantially equal to one of the characteristic periods or frequencies of the substance.

2. A process according to Claim 1 in which the concentrated field is a standing field, as hereinbefore defined.

3. A process according to Claim 1 in which the concentrated field is a radiating field, as hereinbefore defined.

4. A process according to Claim 1, 2 or 3, in which the said characteristic period or frequency is either the period of natural oscillation relative to each other of the charges constituting a dipole or the relaxation time of the orientation of the dipoles when exposed to a varying electric field or a difference of terms characteristic of the molecular structure.

5. A process according to any preceding claim which comprises the step of examining the substance under polarized light, whereby a characteristic period or frequency of the substance is determined. 5
6. A process according to any preceding claim whereby a characteristic period or frequency of the substance is adjusted to that of the oscillating field to which it is exposed by adjusting the temperature and/or the pressure of the substance and/or its concentration relative to that of other substances with which it is mixed. 10
7. A process according to any preceding claim wherein the substance is exposed simultaneously or in regular succession to fields oscillating with two or more periods or frequencies each of such periods or frequencies being substantially equal to one of the characteristic periods of the substance. 15
8. A process according to any preceding claim in which the substance treated is passed continuously through the concentrated oscillating field. 20
9. A process according to any preceding claim in which a constant electrostatic field is superimposed on the oscillating field. 25
10. A process according to any preceding claim in which the substance acted on by the concentrated oscillating field is frozen (as hereinbefore defined) whereby the state of polarisation produced by the field is preserved. 30
11. The method of changing the degree of dispersion of a colloidal solution which comprises a process according to any of claims 1—10. 35
12. A method for influencing chemical reactions comprising the use of a process according to any of claims 1—10 in substitution for or in combination with a catalyst. 40
13. The method of production of insulating materials of increased dielectric strength comprising a process according to any of claims 1—10. 45
14. Insulating materials of increased dielectric strength produced by a method comprising a process according to claims 1—10. 50
15. The method of preserving organic materials which comprises a process according to any of claims 1—10. 55
16. The method of promoting the vitality of a living organism (for example, a seed) which comprises a process according to any of claims 1—10. 60
17. The method of modifying the action of bacteria which comprises a process according to any of claims 1—10. 65
18. The method of preparing a photographic emulsion which comprises a process according to any of claims 1—10. 70
19. The method of promoting polymerisation and the like which comprises a process according to any of claims 1—10. 75
20. The method of accelerating the drying of lacquers and the like which comprises a process according to any of claims 1—10. 80
21. The method of vulcanizing rubber which comprises a process according to any of claims 1—10. 85
22. The method of manufacturing artificial silk which comprises a process according to any of claims 1—10.
23. The method of generating electromagnetic radiation of quasi-optical frequency as a result of chemical action which comprises a process according to any of claims 1—10.
24. An electret whenever produced by a process according to claim 10. 85
- Dated this 15th day of December, 1933.  
 J. Y. & G. W. JOHNSON,  
 47, Lincoln's Inn Fields, London, W.C. 2,  
 Agents.

3rd Edition

[This Drawing is a reproduction of the Original on a reduced scale.]

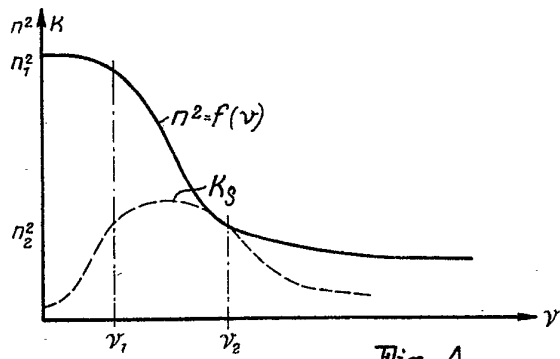


Fig. A

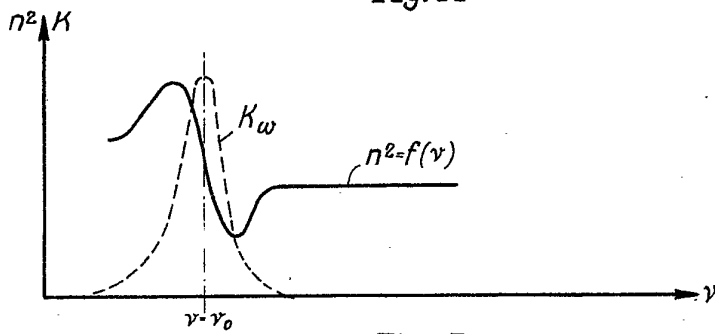


Fig. B

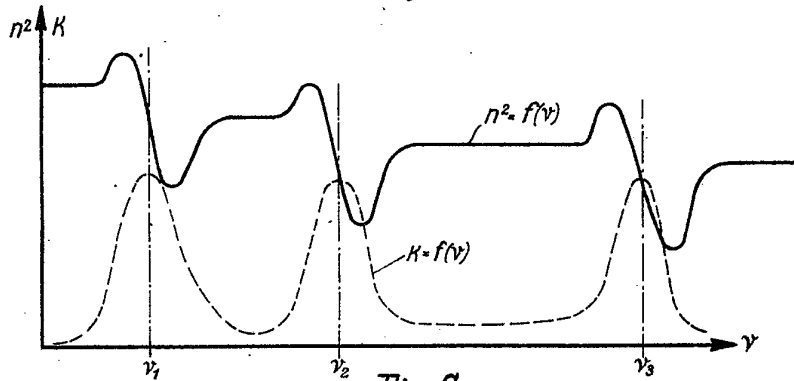


Fig. C

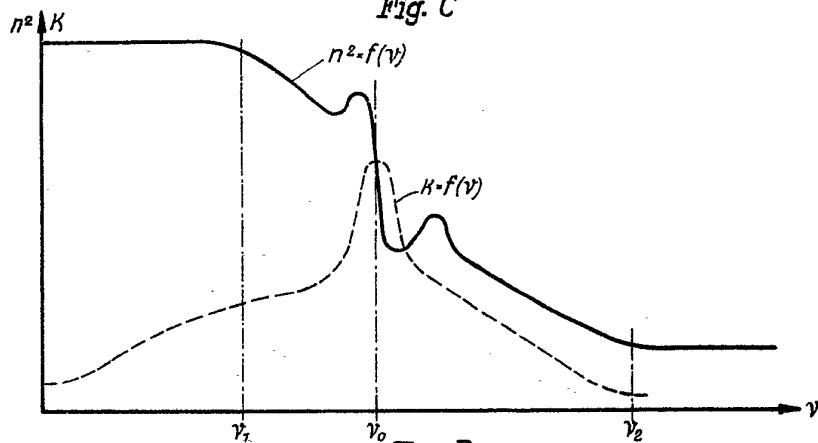


Fig. D