BUTYL TITANATE

TITANIUM PIGMENT CORPORATION
(Subsidiary of National Lead Co.)

No Warranty - Results of tests and formulations listed hereinafter are only for guidance in experimental work with butyl titanate and are not recommendations for finished end products derived from butyl titanate.

We make no warranty of any kind, express or implied, as to the effects of the use of butyl titanate or the results to be obtained as the use of this product is beyond our control.

Responsibility rests with the buyer to determine that the use of butyl titanate is permissible, fit or suitable for his purposes.

Price - Butyl titanate is offered in experimental quantities at $1.90 per pound, f.o.b. Sayreville, New Jersey.

Toxicity - A long experience with titanium dioxide shows this compound to be physiologically inert. Any toxicity exhibited by butyl titanate would be expected to come from butanol inasmuch as butyl titanate hydrolyzes to titanium dioxide and butanol.

Under the type and conditions of use of butyl titanate, any possible toxicity of this compound should be established by the user for his own information.

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BUTYL TITANATE

Many organic compounds of titanium have been prepared, some of which have been mentioned in the literature (8). Work in our laboratories has been concerned with organic compounds of titanium for many years. Of the organic compounds of titanium which have achieved commercial significance - probably titanium phthalate attained greatest importance when it was the additive to contribute chalking resistance to titanium dioxide (TITANOX-A phthalate treated which was discontinued with the advent of the modern chalking resistant types of TITANOX titanium dioxide).

But during the past few years marked interest in organic compounds of titanium has existed. Stimulated by work done in Australia (1) and reviewed in the United States (2), the probability is that such readily aroused interest is the natural result of curiosity bound to be evoked by the discussion of any titanium compound which might be applicable to coatings. The position of titanium in the coating industry as titanium dioxide, the all-dominant white pigment, and one of the major factors in coating progress would seem to impel interest in any other titanium compound.

Recent attention has been centered mainly on butyl titanate or titanium butylate depending upon how one wishes to interpret the amphoteric nature of titanium.

Many titanium esters can be prepared as indicated by work done in our laboratories and work reported in the scientific literature (1,3,4,7). But singling out butyl titanate for first attention is probably the result of its greater stability and less rapid hydrolysis as compared with the lower alkyl homologues such as ethyl and propyl. Although higher homologues are still less prone to rapid hydrolysis, the butyl ester is a good starting point because butyl alcohol or butanol is readily available commercially and at a less expensive cost than some higher alcohols.

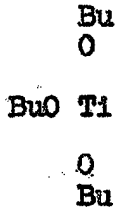
Although the properties (1,2,6) and possible applications (5) of this interesting compound are mentioned in the scientific literature, this discussion will present the properties of butyl titanate prepared in our laboratories on a pilot plant scale plus some of its reactions as we have observed them.

You may find in the following pages some feature of butyl titanate such as the delaying of gelation of epoxy resin solutions in the container, that you may wish to investigate immediately. Some new line of investigation for you might also be suggested by the reactions of butyl titanate.

WHAT IS BUTYL TITANATE?

Butyl titanate is a compound derived from the controlled reaction of n-butyl alcohol with a quadrivalent titanium salt. The chemical formula for butyl titanate is $Ti(OC_4H_9)_4$ which might more logically denote titanium butylate or the butyl ester of orthotitanic acid ($Ti(OH)_4$). Considering the compound as a titanate though may lead to preference for $(C_4H_9)_4TiO_4$ as the formula. Regardless of nomenclature the compound which is an organic liquid can be considered to embody the replacement of hydrogen atoms from the hydroxyl groups of four molecules of n-butyl alcohol by a titanium atom.

Schematically the compound may be pictured as four butoxy groups surrounding a central titanium atom as in the following in which the symbol Bu stands for the butyl group C_4H_9.



Considering spatial relationships, this structure affords titanium an opportunity to enter into coordination reactions since titanium has a coordination number of six.

From our work, evidence points to the titanium atom as being the prime factor which contributes the unique properties of this compound while the effect of the butoxy groups is coincidental.

PROPERTIES OF BUTYL TITANATE

Form	Liquid
Color	Colorless to light yellow
Odor	Like that of Butanol
Flash Point	Determined by free Butanol present Pure Butyl Titanate: 170°F. Butyl Titanate plus 2% free butanol: 130°F. Butyl Titanate plus 4-5% free butanol: 95°F.
Boiling point	160-2°/2 mm., 310-314°C./760 mm
Melting point	Forms a glass below -55°C.
Density	d_{20}^{20} 0.998
Specific Gravity . . .	0.9961
Viscosity	0.799 stokes at 25°C.
Refractive index . . .	n_d^{35} 1.486
Dielectric Constant	3.00 at 20°C.
Dielectric Strength	Breakdown voltage on the order of 40,000 volts has been reported (1)
Solubility	
Benzene	Soluble
Butanol	Soluble
Carbon Tetrachloride	Soluble
Acetone	Ppt. formed
Water	Decomposes - Ppt. formed
Analysis	
TiO_2	23.4 - 23.6%
Formula	$(C_4H_9O)_4$ Ti
Molecular Weight (theory)	340

CHEMICAL PROPERTIES OF BUTYL TITANATE

Butyl titanate has been observed to enter into at least two types of chemical reaction:

hydrolysis and ester interchange

HYDROLYSIS

On exposure to water, moist air or substances containing water or hydroxyl groups which accelerate the hydrolysis of practically all titanium compounds, butyl titanate hydrolyzes rapidly. The hydrolysis proceeds rapidly at first and then in stages to yield eventually titanium hydrate and butanol.

The extent and rate of the reaction are mainly dependent upon the mole ratio of water to butyl titanate.

The reaction can be controlled by the use of organic diluents such as ether, dioxane or butanol.

In our laboratories, reactions carried out in dioxane solution, have clearly illustrated the relationship between the mole ratio of the reactants and the product of hydrolysis. A series of polymers of increasing molecular weight seems to be the best description of the products of hydrolysis, as shown in the following table which summarizes some of this work:

Table I

Hydrolysis of Butyl Titanate

Moles H_2O per mole butyl titanate		Product of Hydrolysis			
Mixed	Reacted	TiO_2(%)	Moles butoxy group to Ti	Molecular Weight	Description
0.0	0.0	23.4	4.0	340	Liquid
0.5	0.5	27.0	3.2	---	Viscous Liquid
0.75	0.75	33.6	2.35	---	Viscous Liquid
1.0	0.98	39.0	1.95	---	Semi-solid
1.5	1.18	49.7	1.20	1075	Solid
2.0	1.58	56.6	0.96	1800	Solid
3.0	1.90	60.6	0.85	---	Solid

With the exception of the last mentioned above, all of the products were soluble in the usual solvents such as benzol, butanol and ether.

ESTER INTERCHANGE

The other prominent reaction of butyl titanate is that of alcoholysis or ester interchange. One to four of the butyl groups (C_4H_9) designated Bu can apparently be interchanged with alkyl, aryl or acyl groups through reaction with alcohols, phenols or organic acids according to the general idealized reaction:

$$(BuO)_4Ti + nROH \rightleftharpoons (BuO)_{4-n}Ti(OR)_n + nBuOH$$

This reaction proceeds rapidly without the need for a catalyst, but under certain conditions is reversible. Equilibrium of this reaction is determined naturally by the concentration of the reactants and the relative reactivity of the ester formed in the reaction, butyl titanate, butanol and the reacting alcohol. Control of the reversibility of this reaction is the most important factor in working successfully with butyl titanate.

Stability of Products Formed from Butyl Titanate through Ester Interchange

The reactivity of the titanium ester formed by the interaction of butyl titanate as illustrated in the above mentioned general reaction, decreases with increasing molecular weight of the alcohol which is reacted with butyl titanate.

This suggests the interaction of butyl titanate with high molecular weight hydroxyl-bearing materials to yield interesting stable derivatives of titanium. In our work, indications are that such stability can be obtained as to resist the action of boiling alkali.

Thus a whole field of investigation is opened on high molecular weight hydroxyl-bearing substances so important to industry in coatings, textiles, etc.

Investigation of titanates or esters other than butyl reveals that their reactivity decreases with increasing acidity of the substituent group. Thus acyl titanates are more stable than phenyl titanates which are more stable than alkyl titanates of which butyl is now representative as a matter of convenience.

Among the alkyl titanates as we go up the series stability toward hydrolysis increases.

If for the reactions you may have in mind you should like to work with titanates or esters other than butyl we shall be pleased to have you discuss your problem with us.

INTERACTION OF BUTYL TITANATE WITH FILM-FORMING ORGANIC MATERIALS OF HIGH MOLECULAR WEIGHT

Indications are that any organic compound of high molecular weight and containing hydroxyl or carboxyl groups presents an opportunity for introduction of titanium into the structure through reaction with butyl titanate. In resins conceived to have a definite structure, up to four resin molecules can apparently be bonded together by a titanium atom. Thus increased structure of the resin is believed to result as evidenced by 1) increase in viscosity 2) increase in setting rate 3) increase in hardness 4) increase in resistance to water, alkali, softening by oils and solvents with the exception of acetone, glacial acetic acid and some alcohols 5) increase in dielectric strength.

All of the above are strong evidence for cross linking of the resin molecules with titanium, particularly the increase in dielectric strength which indicates that more energy is required to separate the resin molecules which are tied tightly together with titanium.

VEGETABLE OILS

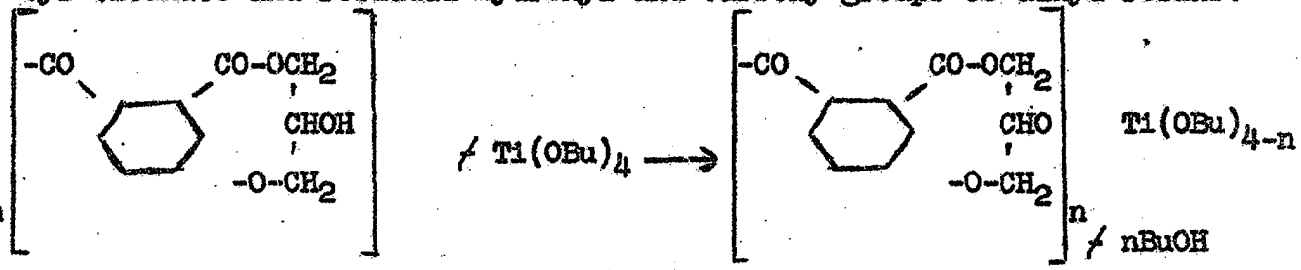
The refined unbodied vehicle oils show little or no reactivity towards butyl titanate. However, oxidation or "blowing" of drying or semi-drying oils introduces alcohol and acid groups into their molecular structure. Raw oils, of course, contain some acid groups with which the titanium ester can react. When a sufficient number of such groups are present in an oil, gelation occurs on addition of a small percentage (3 to 5 percent) of butyl titanate. Blending of the titanate with the oil must be done in a high torque mixer since, otherwise, gelation occurs before a uniform blend is obtained.

Castor oil, because of its unique natural alcoholic nature, reacts readily with butyl titanate. We have observed that the addition of ten percent butyl titanate to castor oil resulted in a marked thickening of the oil while larger additions, thirty to forty percent, gave liquid blends which set to relatively firm, clear, solvent-resistant films. Castor oil-resin combinations have been observed to react similarly to castor oil.

SOME EXAMPLES OF REACTIONS OF BUTYL TITANATE WITH FILM-FORMING RESINS

Alkyds

The following general equation has been postulated for the interaction of butyl titanate and residual hydroxyl and carboxy groups of alkyd resins.



Exploration of butyl titanate as an additive to alkyds would seem to be warranted on the basis of securing films having 1) faster set 2) increased hardness 3) increased chemical resistance 4) reduced tendency to skinning and wrinkling when thick 5) increased resistance to "sagging" 6) modified body, thixotropic in nature.

As an example, for experimental purposes only, as a starting point in exploring the addition of butyl titanate to alkyds, the following results obtained in our laboratory are most interesting. Butyl titanate was carefully added to an alkyd varnish having the following composition. The amount added was 10% of the varnish solids by weight.

Alkyd Varnish

Phthalic Anhydride	25%
Oil acids	60%
Type of oil	Soya
Solvent	Mineral Spirits
Total non-volatile	40%
Viscosity	S-T (Gardner-Holdt)
Acid value	11.4
Acetyl value	23.0
Driers	0.1% Pb) 0.05% Co) as naphthenate

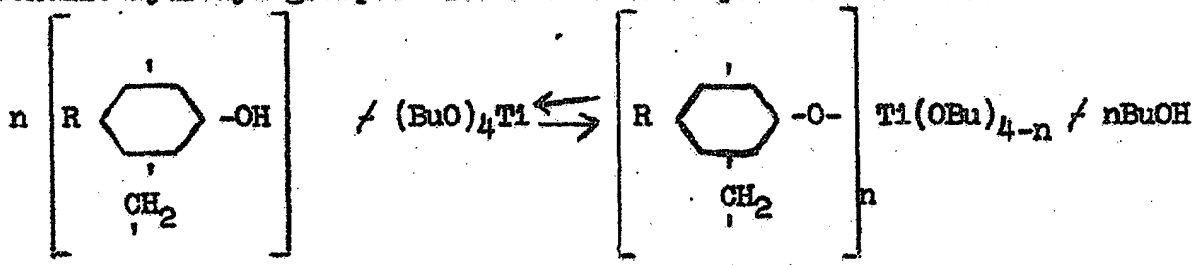
The properties of this varnish compared with properties of the varnish plus butyl titanate were as follows:

	Alkyd Untreated	Alkyd plus 10% Butyl Titanate
Color	Light yellow	Yellow
Tack-free	24 hrs.	2 hrs.
Sward Rocker Hardness		
1. 6 days air dry	10	18
2. 6 hrs. water (25°C.)	4(blush)	16
3. 1/2 hr. water (100°C.)	4(blush)	15
4. 2 hrs. 1% NaOH (25°C.)	Very soft	10
5. 2 hrs. mineral spirits (25°C.)	Very soft	12
Viscosity	S-T	S-T

Because of the complexity of structure of alkyd resins and their many modifications it appears that each type should be considered a specific problem in itself. In the above example gelation did not occur, but where it does the particular solvent system to control it must be worked out selecting volatile alcohols such as butanol to be added to the varnish.

Phenolics

Butyl titanate apparently reacts with phenolic resins through the phenolic hydroxyl groups. The reaction is postulated thus:



High molecular weight of the phenolic plus the probability of three-dimensional polymers being formed should lead to highly stable reaction products. It would thus be expected that phenolics modified by reaction with butyl titanate should provide films having 1) faster set or cure - possibly eliminating the need for baking at elevated temperatures 2) greater resistance to organic solvents, water, acids and alkali 3) higher dielectric strength.

As an example of the effect upon the film properties of a simple phenolic resin varnish modified by reaction with butyl titanate, the following is offered for illustrative purposes only and not as a recommendation for the production of a finished product.

Example of
Effect of Treatment of Phenolic Varnish
with Butyl Titanate

Varnish: Bakelite BR254, 20 gal. oil length, Q bodied linseed oil
(50% n.v. in xylol; driers 0.1% Pb, 0.05% Co on n.v.)

	Untreated	Treated Butyl Titanate 10% of solids by weight
Air dried films (overnight dry) 2 mils thick		
Appearance	Clear	Clear
Color	Light Yellow	Dark Red
Sward Rocker Hardness		
1. dry film	15	41
2. 2 hrs. in mineral spirits	Dissolved	25
3. 2 hrs. in 0.5% NaOH	(blushed)	(no blush)
Dielectric Strength* (volts/mil/2-mil film)	1500	2400
Mandrel Distensibility*	less than 30%	less than 30%
Adhesion (removal with sharp tool)		
Glass	Good	Good
Steel	Good	Excellent

*Steel panels

An unusual effect noted above is the intense red coloration which is due to the formation of chromophoric phenyl titanate linkages. This red color usually characterizes phenolics treated with butyl titanate.

In the above example in which a simple phenolic resin varnish was used, gelation did not occur. Should gelation take place on blending butyl titanate with a phenolic varnish a volatile alcohol as part of the thinner content will suppress the thickening. Another means of retarding such gelation involves replacement of one or more of the butoxy groups of butyl titanate by phenoxy groups or acyl groups such as the acids derived from linseed oil.

Vinyls

Because most organic soluble vinyl resins are pictured with free hydroxyl groups distributed along polyethylene chains these hydroxyl groups may be considered to offer points of linkage to butyl titanate. Butyl titanate may be pictured to react according to the following postulated scheme:

$$n\left[\begin{matrix}CHOH\\CH_2\end{matrix}\right] + (BuO)_4Ti \rightleftharpoons \left[\begin{matrix}CHO\\CH_2\end{matrix}\right]_n + Ti(OBu)_{4-n} + nBuOH$$

Immediate gelation however may result in adding butyl titanate to a vinyl resin solution so that it is usually mandatory to provide alcohol in the solvent system.

As an example, for illustrative purposes only and not as a recommendation for the production of a specific butyl titanate modified vinyl film former, the following is interesting. A medium viscosity type of vinyl resin of the approximate composition:

90 percent vinyl chloride
4 percent vinyl acetate
6 percent vinyl alcohol

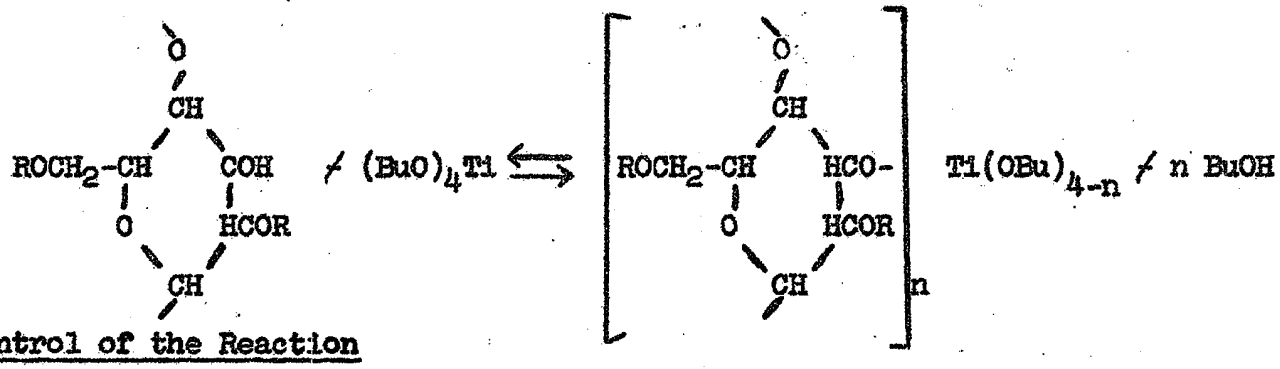
was dissolved at 10 percent solids in an 80:20 mixture (by weight) of xylol and butanol. To this solution was added 10 percent butyl titanate, based on the weight of vinyl resin, and the solution was stirred until homogeneous. Films cast from the mixture on steel panels and air dried had the following properties:

	Vinyl Resin	Vinyl Resin-Butyl Titanate
Color	Water white	Water white
Sward Rocker Hardness	28	35
Mandrel Distensibility	30%	30%
Dielectric Strength (volts/mil/2-mil film)	2500	2900
Effects of Solvents		
Water (100°C.)	Sl. loss of adhesion	None
Mineral spirits	Sl. softened	None
Chloroform	Dissolved	Softened

Many vinyls contain only low concentration of free hydroxyl groups and modifications of such resin solutions with butyl titanate does not present a serious gelation problem. Others, such as the formals, acetals and butyrals, because of a large number of free hydroxyl groups per molecule, are not readily modifiable. Such resins, along with maleic acid modified vinyls, usually gel completely on addition of small amounts of butyl titanate to their solutions. In such cases it is usually preferable first to stabilize the butyl titanate by the addition of amines or amino-alcohols.

Cellulosics

Cellulosics, the simplest of which is ethyl cellulose, are examples of high molecular weight resin alcohols which are film-formers. The addition of butyl titanate to very dilute solutions of ethyl cellulose usually causes immediate gelation. This gelation apparently results from reaction of free hydroxyl groups of the ethyl cellulose with the tetra-functional butyl titanate leading to the cross-linking of up to four cellulosic chains by each titanium atom. The reaction may be pictured by this postulated scheme:



Control of the Reaction

A method is available wherein the interaction of butyl titanate with ethyl cellulose can be controlled or inhibited until such time as it is desired that gelation occur. Such control is obtained through utilization of the reversibility of the ester interchange reaction. Thus, in the reaction of butyl titanate with ethyl cellulose with the formation of a cellulosic titanate, butanol is released as a byproduct. Reversal of this gel-forming reaction is accomplished simply by increasing the concentration of alcohol, e.g. butanol, in the solvent system to the point where the alcohol solvent can compete with the ethyl cellulose for the titanium atoms. Choice of the alcohol depends on the solubility characteristics of the ethyl cellulose. The ethylene glycol mono-ethers and the lactate esters have been particularly useful for this purpose.

When gel-free blends of butyl titanate and ethyl cellulose are applied as films, the solvent, including the alcohol, evaporates and the titanium is apparently free to react with the cellulose resulting in rapid gelation and setting. By this means, hard, clear, water-white, solvent resistant films have been obtained from blends containing as much as 80 parts of butyl titanate to 20 parts of ethyl cellulose. Such films have resisted aliphatic and aromatic hydrocarbons and oils, esters, ethers, chlorinated hydrocarbons, ketones, with the exception of acetone, and boiling water and alkali.

Through modification with relatively small amounts of butyl titanate (5 to 10 percent) the ethyl cellulose is converted to a thermoset resin and its dielectric strength, i.e. voltage required for breakdown, is increased. All of these properties may be ascribed to the strong attraction of the titanium atom for the cellulosic hydroxyls or if not to the mutual linking of hydroxyl groups from titanium and the cellulose complex.

Following is an example for illustrative purposes only of the modification of ethyl cellulose with butyl titanate:

Component	Parts by Weight
Ethyl cellulose*	1
Xylol	6
n-Butanol	3
Butyl titanate	1

*medium viscosity type of ethyl cellulose having an ethoxyl content of approximately 48 percent

The ethyl cellulose was dissolved in the solvent, then the butyl titanate added slowly with stirring. A smooth, clear solution then resulted having a viscosity only slightly greater than that of the titanate-free solution.

The properties of air dried films (thickness 1 to 2 mils) from this composition cast on glass panels are listed below.

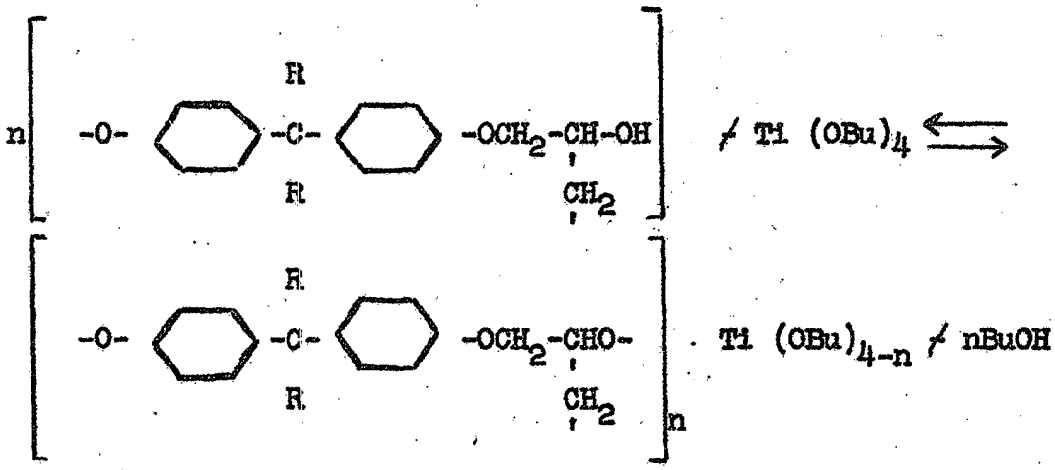
	Ethyl Cellulose	Butyl Titanate-Ethyl Cellulose
Color	Water white	Water white
Sward Rocker Hardness	60-70	70-80
Mandrel Distensibility*	30%	30%
Dielectric Strength* (volts/mil/2-mil film)	2300	2900
Effect of Solvents on Films		
Water (100°C.)	None	None
1% NaOH (25°C.)	None	None
1% HCl (25°C.)	Sl. softened	Softened
1% NaCl (25°C.)	None	None
Mineral spirits	Sl. softened	V. Sl. softened
Benzene	Dissolved	Sl. softened
Chloroform	Dissolved	Sl. softened
Butyl acetate	Dissolved	Softened

*Steel panels

Similar results were obtained on blending butyl titanate with cellulose acetate and nitrocellulose solutions.

Epoxy Resins

Epoxy resins react with butyl titanate essentially through ester interchange involving secondary alcohol groups of the glyceryl ether. The reaction may be postulated, thus:



Apparently titanium links so tenaciously to the epoxy resin that special systems must be devised to prevent immediate gelation on addition of butyl titanate to the resin solution. In some cases the use of solvent systems consisting entirely of alcohols, such as the glycol monoethers or diacetone alcohol, are effective in preventing premature gelation.

Firm, clear, solvent-resistant films result on modification of such epoxy resins with butyl titanate. Such films air dry with evaporation of the solvent but mild baking schedules usually improve their adhesion and flexibility.

The difficulty in controlling the gelation of simple butyl titanate-epoxy resin systems has been overcome by adding certain compounds to butyl titanate in order to increase its stability. Especially useful are amino alcohols, such as triethanolamine, diethanolamine and B-aminoethyl ethanolamine, and polyamines such as ethylene diamine and diethylene triamine. The amine or aminoalcohol is simply added to the butyl titanate.

Butyl titanate thus stabilized appears to offer particular advantages not only over butyl titanate alone but also over conventional amino-type catalysts used in the curing of epoxy resins. The reduced activity effectively depresses gelation which would occur with the simple butyl titanate and permits incorporation of titanium into the resin structure under controllable conditions. Moreover the presence of the titanate reduces the activity of the amine which normally catalyzes the curing of the resin through reaction with epoxy groups. Marked increases in the "pot life" of the resin solution results because the titanate reduces premature gelation in the container.

Following is an example of a composition found to be of interest in our work. Relatively fast cure plus the properties of epoxy resins such as adhesion, flexibility and alkali and solvent resistance were observed. When applied to steel panels and oven cured at 150°C. for 30 minutes the films were lighter in color than those usually obtained from epoxy resins cured with primary polyamines.

	Parts by Weight
Epon Resin 1007	32
Diacetone alcohol	32
Cellosolve	31
Butyl titanate	2.5
B-aminoethylethanolamine	2.5

Whereas gelation occured in a week when the titanate was omitted from the above formulation, the complete varnish did not gel in six months although there was a gradual increase in viscosity. Compositions along this line should offer definite possibilities for increasing the "pot life" of the resin solution.

Oil modified epoxy resins react with butyl titanate to a lesser extent than do the pure resins. However, the varnishes contain apparently a sufficient number of free hydroxyl groups to permit cross linking of the resin molecules by titanium atoms. The results of such cross linking are 1) faster curing, 2) firmer films, 3) improved resistance to organic and aqueous solvents and 4) increased dielectric strength.

An epoxy resin varnish consisting of 40 percent Epon Resin 1004, 10 percent WG rosin and 50 percent linseed oil fatty acids (0.1 percent Pb and 0.05 percent Co driers) and thinned to 50 percent non-volatile in xylol was modified with 10 percent by weight butyl titanate. Properties of films formed from the varnish, both with and without the titanate, are shown in the following table which is presented only as an illustrative example for experimental purposes as a starting point for the modification of an epoxy resin varnish with butyl titanate.

	Epoxy Varnish	Epoxy Varnish plus 10% Butyl Titanate
Color	Light Yellow	Yellow
Set to touch (air dry)	4 hrs.	1/2 hr.
Sward Rocker Hardness		
48 hr. air dry	12	26
24 hr. water immersion	8 (temporary blush)	18
Mandrel distensibility	>30 percent	>30 percent
Dielectric strength (volts/mil/2-mil film)		
48 hr. air dry	2300	2800
24 hr. water immersion	1200	2000

BUTYL TITANATE AS VEHICLE OR CARRIER IN ALUMINUM PIGMENTED COATINGS

Butyl titanate when applied as a film and exposed to the air at room temperature, hydrolyzes and solidifies. The released butanol evaporates leaving a film which at first transparent breaks up into a friable yellowish powder with complete loss of adherence to the substrate.

Work in Australia (1) early indicated that butyl titanate when pigmented with a leafing type pigment such as aluminum powder would form a continuous film on air drying and this film could be heated to burn off the organic matter.

Various factors affect the performance of such films applied to steel surfaces, particularly the ratio of aluminum to butyl titanate and the preparation of the surface. Many of these factors have been discussed by Hancock and Sidlow (5).

The outstanding property of butyl titanate - aluminum coatings thus far is resistance to high temperatures. The maximum temperature which these coatings will withstand on steel and still provide protection against ordinary atmospheric corrosion seems to be governed by the melting point of the aluminum pigment - about 1200°F. Of course, it must be recognized that all organic matter is removed in these coatings by burning off, so that what remains is a coating of aluminum and titanium dioxide in extremely fine particle size. For practical purposes a temperature of 1000°F. is the maximum to which such coatings should be subjected.

In our work a starting point formula as follows has given promise as the basis for further work on this type of paint:

	Parts by Weight
Butyl titanate	5
Aluminum power (Alcoa #422 or equivalent)	4
Mineral spirits	4

To improve adhesion, one part of aluminum powder may be replaced by one part of zinc dust (New Jersey Zinc Co. #22 or equivalent).

Preparation of Iron or Steel Surface: In our work we often found it necessary to heat the metal to some 700°F. to degas it, then clean thoroughly by wire brushing and sanding followed by a wash with 10% nickel sulfate. Generally, thorough cleaning of the surface is recommended particularly to remove any mill scale which can be harmful when detached. Flame-cleaning (8) has been recommended followed by wire brushing.

Application: Spraying is generally indicated because brushing is generally difficult and productive of uneven films due to gelling.

"Drying" or "Curing": After application about 1/2 hour air drying time is allowed followed by heating usually at not lower than 750°F. to remove all organic matter.

Some Precautions to be taken with this Type of Paint: Alcoholic and acidic substances are generally avoided in formulating these paints because of generation of gas in the container upon storage leading to exploding containers. Of course, butyl titanate must not be exposed to moisture during handling.

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