United States Patent [19]

Alburger

[11] **3,715,227**

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[54] **INSPECTION PENETRANT DEVELOPMENT PROCESS EMPLOYING FUSIBLE WAXES**

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[21] Appl. No.: **127,181**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 799,701, Feb. 17, 1969, Pat. No. 3,607,333.

[52] **U.S. Cl.** .....**117/37 R,** 117/2 R, 117/45, 117/62, 117/168, 106/270, 252/301.2 R

[51] **Int. Cl.**.....**B23p 7/04,** B23p 7/00

[58] **Field of Search** .....106/270, 271, 272; 252/102, 252/163, 301.2 R, 301.2 P; 117/37 R, 45, 2 R, 168

[56] **References Cited**

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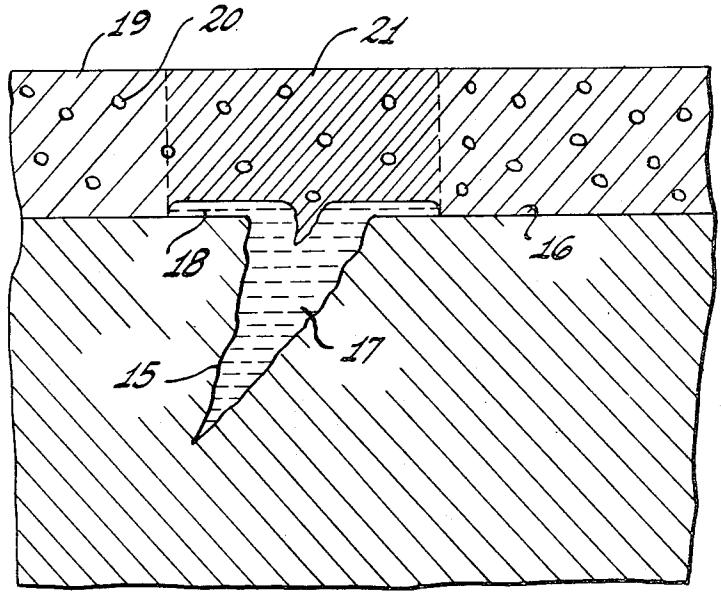
3,184,596	5/1965	Alburger	252/301.2 P
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3,349,041	10/1967	Alburger	252/301.2 P
3,429,826	2/1969	Alburger	252/301.2 P

Primary Examiner—Alfred L. Leavitt
Assistant Examiner—M. F. Esposito

[57] **ABSTRACT**

An improved process of inspection penetrant development employing a high-sensitivity, high-resolving power inspection penetrant developer in which the active developing ingredient is a waxy substance which is a solid or near-solid at room temperature but which becomes fluid at slightly elevated temperatures. The waxy developer material mat be dissolved in a suitable carrier liquid, such as water or other inert volatile solvent, and is deposited on test parts by dipping, brushing or spraying, and allowing the carrier liquid to evaporate. The development process includes the step of applying heat to the test parts, during oven drying or by hearing subsequent to air-drying, whereby the waxy developer layer becomes a fluid, and carries into solution any dyed penetrant entrapments present in the surface defects. When the test parts cool to room temperature, the fluid waxy layer, which now contains developed defect indications, solidifies and prevents excessive bleeding and migration of the indications.

2 Claims, 2 Drawing Figures



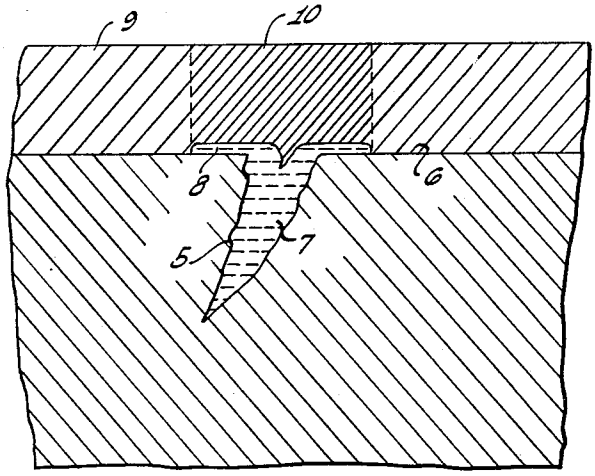


Fig. 1

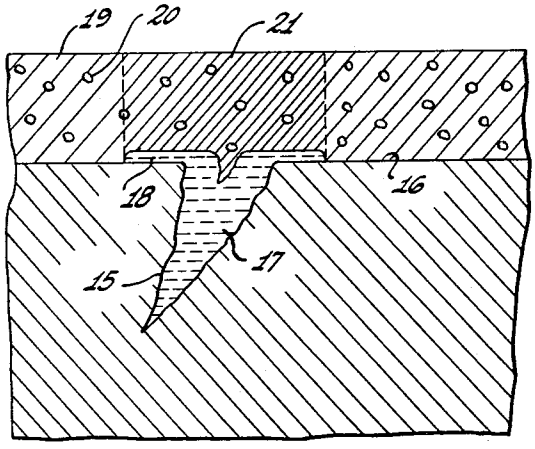


Fig. 2

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INSPECTION PENETRANT DEVELOPMENT PROCESS EMPLOYING FUSIBLE WAXES

This application is a continuation-in-part of my co-pending application, Ser. No. 799,701, filed Feb. 17, 1969, for "Developer for Inspection Penetrants Employing Fusible Waxes," now issued U.S. Pat. No. 3,607,333.

RELATED PATENTS AND PATENT APPLICATIONS

U.S. Pat. No. 3,184,596, "Flaw Detection Method Using a Liquid Solvent Developer."

U.S. Pat. No. 3,415,112, "Water-Free Inspection Penetrant Process and Compositions."

U.S. Pat. No. 3,282,843, "Emulsifier Compositions."

U.S. Pat. No. 3,311,479, "Penetrant Inspection Process and Compositions."

U.S. Pat. No. 3,349,041, "Gel-Forming Inspection Penetrant and Emulsifier Compositions and Processes."

U.S. Pat. No. 3,386,920, "Process for Fluorescence Detection of Extremely Small Flaws."

U.S. Pat. No. 3,429,826, "Gel-Forming Inspection Penetrant Employing Hydrophylic and Lipophylic Surfactants."

Application Ser. No. 787,381, "Oil-Water Compatible Compositions and Methods of Preparing Same."

Application Ser. No. 699,536, Now U.S. Pat. No. 3,506,827, "Method of Masking Fluorescence in Fluorescent Dye Tracer Inspection Process Materials."

This invention relates to developers as used in inspection penetrant processes. More particularly, the invention relates to an improved process of liquid-film dilution-expansion development in which a fusible waxy substance is the active developing ingredient.

There are, at present, two basic processes of inspection penetrant development available, these being the powder particle process and the liquid-film dilution-expansion process. Both developer processes have as their purpose the enhancement of color intensity or fluorescent brightness, as the case may be, in defect indications which consist of entrapments of dyed penetrant in surface flaws.

In the conventional powder particle development process, a thin layer of powder particles is deposited on a test surface which has been treated with a dyed penetrant liquid. Entrapments of the dyed penetrant which remain in surface cracks after surface penetrant has been removed tend to exude from the cracks and become absorbed onto the layer of powder particles, the layer of particles exerting a "blotter" action on the entrapments of dyed liquid. The effective size of a given entrapment is enlarged by this blotting action, and apparent color intensity or fluorescent brightness is thereby enhanced.

In the dilution-expansion development method, which is described and claimed in my U.S. Pat. No. 3,184,596, for "Flaw Detection Method Using a Liquid Solvent Developer," a similar enhancement of color or brightness is achieved, but through a somewhat different mechanism. In this case, a liquid layer of developer is applied onto the test surface. Exuded entrapments of dyed penetrant diffuse out into this liquid layer so that the dye in the penetrant becomes diluted in its concentration, while at the same time the thickness of the layer of dyed liquid is increased or "expanded." This step of simultaneous dilution and expansion acts to move the operating point of the indication from a point below the threshold of see-ability to a point above the threshold of see-ability; that is, in the case of sub-threshold indications. It will be understood, of course, that dilution-expansion developers may also act to expand and augment dye-entrapment indications which are already above the threshold of see-ability.

The conventional powder-type developer may be utilized in at least three forms, i.e., wet, dry, or nonaqueous, the most common form being the wet form which consists of a slurry of pigment material, such as diatomaceous earth or talc in water suspension. This wet-type developer has the advantage of being adaptable for use in large tanks for volume testing development of large objects or of large numbers of small parts arranged in dip-baskets. It suffers from a detriment in that the powder particles tend to settle from the water suspension, so the mixture must be periodically agitated in order to maintain a uniform performance characteristic. Another difficulty which is experienced with the powder-type wet developer, and all powder-type developers, is that the powder particles may be larger than the defect indication which is sought, thereby obscuring the desired indication. Still another common difficulty is that in the course of development, where penetrant entrapments exude from surface cracks, the exudation continues to act over a period of time, with the result that the developed indication quickly becomes blurred and diffused in appearance, so that resolving power for defect detail may be considerably diminished or lost.

Up to the present time, dilution-expansion-type developers have been practical for use only in the spray-applied form, in which the active liquid developer ingredient is diluted to spraying consistency with an aerosol propellant liquid or other volatile solvent. In the course of spray application, the volatile diluent liquid flashes off by evaporation, leaving a thin coating of developer liquid on the test parts. Liquid developers of this kind do not yield satisfactory development results in dip-tank usage, due to the fluid character of the developer. An excessive bleeding and smearing of defect indication almost always occurs.

I have found it possible to formulate a dilution-expansion-type developer for dip-tank usage, wherein the active developer ingredient is a normally solid waxy material dissolved in a relatively inert carrier liquid. With developer formulations of this kind, I have found that all of the advantages may be obtained of high development sensitivity and high resolving power of the dilution-expansion developers, as well as the advantage of dip-tank usage, which is a feature of the conventional wet developer. At the same time, objectionable features, such as pigment settling and bleeding and obscuring of defect indications, are avoided. In addition to the foregoing, I have found it possible to adapt my wax-type developers for use in connection with my so-called "Inverted Penetrants", which are described and claimed in my U.S. Pat. No. 3,415,112, for "Water-Free Inspection Penetrant Process and Compositions." In addition, I have found it possible to adapt my wax-type developers for spray application to test parts.

The principal object of the invention, therefore, is to provide an improved dip-tank type inspection penetrant developer process.

Another object of the invention is to provide an improved dilution-expansion type developer which may be employed in dip-tank or spray processes.

Still another object of the invention is to provide an improved dip-tank dilution-expansion developer process which is adaptable for use in connection with the so-called "Inverted Penetrant System."

These and other objects of the invention will in part be obvious, and will in part become apparent from the following specification when read in conjunction with the accompanying drawings, in which:

FIG. 1 is an illustration, in cross-section, of an embodiment of the invention wherein a layer of a fusible wax developer is applied over a surface defect containing an entrapment of dyed penetrant liquid; and

FIG. 2 is an illustration, in cross-section, of an embodiment of the invention wherein a fusible wax developer of the invention contains a particulate thickener or support agent.

The present invention contemplates the use of solid or semi-solid fusible waxy developer ingredients which may be dissolved or suspended in a relatively inert carrier liquid. When a thin layer of the waxy material is deposited on a test surface, and when the test part is heated to a temperature above the melting point of the wax, then the dilution-expansion development action of my above-mentioned U.S. Pat. No. 3,184,596 may come into play. Accordingly, the present invention is a continuation and an improvement over the above-identified patent. It will be seen from the following description and examples that the use of waxy developer ingredients may be extended to various penetrants, leak detector systems, and contaminant detection systems, other than the conventional oil-phase penetrants which are in common use.

The operation of the waxy developers of the invention may be best understood by referring now to FIG. 1, in which there is illustrated a view in cross-section of a crack 5 in a surface 6 of a test part. Test parts may be made of virtually any material, such as metal, ceramic, glass, plastic, etc., some examples being jet engine turbine buckets or critical aerospace structural members, insulator components for electronic usage, electronic circuit boards, and the like.

In FIG. 1, the crack 5 which is shown contains an entrapment of dyed penetrant 7 which is shown to be partially exuded from the crack so as to form an exuded layer 8 on the surface 6. The dyed penetrant may be any one of the known oil-phase inspection penetrants, or it may be a more sophisticated penetrant similar to those which are described in my U.S. Pat. No. 3,282,843, for "Emulsifier Compositions," U.S. Pat. No. 3,311,479, for "Penetrant Inspection Process and Compositions," U.S. Pat. No. 3,349,041, for "Gel-Forming Inspection Penetrant and Emulsifier Compositions and Processes," U.S. Pat. No. 3,386,920, for "Process for Fluorescence Detection of Extremely Small Flaws," U.S. Pat. No. 3,429,826, for "Gel-Forming Inspection Penetrant Compositions Employing Hydrophylic and Lipophylic Surfactants," or in my co-pending application, Ser. No. 787,381, now abandoned for "Oil-Water-Compatible Compositions and Methods for Preparing Same."

It may also be a so-called "Inverted Penetrant," such as is described in my above-mentioned U.S. Pat. No. 3,415,112, for "Water-Free Inspection Process and Compositions."

In addition, the entrapment may be a dyed soldering flux of the conventional rosin type or of a glycol (Batelle) type. It will be understood that the term "penetrant," as used in this specification, includes any dyed material which forms entrapments in surface defects, and which may be developed using the compositions of the invention.

In any case, the entrapment 7 and any exuded portion 8 contains a dye or dyed material which permits a visual examination and detection of the entrapment under suitable conditions of inspection. Where the dye is of a visible color, inspection is carried out under white light, whereas in cases where the dye is fluorescent, the inspection is carried out under ultraviolet irradiation. Virtually, any dye may be used, provided it is soluble in the particular penetrant or flux carrier which is employed. A number of preferred fluorescent dye materials, and methods for their use in high sensitivity applications, are described and claimed in my above-mentioned U.S. Pat. No. 3,386,920.

The development step of the invention is a special adaptation of the conventional development process employing powder-type developers. The process is carried out after the penetrant entrapment is formed and excess penetrant is cleaned from the surface 6. The test part is dipped into a solution of a waxy developer material, as specified herein, so that the test surface is wetted by the wax solution. The surface is then drained and dried, leaving a thin layer of solid wax 9 on the surface 6. If the volatile liquid portion of the waxy solution is relatively inert and relatively nonsolvent for the exuded entrapment 8, then little or no development will take place, at least so long as the drying of the developer coating takes place at or about room temperature.

If, now, the test part is heated in some manner to a temperature above the melting point of the wax, layer 9 becomes fluid, and the effect of dilution-expansion development may take place, provided, of course, that the waxy liquid is a solvent for the dyed penetrant and the dyes dissolved therein. Accordingly, the exuded penetrant layer 8 diffuses out into the fluid wax overlay 9 to form a zone 10 in which the dyed penetrant entrapment is diluted and expanded, thereby forming a developed indication.

It is important to note that very little or no development takes place until the test surface 6 is heated to a temperature above the melting point of the wax layer. It should also be understood that the drying of the wax layer 9 and the heating of the test surface 6 to render the wax layer liquid need not be carried out as separate steps. Drying of the surface 6 may be accomplished in a heated oven, whereupon development takes place during drying or immediately thereafter.

It will be understood from the foregoing that the essence of the process of the invention lies in the step of applying heat to test parts coated with a thin layer of fusible wax, raising the temperature of the parts to above the fusion temperature of the wax coating.

It should be mentioned that in the conventional process of powder particle development (i.e., water-suspendible "wet" developers), heat is applied to test parts which have been coated with a slurry of powder particles for the dual purpose of evaporating water from the developer coating, and forcing out any entrapments of penetrant from surface cracks. The process of

the present invention which is, in part, a process of melting a layer of waxy developer on test parts, is clearly different and unique as compared with the conventional process of drying a layer of wet powder particles and exuding penetrant from entrapments. Obviously, fusion of the developer layer cannot take place unless the developer layer is a fusible substance, and this effect does not take place in powder-type developers.

Another clear and obvious difference between the present process of development and the conventional process employing powder-type developers is that in the process of the invention there is no effect of "-blotting" and absorption of penetrant entrapments onto powder particles, for the reason that no powder particles are present in fusible wax developers of the invention; that is, under ordinary use conditions. Any penetrant entrapments which may be present in surface cracks enter the fused layer of wax through a process of solution rather than by absorption or adsorption onto the surfaces of powder particles.

It is, therefore, apparent that a second essential feature of the present development process is that the fusible wax developer must be capable of dissolving the indicator dye or dyes of the penetrant; that is, in its molten condition.

Following development with heat, as described above, the part may be cooled to room temperature, at which point the wax layer **9** solidifies and the indication **10** becomes frozen in situ.

A wide variety of waxy substances have been found useful for the development purpose of the invention, and they may be selected in accordance with the desired mode of usage and the particular penetrant which is employed. For example, where the developer is to be a water solution of wax material for dip-tank usage, any one of a variety of water-soluble waxes may be employed. Among the many suitable water-soluble waxy materials are the following:

Ethoxylated alkylphenols
Ethoxylated ether alcohols
Ethoxylated polyoxypropylene glycols
Polyethylene glycols
Surface-active waxes
"Neutralized" surfactant waxes

In the above categories of materials, the ethoxylated compounds should have sufficiently high mol ratios of ethylene oxide so as to provide materials which are semi-solid or solid at room temperature (about 75° F.). Usually, an ethylene oxide content of about 12 to 15 mols or more will satisfy this requirement. For example, ethoxylated nonylphenol, having about 15 mols ethylene oxide, is a soft pasty wax at room temperature. Similar waxy features or harder wax characteristics may be obtained with other ethoxylated alkylphenols, or as the mol ratio of ethylene oxide is increased. It will be understood that the group of ethoxylated alkylphenols also includes substances which have nucleii of the naphthol or biphenol structures, as is described in my above-mentioned U.S. Pats. Nos. 3,282,843 and 3,349,041, it being understood that the ethylene oxide content shall in each case be sufficient to provide a material which is semi-solid at room temperatures.

Polyethylene glycols which are suitable for the purpose of the invention may be those which have molecular weights in excess of about 600 up to as much as 6,000 or more, whereby a solid waxy substance is obtained. In the category of surfactant waxes, there exists a large number of waxy water-soluble detergent soaps which are commercially available, and which may have a waxy character suitable for the purpose of the invention.

In the category of "Neutralized" surfactant waxes, these may be waxy surfactant materials which are combined with so-called synergist materials in accordance with the method set forth and claimed in my above-mentioned co-pending application Ser. No. 787,381 now abandoned. As an example of a neutralized surfactant wax, an ethoxylated polyoxypropylene glycol wax (Wyandotte Pluronic F68LF) may be melted and blended with a "synergist" consisting of an oil-soluble detergent such as ethoxylated nonylphenol (1.5 mols ethylene oxide). When two parts by weight of the surfactant are blended with one part by weight of the synergist, the resulting material is water "soluble" or emulsifiable, but is "neutralized" to a point where its water washability is marginal. The result is that when a water mixture of the neutralized surfactant wax is applied to a test surface, any tendency toward bleeding and blurring of small indications is minimized.

A neutralized surfactant wax may be constructed from any strongly surface-active water-soluble detergent wax, merely by adding a sufficient quantity of oil-soluble synergist to a point where the water washability of the surfactant is almost completely inhibited. Such neutralized materials will mix with water to from stable emulsions, and these emulsion mixtures may be used in the same manner as an ordinary water-soluble wax to deposit a waxy developer layer on the surface of a test part.

In certain cases, the combination of a liquid "surfactant" with a liquid "synergist" will, in the presence of water, form a semi-solid or solid gel, as described in my aforesaid application Ser. No. 787,381 now abandoned, and such gels may be melted to a liquid form at slightly elevated temperature. Accordingly, it will be understood that fusible gel-forming compositions, consisting essentially of mixtures of surfactants, synergists, and water, fall within the definition of fusible waxes, insofar as the present invention is concerned.

When the carrier liquid is to be a volatile mineral solvent or other organic solvent, such as methylene chloride, trichloroethylene, or similar materials, solvent-soluble waxes may be employed. Among the various suitable wax materials for this mode of usage are the following:

Paraffin
Carnauba wax
Beeswax
Triphenyl phosphate

Various greases and creams, such as for example petrolatum and lanolin, may be semi-solid or solid at room temperature, and may be melted to liquid form at slightly elevated temperatures. It will be understood, therefore, that such substances fall in the category of "-fusible waxes" insofar as the present invention is concerned. Any fusible wax substance will function in the process of the invention, provided that the wax is compatible with the dye which is employed in the penetrant. By this is meant that the wax, in its molten

state, must be capable of dissolving the particular dye which is used.

The solvent carrier for a solvent-soluble fusible wax may be any one of a wide variety of solvent liquids. Among such liquids may be the following:

Volatile mineral solvents
Kerosene
Benzene
Naphtha
Volatile ketones
Acetone
Methyl ethyl ketone
Volatile chlorinated hydrocarbons
Methylene chloride
Trichloroethylene
Perchloroethylene
Fluorocarbon propellant liquids and liquified gasses
Nitroethane

Regardless of the type of fusible wax which is used, it is, of course, necessary to make an appropriate selection of materials, taking into consideration the solvency of the indicator dyes, the carrier liquid for the dyes, the carrier liquid for the wax, and the particular mode of usage of the complete developer system.

In some cases, it may be found desirable to include in the developer composition a more-or-less inert particulate substance which will serve to enhance the ability of the developer to absorb penetrant entrapments as they exude from surface defects. Referring, now, to FIG. **2**, there is here illustrated in cross-section a crack **15** in surface **16** of a test part. In a manner similar to that illustrated in FIG. **1**, an entrapment **17** is formed in crack **15**, and an exuded portion **18** of the entrapment is usually formed. In this illustration, a layer of waxy developer **19** is deposited on surface **16**, and within this layer there are particles of solid material, as indicated by particle **20**.

Any one of a number of materials may be selected for use as the particulate support ingredient. For example, where the developer carrier liquid is water, sodium benzoate may be dissolved in the water along with the waxy developer ingredient.

As the water evaporates, the sodium benzoate precipitates out of solution as an amorphous layer of material mixed in with wax deposit. Although the sodium benzoate, if used alone, will not act as a dilution-expansion developer, it serves to augment the development action of a waxy material, apparently by providing a thicker than normal layer or by increasing the porosity and permeability of the layer to penetrant entrapments which may diffuse into it.

Similar effects of development augmentation may be obtained by use of insoluble particulate materials, such as silica aerogel, inorganic salts, such as sodium nitrite, which precipitate from solution as small crystals, or water-soluble resins, such as methyl cellulose, and the like, which act to form a porous lattice structure in situ with the wax layer. Even particulate substances such as talc, magnesium oxide, calcium carbonate, or diatomaceous earth may be utilized in conjunction with the wax developers of the invention, although it will be understood that such modes of usage are not preferred for the reason that large particles of material introduce problems of settling from suspension and obscuring of indications, as mentioned above. Some of the useful additives, such as silica aerogel or methyl cellulose, may cause a thickening or viscosity increase of the developer mixture, thereby producing an increase in thickness of the applied developer film, with a corresponding increase in thickness of the waxy developer layer.

Again, as indicated in FIG. **1**, heating of the test surface **16** causes the waxy layer **19** to melt to a fluid character, and the entrapment layer **18** diffuses into the developer layer to form a developed zone **21** which exhibits an enhanced color intensity or fluorescent brightness. When the part is cooled, the waxy layer **19** solidifies, thereby freezing the indication zone **21** in situ.

In subjecting test parts to heat, so as to initiate a dilution-expansion development, it will be understood that it is merely necessary to raise the temperature of the part above the melting point of the fusible developer wax. Most of the waxes mentioned above have melting points ranging from slightly above room temperature (75° F.) up to about 130° F. to 150° F. In theory, very high melting point waxes might be used, but in practice, it is found that temperatures above about 225° F. may have a deleterious effect on the dye or dyes which are used in the penetrant. Furthermore, at temperatures above about 225° F., test parts become inconvenient to handle. Accordingly, it will be understood that a preferred range of melting points for the developer waxes of the invention is the temperature range of from about 75° F. to 225° F.

Various modes of usage may be employed, in addition to dip-tank usage. Any of the developers of the invention may be applied by spray, and in many cases, it will be found that brush application is effective. In the case of oil-soluble wax developers dissolved in a volatile mineral solvent, these are intended usually for use with the above-mentioned Inverted System glycol type penetrants. However, they may also be used with oil-phase penetrants, provided the developer is applied by spray in such a way that the sprayed-on layer dries rapidly so as to minimize bleeding and blurring of indications.

Certain of the developer compositions of the present invention may employ solid, insoluble particulate ingredients as support agents, as indicated above. It will be understood that such usages are different and distinct from the conventional usage of particulate substances as penetrant developers. In conventional usage of particulate slurry developers, the particulate substance is the essential developer ingredient, and acts, as indicated above, through a "blotter" effect, to absorb penetrant entrapments exuded from surface cracks. In the present instance, a particulate substance may be employed to augment the developer action of the fusible wax ingredient, but is not essential to the developer composition. When thus used, particulate substances act as fluorescence brighteners.

In many of the presently known wet developers of the pigment slurry type, it is customary to employ a wetting agent for the purpose of insuring that the developer slurry will properly wet and coat test surfaces to which the developer is applied. Wetting agents, as thus employed, are usually hydrophylic surfactant substances, and they are normally used in very small concentrations in the slurry mixture, on the order of

100 to 400 parts per million, or about 0.01 to 0.04 percent.

It will be understood that the conventional usage of surfactant substances as wetting agents falls outside the scope of the present invention, for the reason that such surfactants, when used in the low concentrations suitable for wetting-agent-action, are not effective as developers. In the past, the use of wetting agents, in developers, in concentrations much greater than a few hundred parts per million, has been contra-indicated for the reason that an excessive concentration of wetting agent causes an excessive degree of wetting in a slurry-type developer, and this in turn may act to cause an excessive degree of bleeding and blurring of penetrant entrapments which are desired to be developed.

An important consideration with regard to the use of the fusible wax materials of the invention is that the wax substance must be present in a developer composition at a concentration which is sufficient so that when a thin coating of the liquid composition, as may remain on test surfaces after dipping and draining, will leave a coat of wax which is thick enough to yield a satisfactory development of small penetrant entrapments. A wax coating having a thickness of about 100 millimicrons or more may be sufficient to provide development, depending on the type of penetrant which is employed. Accordingly, a concentration of fusible wax in the developer mixture on the order of 500 parts per million or more is necessary; that is, to provide a satisfactory developer action. In practice, it has been found that a concentration of fusible wax in the range of 1 percent is preferable for most development operations. For many of the useful fusible waxes, a concentration range of from 0.1 to 10 percent may be found acceptable.

Inasmuch as the developer composition of the invention might be furnished in a "dry" or solid form, such that they may be dissolved for use in a suitable carrier liquid, it is apparent that the user may elect to employ a value of wax concentration selected from a wide range of possible concentrations. Also, a given solution of fusible-wax developer might be extended or further diluted with the carrier liquid, so as to provide a concentration of wax somewhat less than a recommended "minimum" concentration of 500 parts per million, as mentioned above. However, in such cases, it is possible to evaporate the excess carrier liquid during the course of application to test parts, so as to apply a sufficiently thick coating of wax to the test surface. In any event, a solution of fusible developer wax may be employed at practically any desired concentration, so long as a dried wax coating is applied which is thicker than about 100 millimicrons.

The fusible wax developer materials of the invention may be used without being dissolved in a carrier liquid. For example, the waxy substance may be melted to a liquid and then sprayed onto test surfaces either by a conventional air spray, airless spray, or electrostatic spray. In this mode of usage, it is desirable to adjust the spray equipment in such a way that the spray droplets are extremely small, and so that the droplets tend to freeze and solidify as they impinge on the test surface.

Parts which are thus sprayed with a thin coating of melted wax may be heated to liquify the wax layer, whereupon the dilution-expansion development may take place, as described above. For a satisfactory development to take place, it is first necessary that the waxy material shall be compatible with the indicator dye used in the inspection penetrant, and second that it shall be applied to the test surface to a film thickness in excess of about 100 millimicrons.

EXAMPLE NO. 1:

A wet developer composition, in dry form, was prepared as follows:

Ethoxylated polyoxypropylene glycol — fusible wax (Wyandotte Pluronic F68LF)	2 lb.
Sodium Benzoate — (assist)	5 lb.
Ethoxylated ether alcohol — urea complex (Atlas Renex 35 — wetting agent)	28 grams
Sodium Chromate (rust inhibitor)	17 grams

The above granular ingredients were tumbled together to make a uniform powdered composition. One third pound of this dry mixture was dissolved in a gallon of water to form a clear pale yellow solution. A cracked aluminum test block, treated with a fluorescent penetrant and properly washed to leave penetrant entrapments in surface cracks, was dipped in the developer solution, and was allowed to drain and dry at room temperature. It was observed that a thin, whitish, coating of developer was deposited on the surface of the test block, but examination of the block surface under black light showed that practically no development of indications had taken place up to this point.

The test block was placed in an oven and was heated to a temperature of 150° F. for about 5 minutes, and was then allowed to cool to room temperature. Examination of the block under black light showed that the many penetrant entrapments in fine surface cracks had been developed to form brilliantly fluorescent, sharply defined indications.

Similar tests were made on two modified developer solutions, in the first of which the sodium benzoate ingredient was deleted, and in the other of which the ethoxylated polyoxypropylene glycol ingredient was deleted. It was observed that in the first solution, containing no sodium benzoate, a satisfactory developer action was obtained, although the action was slightly less than with the solution containing both sodium benzoate and the fusible wax.

It was further observed that the second test solution, containing no fusible wax, provided practically no development action, before or after heating the test block. From the foregoing tests, it was concluded that the active ingredient in the developer composition was the ethoxylated polyoxypropylene glycol fusible wax, and that the sodium benzoate ingredient provided an assist or augmentation of the development action of the fusible wax. It was also concluded that the wetting agent ingredient which was employed was not effective as a developer.

EXAMPLE NO. 2:

A cracked aluminum test block was treated with a glycol-type penetrant in accordance with the so-called "Inverted" penetrant process which is described in detail in my U.S. Pat. No. 3,415,112. In accordance with this process, the glycol penetrant was applied to the test block, the penetrant-coated block was im-

mersed in a glycol-mineral solvent coupler for 30 seconds, and was then rinsed with a mixture of a glycol-ether and mineral thinner to remove surface penetrant, and leaving entrapments of the glycol penetrant in surface cracks. A fusible wax developer composition was prepared as follows:

Triphenyl phosphate	1 oz.
Benzene	1 gallon

The rinsed test block was immersed in the above developer solution, and was allowed to drain and dry, leaving a thin coating of the waxy triphenyl phosphate on the test surface. At this point, the test block was examined under black light, and it was observed that little or no development action had taken place. The block was placed in an oven and was warmed for a few minutes to a temperature of about 140° F., and the block was then allowed to cool to room temperature. Upon examination under black light, it was observed that the many surface cracks in the test block were revealed as well-defined, brilliantly fluorescent indications.

The above developer formulation was modified by the addition of 40 grams of silica aerogel per gallon of the using mixture. A development test using this modified formulation showed that an improved brightness of developed indications was obtained. A further test using a slurry of silica aerogel, without the presence of the triphenyl phosphate, resulted in practically no development action. It was, therefore, concluded that the triphenyl phosphate was the active developer ingredient in this process, and that the silica aerogel had the ability to augment the effectiveness of the triphenyl phosphate as a developer.

EXAMPLE NO. 3:

A neutralized fusible wax developer composition was prepared as follows:

Ethoxylated polyoxypropylene glycol — fusible wax (Wyandotte Pluronic F68LF)		6 grams
Ethoxylated nonylphenol — synergist (1.5 mols ethylene oxide)		3 ml.
Ethoxylated ether alcohol — urea complex (Atlas Renex 35 — wetting agent)		0.15 gram
Sodium chromate — rust inhibitor		0.15 gram
Sodium Benzoate — (assist)		19 grams
Water	to make	700 ml.

The ethoxylated polyoxypropylene glycol and the ethoxylated nonylphenol ingredients were melted and mixed separately, after which about one half pint of water was added to form a milky emulsion. The remainder of the listed ingredients was added, and the mixture was made up to the 700 ml. volume with water.

Development tests were carried out in a manner similar to the procedure outlined in Example No. 1 above, and it was observed that prior to heating the test block, there was somewhat less tendency toward bleeding of defect indications than occurred in the composition of Example No. 1. After heating the test block, it was observed that brilliantly fluorescent indications were developed which appeared to be somewhat sharper and more well defined than those obtained by the developer of Example No. 1.

EXAMPLE NO. 4:

A fusible wax developer composition was prepared as follows:

Ethoxylated nonylphenol (30 mols ethylene oxide)		10 grams
Methylene chloride	to make	1 pint

The above developer solution was sprayed onto a cracked aluminum test block which had been treated with a fluorescent penetrant as described in Example No. 1. The spray application was carried out as a "dry" spray, so that the spray droplets dried almost completely before impinging on the test surface. After the spray application, the test block was examined under black light, and it was observed that little or no development of defect entrapments had taken place. The test block was then heated in an oven for a few minutes to a temperature of about 150° F., after which it was allowed to cool to room temperature. The test block was again examined under black light, and it was found that the defect entrapments on the surface of the block were properly developed to yield sharp, high-resolution indications.

EXAMPLE NO. 5:

A fusible wax, consisting of ethoxylated polyoxypropylene glycol, was heated to a temperature of 150° F. to form a low viscosity liquid. A cracked aluminum test block was treated with a fluorescent penetrant, as outlined in Example No. 1, and the melted wax was applied by electrostatic spray to form an extremely thin coating of wax on the test surface. In applying the wax spray, the spray was adjusted so that the spray droplets froze to a solid immediately on contact with the test surface. Examination of the test surface immediately after the spray application showed that little or no development of defect indications had taken place. Following the heating of the test block for a few minutes at 150° F., however, fine surface cracks in the test block were revealed as brilliantly fluorescent, sharply defined indications.

It will, of course, be understood that various of the suitable fusible wax materials may be employed selectively, singly, and in combination, and it is thereby possible to prepare developer formulations having specified characteristics of solvency, melting points, compatibility with indicator dyes, and other features. Furthermore, it will be understood that various ingredients may be added to the compositions of the invention for purposes which may be partially or completely unrelated to the development performance of the compositions. For example, small amounts of sodium chromate or relatively large quantities of sodium nitrite might be added for the purpose of inhibiting corrosion effects of water solutions of developer. Deodorant ingredients might be added to mineral-solvent type developers, for the purpose of improving the odor of the product. Also, ultraviolet absorber dyes might be added for the purpose of depressing or cancelling out residual fluorescence in accordance with the method of my co-pending application, Ser. No. 669,536, now U.S. Pat. No. 3,477,536, for "Method of Masking Fluorescence in Fluorescent Dye Tracer Inspection Process Materials."

It will also be understood that the step of fusing or melting the coating of developer wax on test parts may be carried out in a variety of ways. For small parts which are being processed in trays or on racks, oven heating may be employed. The same is true for many large parts which are handled individually but which are small enough to fit in an oven. For very large parts or for parts which must be inspected without removing them from another assembly, as for example aircraft landing gear parts which must be inspected under field conditions, it is possible to employ a heat gun or a similar source of hot air to warm the test area to a temperature above the fusion point of the developer wax. In any event, the step of melting the developer wax is an essential part of the development process of the invention.

Finally, it will be understood that although the process of the invention is primarily intended to provide dilution-expansion development of sub-threshold indications, it will also act to provide augmentation of visible color or fluorescence of dyed indications, which indications are already above the threshold of see-ability. It is not even necessary that the dyed indications be in the form of entrapments of dyed liquid or dye without liquid in surface cracks. The process of the invention provides development or augmentation of color or fluorescence response of thin surface films or layers of dyed liquids or microscopic deposits of dyed substances.

Accordingly, the process of the invention is not limited to the development of sub-threshold indications or entrapments of dyed tracer materials in surface cracks, and it may be used for the development or augmentation of visible color or fluorescent indications of deposits or residues of dye and material on the surfaces of test parts.

Although the invention has been described with reference to particular embodiments thereof, it will be understood that various changes may be made therein without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. In an inspection penetrant process in which a tracer-dyed penetrant material is applied to a test surface, excess surface penetrant is removed, and entrapments of the tracer-dyed penetrant are developed in an applied coating of developer material, an improvement being the step of heating said test surface to a temperature above the fusion point of said developer material, thereby melting said developer material, said developer material consisting essentially of a tracer-dye-compatible heat-fusible wax, said fusible wax having a melting point falling within the range of from 75° to 225° F.

2. In an inspection tracer process in which a dyed tracer substance is applied to a test surface, and the presence of said substance on said test surface is detected by visual examination of color or fluorescence response of the dye in said tracer substance, the steps of applying a coating of a tracer-dye-compatible heat-fusible wax to said test surface, and heating said test surface to a temperature above the melting point of said fusible wax, thereby melting said fusible wax, said fusible wax having a melting point falling within the range of from 75° to 225° F.

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