A cable for camera and light extends from Earth's surface into the well bore. A slug of transparent, heavier than water, oil and water insoluble liquid medium is placed in the well bore. A camera with a light source is lowered into the well bore to photograph the object to be photographed. Figure 1 is an illustration of this setup.
WELL BORE PHOTOGRAPHY

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6 Claims. (Cl. 95—11)

This invention has reference to an improved technique for photographing by various means the walls and other subterranean surfaces of and within wells and the like bores that penetrate into the earth's surface.

It has been proposed and is known to visually examine for various purposes the interior of bore holes into the earth's surface through the agency of photography. Such practice in openings of the type that prohibit human access greatly aids the study of subsurface formation; characteristics and permits other desirable introspection to be accomplished. In oil or gas wells, for example, it also affords an easy means for examining, in situ, the interiors of casing strings and the like installations and for viewing tools and other instruments that may be lost in the hole.

As the procedure is conventionally practiced, the particular photographing device that is employed is immersed within the hole in various naturally-occurring or specially-provided water (including salt water) or oil media through which the well bore photography must usually be accomplished. Although optical transparency is an obviously significant desideratum for such media to possess, it may oftentimes be a difficult condition to achieve and maintain. This is particularly the case when pictures and other visualizations are being taken and made in oil wells. Thus, it is mentioned typical vexations that may occur, aqueous media may become cloudy and opaque from black sulfide water or other contaminants such as drilling muds and other fluids that are already present in the wells. Dark crude oils may likewise affect an oil medium.

It would be advantageous to provide an improved technique for well bore photography that would not be subject to the serious drawbacks and deficiencies that have prevailed. The attainment and realization of this and corollary ends as will be manifest in the ensuing description and specification are among the major objectives of the present invention.

Accordingly, photography in well bores and the like openings in the earth's surface may be performed in an eminently suitable manner by practice of the present invention which comprehends providing at a desired point in a well or the like boring into the earth's surface that is desired to be photographed a slug of an oil and water immiscible and insoluble transparent liquid having a specific gravity greater than that of water; said liquid slug being provided in an adequate and sufficient volume to fill a portion of said boring at the point that is desired to be photographed so as to encompass said point with said liquid; immersing said slug liquid medium both a light source for illuminating the object to be photographed and an underliquid operable photographing device or means; and photographing through said transparent liquid medium the desired point or object at said point in said boring that is encompassed by and with said liquid medium.

Practice of the technique of the present invention reliably facilitates the accomplishment of clear legible photographs and other visual reproductions in which the surfaces or other objects in the bores that are desired to be visually examined are plainly discernible. As is apparent, and as has been indicated, both wall and bottom hole surfaces may advantageously be photographed as may other objects and installations in the bore hole.

And, quite advantageously in some cases, scanning or panoramic viewing procedures (either axially or circumferentially, or both, of all or any desired portion of the bore) may be observed to provide integrated sequential series of photographs or image reproductions of larger areas of the bore surface that can be encompassed in or with a single, stationary photographic view. The presence of black sulfide water, dark crude oil, drilling muds or the like light-occluding contaminants does not hamper the intended photographic accomplishment.

In Figure 1 or the hereto annexed drawing there is a schematic representation that portrays the present invention. In the illustration, the dimensional proportions have been distorted for purposes of clarity.

The transparent liquid medium that is employed with such great benefit in the practice of the present invention may advantageously be an oil and water insoluble liquid condensation product, having a specific gravity between about 1.2 and 2, of from about 0.75 to 4 moles of formaldehyde with such unmolar proportion of a phenolic constituent selected from the group consisting of mixtures of tribromophenol and the common, trifunctional phenol, C₆H₅OH, that, expediently, contain mole fractions of the latter between about 5 and 95 percent; mono- and dibromophenols that, optionally, may contain minor proportions (as, say, mole fractions that are up to about 10 percent) of the common phenol; mono-, di- and trichlorophenol that, optionally, may contain minor proportions, on the same basis as above, of the common phenol; and mixtures thereof. More advantageously, the liquid condensation products that are employed contain about 1 to 1.5 moles of formaldehyde to each mole of the phenolic constituent that is present therein and have an absolute viscosity at room temperatures from about 300 to 1,000 centipoises. Such materials are most desirably suited for purposes of the invention. They have the requisite gravity to be heavier than the fluids that are encountered in the usual wells and other bores that may be made into the earth's surface. This facilitates the satisfactory positioning and maintenance, in a ready manner, at desired points or levels in the bore hole. They also have suitable thermal stability for the intended application. And, in addition, they are generally obtainable as colorless, syrupy liquids that are well adapted to transmit light and function as a photographic medium. Furthermore, they ordinarily remain in this condition for sufficiently long periods of time after their preparation to enable their practical utilization.

The ratio of the formaldehyde to the phenolic constituent that is utilized in the syrupy liquid resinous condensation products is of great importance and must be critically observed in order to achieve the desired results. When less than the minimum proportion of the aldehyde is employed, the molecular weight of the resinous product is generally found to be so low as to render it difficult to obtain liquid products having the desired gravity. When proportions of formaldehyde are
employed that exceed the maximum mentioned propor-
ons, the resin product assumes such a marked increase in reactivity
that it tends to cross-link to a sufficient extent
to form a solid. While it is highly advantageous
or the phenolic constituent to be comprised of mixtures
of tri-bromophenol with the common phenol, suitable
liquid resins can also be obtained with other of the men-
tioned phenolics. In this connection, the specific gravity
of the liquid resin product can be altered and varied
by heating or cooling in proportion of the various phenolic
constituents (having different individual gravities) that
may be employed therein. This is particularly the case
when the amount of common phenol that is condensed
the resin is varied. Greater amounts of the common
phenol ordinarily reduce the specific gravity of the liquid
resin product.

The condensation products can be readily prepared
in a known manner by reacting the phenolic constituent
with formaldehyde or paraformaldehyde to the point
where a syrupy liquid product having the desired char-
acteristics is formed. Ordinarily, this may be accom-
plished under basic catalysis using alkali metal hydrox-
ides or carbonates for this purpose. Generally, from
about 0.01 to 0.6 and preferably from 0.012 to 0.3
mole of the basic catalyst are employed per mole of the
phenolic constituent being condensed. The condensa-
tion reaction which is best accomplished at an ele-

ated temperature, say in the neighborhood of 170–200°
F., may be terminated at a desired point by acidifica-
tion to neutralize the catalyst with hydrochloric, formic
or other suitable acid materials. When tri-bromophenol
is being condensed, however, it is not ordinarily neces-
sary to employ an acid neutralizer for terminating the
reaction since the hydrogen bromide that evolves during the
condensation effectively serves this purpose.

The transparent liquid medium is placed at the bottom
of the well bore or other desired point to be photo-
graphed by means of liquid displacement techniques that
are common to, and frequently practice in connection
with well operations. Thus, for example, in a well that
may contain casing or tubing and which may be filled
with either water, brine, crude oil or drilling mud, the
liquid may be spotted at any desired point or level in
the bore hole by positioning the end of a tubing, for ex-
ample, at the desired point; pumping the slug of liquid
by means of positive displacement apparatus down the

tubing wherein it is displaced downwardly as a distinct
layer to the point of discharge from the tubing; then
discharging the pumping when the slug of liquid has
arrived at the desired point or level. During the in-
jection of the liquid medium through the tubing into the
well bore, an equivalent volume of well fluid is with-
drawn from the casing. This sort of procedure is known
conventionally in the trade as "circuiting a well." It
and similar or analogous techniques are well adapted
for locating the slug of liquid medium that is employed
in the practice of the invention. As mentioned, the
volume of the liquid medium that is used for the slug
should be large enough to fill the bore hole and encom-
pass the subject desired to be visually reproduced at
the point in the bore hole where the photography is to
be undertaken.

In the cases where it may be necessary to spot the
liquid medium at a point in the boring above its bottom,
perience the invention. As mentioned, the
volume of the liquid medium that is used for the slug
should be large enough to fill the bore hole and encompass
the subject desired to be visually reproduced at
the point in the bore hole where the photography is to
be undertaken.

In the cases where it may be necessary to spot the
liquid medium at a point in the boring above its bottom,
it may oftentimes be advantageous to employ a temporary
plugging material such as gellable aqueous solutions
of various natural and synthetic gums, aluminum soap
paste or other non-penetrating liquids which may contain
fine particulate filler ingredients just below the desired
location of the medium. The heavy liquid medium may
then be stationarily positioned over the plug. Of course,
in the event that the liquid resin should solidify during
its residence in a well, it can easily be removed and the
well reopened by reboring operations.

Liquid media of the indicated formaldehyde condensed
phenolic constituent variety may generally be employed
and spotted at desired points which occur in bore holes
at levels as deep as 20,000 feet since, in many wells, the
average temperature at such depths is not much in excess
of about 400° F. It may be preferable in the practice of
the invention with such phenolic liquid resin media,
however, when the point or object to be photographed
is situated in a location having an average temperature
that is much in excess of about 400° F. Such elevated
temperatures may harden, solidify, degrade or disinte-
grate the phenolic liquid resin which may then minimize or
nullify the benefit of its use in the practice of the inven-
tion. In connection with this, care should be taken
when employing photographic film in well locations hav-
ing high average temperatures to use heat-resisting varie-
ties of film or to employ cooling means in the camera or
to avoid keeping the camera exposed to the high tem-
peratures for such periods of time as might allow its
internal temperature to rise to that of the well. Such
means may preclude the possibility of break-down of the
film.

After its introduction and spotting in the well bore,
the light source and photographic device or means are
lowered into the well bore and immersed in the liquid
medium to enable the pictures or other visual reproduc-
tions to be made. Of course, both the light and the
camera are trained in the best possible manner on the
object or surface to be photographed. In some cases,
it may be necessary to remove tubing or other installa-
tions from a well before introducing the photographic
apparatus down the bore hole; this being governed by
the demands of the occasion. Practically any incan-
descent or other light source that is capable of
liquid submersion and which may be integral with or
separate from the camera assembly may be utilized for
illumination when photographic pictures are being taken
in the practice of the invention. The photographic
means that is employed, as has been indicated, must be
of the underliquid variety that is adapted while submerged in a liquid medium. Suitable camera
apparatus may be similar to or analogous with that which
has been described by E. M. Barstow and C. M. Bryant
in their article on a "Deep-Well Camera" which appeared
at page 74 in the March 15, 1947 issue of The Oil and
Gas Journal. When photographic cameras are utilized in
the practice of the invention, it is generally ad-

advantageous to employ a photographic film of the infra-
red light sensitive variety which is adapted to record
images flooded by light having a wave length in the
range from about 6700 to 8700 Angstrom units. This
site of light which is substantially out of the visible
spectrum may be considered to be in the "near infra-red
range." This accommodates employing suitably short
exposures in the taking of the pictures, especially when
the described species of condensation resins are em-
ployed which have relatively poor light transmitting
characteristics in the visible range but afford good trans-
mission of light in the near infra-red range. If desired,
the photographic device may alternatively be a television
camera for photographing the desired objects and elec-
tronically transmitting the pattern to cooperating surface
apparatus and means for visual reproduction. Television
devices for such purposes may be built and employed in
a generally similar manner to the referred-to type of
photographic camera equipment, taking the necessarily
diverse structural and functional design requirements
into account. When televising cameras are employed, it
is advantageous to utilize especially intense light sources
for illumination in the well bore.

By way of further illustration, several suitable liquid
media were prepared by condensing various phenolic
constituents with formaldehyde using various molar pro-
portions of the reactant ingredients. In each case, the
products were obtained by melting the phenolic constituent then adding the formaldehyde. The reaction mass was then placed at which the paraformaldehyde dissolves. This is necessary to obtain transparency in the liquid resin product. The reaction mass was then continued until a drop of the reaction mass was insoluble in kerosene, a condition that was generally obtained after a total cooking period of 20–25 minutes. The oil insoluble condition of the reaction mass necessarily indicates its water insolubility since the former characteristic invariably occurs when the latter in phenol-formaldehyde type condensation products. Excepting for the media prepared with tribromophenol, the reactions were terminated by neutralization of the catalyst in the reaction mass with either 50 percent aqueous formic acid or 28 percent aqueous hydrochloric acid. With the tribromophenol constituent, the evolved hydrogen bromide neutralized the catalyst to obviate the necessity for employing additional acid for the purpose. In the following Table I, there is set forth the ingredients and materials that were utilized in each of the products that were prepared as well as the specific gravity of each of the liquid resin syrups that were obtained.

Table I.—Formulations of various liquid media for well bore photography

<table>
<thead>
<tr>
<th>Medium</th>
<th>Ingredients</th>
<th>Quantity of Ingredients</th>
<th>Approximate Mole Ratio of Phenolic Constituent to Formaldehyde</th>
<th>Mole Fraction of Individual Ingredients</th>
<th>Specific Gravity of Liquid Resin Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;A&quot;</td>
<td>Tyraminephenol</td>
<td>76 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Phenol</td>
<td>25 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Paraphenylene</td>
<td>15 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Caustic Soda</td>
<td>4 cc.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td>&quot;B&quot;</td>
<td>Tetrabromophenol</td>
<td>50 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Phenol</td>
<td>20 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Glycol</td>
<td>3 cc.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td>&quot;C&quot;</td>
<td>Pyridinephenol</td>
<td>25 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Phenol</td>
<td>75 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td>&quot;D&quot;</td>
<td>Paraphenylene</td>
<td>25 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Caustic Soda</td>
<td>5 cc.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Orthophenol</td>
<td>60 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td>&quot;E&quot;</td>
<td>Tetrabromophenol</td>
<td>50 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Caustic Soda</td>
<td>1 cc.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td>&quot;F&quot;</td>
<td>Formaldehyde</td>
<td>37 percent Aq. Soln.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Caustic Soda</td>
<td>50 lbs.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>Urohydrocrotalic Acid</td>
<td>7.3 g.</td>
<td>111</td>
<td>0.25</td>
<td>1.25</td>
</tr>
</tbody>
</table>

When a product was attempted to be made in the foregoing manner using tribromophenol as the sole phenolic constituent, a solid resinsium material was obtained. All of the liquid media were optically clear, and transparent and remained so at room temperature for periods of at least two weeks after their preparation. When maintained at a temperature of about 175° F. all of the liquid media remained fluid and clear for at least about three weeks, although they were observed to become cloudy in less time when cooled from the elevated temperature. The absolute viscosity of each of the liquid products at room temperature was found to be in the range from about 140 to 300 centipoises. The light transmitting characteristics for light of various wave-lengths of medium "A," as determined with a Beckman Model DU Spectrophotometer, are set forth in the following Table II. The test was conducted in the standard way for such evaluations by simply measuring the percentage transmission per wave length through the medium being tested.
is desired a slug of an oil and water immiscible transparent liquid medium having a specific gravity greater than that of water, said transparent liquid medium being an oil and water insoluble liquid condensation product having a specific gravity between about 1.2 and 2.5 from about 0.75 to 4 moles of formaldehyde with each unimolar proportion of a phenolic constituent selected from the group consisting of mixtures of tribromophenol and the common, trifunctional phenol, C₆H₄OH, that contain mole fractions of at least about 5 percent of the latter; mono- and di-bromophenols and their mixtures with common phenol; mono-, di- and tri-chlorophenol and their mixtures with common phenol; and mixtures thereof; said liquid slug having a volume equal to that of the portion of the well bore that encompasses the point at which the visual reproduction is desired; introducing in said well bore and immersing in said medium both a light source for illuminating the object to be visually reproduced and an underliquid operable photographic means; and visually reproducing with said photographing means through said transparent liquid medium the desired object at said point in said boring that is encompassed by and with said liquid medium.

2. The improvement in the art as set forth in claim 1, wherein the liquid condensation product contains from about 1 to 1.5 moles of formaldehyde for each mole of the phenolic constituent therein contained.

3. The improvement in the art as set forth in claim 1, wherein the phenolic constituent in the liquid condensation product is a mixture of tribromophenol and the common phenol.

4. The improvement in the art as set forth in claim 1, wherein the photographic means is a camera that is adapted to record images on light-sensitive photographic film.

5. The improvement in the art as set forth in claim 1, wherein the photographic means is a camera that is adapted to record images on light-sensitive film and the light source is an incandescent lamp; and wherein the desired object is visually reproduced on a photographic film that is sensitive to infra-red light.

6. The improvement in the art as set forth in claim 1, wherein the photographic means is a televising camera that is adapted to electronically photograph an object and transmit an image to cooperating means for visual reproduction.

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3. The improvement in the art as set forth in claim 1, wherein the phenolic constituent in the liquid condensation product is a mixture of tribromophenol and the common phenol.

4. The improvement in the art as set forth in claim 1, wherein the photographic means is a camera that is adapted to record images on light-sensitive photographic film.

5. The improvement in the art as set forth in claim 1, wherein the photographic means is a camera that is adapted to record images on light-sensitive film and the light source is an incandescent lamp; and wherein the desired object is visually reproduced on a photographic film that is sensitive to infra-red light.

6. The improvement in the art as set forth in claim 1, wherein the photographic means is a televising camera that is adapted to electronically photograph an object and transmit an image to cooperating means for visual reproduction.

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