NORTHWEST LABORATORIES

of Seattle, Incorporated

ESTABLISHED 1898

Technical Services for: Industry, Commerce, Legal Profession & Insurance Industry

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Report To: Sonotech, Inc.

Date: 1/5/93
REVISED 1/6/93
Lab No: E 60731-2 ,

Report On: Ultrasonic Couplants/
Crevice Corrosion Testing

PURPOSE:

Perform crevice corrosion tests on carbon steel discs using samples of Echo Ultrasound Products, Ultragel II and Sonotrace 30.

ULTRASONIC COUPLANT MATERIALS TESTED:

Materials from Echo Ultrasound (Purchased by Northwest Laboratories from Echo Ultrasound Distributors)

1. Ultragel II - Batch 092061
2. Sonotrace 30 - Batch 092033

TEST SUBSTRATE:

Carbon steel discs, 3 in. x 1/2 in., Alloy 1018. Please note that these are the same discs as those used in the previous set of tests (reported in E60731 and E60731-1).

SUMMARY OF FINDINGS:

Under the conditions of this test Sonotrace 30 caused considerable corrosion damage to the steel disc, including areas of general surface attack as well as pitting of the steel. Several pits were found with a depth of greater than 0.001 inch and the depth of one pit was measured as 0.0024 inch.

The steel disc prepared with Ultragel II showed only light surface corrosion damage along the edges of the contact area with the glass plate.

TEST PROCEDURE:

A. The test surfaces of the steel discs were prepared for the corrosion tests in the following manner:

1. Cleaned with acetone
2. Sanded with medium grit (120) abrasive paper
3. Cleaned with acetone
5. Cleaned with acetone
6. Applied couplant from top, middle and bottom of container and spread the couplant over half of the disc surface.
7. Formed crevice by covering one half of each disc under a portion of a clean glass plate measuring 12 x 12 x 1/2 inches.

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B. The specimens were stored for seven days at a temperature of approximately 75 deg. F away from sunlight.

C. The specimens were photographed after the seven days of storage.

D. The couplant material was removed from the steel discs using cold water and paper towels to wipe the surfaces.

E. The surfaces were then examined by means of a stereo zoom microscope (10x - 30x magnification) to determine the extent of chemical attack.

F. The rust on the Sonotrace 30 specimen was partially removed by means of an alkaline cleaner in an ultrasonic bath.

G. The clean surfaces were then photographed to document appearance.

H. Pitting depth on the Sonotrace 30 specimen was determined by means of a metallographic microscope.

TEST RESULTS:

A. Appearance of steel test surfaces before removal of couplant materials.

1. Sonotrace 30 - Photo #1
Heavy areas of brown discoloration on the steel disc under the glass plate and along the edge of the glass plate.

2. Ultragel II - Photo #2
Very light brown discoloration on the steel disc along the edge of the glass plate, and some brown discoloration along the edge of the disc.

B. Appearance of steel test surfaces after removal of couplant materials.

1. Sonotrace 30 - Photo #3
Heavy areas of brown discoloration as seen before removal of the corrosion products.

2. Ultragel II - Not photographed.
Visible surface attack on the steel disc along the edge of the glass plate, and some brown discoloration along the edge of the disc.

C. Appearance of steel test surface (Sonotrace 30 test) after partial removal of corrosion products.

Visible surface attack was observed where there had been brown corrosion products. The edges of the chemically attacked areas were marked by deeper pits. See photos 4 and 5.

D. Measurement of pitting depth.

Various pits were examined and measured for depth by means of a metallographic microscope.

Results: Several pits were found to be greater than one mil in depth and the depth of one pit was measured as 2.4 mils. See photo 6.

DISCUSSION OF CREVICE CORROSION:

Intensive localized corrosion frequently occurs within crevices and other shielded areas on metal surfaces exposed to corrosives. This type of attack is usually associated with small volumes of stagnant solution caused by holes, gasket surfaces, lap joints, surface deposits, and crevices under bolt and rivet heads. As a result, this form of corrosion is called crevice corrosion or, sometimes, deposit or gasket corrosion.

Contact between metal and nonmetallic surfaces can cause crevice corrosion as in the case of a gasket. To function as a corrosion site, a crevice must be wide enough to permit liquid entry but sufficiently narrow to maintain a stagnant zone. For this reason, crevice corrosion usually occurs at openings a few thousandths of an inch or less in width.

For the purpose of this test, a crevice was created by placing a flat glass sheet over part of the flat steel disc with the couplant material between. The glass is an inert material to the chemical involved and therefore could not have taken part in the corrosion reaction.

Additional tests should be performed using these couplants in case of any variation in composition between lots or within a single lot. In addition, field tests should be run on actual materials which contain crevices and which are likely to be exposed to this type of couplant.

Discussion of Test Specimen Preparation Procedure

The purpose of the specimen preparation method employed in these tests was to provide a homogeneous surface for comparative testing and to simulate a recently machined and cleaned surface.

The cleanliness of the surface, the existence of surface films and the presence of foreign matter can exert a very strong influence on the initiation and speed of corrosion. The influences of various surface conditions can be either positive or negative and the surface conditions may vary from place to place, even on a single surface. Therefore, the test surfaces must be uniformly prepared so that meaningful test results can be obtained.

Reference: Corrosion Engineering, Third Edition, by Mars G. Fontana, McGraw-Hill, 1986.

NORTHWEST LABORATORIES

SAM LEBARRON, Director
Analytical Laboratory

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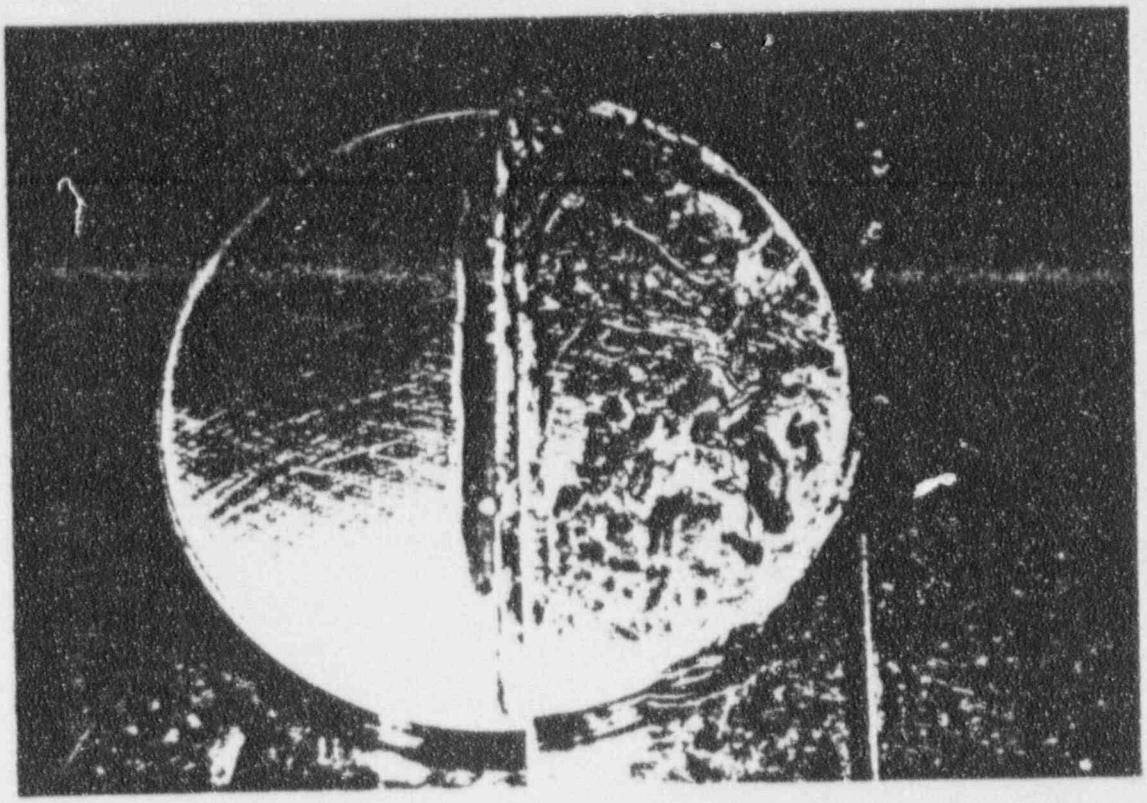

Photo 1 - Sonotrace 30 sample after seven days exposure. The glass plate is covering the right half of the disc.

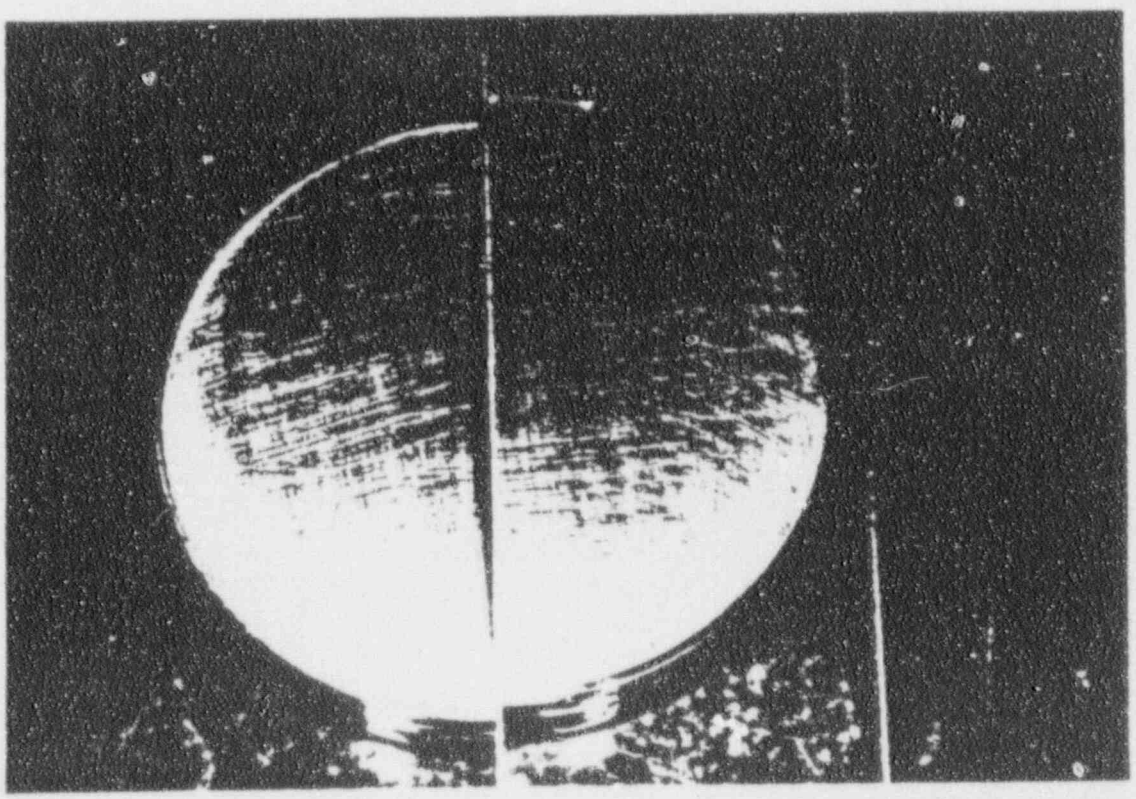

Photo 2 - Ultragel II sample after seven days exposure. The glass plate is covering the right half of the disc.

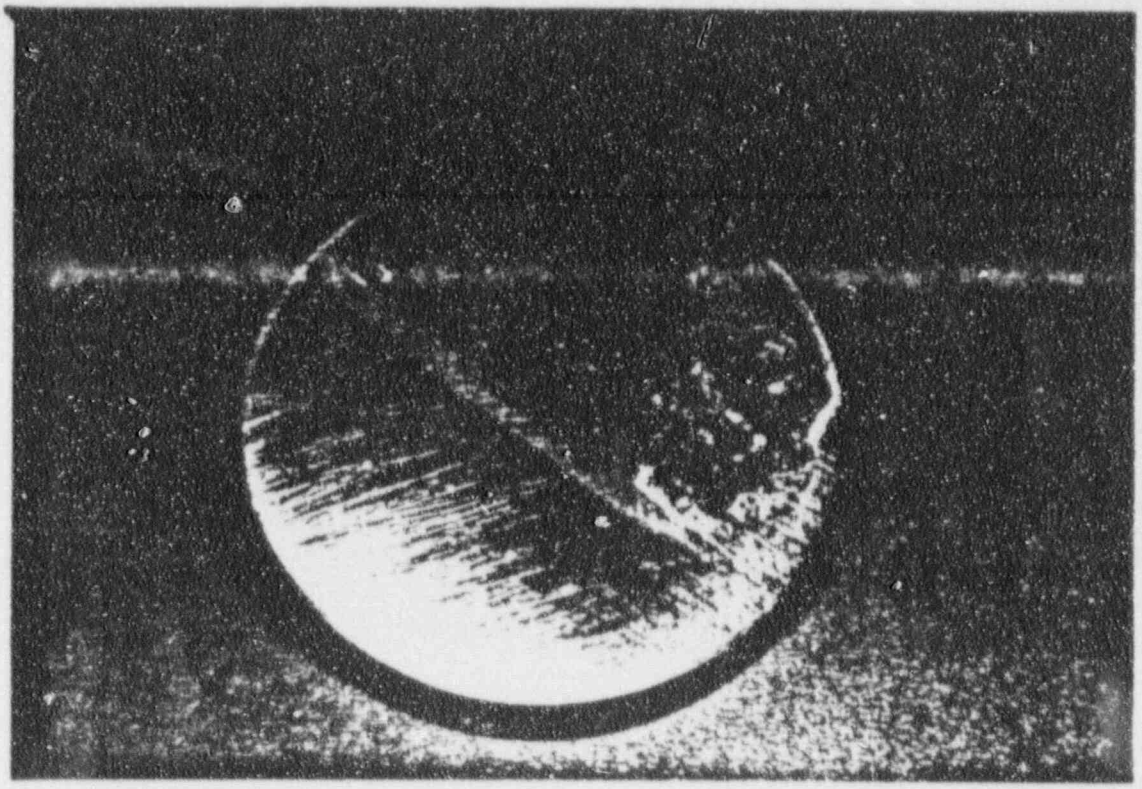

Photo 3 - Sonotrace 30 sample before removal of corrosion products.

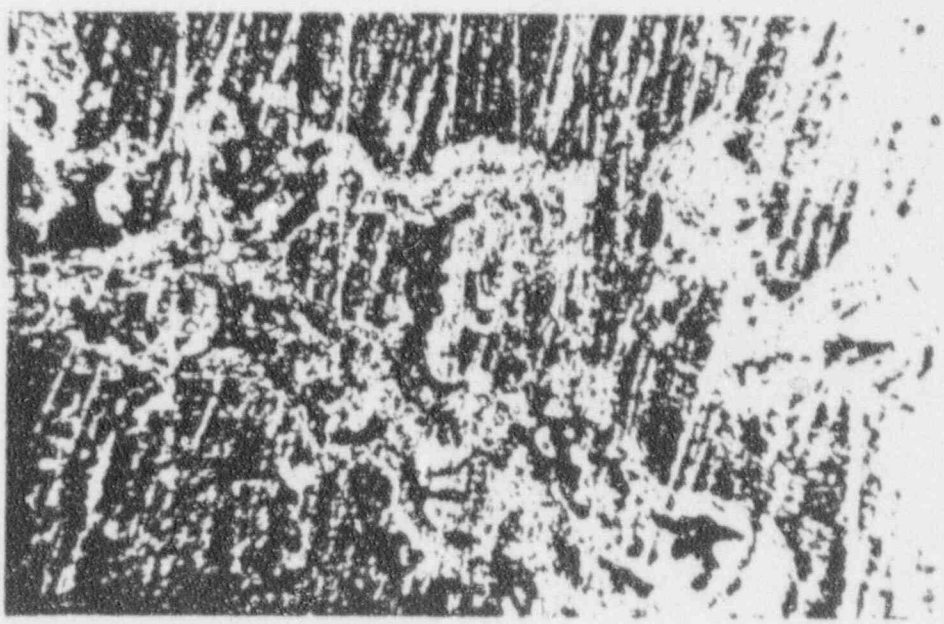

Photo 4 - Sonotrace 30 sample - detail of surface after partial removal of corrosion products. Light colored areas are chemically attacked areas and dark areas are remaining corrosion products. Approximately 10X magnification.

Photo 5 - Sonotrace 30 sample - Detail of chemically attacked area after removal of corrosion products. Arrows indicate some of the pitted areas around the border of the chemically attacked area and extending into it. Approximately 35X magnification.

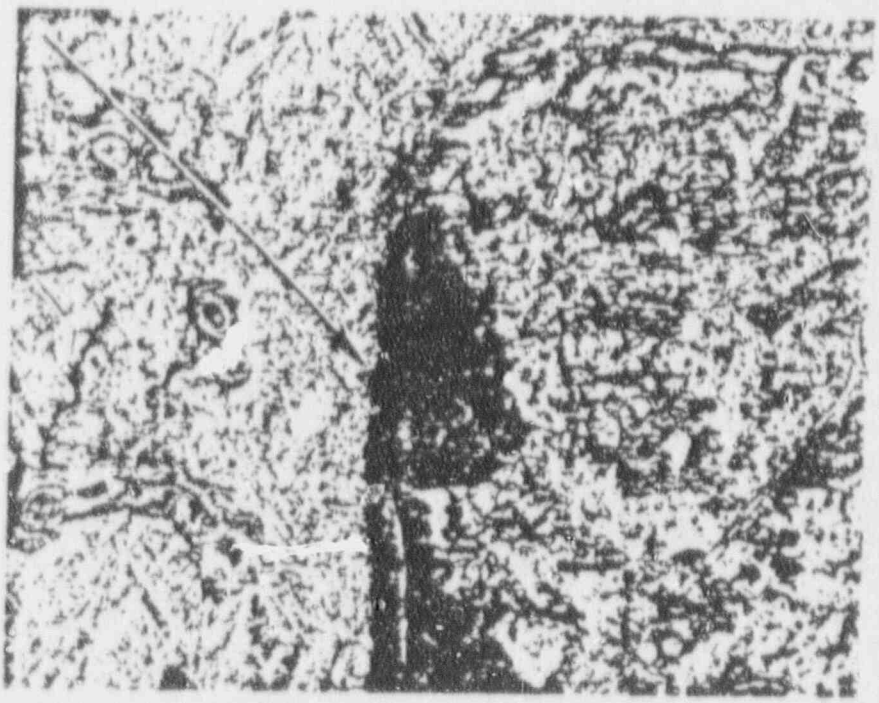

Photo 6 - Sonotrace 30 sample - Detail of chemically attacked area. Arrow at dark area indicates pit which was measured as 2.4 mils deep. 100X magnification.

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FAX (206) 622-0159 Telephone (206) 622-0680

Report To: Sonotech Date: September 21, 1992

Report On: Ultrasonic Couplants/ Corrosion Testing Lab No.: E 60731

PURPOSE:

Run comparative corrosion tests on steel surfaces using samples of Sonotech products, Soundsafe and Soundclear, to compare with samples of Echo Ultrasound products, Ultragel II and Sonotrace 30.

ULTRASONIC COUPLANT MATERIALS TESTED:

A. Materials from Sonotech, Inc.
   1. Soundsafe - Batch 92220
   2. Soundclear - Batch 31923

B. Materials from Echo Ultrasound (Purchased by Northwest Laboratories From Echo Ultrasound Distributors)
   1. Ultragel II - Batch 092061
   2. Sonotrace 30 - Batch 092033

TEST SUBSTRATE: Steel discs, 3 in. X 1/2 in., Alloy 1018.

SUMMARY OF FINDINGS:

1. Both Ultragel II and Sonotrace 30 chemically attacked the steel discs, resulting in visible corrosion products and corroded surfaces. However, the level of corrosion attack varied with samples taken from different parts of the containers.

2. Neither Soundsafe nor Soundclear showed any indication of corrosion attack under the same test conditions as for Ultragel II and the Sonotrace 30.

TEST PROCEDURE:

1. The test surfaces of steel discs were prepared for the corrosion tests in the following manner:

   A. Cleaned with acetone.
   B. Sanded with medium grit (120) abrasive paper.
   C. Cleaned with acetone.
   D. Labels Attached.
   E. Cleaned with acetone.
   F. Applied beads of couplant from top, middle and bottom of container.
   G. Photographed prepared specimens.

TEST PROCEDURE: (Continued) -

2. The specimens were stored for six days at room temperature, away from direct heat and sunlight.

3. The specimens were photographed again on the second day using sunlight rather than electronic flash.

4. After six days, test specimen number 5 was cleaned and reprepared due to inconsistent results. The Sonotrace 30 in Test #3 had caused some corrosion of the steel surface, but the same material in Test #5 dried completely and no corrosion was observed after 6 days.

5. Final photographs were taken after 12 and 13 days, and the test was stopped at the end of 13 days.

6. The couplant material was removed from the steel discs using cold water and paper towels to wipe the surfaces.

7. The clean surfaces were then examined by means of stereo zoom microscope (10x - 30x magnification) to determine the extent of chemical attack.

8. The clean surfaces were then photographed to document appearance.

IDENTIFICATION OF TEST SPECIMENS:

Test #1 - Soundsafe
Test #2 - Soundclear
Test #3 - Sonotrace 30
Test #4 - Ultragel II
Test #5 - Sonotrace 30 and Soundclear
Test #6 - Ultragel II and Soundsafe

Note:

In all cases, the three beads of couplant are from the top, middle and bottom of the container. The beads are in descending order above the label, (and in ascending order below the label).

TEST RESULTS:

A. Appearance of steel test surfaces before removal of couplant materials.

Test 1 - Soundsafe - No indication of any surface attack.

Test 2 - Soundclear - No indication of any surface attack.

Test 3 - Sonotrace 30 - Photo 3
a) Top bead - brownish discoloration
b) Middle bead - light yellow-brown discoloration
c) Bottom bead - light yellow-brown discoloration

Test 4 - Ultragel II - See Photo 7
a) Top bead - yellow-brown discoloration
b) Middle bead - little or no discoloration
c) Bottom bead - little or no discoloration

Test 5 - Sonotrace 30 and Soundclear - See Photo 10
Sonotrace 30
a) Top bead - brownish discoloration
b) Middle bead - yellow-brown to brown discoloration
c) Bottom bead - yellow-brown to brown discoloration
Soundclear
a) No indication of any surface attack.

Test 6 - Ultragel II and Soundsafe - See Photo 14
Ultragel II
a) Top bead - brownish discoloration
b) Top bead - brownish discoloration
c) Bottom bead - brownish discoloration
Soundsafe - No indication of any surface attack

Note: The above noted discolorations are undoubtedly iron oxide corrosion products resulting from chemical attack of the steel by the couplant.

B. Appearance of steel test surfaces after removal of couplant materials.

Test 1 - Soundsafe - No indication of any surface attack

Test 2 - Soundclear - No indication of any surface attack

TEST RESULTS: (continued) -

Test 3 - Sonotrace 30 - See Photo 7
- a) Top bead - a very visible surface attack with the deepest attack along the edge.
- b) Middle bead - a visible surface attack with the deepest attack along the edge.
- c) Bottom bead - a visible surface attack with the deepest attack along the edge.

Test 4 - Ultragel II - See Photo 8
- a) Top bead - A very visible surface attack with the deepest attack along the edge.
- b) Middle bead - A slight surface attack
- c) Bottom bead - A slight surface attack

Test 5 - Sonotrace 30 and Soundclear - See Photo 11

Sonotrace 30 -
- a) Top bead - A visible surface attack with the deepest attack along the edge.
- b) Middle bead - A very visible surface attack with the deepest attack along the edge.
- c) Bottom bead - A very visible surface attack with the deepest attack along the edge.

Soundclear - No indication of any surface attack.

Test 6 - Ultragel II and Soundsafe

Ultragel II -
- a) Top bead - A visible surface attack with some deeper attack along the edge.
- b) Middle bead - a visible surface attack with a small amount of deeper attack along the edge.
- c) Bottom bead - A barely visible surface attack.

Soundsafe - No indication of any surface attack.

Discussion of Steel Corrosion:

Since iron and steel alloys, excluding the stainless steels, have generally similar corrosion characteristics; it can be expected that other steel alloys would give similar corrosion reactions under the conditions of the above tests.

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Sam LeBarron
Director, Analytical Laboratory

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Sonotech
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September 21, 1992

Photo 1 -
Test 3 on
first day
of test

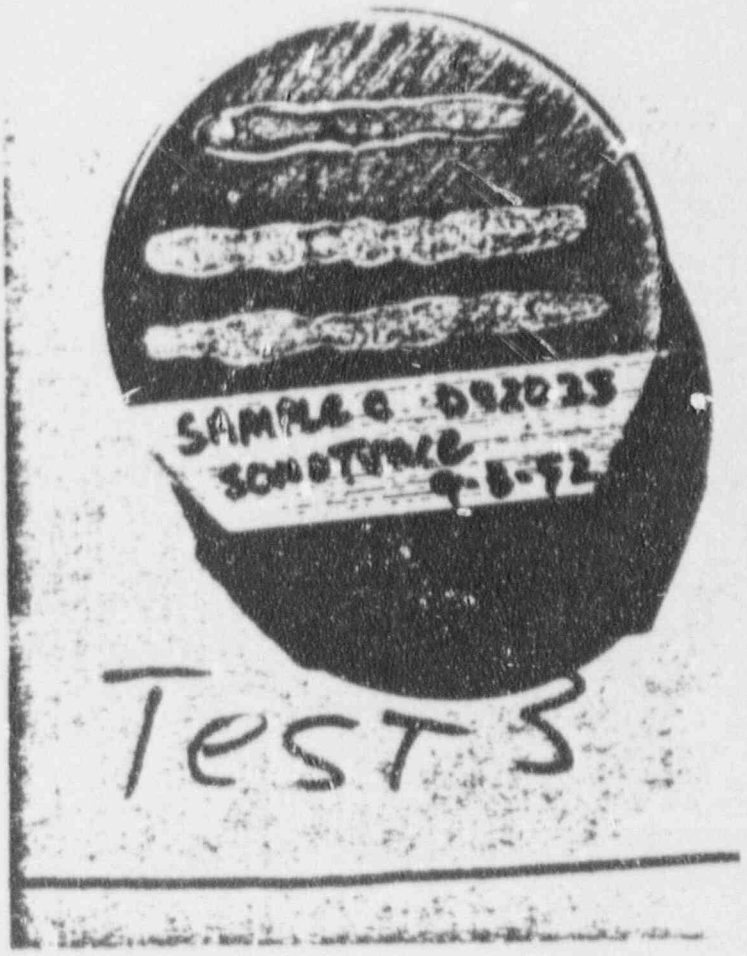

Photo 2 -
Test 3 on
second day
of test

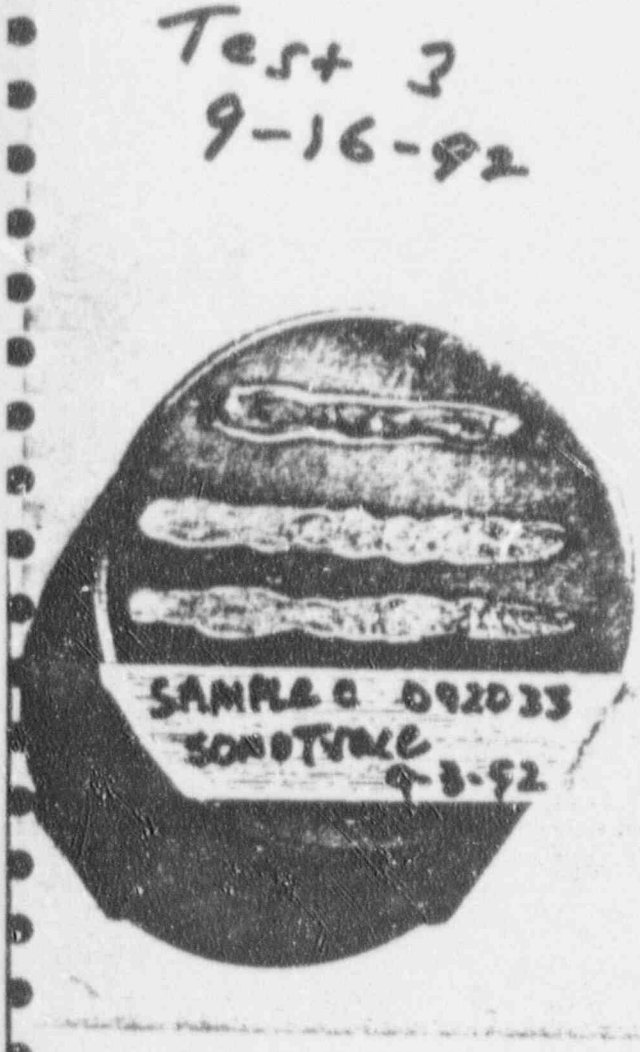

Photo 3 -
Test 3
after 13 days

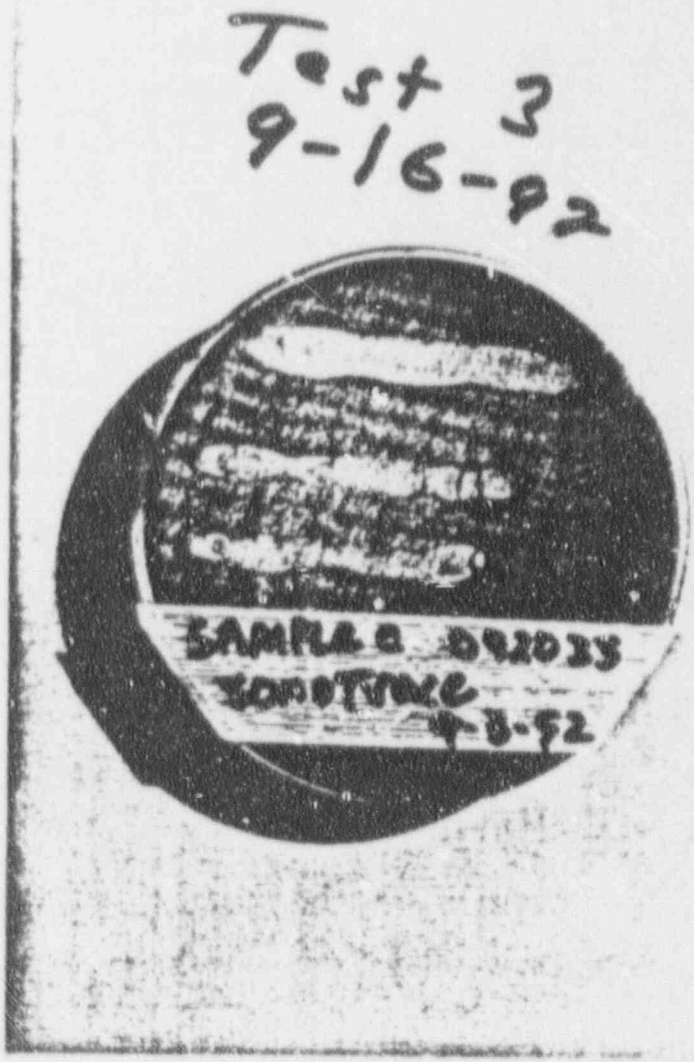

Photo 4 -
Test 3
steel surface
after removal
of couplant

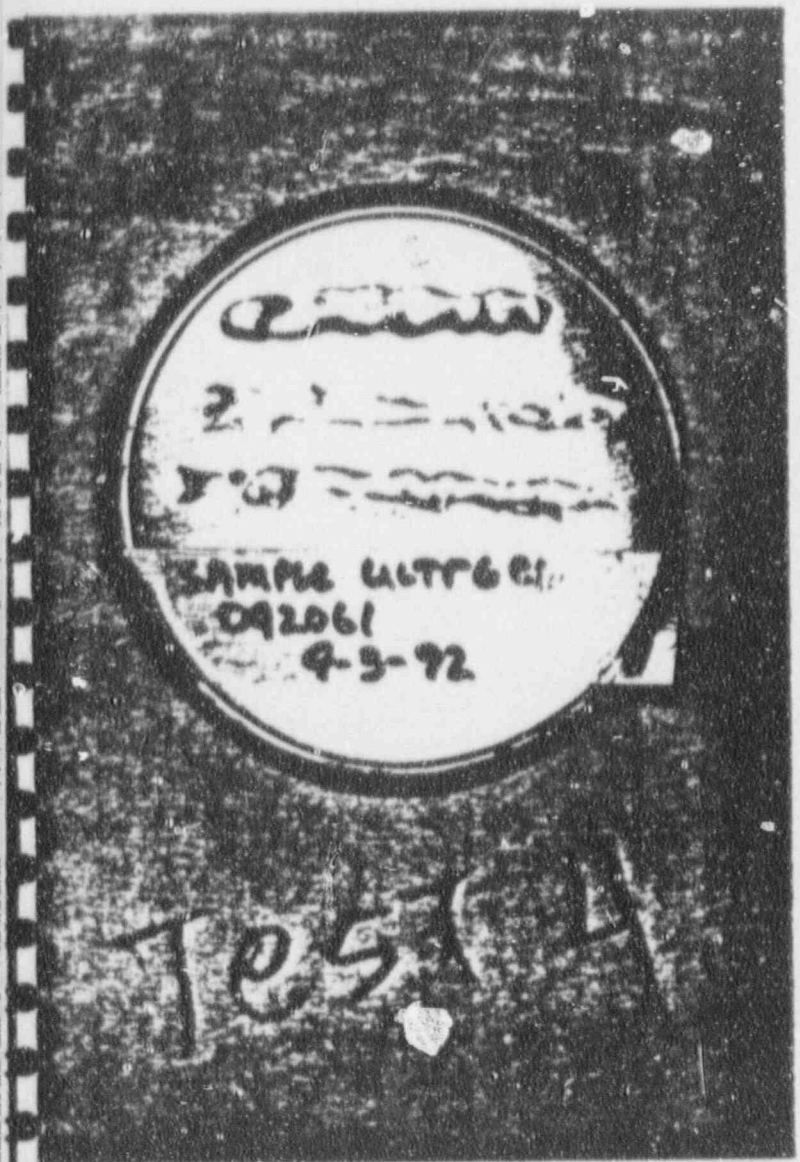

Photo 5 -
Test 4 on
first day
of test

Photo 6 -
Test 4 on
second day
of test

Photo 7 -
Test 4
after 13 days

Photo 8 -
Test 4
steel surface
after removal
of couplant

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September 21, 1992

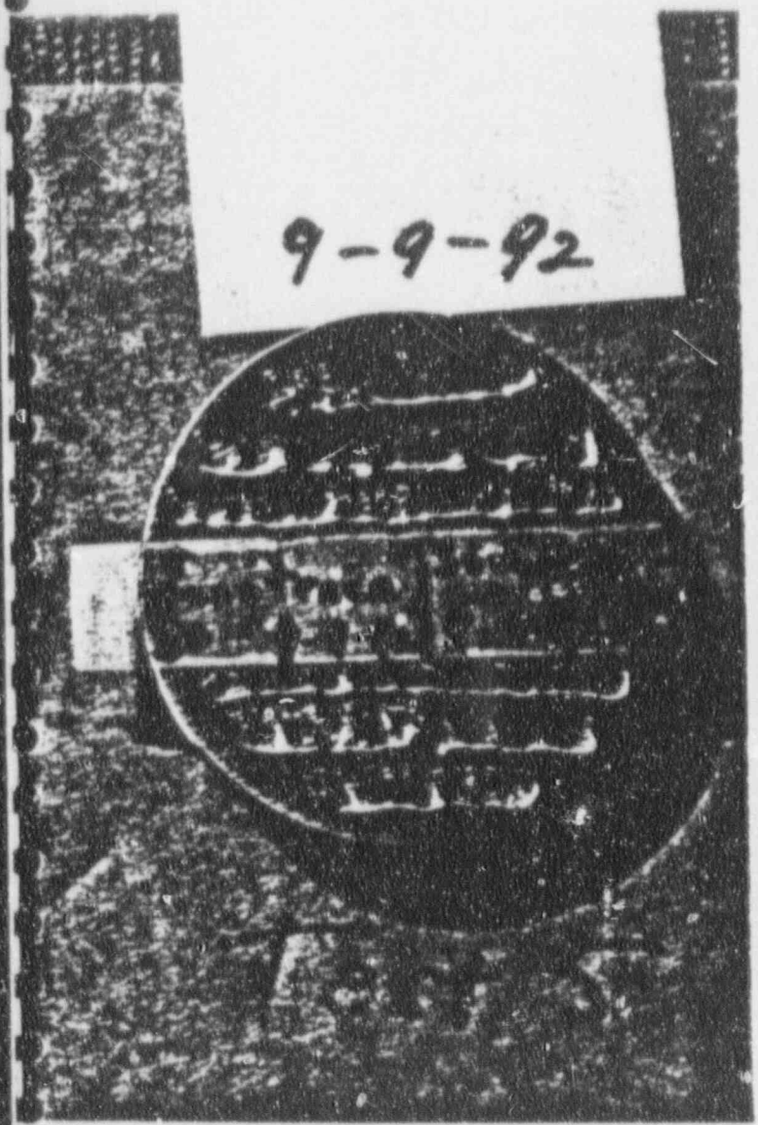

Photo 9 -
Test 5 on
first day
of test

Photo 10 -
Test 5
after 6
days

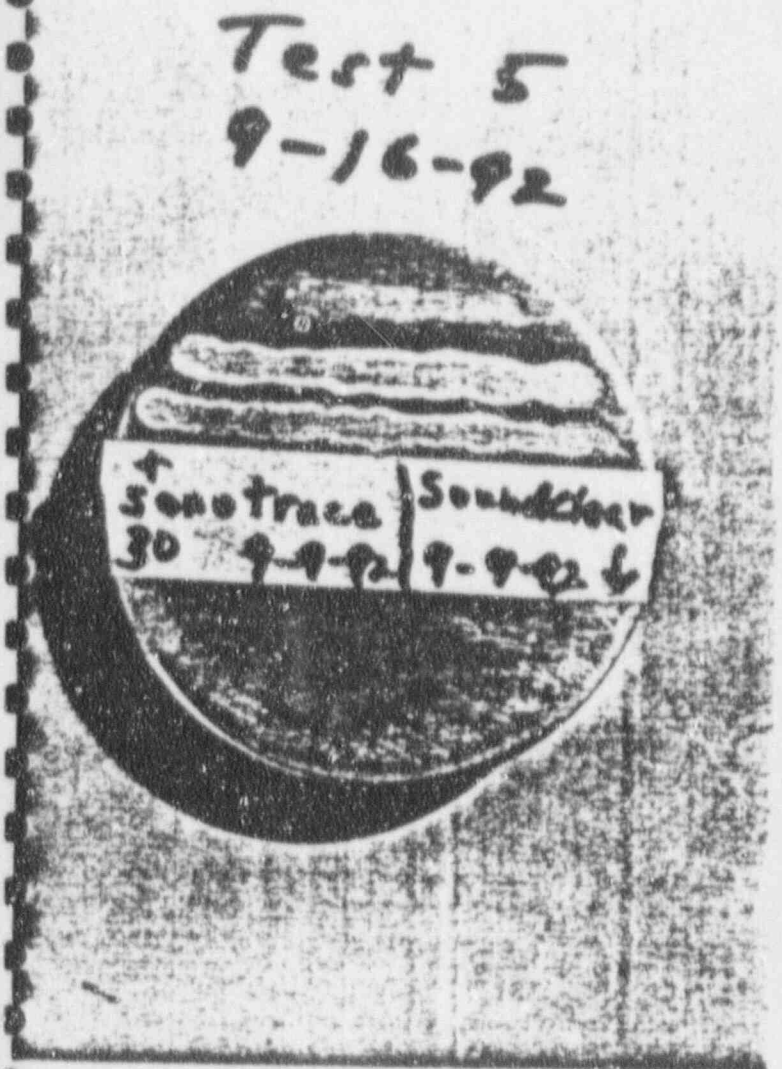

Photo 11 -
Test 5
Steel surface
after removal
of couplants

Photo 12 -
Test 6
on first
day of test

Photo 13 -
Test 6
on second
day of test

Photo 14 -
Test 6
after 12 days

Photo 15
Test 6
Steel surface
after removal
of couplants

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FAX: (206) 622-0159 Telephone: (206) 622-0680

Report To: Sonotech Da 12/3/92

Report On: Ultrasonic Couplants/ Corrosion Testing Lab No: E 60731-1

PURPOSE:

Repeat corrosion tests as reported in Northwest Laboratories' Report No. E 60731 using samples of Echo Ultrasound Products, Ultragel II and Sonotrace 30.

ULTRASONIC COUPLANT MATERIALS TESTED:

Materials from Echo Ultrasound (Purchased by Northwest Laboratories from Echo Ultrasound Distributors)

1. Ultragel II - Batch 092111
2. Sonotrace 30 - Batch 092023

Note: the couplants from Echo Ultrasound are new samples received since the time of our original report on 9/21/92.

TEST SUBSTRATE:

Steel discs, 3 in. x 1/2 in., Alloy 1018.

SUMMARY OF FINDINGS:

Both Ultragel II and Sonotrace 30 chemically attacked the steel discs, resulting in visible corrosion products and corroded surfaces. The chemical attack was quite similar to that reported in E 60731.

TEST PROCEDURE:

A. The test surfaces of steel discs were prepared for the corrosion tests in the following manner:

   1. Cleaned with acetone
   2. Sanded with medium grit (120) abrasive paper
   3. Cleaned with acetone
   4. Labels attached
   5. Cleaned with acetone
   6. Applied beads of couplant from top, middle and bottom of container
   7. Photographed prepared specimens.

C. The specimens were photographed again on the second and the sixth day.

D. The couplant material was removed from the steel discs using cold water and paper towels to wipe the surfaces.

E. The clean surfaces were then examined by means of a stereo zoom microscope (10x - 30x magnification) to determine the extent of chemical attack.

F. The clean surfaces were then photographed to document appearance.

TEST RESULTS:

A. Appearance of steel test surfaces before removal of couplant materials.

1. Sonotrace 30 - Photo #1
   a) top bead - yellow-brown to brown discoloration
   b) middle bead - yellow-brown to brown discoloration
   c) bottom bead - yellow-brown to brown discoloration

2. Ultragel II - Photo #2
   a) top bead - yellow-brown discoloration
   b) middle bead - yellow-brown discoloration
   c) bottom bead - yellow-brown discoloration

B. Appearance of steel test surfaces after removal of couplant materials.

1. Sonotrace 30 - Photo #3
   a) top bead - visible surface attack
   b) middle bead - visible surface attack
   c) bottom bead - visible surface attack

2. Ultragel II - Photo #3
   a) top bead - visible surface attack
   b) middle bead - visible surface attack
   c) bottom bead - visible surface attack

Discussion of Test Specimen Preparation Procedure

The purpose of the specimen preparation method employed in these tests was to provide a homogeneous surface for comparative testing and to simulate a recently machined and cleaned surface.

The cleanliness of the surface, the existence of surface films and the presence of foreign matter can exert a very strong influence on the initiation and speed of corrosion. The influences of various surface conditions can be either positive or negative and the surface conditions may vary from place to place, even on a single surface. Therefore, the test surfaces must be uniformly prepared so that meaningful test results can be obtained.

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SAM LEBARRON, Director

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E 60731-1
Photo Page 1

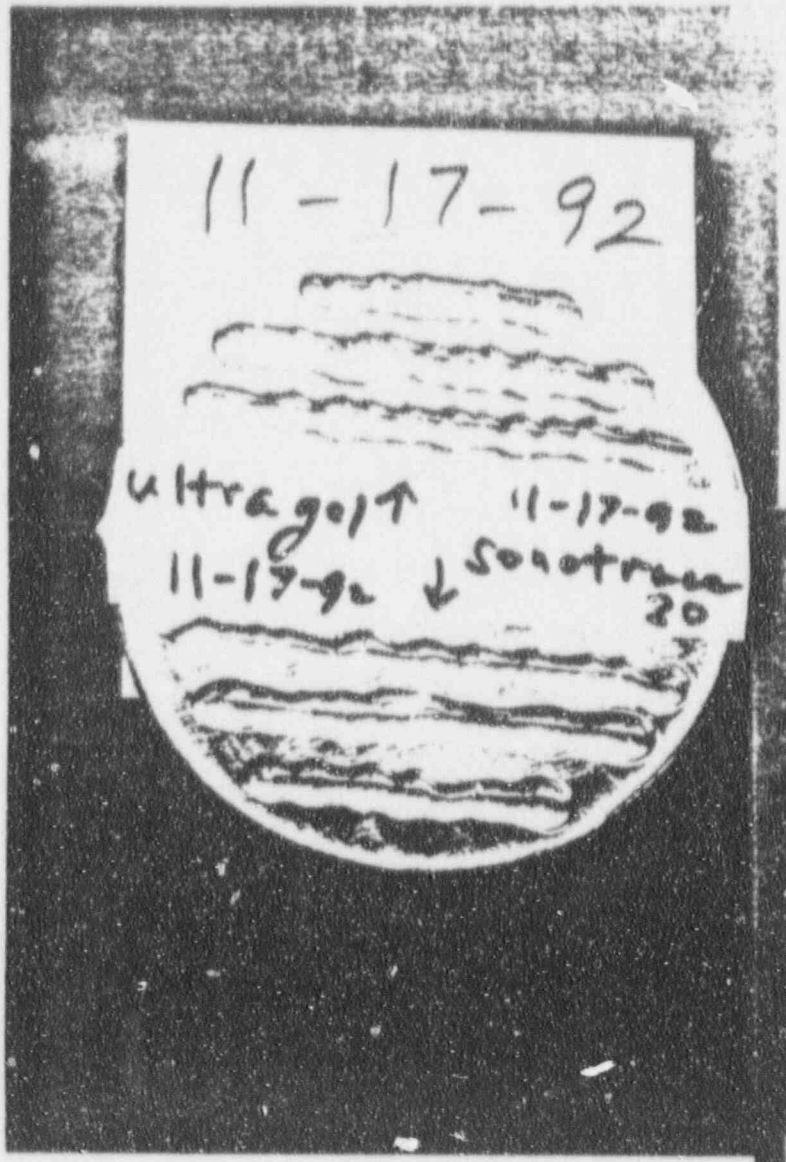

Photo #1.

Test specimen at start of test.

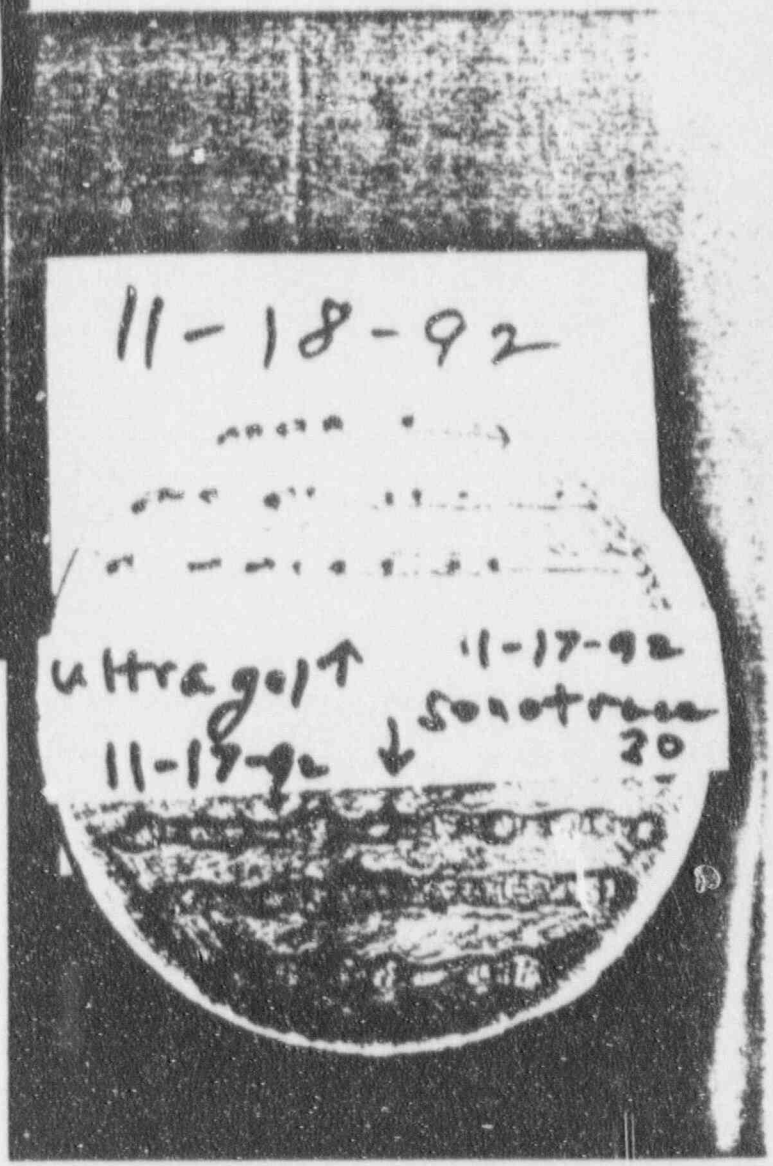

Photo #2.

Test specimen on second day of test.

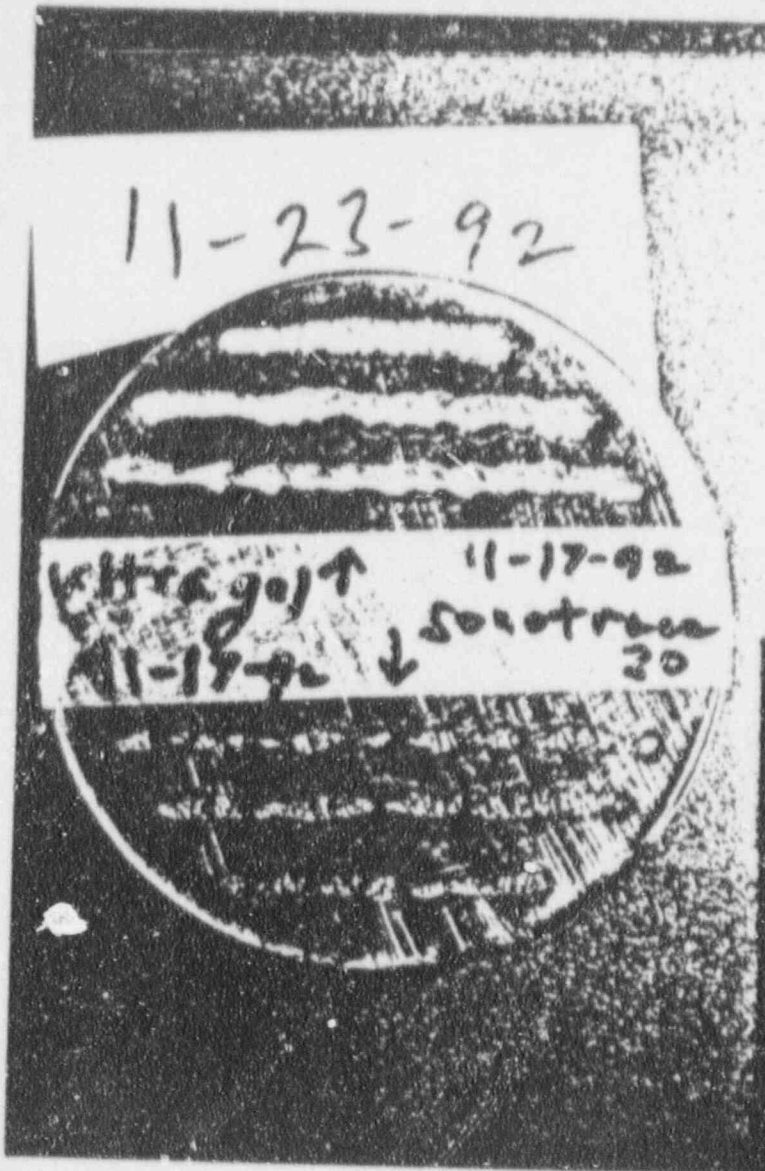

Photo #3.

Test specimen on last day of test.

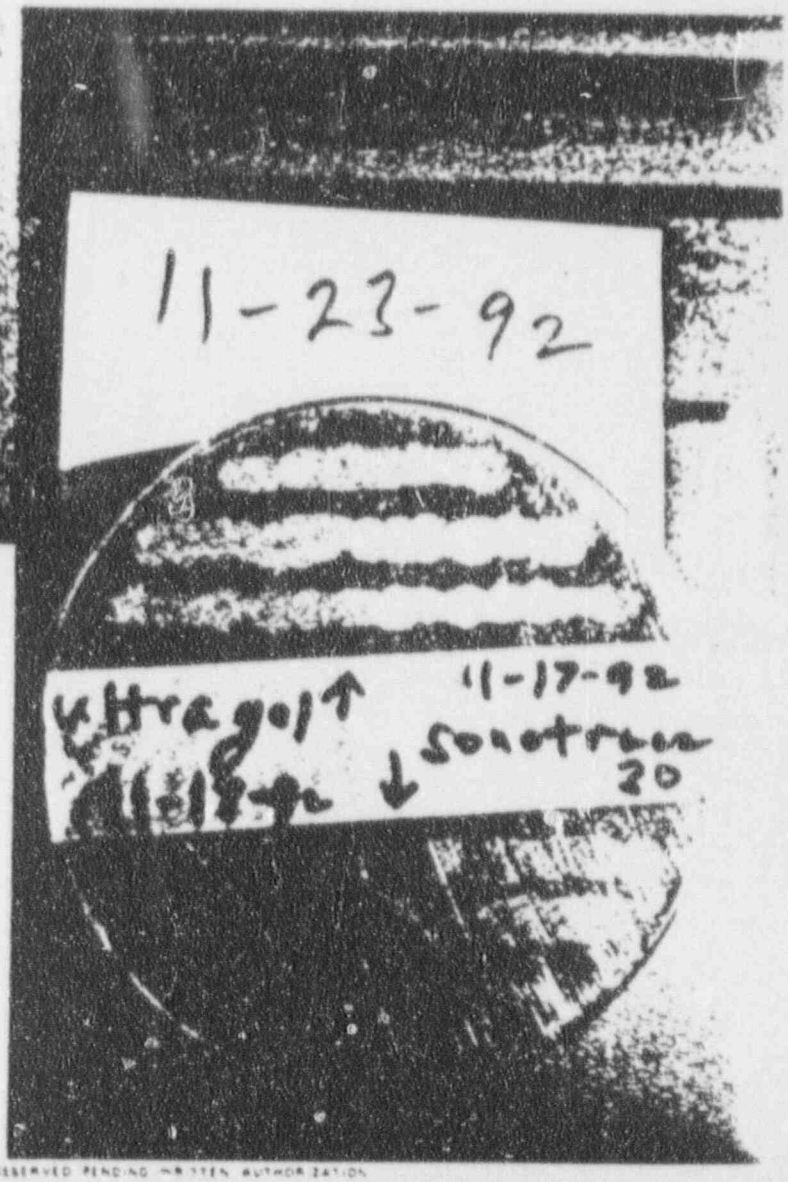

Photo #4.

Test specimen after removing couplants.