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TECHNICAL DATA SHEET GALVANIC CORROSION			TDS 0023
Issued by HR & RS	Issued date 14/04/2009	Rev.2	Rev date 02/01/2019

Introduction and Conclusion

As the natural gas distribution industry switches from the traditional iron plug valves to brass ball valves some gas utilities have expressed concern that the brass valves will cause galvanic corrosion of the steel pipes to which they are attached. The following is a review of the technical data on that subject. Also included is a statement from Entela, a consulting firm, and a report of accelerated salt spray tests run by a manufacturer of gas service systems. The conclusion is that brass valves joined to steel pipes will resist corrosion better than iron valves because, in spite of the larger galvanic voltage which is created by the brass/steel interface, compared to the voltage created by an iron/steel interface, the other factors which affect corrosion far outweigh this difference. The photos attached make this dramatically clear.

Background

In order to address this statement, one must realize that quite often the terms electrolysis and galvanic corrosion get intermixed. Both terms describe a type of corrosion occurring between two dissimilar metals, with the corrosion taking place at the anode.
However, it should be noted that with electrolysis, an outside electrical current (such as a stray current originating from a nearby DC welding machine, a series of batteries, etc.) is applied to cause the corrosion. Thus in our case we will be referring to galvanic corrosion because we are assuming that an outside current is not supplied to our system.
Galvanic corrosion occurs when dissimilar metals are in contact with one another in a liquid (electrolyte) wherein on metal becomes an anode and corrodes, while the other act as a cathode. In order to predict which metal is the anode or cathode and which metals are relatively safe to use in contact with one another, a galvanic series table can be used.
The factors influencing galvanic effect:

1. the distance apart in the galvanic series of the two metals
2. the amount of liquid around the system (if liquid is water, the pH level is a factor)
3. the relative areas of the two metals

Galvanic Corrosion

If an electric current passes out of a metal object into an electrolyte, the metal will suffer a corrosive attack in that area. No damage is caused by current flowing <u>into</u> metals from electrolytes. But outflow can cause damage.

There are two common sources of such electric current

- **Stray currents** (flows from badly grounded nearby DC electric sources such as welding machines, electric trolley car lines, electroplating plants, etc.) But these stray currents are unusual because a well designed and maintained electric system will have good wire connections which easily return current to the power source. Only if the intended return is badly maintained, and develops resistance will the current seek an easier route such as nearby buried gas pipes. In plastic pipes there is no stray current problem, and in metal systems dielectric unions can prevent stray currents. .
- **Galvanic generation**. This occurs when two dissimilar metals are in electrical contact with each other and at the same time are both in contact with an electrolyte. A small voltage is developed at the metal-to-metal boundary (usually a fraction of a volt) and current will pass from one metal (called the cathode, which see below) into the other, called the anode. From there the current flows out of the anode into the electrolyte and back to the cathode to complete the circuit. The outflow from the anode will cause corrosion of that part.

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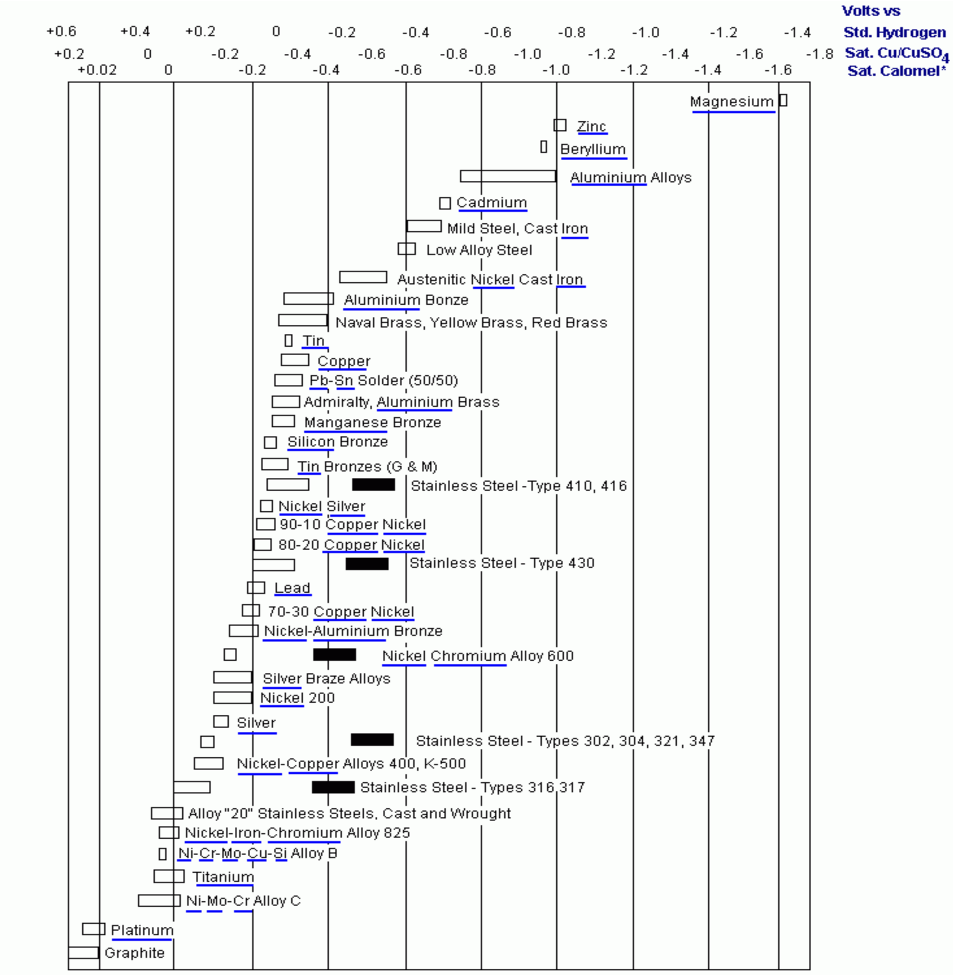
The severity of this attack depends on several variables

- The amount of electricity (amps) which passes across the boundary
- The chemistry of the metal and of the electrolyte
- The length of time the current flows
- The relative surface areas of the metal-to-metal boundary and of the anode-to-electrolyte boundary

The Galvanic Scale

Every metal has a natural ability to create voltage. Different metals have different voltage potentials, and they can be compared by testing different combinations of metals in the presence of an electrolyte. This ranking is called the Galvanic Scale, which is shown below. Voltage potentials for the various metals are shown for three different electrolytes, Standard Hydrogen, Saturated Copper Sulfate in water, or Saturated Calomel. The voltages are different for each electrolyte, and would differ also for other electrolytes, but the ranking of the different metals would be the same for all electrolytes. The left side of the chart is called “active” or “anodic.”
The right side is called “noble” or “cathodic.” If two metals – say brass and steel – were in contact a voltage would be created equal to the difference between their positions on the scale, and, since it is further to the right on the scale, the steel would be he anode in that pair and would be attacked.



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Using the calomel voltages above, mild steels and cast irons all fall in the range of -.6 to -.69 volts. Steel used in pipe might be at the less negative end – say -.61. The different brasses have various voltages ranging from -.27 to -.40 volts. If C37700 brass (used in Bonomi Industries Srl) falls in the middle of that range it would have a voltage of about -.34 volts. The difference between the steel pipe and the brass valve would be -.61 vs. -.34, or .27 volts, while the difference for the steel pipe and the iron valve would be only -.61 vs. -.69 or .08 volts. That is why the utilities are fearful that brass valves will create more corrosion of the steel pipes than the iron valves they have used in the past. But notice that in the steel/brass pair the valve is the cathode, and will not corrode, but in the steel/iron pair the valve is the anode. This is a serious difference because of the area effect, which see below. With a brass valve the steel pipe will suffer a very slow and harmless attack, but with an iron valve the corrosion will attack the valve rapidly. These theoretical expectations are supported by the corrosion tests done at Customer. (Please see the pictures below.)

galvanic table from MIL-STD-889

for any combination of dissimilar metals, the metal with the lower number will act as an anode and will corrode preferentially.

Active (Anodic)	33. Copper (plated, cast, or wrought)	66. Stainless steel 321 (active)
1. Magnesium	34. Nickel (plated)	67. Stainless steel 316 (active)
2. Mg alloy AZ-31B	35. Chromium (Plated)	68. Stainless steel 309 (active)
3. Mg alloy HK-31A	36. Tantalum	69. Stainless steel 17-7PH (passive)
4. Zinc (hot-dip, die cast, or plated)	37. AM350 (active)	70. Silicone Bronze 655
5. Beryllium (hot pressed)	38. Stainless steel 310 (active)	71. Stainless steel 304 (passive)
6. Al 7072 clad on 7075	39. Stainless steel 301 (active)	72. Stainless steel 301 (passive)
7. Al 2014-T3	40. Stainless steel 304 (active)	73. Stainless steel 321 (passive)
8. Al 1160-H14	41. Stainless steel 430 (active)	74. Stainless steel 201 (passive)
9. Al 7079-T6	42. Stainless steel 410 (active)	75. Stainless steel 286 (passive)
10. Cadmium (plated)	43. Stainless steel 17-7PH (active)	76. Stainless steel 316L (passive)
11. Uranium	44. Tungsten	77. AM355 (active)
12. Al 218 (die cast)	45. Niobium (columbium) 1% Zr	78. Stainless steel 202 (passive)
13. Al 5052-0	46. Brass, Yellow, 268	79. Carpenter 20 (passive)
14. Al 5052-H12	47. Uranium 8% Mo.	80. AM355 (passive)
15. Al 5456-0, H353	48. Brass, Naval, 464	81. A286 (passive)
16. Al 5052-H32	49. Yellow Brass	82. Titanium 5A1, 2.5 Sn
17. Al 1100-0	50. Muntz Metal 280	83. Titanium 13V, 11Cr, 3Al (annealed)
18. Al 3003-H25	51. Brass (plated)	84. Titanium 6Al, 4V (solution treated and aged)
19. Al 6061-T6	52. Nickel-silver (18% Ni)	85. Titanium 6Al, 4V (anneal)
20. Al A360 (die cast)	53. Stainless steel 316L (active)	86. Titanium 8Mn
21. Al 7075-T6	54. Bronze 220	87. Titanium 13V, 11Cr 3Al (solution heat treated and aged)
22. Al 6061-0	55. Copper 110	88. Titanium 75A
23. Indium	56. Red Brass	89. AM350 (passive)
24. Al 2014-0	57. Stainless steel 347 (active)	90. Silver
25. Al 2024-T4	58. Molybdenum, Commercial pure	91. Gold
26. Al 5052-H16	59. Copper-nickel 715	92. Graphite
27. Tin (plated)	60. Admiralty brass	**End - Noble (Less Active, Cathodic)**
28. Stainless steel 430 (active)	61. Stainless steel 202 (active)	
29. Lead	62. Bronze, Phosphor 534 (B-1)	
30. Steel 1010	63. Monel 400	
31. Iron (cast)	64. Stainless steel 201 (active)	
32. Stainless steel 410 (active)	65. Carpenter 20 (active)	

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The severity of corrosive attack depends on several factors – not on galvanic voltage potential only.

Area Effect

The thing which causes damage is the current density flowing out of an anode. That depends on the voltage difference, but also on the area difference. In the case of a brass valve screwed onto a steel pipe, the metal-to-metal boundary which produces the current is only the surface area of the pipe threads where the two metals touch. But the area where the current leaves the pipe is much greater, depending on the length of the pipe and how much of the pipe is in wet ground or otherwise touching an electrolyte. (Please refer to this area effect in the Entela Report attached.) Therefor the current generated is small and the area from which it leaves the pipe is large. Current density along the pipe would be low, and minimal corrosion would occur. Conversely, with the iron valve, the valve will be the anode, and flow from it will be concentrated because of the smaller surface area of the valve compared to the pipe. The valve will be attacked rapidly. (Please see the photos in the Customer test report attached.)

Time Factor

A second variable is the length of time that the current flows. In above ground situations (like outdoor meter sets) there is no electrolyte in contact with the pipe and valve except when it rains, or when there is dew or splashed water contacting both parts.

Protective Coatings

Another important factor is paint or other coatings applied to the parts. Paint can sharply reduce or eliminate the surface area which is in electrical contact with the electrolyte. Without a complete circuit there will be no galvanic attack. But paint can also be harmful. If there are small defects in the coating (like wrench marks on a pipe, or partial threads cut by a thread dye and not then recoated) the corrosive attack can be concentrated at the small defect, and the paint will undermined at that point and produce rapid local corrosion.

Salt Spray Tests

Three sample valve/pipe assemblies were tested by Customer in their salt spray test booth. The samples were:

- A ¾" brass ball valve painted grey
- A ¾" brass ball valve with insulating union, unpainted
- A ¾" iron plug valve, unpainted

All three samples had painted steel pipe nipples installed. The paint covered most of the surface of the nipples, but a small area of unpainted steel was exposed in the threads near the valves.

The report with photographs of these parts is attached.
The corrosion of the painted pipes with brass valves was accelerated by the paint, as described above. Both brass valves also showed minimal corrosion, as would be expected since the brass was the cathode in the test. Most importantly, **the pipes joined to brass valves showed no more corrosion those joined to iron valves.** In spite of the greater galvanic voltage created by the brass/steel junctions the only serious corrosion revealed in the tests was of the iron, because the iron valve, was the anode in that pair.

Non-Galvanic Corrosion

Not all corrosion is galvanic. Iron which is exposed to the weather, or worse, immersed in salt water, will rust, even though there is no second metal involved. The bigger (that is, less negative) voltage of brass compared to iron makes brass a more potent voltage source in a galvanic pair, but that same bigger voltage also makes brass less likely to corrode when it is exposed to weather. As can be seen from the Customer photos, the worst corrosion by far was of the iron valve, not the pipes screwed into the brass valves. Brass is widely used for its superior resistance to non-galvanic corrosion, and many millions of brass valves are joined to steel pipes in many different services around the world, but they suffer no damage, either from galvanic or non-galvanic corrosion. **Bonomi Industries Srl has about 25 million brass valves in the field attached to steel pipes, and has not had any case of corrosive failure due to galvanic attack.**

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Glossary of Terms

Anode – The metal in a galvanic pair which has the lower voltage potential, and therefore suffers from outflow of electrons to the electrolyte.

Cathode – The metal in a galvanic pair which has the higher voltage potential. It is not damaged because the electron flow is into, not out of, the metal.

Electrolyte – a liquid capable of carrying an electric current. Pure water is an insulator, and will not carry current, but if there are ions in the water (from the presence of salts) it will easily conduct electricity. The pH factor of water indicates how acidic or basic it is, and therefore how easily it will conduct electricity. Either high or low pH makes the water more conductive. Pure water has neutral pH (6.0) and is non-conductive.

Galvanic Cell – A galvanic pair which also has present an electrolyte to complete the electric circuit and allow current to flow.

Galvanic Corrosion – Corrosion which occurs at more chemically active of two metals that are electrically coupled and exposed to an electrolyte (the anode of a Galvanic Cell)

Galvanic Pair – Any pair of metals which have different voltage potentials and are in electrical contact with each other.

Galvanic Series – A ranking of metals and alloys as to their relative electrochemical reactivity in seawater

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Corrosion Prevention for Practicing Engineers
Joseph F. Bosich
Barnes & Nobel 1970

ENGINEERING TEST REPORT

SUBJECT :	Corrosion Comparison: Brass valves vs. BMI valves
Prepared by:	Jim Drain
Date:	October 13, 2005
Requested By :	Steel Business Unit

I. Introduction

Product Tested:

- ✓ 3 ea- PN 10001418 PIPE NIPPLE,0.75 NPT,SCH40,8.00LG,TBE,POLY,,,API 5L,ANSI B1.20.1,AGA49 GRAY
- ✓ 1 ea.-PN 6470173 VALVE BALL JOMAR 3/4 X 3/4 175# NON-INSULATING LW PAINTED GRAY #240-004
- ✓ 1 ea.-PN 6470009 VALVE NON-INSULATED METER STOP 100# 3/4 FPT X 3/4 FPT BMI MUELLER #H-11118 LOCKWING TYPE
- ✓ 1 ea.-6470066 VALVE INSULATED METER STOP #175 3/4 FPT X 3/4 FPT BRASS LOCKWING JOMAR #241-004B

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II.Background

- ✓ The purpose of this test was to compare the corrosion performance of Brass valves & BMI valves

III.Procedure

The test was performed in accordance with the following standard:

- ✓ **Standard Practice for Operating the Salt Spray Apparatus (per ASTM B 117)** 1.1 This practice covers the apparatus, procedure, and conditions required to create and maintain the Salt Spray (fog) test environment

IV.Results/Discussion

- ✓ Picture #1 Before test
- ✓ Picture #2 After 70 hours in the Salt Fog
- ✓ Picture #3 After 237 hours in the Salt Fog
- ✓ Picture #4 After 545 hours in the Salt Fog
- ✓ Picture #5 After 3500 hours in the Salt Fog

V.Conclusions

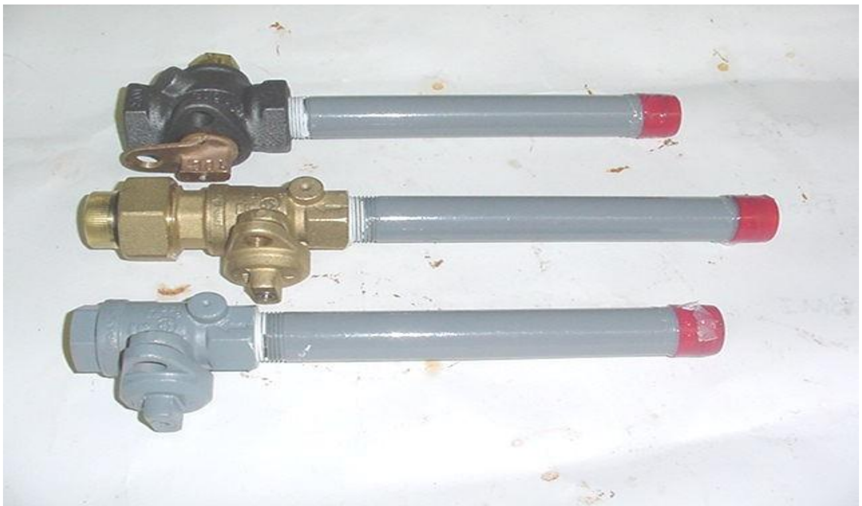
- ✓ The Brass valves were more resistant to corrosion than the BMI valves3500 hours in the Salt spray did not adversely affect the brass valves.

Appendix 1

CORROSION TEST PICTURES

PICTURE #1

BEFORE TEST WAS PERFORMED



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Appendix 1

CORROSION TEST PICTURES

PICTURE #2

AFTER 70 HOURS IN SALT FOG

Appendix 1

CORROSION TEST PICTURES

PICTURE #3

AFTER 237 HOURS IN SALT FOG

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Appendix 1

CORROSION TEST PICTURES

PICTURE #4

AFTER 545 HOURS IN SALT FOG

Appendix 1

CORROSION TEST PICTURES

PICTURE #5

AFTER 3500 HOURS IN SALT FOG

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RUBINETTERIE UTENSILERIE BONOMI
Date: December 12, 2003
P.O. No.: 8502

Attention: Hank Rose
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REVIEW OF ARTICLES AND RESOURCES ON GALVANIC CORROSION BETWEEN EN 12165 CW 617N BRASS AND BLACK IRON PIPE.

BACKGROUND:
Concerns of galvanic corrosion exist for use of brass valves in steel piping systems. This report reviews some published articles on galvanic corrosion in an effort to provide some guidance. It is assumed the typical pipe used to attach to the valve would be ASTM A53 Type F Grade A Schedule 40. The chemistry maximums are as follows:

C – 0.30
Mn – 1.20
P – 0.05
S – 0.045
Cu – 0.40
Ni – 0.40
Cr – 0.40
Mo – 0.15
V – 0.08

The combination of Cu, Ni, Cr, Mo, and V shall not exceed 1.00%.The brass is considered to be similar to C37700 alloy (forging brass), this alloy is assumed for the purpose of this document.

THE GALVANIC SERIES:
The following text and table are from ASM Metals Handbook 9th edition, volume 13: "When the only information needed is which of the materials in the system are possible candidates for galvanically accelerated corrosion and which will be unaffected or protected, the information from the galvanic series in the appropriate media is useful." "The material with the most negative, or anodic corrosion potential has a tendency to suffer accelerated corrosion when electrically connected to the material a more positive, or noble, potential. The disadvantages are:

- No information is available on the rate of corrosion
- Active-passive metals may display two, widely differing potentials
- Small changes in electrolyte can change the potentials significantly
- Potentials may be time dependent

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Although the series above is for seawater, differences with other solutions of moderately high corrosivity are usually minor[1]. The pipe can be classified as low carbon steel. The valve material is most like the naval, yellow and red brass category. All of the brasses are more noble in seawater than low carbon steel. It appears that the brass valve will be the cathode and the pipe will be the anode. The corrosion effects from the galvanic couple will tend to corrode the pipe and not the valve. It should be noted: "The best prevention for galvanic corrosion is to eliminate the galvanic couple by design, if possible"[1]. Any isolation of the two metals by a non-conductor will tend to limit galvanic corrosion.

AREA EFFECTS:
"The large ratio of cathode-to-anode surface area is to be avoided because the galvanic attack is concentrated in small areas, and penetration of the anode thickness is hastened. Larger anode surface spreads the attack over a greater area and reduces the rate of penetration"[1]. In this case the valve will have a very small surface area as compared to the pipe. This will help to spread the corrosion over a large area and increase the time to perforation.

COATINGS:
The coatings that will be applied to the couple of the valve and pipe should be considered. "If a galvanic couple is to be coated, it should be applied only to the cathode, if at all. Coatings on the anode only serve to concentrate further the galvanic attack at coating defects[1]. It is assumed the interior of the pipe will be uncoated. Painting of the valve should not be a problem. If the exterior of the pipe is painted the interior may still provide a large area of anode.

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DISCUSSION:

Although the use of dissimilar metals in electrical contact will create a galvanic cell, it may be acceptable in this application due to the relatively small size of the valve as compared to the anodic pipe. The pipe will tend to protect the valve from corrosion. It would appear the complete coating of the pipe should be avoided to prevent accelerated corrosion at defects in the coating system.

This paper considers only the potential of galvanic corrosion from use of forging brass valves in a steel pipe system. Other forms of corrosion to either the pipe or the valve were not explored. Concerns of material strength or chemical compatibility with the transported gas were not examined. This paper is offered only as an overview of information from published works and should not be considered an endorsement of any material selection.

1 Principles and Prevention of Corrosion, 2nd Ed. Denny A. Jones, Prentice Hall

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Società soggetta ad attività di direzione e coordinamento di HADRON S.R.L.

13. Any order or agreement for testing services by ENTELA, Inc. may be terminated in writing by the client before completion thereof with ENTELA, Inc.'s written consent in which event the client shall pay to ENTELA, Inc. an amount to be determined by ENTELA, Inc. as being sufficient to reimburse ENTELA, Inc. for all direct and indirect costs and expenses, including (but not limited to) supplies, materials, labor, and overhead incurred with respect to the order or agreement through the date of termination.
14. ENTELA, Inc. shall not be liable for any failure or delay in performance which is caused in whole or in part by fire, flood, accident, riot, war, operation of law, government action, strikes or other labor disturbances, fuel shortages, or any other cause beyond the control of ENTELA, Inc.
15. All contracts between ENTELA, Inc. and the client shall be deemed to be made in and governed by the laws of the State of Michigan.
16. Should ENTELA, Inc. be required to subcontract any testing or other services, the client will be informed of such arrangement either verbally or in writing. ENTELA, Inc. shall have no liability for any deductions, inferences, or generalizations drawn by the client or others from subcontractor's data.
17. Should witness of testing or services on ENTELA, Inc. premises be requested, the client shall comply with all applicable safety regulations and precautions. Client shall supply, if requested, evidence of workers compensation coverage prior to visit.

It is the client's responsibility to understand the procedures utilized in the testing process. Any action taken by a client based on any consulting, recommendations, results, observations, conclusions, discussions, or data as provided by ENTELA are the sole responsibility of the client." **Rev 10/1 5//02**

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