Note: () brackets indicate optional reaction, - X – X – indicates the intermediate reaction codes are not of major significance compared to the terminal reaction 8 code; the + signs indicate the level that should be placed on that form of treatment (+++, high intense, +, marginal importance).

What do the reaction patterns in an IRB-BART™ test mean?

This question is one of the most difficult because there are so many communities of iron related bacteria that each has their own signature. In the IRB-BART™ tester, there is a sequence of reactions that can be used. These are addressed below in the type of order in which they are likely to occur. Reactions occur in four time intervals with the first reaction (primary when it occurs) happening within twelve hours while the secondary, tertiary and terminal reactions occur in a sequence that relates to the type of bacteria that are present and active. These reactions are listed in the table below in the sequence in which they can commonly occur:

Reaction	Descriptor	Characteristics	Sequence
WB	White Base	White crystalline deposit forms within the base of the tester in less than 12 hours. Indicates biological formation of carbonates.	Primary
CL	Clouded (turbid)	Liquid in tester may turn yellow or green (not significant for this reaction) and cloudiness (turbidity) will be seen in the water when held up to the light.	Secondary
FO	Ring of foam bubbles around ball	Gas bubbles on the walls of the tester should be ignored and an FO reaction only occurs when there is a ring of bubbles forming a foam ring around the ball.	Secondary
BC	Brown clouded	Liquid in the tester generates a brown color throughout its length and the tester is too clouded to allow objects to be clearly viewed through the tester	Tertiary
BR	Brown ring around ball	Brown slime ring forms around the ball. Usually 2 to 4mm thick and generally not reflective in light.	Tertiary
BG	Brown gel	Bottom quarter to a third of the tester becomes a brown gel with the liquid above being clear or slightly yellow but not clouded. This reaction will commonly move to BC.	Tertiary
GC	Green clouded	Liquid becomes universally green beginning with a light lime green and moving to a darker shade of green with heavy clouding.	Tertiary
RC	Red clouded	Liquid becomes a distinct shade of red with the color intensifying and becoming clouded before shifting commonly to a BC reaction.	Tertiary
BL	Black liquid	Liquid becomes blackened generally starting at the bottom first and creeping up the walls of the tester to the ball. When this happens the liquid contents of the tester will appear to crystal clear if the tester is tipped.	Terminal

What do all of these IRB-BART™ reactions mean to me?

In waters that contain IRB then these reactions mean a lot not only through the time lags generated but by the sequence in which the reactions occur. While the possible permutations appear endless there are some clear trends that can tell you a lot about the water. These will be tackled in two ways: (1) what the individual reactions mean as far as bacterial population make up are concerned; and (2) coding the reactions to form a treatment strategy. Each of these aspects is addressed in the two tables below:

Table (1), interpretation of reaction patters and bacterial characterization

Reaction	Descriptor	Bacterial Characterization	Sequence
WB	White Base	Carbonate producing bacteria. In treating such bacteria consideration should be given to the use of acidic treatments to break up these carbonate deposits.	Primary
CL	Clouded (turbid)	Aerobic IRB community growing in oxidative or redox front conditions. Treatment may require the use of a penetrant as well as a biocide	Secondary
FO	Ring of foam bubbles around ball	Anaerobic IRB community generally deep set and much more difficult to treat. Longer treatments able to break up the biomass would be very important	Secondary
BC	Brown clouded	Usually aerobic IRB that have an ability to accumulate very significant levels of iron within the biomass which may require the use of an iron sequestering agent as well as biocidal penetrant.	Tertiary
BR	Brown ring around ball	Very aerobic IRB found restricted to the redox front and able to cause radical plugging which is commonly easier to treat since the biomass is focused. Treatment can be successful with a good penetrant and biocide or acidic treatment	Tertiary
BG	Brown gel	Generally aerobic, these bacteria produce very thick slime mats that are rich in iron. They generally take longer treatment times to break the biomass down. Often dominated by enteric bacteria.	Tertiary
GC	Green clouded	Commonly aerobic bacteria belonging to the pseudomonad bacteria. These bacteria can produce large volumes of slime that can be controlled by the application of penetrants along with dropping the pH by at least four pH units. It should be recognized that it will take significant time for a treatment to penetrate all of the slime material.	Tertiary
RC	Red clouded	These bacteria can grow aerobically or anaerobically and so can penetrate deeper into the biofouled regions. Treatments have to be moiré vigorous involving pH amendment, iron sequestering agents, penetrants and biocides. Often dominated by enteric bacteria.	Tertiary

BL	Black liquid	This is a mixed community of aerobes and anaerobes including enteric and pseudomonad bacteria. Treatment is challenging because the biomass extends right through the redox front making any treatment more difficult. General treatment should include of biocides, penetrants, pH amendment by at least 4 units and consideration of a large than usual treatment zone. Coliform testing is recommended if there is a "safe" water concern.	Terminal

Note: Consideration should be given to the application of heat as a part of the treatment since this has the double advantage of speeding up the chemistry and traumatizing the bacteria. An example of such blended chemical heat treatments is the patented BCHT process.

Table (2), Coding in a Treatment Strategy for the IRB-BART™ reactions

Reaction	Descriptor	Code number	Sequence
WB	White Base	0	Primary
CL	Clouded (turbid)	1	Secondary
FO	Ring of foam bubbles around ball	2	Secondary
BC	Brown clouded	3	Tertiary
BR	Brown ring around ball	4	Tertiary
BG	Brown gel	5	Tertiary
GC	Green clouded	6	Tertiary
RC	Red clouded	7	Tertiary
BL	Black liquid	8	Terminal

Common reaction patterns may start with code 0, 1 or 2. It is rare for another reaction to occur first. Each of these three codes reflects a specific challenge to treatment. For example code "0" means that there is a high probability of carbonate involvement in the biofouling and that some acidic treatment may have to be applied to break up the carbonates. If "0" has occurred than it is most likely to be followed by either a "1" or a "2" and it is must be treated as a carbonate event as well the treatment associated with the second code. Code "1" indicates that the biofouling is likely to be aerobic (oxidative) and growing closer to the sampling source. Code "2" on the other hand indicates a reductive environment and the possibility that the biofouling is more diffuse and difficult to treat. Treatment should be based for the IRB and the full code observed during the testing period. Code "0" is an overriding code that indicates acidic treatments will be required to break up the carbonates regardless of what other codes were entered. Some of the common code patterns and the potential impact on treatment strategies are listed below:

Code stream	Biocide	Penetrant	pH modification	Physical treatment
1 – 6	+++	+++		++
1 – 3 – (4)		+++	+++	+++
1 – 5 – 3 – (4)	+++	+++	+++	+++
1 – X – X - 8	+++	+++	+++	+++
1 – 7	++	+++	+	+++
2 – 3 – (5)	+++	+++	++	++
2 - 7	+++	+++	+	++
2 – X – X - 8	+++	+++	+	+++