REMOVAL OF IRON AND MANGANESE BY AERATION

It is a straight forward task to determine the theoretical amount of air which is required to oxidize and precipitate iron and/or manganese from water. The actual amount of air can then be estimated quite accurately so as to determine the correct Mazzei Injector to use and the recommended operating conditions for that injector.

A. Water Chemistry

Water pH is a critical parameter in the oxidation and precipitation of iron and manganese. For iron oxidation by aeration, the water pH should be at least 7.2, and ideally, maintained in the range of 7.5 to 8.0. If manganese is present, the minimum recommended pH is 9.5. Below that pH, air oxidation of manganese is quite slow. In water with low pH or low levels of alkalinity, it may be necessary to feed supplemental alkaline materials such as sodium hydroxide to elevate water pH.

B. Other Factors

Air oxidation of iron and manganese is not instantaneous. For this reason it is advisable to employ a retention, or contact tank to allow for sufficient residence time for complete oxidation and precipitation to occur. Depending upon actual conditions, contact times may range from 5 to 15 minutes.

C. Formulas

The following reaction describes the oxidation of ferrous iron by oxygen

$$4Fe\ (HCO_3)\ 2 + O_2 + 2H_2O\ 4Fe\ (OH)\ 3 + 8CO_2$$

The following reaction describes the oxidation of manganous manganese by oxygen

$$2Mn\ (HCO_3)\ 2 + O_2 + 2H_2O\ 2Mn\ (OH)\ 4 + 4CO_2$$

D. Ratios

1. Iron

The atomic weight of iron is 55.847. As one oxygen molecule reacts with four iron atoms, the iron reaction weight is four times this, or 223.39. The molecular weight of oxygen is 31.999. The reaction ratio is thus (31.999) / (223.39), or 0.1432. This means that 0.1432 mg/l of oxygen is required for each mg/l of iron (measured as iron).

2. Manganese

The atomic weight of manganese is 54.938. As two atoms of manganese react with one molecule of oxygen, the manganese reaction weight is twice times this, or 109.88. The molecular weight of oxygen is 31.999. The reaction ratio is thus (31.999) / (109.88), or 0.2912. This means that 0.2912 mg/l of oxygen is required for each mg/l of manganese (measured as manganese).

E. Oxygen Residual

Sufficient air must be injected to maintain the required oxygen residual. Maintaining an oxygen residual serves several purposes. First, it provides a buffer of oxygen to react with surges of iron or manganese. Second, it produces a more palatable water. Third, the air required to maintain the oxygen residual provides mixing so that iron and manganese can react quickly and efficiently with oxygen.

An accepted value of residual oxygen is 5.0 mg/l. Sufficient air must be injected to maintain this level. The initial oxygen level in waters with iron and/or manganese present is typically zero. If there is an initial oxygen residual present, this may be subtracted from the desired level of 5.0 mg/l when determining the amount of oxygen required.

F. Theoretical Oxygen Required

The theoretical amount of oxygen required to oxidize iron and manganese may be calculated from the following formula:

$$\text{Oxygen Required} = Xf \bullet (Fe) + Xm \bullet (Mn) + R$$, where

Xf = Iron reaction factor
(Fe) = Iron concentration in mg/l
Xm = Manganese reaction factor
(Mn) = Manganese concentration in mg/l
R = Final oxygen residual = (5.0 – Initial Oxygen) in mg/l

An example for (Fe) = 10 mg/l, (Mn) = 2.5 mg/l and Initial Oxygen = 0.0 mg/l:

$$\text{Oxygen Required} = (0.1432)(10) + (0.2912)(2.5) + (5.0 - 0.0)$$
$$= 1.432 + 0.728 + 5.0$$
$$= 7.16 \text{ mg per liter of water flow}$$

G. Theoretical Air Required

Air has a density of 1.2047 g/l at 20o C. and 1.0 atmosphere of pressure. Under these same conditions, air contains 20.95% oxygen. Thus, each liter of air contains (1.2047 g/l)(0.2095) = 0.2524 g/l of oxygen = 252.4 mg/l of oxygen. In order to determine the theoretical amount of air required for oxidation of iron and manganese, the water flow rate must be known. If the levels of iron and manganese are known, a convenient unit of flow is “per 1,000 liters”.

For example, using the contaminant levels in the previous example, and a flow rate of 100 l/min, the theoretical amount of air required would be:

$$\frac{(100 \text{ l/min})(7.16 \text{ mg/l})}{252.4 \text{ mg/l}} = 2.84 \text{ l/min of air}$$

Using this value, the theoretical amount of air required would be 28.4 liters per 1,000 liters of water.

H. Actual Amount of Air Required

The oxygen transfer efficiency of aeration devices ranges from a low end of ~5% to a high end of 25% to 35% for Mazzei Injectors. Using a figure of 25% for Mazzei Injectors is conservative and is supported by both laboratory and field data. This means that the actual amount of air required is approximately four times the theoretical amount of air required.

For the examples above, if the theoretical amount of air required is 2.84 l/m (or 28.4 liters per 1,000 liters of water), the actual amount of air required would be four times this amount or 11.4 l/m (or 113.6 liters per 1,000 liters of water). Depending upon particular circumstances, it may be wise to add to this amount an additional “safety factor” of 10% to 20%.

To aid in converting to English Units:

1 l/m of water flow	= 0.264 gal/min
1 gal/min of water flow	= 3.785 l/m
1 l/m of air flow	= 0.03531 ft^3/min
1 ft^3/min of air flow	= 28.3 l/m