



# Water Talk

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## Neutralizing Amines

### BASICITY

This paper discusses the factors that go into the choice and use of neutralizing amines to neutralize the pH in the condensate system which include: basicity, neutralizing capacity, distribution ratio, and USDA and FDA requirements.

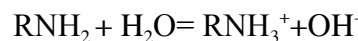
Carbon dioxide is formed by the breakdown of carbonate alkalinity in the boiler and is very volatile. This means that most of it passes into the steam, then forming carbonic acid in the condensate. The pH of the condensate can then reach low levels, sometimes below 3 because the

carbon dioxide is not in equilibrium with the atmosphere. The limiting pH in the atmosphere is about 5.8

Carbonate alkalinity can be removed by dealkalization and decarbonation in the pretreatment train. In most medium and low pressure systems the carbon dioxide is neutralized by adding neutralizing amines to the feedwater. The amines can also be fed directly into the steam lines.

These amines adjust feedwater pH to an optimum range of about 8.8 to 9.2. Amines are distributed into the steam as they pass through boilers and condense with the steam and carbon dioxide.

The general reaction of amines with water is:



The base hydrolysis constant for amines is defined as:

$$K_b = \frac{[\text{RNH}_3^+][\text{OH}^-]}{[\text{RNH}_2]}$$

The greater the value for  $K_b$  the more basic the amine will be. Basicity relates to the ability of the amine to raise the pH of neutralized water. On a molar basis, an amine with a larger value of  $K_b$  will raise the pH of pure water higher than will an amine of a lower  $K_b$ . Higher basicity doesn't always mean that the pH will be higher. The molecular weight will also play a role due to the fact that it is in mg/L.

Tables 1 and 2 show the pH of pure water as adjusted by the indicated amount of four volatile neutralizing amines.

CYCLO= cyclohexylamine  
DEAE= diethylaminoethanol  
MORPH= morpholine  
NH3= ammonia

**pH adjustment capacity of amines pH vs/ Amine concentration**

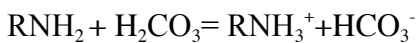
	CYCLO	DEAE	MORPH	NH3
<b>pH</b>				
Mg/L				
0.5	8.71	8.62	8.48	9.20
2	9.29	9.15	8.85	9.58
4	9.57	9.40	9.02	9.75
6	9.73	9.53	9.12	9.85
8	9.84	9.62	9.19	9.92
10	9.93	9.69	9.24	9.97
12	10.00	9.75	9.29	10.02
14	10.05	9.79	9.32	10.05

**pH adjustment by amines: amine concentration vs pH**

	CYCLO	DEAE	MORPH	NH3
<b>pH</b>		<b>Mg/L</b>		
7.00	0	0	0	0
7.30	0.010	0.02	0.01	0.00
7.60	0.04	0.04	0.04	0.01
7.90	0.08	0.09	0.09	0.01
8.20	0.16	0.19	0.21	0.03
8.50	0.32	0.39	0.56	0.06
8.80	0.63	0.81	1.67	0.14
9.10	1.28	1.75	5.54	0.36
9.40	2.63	4.06	19.89	1.02
9.70	5.53	10.32	74.85	3.22
10.0	12.15	29.43	289.34	11.14
10.3	28.71	93.92	1134.63	40.99
10.6	75.07	327.54	4482.56	156.45

**NEUTRALIZING CAPACITY**

The formula to express the capacity of the amine to neutralize CO<sub>2</sub> is expressed as:



The reaction is stoichiometric; the lower the molecular weight of the amine, the greater the neutralizing capacity.

**VOLATILE AMINES & DISTRIBUTION RATIOS**

Neutralizing amines follow the steam into the distribution system and the distribution ratio is a measure of the volatility of the amine that shows the ability of the amine to carry over into the steam where it can neutralize the carbon dioxide in the condensate. The higher the distribution ratio (like cyclohexylamine), the more the amines carries through the steam lines to the far end of the condensate system.

The amines with a low distribution ratio (like morpholine) tend to condense close to the boiler. The distribution ratio of amines is pressure dependent. The attached chart summarizes the properties of the neutralizing amines and lists the distribution ratio at 200 psig.

**Neutralizing amine properties**

Amine	MW	Neutr alizing capaci ty	K <sub>b</sub>	Distri butio n Ratio n (vs Press ure psig)		
		ppm CO <sub>2</sub> /m g/L amine		0	200	1000
<b>NH3</b>	35	2.59	1.8x10 <sup>-6</sup>	10	7.1 4	3.57
<b>CYCLO</b>	99	0.44	440x10 <sup>-6</sup>	4	23. 3	9.3
<b>DEAE</b>	117	0.376	66x10 <sup>-6</sup>	1.7	4.5	3.4
<b>MORPH</b>	87	0.506	3.1x10 <sup>-6</sup>	6.4	1.6	0.98

When choosing an amine, or amine combination, the length of the condensate lines and amount of carbon dioxide generated in the boiler need to be considered.

## **FDA AND USDA LIMITATIONS**

The four amines that are discussed in this water talk are acceptable for use in meat and poultry plants according to the FDA and USDA. The limitations of the amine in steam, as determined by the FDA, for steam contacting food is listed below:

<b>Substance</b>	<b>Limitations</b>
MORPH	10 ppm
DEAE	15 ppm
CYCLO	10 ppm
NH3	Good manufacturing practices

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