

## Key Performance Advantages

- Longer equipment life
- Higher energy efficiency
- Lower operating risks and costs



Industrial Water

# HYDROGUARD<sup>®</sup> I-15 OXYGEN SCAVENGER

## High Performance Oxygen Scavenger & Metal Passivator for Corrosion Control in Steam Generation Systems

HYDROGUARD<sup>®</sup> I-15 Oxygen Scavenger is a proven product which has been used successfully for many years to treat a variety of boiler systems. HYDROGUARD I-15 is cost effective and does not require a catalyst. Some of the key benefits that you can expect with HYDROGUARD I-15 are the following:

- Efficient catalyst-free oxygen scavenging
- Passivation of steel surfaces in pre-boiler, boiler and condensate areas
- Equally effective in both vapor and liquid phases
- No secondary amines
- Easier to handle than hydrazine and hydroquinone
- Economical relative to other products, such as sodium erythorbate
- Compatible with other commonly used treatment chemicals
- Lower evaporative loss of actives than diethylhydroxylamine (DEHA) in vented bulk storage containers

HYDROGUARD I-15 is designed for treatment of steam generation systems operating up to 1200 psig, and has successfully replaced hydrazine and sodium erythorbate in these systems. In some cases, cost may be reduced with the elimination of catalysts.

# Typical Physical/Chemical Properties

The following are typical physical/chemical properties of HYDROGUARD I-15; they are not to be considered product specifications.

Characteristic	Details
Active Ingredient	15 – 16% by wt.
Water	84 – 85% by wt.
Appearance	Water-white liquid
Flash Point (Setaflash Closed Cup)	46°C (114°F)
Fire Point (Cleveland Closed Cup)	>100°C (>212°F)
pH	10.6
Specific Gravity @ 25°/4°C	1.00
Pounds per Gallon @ 25°C	8.36
Color (APHA)	20
Crystallization Point	-5°C (23°F)
Refractive Index @ 25°C	1.3570

## Reaction Mechanism

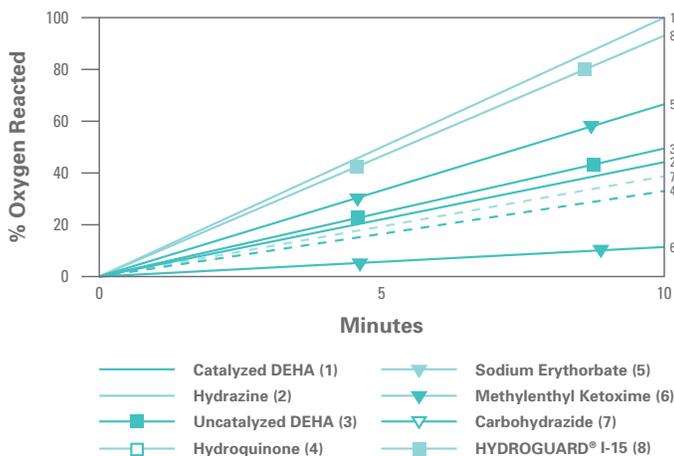
HYDROGUARD I-15 is believed to control corrosion by two mechanisms. One mechanism is the scavenging of oxygen in order to minimize the electrochemical reduction of oxygen at cathodic areas on the metal surface. This effectively inhibits one of two key electrochemical processes driving the corrosion reaction. The initial reaction between HYDROGUARD I-15 and oxygen occurs rapidly without any catalyst, even at temperatures as low as 55°C (131°F).

The following oxygen scavenging data were presented at an International Water Conference meeting in 1993 (Grace Dearborn IWC-93-40). The initial dissolved oxygen level was 125 ppb, and scavengers were added at 700 ppb (actives). Water temperature was 55°C, and pH was adjusted to 9.0.

**Figure 1**

### Scavenging of Feedwater O<sub>2</sub>

Reaction rate comparison after 10 minutes at 55°C/131°F and pH 9



Non-catalyzed HYDROGUARD I-15 is just as effective as catalyzed DEHA

The active ingredient in HYDROGUARD I-15 Oxygen Scavenger reacts much faster with oxygen under these conditions than do any of the other uncatalyzed oxygen scavengers. In addition, the uncatalyzed HYDROGUARD I-15 reacts just as fast as catalyzed diethylhydroxylamine (DEHA). Because HYDROGUARD I-15 has a favorable distribution ratio and does not require a catalyst, it is just as effective at scavenging oxygen in vapor phase areas as in the liquid phase. HYDROGUARD I-15 has a distribution ratio of ~1.4 (varies with pressure), and therefore partitions almost equally between liquid and vapor areas of the boiler system. A comparison of distribution ratios for various oxygen scavengers is shown below.

Scavenger	Distribution Ratio
Hydrazine	0.1
DEHA	1.3
HYDROGUARD I-15 (Active Ingredient)	1.4
Methylethylketoxime (MEKO)	2.2

Although diethylhydroxylamine (DEHA) has a similar distribution ratio to the active ingredient in HYDROGUARD I-15, DEHA requires a catalyst for rapid oxygen scavenging at lower pre-boiler temperatures. Since the catalyst is often hydroquinone (non-volatile), DEHA may not provide adequate protection of the vapor phase areas of pre-boiler equipment (feedwater tank, piping, etc.).

The second mechanism driving the electrochemical corrosion process is direct metal loss at anodic surfaces on the metal. HYDROGUARD I-15 inhibits this anodic reaction by providing a reducing environment to maintain iron in a lower oxidation state. Very low dissolved oxygen levels combined with reducing conditions and elevated temperatures result in formation of a passive magnetite layer on the iron surface.

## Application Guidelines

ANGUS recommends short-term field trials of HYDROGUARD I-15 Oxygen Scavenger as the best way of evaluating performance and optimizing treatment dosage. The optimum HYDROGUARD I-15 dosage will vary with each plant, based primarily on feedwater oxygen levels (after heating in the deaerator tank). The following dosage guidelines should be followed for first-time trials:

- For feedwater oxygen levels above 500 ppb, add 20 parts HYDROGUARD I-15 per 1 part oxygen (by weight). For example, if the oxygen level is 600 ppb, add 12,000 ppb (12 ppm) HYDROGUARD I-15.
- For feedwater oxygen levels of 50-500 ppb, add 33 parts HYDROGUARD I-15 per 1 part oxygen. For example, at 100 ppb oxygen, the HYDROGUARD I-15 dosage should be 3,300 ppb (3.3 ppm).
- For feedwater oxygen levels below 50 ppb, add 50 parts HYDROGUARD I-15 per 1 part oxygen. At an oxygen level of 20 ppb, roughly 1,000 ppb HYDROGUARD I-15 (1.0 ppm) should be added.

The treatment ratio of HYDROGUARD I-15 to oxygen increases with lower starting oxygen levels because of kinetic effects. This is true with all oxygen scavenger products.

HYDROGUARD I-15 Oxygen Scavenger is compatible with most boiler water treatment chemicals, and can therefore be added to the chemical mix tank. ANGUS suggests adding HYDROGUARD I-15 as the last chemical and mixing for the shortest time possible, with minimum vortex. This will minimize contact between HYDROGUARD I-15 and air (i.e. oxygen), which can result in loss of active ingredient prior to entering the deaerator tank.

Ideally, it is best to monitor oxygen levels in the feedwater exiting the deaerator tank, in order to optimize the HYDROGUARD I-15 dosage. However, since oxygen monitoring equipment is often not available, most plants monitor HYDROGUARD I-15 residuals using a Hach test kit; for more information please see the section under "Analysis for HYDROGUARD I-15 residuals in boiler water." Residuals of HYDROGUARD I-15 should generally be maintained between 300-1,000 ppb, however this is a guideline. The optimum level of residuals will vary with the plant and its performance requirements.

During initial trials it is critical to analyze levels of dissolved metals in the feedwater and boiler blowdown water, as well as the condensate, especially if it is recycled. Dissolved metals can be a sensitive indicator of corrosion, allowing HYDROGUARD I-15 dosages to be rapidly optimized as required. Another alternative is to install metal coupons at various points to monitor corrosion rates, as well as formation of protective oxides (i.e. magnetite, etc.).

## Performance in the Field

HYDROGUARD I-15 has performed very well in the field. For example, one plant wanted to replace hydrazine due to toxicity concerns. This plant operated a coal-fired boiler at ~ 54 bar (800 psig), for power generation (turbines) and process heating, with average steam production of 55 metric tons per hour. In order to maintain feedwater oxygen levels below 25 ppb, the plant had been adding 4,500 ppb of a 15% active hydrazine solution (catalyzed with hydroquinone). The plant was able to replace the hydrazine treatment with 1,125 ppb HYDROGUARD I-15, maintaining feedwater oxygen levels at an average 11 ppb, while providing good passivation of boiler surfaces. This plant was able to save money by switching from hydrazine to HYDROGUARD I-15.

Another plant operating a gas-fired boiler system rated at ~ 40 bar (600 psig), and producing 60 metric tons steam per hour, had been using a sodium erythorbate treatment but wanted to evaluate HYDROGUARD I-15 for possible cost savings. This plant had been adding ~ 3,980 ppb of the sodium erythorbate product as supplied (~ 13% active). The plant found they could replace sodium erythorbate with ~ 1,000 ppb HYDROGUARD I-15 and still achieve excellent control of oxygen levels and boiler corrosion. HYDROGUARD I-15 residuals in the feedwater ranged from ~ 250-1,000 ppb, while oxygen levels fluctuated from 8-20 ppb. The corrosion rates for mild steel coupons inserted into the process were 0.6 mils per year (feedwater tank) and less than 0.1 mpy in the boiler blowdown. These corrosion rates were comparable to those with the sodium erythorbate treatment, and this plant was able to save money by switching from sodium erythorbate to HYDROGUARD I-15.

## Storage/Analysis

Hydroguard I-15 should meet original specifications for one year when stored at normal ambient temperatures in the original unopened containers. Suitable shipping container materials of construction include high-density polyethylene (HDPE) and stainless steel. Corrosion-free mild steel construction is acceptable for bulk storage of HYDROGUARD I-15. During first-time storage in mild steel tanks, active HYDROGUARD I-15 levels should be monitored for the first several weeks; "passivation" of fresh steel surfaces may result in some initial loss of actives. Acceptable gasket/seal materials are HDPE, polypropylene, Teflon, and Teflon-encapsulated Viton.

HYDROGUARD I-15 is relatively stable even when stored in vented containers at temperatures up to 50°C (122°F). This does not mean the product will meet original specifications when stored in this fashion, because some loss of actives will occur due to evaporation and reaction with atmospheric oxygen. The concentration of active ingredient in HYDROGUARD I-15 is determined using the colorimetric titration procedure described below.

In order to investigate the storage stability of HYDROGUARD I-15, a study was done using two-gallon polyethylene containers vented to the atmosphere. One container held HYDROGUARD I-15, and the other vessel contained an approximate 27% active diethylhydroxylamine (DEHA) solution (aqueous). The containers were placed into a 52°C (126°F) oven and approximately 20 mLs of each product were drained daily and discarded; this was done to simulate field use conditions for vented containers. The active levels in each product were measured after four weeks to determine the change from the initial amounts. The results were as follows:

% Actives	Initial	4 Weeks @ 52°C (126°F)
HYDROGUARD I-15	15.5%	14.2%
DEHA Solution	26.8%	17.2%

The loss of actives in HYDROGUARD I-15 oxygen scavenger was considerably less than in the DEHA solution. It is believed that the observed difference is due to the differing volatilities of the active ingredients in HYDROGUARD I-15 and DEHA; the active ingredient in HYDROGUARD I-15 has a higher boiling point and lower vapor pressure than DEHA, resulting in better retention at normal storage temperatures.

In one of the plant trials discussed above, a 5-gallon container of HYDROGUARD I-15 was opened daily, re-sealed, and analyzed after 82 days for the remaining active ingredient; the HYDROGUARD I-15 was stored in the chemical feed tank house at an ambient temperature range of 27-38°C (81-100°F). The active HYDROGUARD I-15 level was reduced from ~15.5% initially to 14.5% at the end of the 82-day period, indicating good storage stability.

For maximum product life, it is recommended that HYDROGUARD I-15 be stored in closed containers under nitrogen. This will minimize losses due to reaction with oxygen, as well as evaporation.

# Titration Procedure to Determine % Active Ingredients in HYDROGUARD I-15

- Obtain the following materials:
  - 150 mL glass beaker and magnetic stir bar
  - 25 mL capacity buret
  - Standardized 0.5 N aqueous sulfuric acid solution
  - Deionized water
  - Bromophenol blue, sodium salt (dilute 100 mg of salt to 100 mL with deionized water)
- Testing of HYDROGUARD I-15 product:
  - Fill buret with fresh 0.5 N sulfuric acid solution.
  - Add about 50 mL of deionized water to beaker containing stir bar. Tare beaker on analytical balance.
  - Weigh approximately 1.0 g of HYDROGUARD I-15 into beaker containing water. Record exact weight to nearest 0.0001 g.
  - Add 8 drops of bromophenol blue, sodium salt solution (Step 1.e.) to beaker.
  - Place beaker on stir plate and mix, but not too vigorously.
  - Titrate to yellow endpoint with 0.5 N sulfuric acid.
- Testing of dilute solutions of HYDROGUARD I-15 in water (containing 1% actives or more):
  - Fill buret with fresh 0.5 N sulfuric acid solution.
  - Weigh into beaker containing stir bar about 50 g of diluted HYDROGUARD I-15. Record weight on analytical balance to the nearest 0.0001 g. Please note that the ideal volume of diluted HYDROGUARD I-15 solution will depend upon the expected percentage of active ingredient present. For example, if the solution is expected to contain 1-2% active ingredient, then 50 g of solution is fine. If the active ingredient concentration is expected to be higher, then smaller solution volumes may be used.
  - Add 8 drops of bromophenol blue, sodium salt solution (Step 1.e.) to beaker.
  - Place beaker on stir plate and mix, but not too vigorously.
  - Titrate to yellow endpoint with 0.5 N sulfuric acid.
- Calculations:

The concentration of active ingredient is calculated as follows:

$$\% \text{ Active} = \frac{3.755 \times V}{W}$$

Where:

V = Volume of 0.5 N sulfuric acid titrant required (mL)

W = Weight of HYDROGUARD I-15 sample

Please note that "W" for Part #2 is the weight of HYDROGUARD I-15 Oxygen Scavenger, which is added to the deionized water. For Part #3, "W" is the total weight of diluted HYDROGUARD I-15 solution.

A potentiometric titration method is also available; please contact an ANGUS technical representative to obtain a copy of this procedure.

## Analysis for HYDROGUARD I-15 Residuals in Boiling Water

Low levels of HYDROGUARD I-15 residuals can be easily measured using the Hach kit for DEHA. This kit is available as Model DH-1, Catalog No. 21682-00 from The Hach Company, Loveland, Colorado USA. The Hach Company can be reached at 1-800-227-4224 (within the U.S.) and at 1-970-669-3050 (outside the U.S.).

The values determined by this kit (as DEHA) must be multiplied by 8.0 to convert to HYDROGUARD I-15 residuals. For example, if the reading according to the kit is 150 ppb (as DEHA), the value for HYDROGUARD I-15 residuals is  $8 \times 150 = 1,200$  ppb. To determine the active HYDROGUARD I-15 residuals, the HYDROGUARD I-15 value must be multiplied by 0.15.

## Product Stewardship

ANGUS encourages its customers to review their applications of ANGUS products from the standpoint of human health and environmental quality. To help ensure that ANGUS products are not used in ways for which they are not intended, ANGUS personnel will assist customers in dealing with environmental and product safety considerations. For assistance, product Safety Data Sheets, or other information, please contact your ANGUS representative at the numbers provided in this document. When considering the use of any ANGUS product in a particular application, review the latest Safety Data Sheet to ensure that the intended use is within the scope of approved uses and can be accomplished safely. Before handling any of the products, obtain available product safety information including the Safety Data Sheet(s) and take the necessary steps to ensure safety of use.

For further information, please visit our website, [angus.com](http://angus.com), or call (in North America): **+1-844-474-9969**.

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