# HEI vs Altair Deaerator Design

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## History

In December of 1986, the Heat Exchange Institute (HEI), through Thomas Associates, coordinated a meeting among deaerator manufacturers in an effort to determine if there was enough interest in reactivating the Deaerator Section of the Institute (Thomas Associates handles administration duties for the Institute, such as dues payments, market information, disbursement of funds, etc.). At the time of the meeting in 1986, at least ten (10) manufacturers were involved with the assessment, and the general consensus was that there was no real value in reactivating the deaerator section. The Deaerator Section had been inactive since around 1963, when the fourth (4th) edition of the Deaerator Standards had been published.

Again in 1990, a meeting was held in order to evaluate the interest in reactivating the standard. At that time, only four (4) manufacturers were in attendance, including one counterflow manufacturer. After discussion among the manufacturers present and a second meeting, the counterflow manufacturer decided that an updated deaerator standard was not necessary, as it would not add to the industry’s knowledge of deaerator design, construction and operation.

The three (3) remaining counterflow manufacturers decided to proceed with updating the standard.

As a result of all this, the fifth (5th) edition of the standard was published in the fall of 1992, written and updated by Kansas City Heater, Permutit and Stickle Steam Specialties. Sterling Deaerator and Great Lakes “jumped on the bandwagon” when they learned that the updated standard was actually proceeding, but these two companies did not contribute to the content of the document.

## Content of the New Edition

The essence of this latest edition of the HEI Standard for Deaerators is the incorporation of the recommendations developed by NACE in NACE Standard RPO590-90 as new construction requirements. These new construction requirements include:

1) A minimum corrosion allowance of l/8” required for shell and heads. When a unit is designed for vacuum, l/16” of the l/8” corrosion allowance may be used in the vacuum calculation. (NACE recommended a minimum 1/16” c.a.)

2) Post Weld Heat Treated (PWHT) of the vessels - as described in the ASME Code.

3) Grinding smooth of internal weld seams.

4) Wet Fluorescent Magnetic Particle Testing (WFMPT) of nozzles.

5) Full radiographic examination of all vessel longitudinal and circumferential shell and head seams.

Although the new members of HEI deaerator section took it upon themselves to require these features as standard construction for deaerators, it is interesting to note that the NACE Standard itself, which is referenced in the HEI document states quite clearly that "neither is this standard (NACE RP0590-90) intended to apply to all cases relating to the subject (prevention, detection and correction of deaerator cracking)". The NACE Standard is by far, in our opinion, the preferred authority and reference for a specifying engineer in determining which construction features are to be incorporated into a specific application.

Triggered by a series of deaerator failures in the early 1980's, NACE and TAPPI have done extensive investigation into the problem of deaerator cracking. Altair fully supports their findings and recommendations as correctly applied, but does not support arbitrarily requiring all deaerators be designed and constructed with these features.

The manufacturers active in revising the HEI Standard claim that the latest edition "adds considerable information" to the previous standard (Power Magazine article February 1993), but upon review, it is apparent that the new edition adds very little to the previous 1963 issue, and it certainly is remiss in addressing some of the latest developments in deaerator applications, such as deaeration for integral HRSG service, vacuum deaeration (cold water and with heating), and vacuum deaeration in which the deaerator is coupled directly with a condenser to deaerate makeup water. One would think that it would be a priority of the "new" 1992 edition of the deaerator standard to address such important developments and technologies and it is Altair's opinion that the manufacturers involved, do not have the technical capabilities or experience with such designs to incorporate these into the standard.

Other requirements of the 5th Edition of the HEI Standard include:

1) Minimum tray thickness of 20 gauge.
2) "All materials including heads and shells in contact with steam, which has previously been in contact with undeaerated or partially deaerated water shall be stainless steel or stainless steel lined.
3) Minimum thickness of tray compartment, l/4" if carbon steel or l/8" if stainless steel.

The new standard essentially reads like a tailored specification for counterflow tray type units, and you will note that all of the manufacturers involved in developing this new standard manufacture only a counterflow tray deaerator (neither this discussion nor the HEI Standard address other types of thermal deaerators, such as spray-scrubber or spray atomizing). It seems the primary goal of the group which developed the new edition was to get a standard published (as soon as possible), that favors the counterflow tray design (the only tray type that they manufacture), or at least makes it more difficult for other designs (of proven technical capability) to be competitive and ultimately utilized in cases when the HEI Standard is referenced.

These requirements, especially Item 2) above, essentially make it very difficult for a Coflow downflow tray deaerator to be competitive due to the hardware modifications required to bring a Coflow downflow design into compliance with the new standard. **It is not an improvement that reduces corrosion problems. If anything it only passes them downstream to the storage tank.**

Because the companies involved in revising the fourth (4th) edition of the standard manufacture only the counterflow tray type deaerator, it is Altair's opinion that the recommendations and requirements defined by the new standard, should apply only to counterflow designs; certainly, these manufacturers should not define requirements concerning the design of a product with which they have no experience and which they do not manufacture.

Elaborating on the requirements listed above, Altair's Coflow flow design utilizes 22 gauge or 16 gauge trays, with the 22 gauge being "standard construction. Altair offers 16 gauge trays when the operating conditions dictate the use of such. It is important to realize that the counterflow tray and the Coflow downflow tray are very different in design, as are the ways in which they are secured inside the deaerator; the counterflow tray is much larger, is of riveted design and has much more "open air" - features dictated by the nature of a counterflow deaerator's operation (in which the steam and water flows oppose one another), and features that dictate the use of heavier gauge tray material. It should be noted that riveted connection has proven to be troublesome due to the stress's setup when pinning and constantly failing, causing the counter current tray slats to break and drop off.

Altair's trays for Coflow downflow service are smaller, one piece formed stampings which interlock in place with one another, forming a compact tray section. All trays are then "sandwiched" by carbon steel grating or angle beams and the entire structure than locked in place by the use of angle and stainless steel hardware. The 22 gauge trays are suitable for a majority of applications due to the structural integrity of this entire tray section. It is peculiar that the minimum tray thickness required by the new edition is 20 gauge, just above Altair's standard design thickness of 22 gauge. There is not any evidence that 22 gauge Coflow down flow trays are mechanically unsuitable, in fact there are thousands of units operating successfully with trays of 22 gauge. Thus, one wonders why such a requirement would appear in a publication, which claims authority on the subject.

Items 2) and 3) are requirements targeted at Coflow downflow tray type units that can better be understood after becoming familiar with the way a Coflow downflow tray unit operates and the features that distinguish it from a counterflow tray deaerator.

Both designs have features that make them suitable for certain applications, but for the purposes of presenting our exceptions to the latest edition of the HEI deaerator standard, those applicable to the Coflow downflow design will be elaborated.

A Coflow downflow design is more flexible and can be used successfully in applications where a counterflow of fixed size will fail.

## Coflow Downflow Deaerator - Principle of Operation

A Coflow downflow design operates as follows (see attached drawing for illustrated depiction):

Water enters the pre-heating compartment through stainless spring loaded spray nozzles. Water is sprayed in very thin hollow cone sheets into an atmosphere of steam where the water is heated to practically steam temperature. This spraying and heating results in a major portion of the dissolved gases being released from the water (approximately 95% or more). The partially deaerated water falls to the bottom of the pre-heating compartment from which it flows through a downcomer to the water seal in the tray stack compartment.

Inlet deaerated water flows from the water seal to the trays. This water seal, a unique feature of Coflow downflow deaerators, serves to prevent the bypassing of steam from the tray compartment to the pre-heating compartment and insures that no non-condensable gases pass from the pre-heater to the tray compartment. In addition, the water seal is designed with troughs that evenly distribute the water over the trays.

Steam in conjunction with tray stack and steam are now available to scrub and remove the final traces of oxygen.

Water leaving the tray stack is completely deaerated and falls to the storage section where it is available for immediate use.

Steam leaving the tray stack contains 7 ppb or less O2 is directed around the outside of the stack to the pre-heater where it is condensed by the incoming water with a small amount being vented to atmosphere along with the removed non-condensable gases.

The features of significance are as follows:

In the Coflow downflow deaerator design, the steam and water flow concurrently downward through the trays. Since the steam flow through the tray stack assists (rather than opposes) the water flow, the Coflow downflow deaerator will meet performance requirements with lower inlet feedwater temperature than a counterflow unit of equal size.

A Coflow downflow deaerator can be designed for operation with 100% make-up feedwater at temperatures as low as 33 degrees F. Counterflow deaerators may require as much as 60% more tray area than a Coflow downflow unit when designed to handle water below 50 degrees F. and it is our experience that counterflow units experience performance problems when handling 100% (or a similar high percentage) of makeup returns due to the high O2 levels.

Since the Coflow downflow design can handle higher steam flows through the tray stack than counterflow deaerators of equal size, there is no need to pre-heat the make-up water ahead of the deaerator nor to bypass steam around the tray stack (techniques for reducing tray box area in some counterflow units). In the Coflow downflow unit, all of the steam needed to heat the incoming water to saturation pressure is actively used as a stripping agent.

Since there is no requirement to pre-heat cold make-up water, the cost of installing and operating heat exchangers ahead of the deaerator is avoided. Also avoided is the increased aggressiveness of hot aerated water leaving the pre-heater on piping upstream of the deaerator.

All water and steam is processed through the tray stack, including the steam and water produced by flashing condensate. Flashing returns in a counterflow type unit are introduced into the heater outside and below the tray compartment, essentially being “dumped” directly to storage. Since the condensate may contain small amounts of dissolved gases under certain operating conditions, it is important to process the condensate in the tray stack.

The presence of a water seal between the trays and the spray (preheater) section of a Coflow downflow unit eliminates direct impingement of the sprays on the trays and insures even and consistent distribution of the water over the tray stack. It also eliminates water bypassing the first few layers of trays by part of the water. Fewer spray valves are required because of this improved distribution system. This, along with higher permissible design loadings on the trays means that the Coflow downflow deaerator will exhibit the highest turndown capability of any design.

Also, since higher steam velocities are permissible in the Coflow downflow design, it is possible to use trays with less open area than in counterflow deaerators. This maximizes spilling edge and exposes a greater surface of the water to the stripping action of the steam. Less open area also means that a higher percentage of the tray area is available to intercept the water and steam flows as they pass from tray to tray, thereby maximizing mixing and turbulence on the trays. This optimized mixing, plus the effect of higher steam velocity through the trays, results in gas removal efficiency not attainable by counterflow deaerators.

Because of the presence of the water seal between the tray and spray areas, preheater performance of the Coflow downflow  deaerator is superior to that obtained in counterflow units, resulting in lower oxygen concentrations on the top tray. This lower oxygen concentration permits the use of carbon steel tray supports without corrosion problems. The use of carbon steel plate in heavier gauges (3/16”- to l/4”) for Coflow downflow units vs. 1/8” or lighter stainless steel normally used in the counterflow units) provides maximum strength and durability at no economic penalty.

A final feature of the Coflow downflow design is the fact that incoming steam is routed directly into an internal steam chest which connects to the steam space above the trays. This feature of the design provides a distinct advantage when superheated steam may be used as a source of heating steam for the deaerator. During normal operation (water flowing through the trays), the heating steam will be de-superheated prior to coming into contact with the deaerator pressure shell. This minimizes the thermal gradients in the shell and the stresses associated with these gradients.

Getting back to the requirements of the new standard  as itemized  previously, item 2) essentially can be interpreted as requiring the heads and shell of Coflow downflow unit to be constructed of stainless steel. This requirement has no theoretical basis, nor does it have any experimental basis. As can be easily understood this particular mew requirement impacts the cost of a Coflow downflow type unit substantially.

Dilution of the non-condensable gases in the steam atmosphere is so great, the steam which strips the final traces of gases in the tray section has no corrosive potential as it carries the residual non-condensable gases to the preheater. As described, approximately 95+% of the dissolved non-condensables have been removed before the water reaches the top tray and contacts the new incoming steam. It is impossible for the residual noncondensables which have diffused into the gas stream phase in the tray section to cause corrosion problems in the area which is required by the HEI standard to be stainless steel or stainless steel lined. Coflow downflow units have never experienced corrosion problems associated with the type of phenomenon that the counterflow developers of the new edition profess as a concern. This phenomenon (that steam which has been in contact with partially deaerated water causes corrosion of the heater heads and shell) is a fabrication by the authors of the standard to insure a more competitive position for a counterflow design In fact this type of corrosion is more associated with counterflow units when spray nozzles fail. this is no doubt due to the fact that the steam moves straight up through the trays to the nozzles from below and impinges on the head or shell with a high O2 content if there spray nozzle failure. In the Coflow downflow design the spray nozzles are fed from the side before contacting water saturated with O2.

What is interesting to note is that the previous editions of the HEI standards for deaerators did not include any requirements in this regard. Coflow downflow deaeartors have been in successful operation for over 60 years and certainly if a problem existed concerning the materials of construction in this type of design then Altair would be aware of it, as would the thousands of those who own and operate downflow units.

Concerning item 4) and the minimum thickness associated with the tray compartment, Coflow downflow deaerating trays are designed in a way which requires that only the two short ends of the tray compartment need be provided with closure plates (sides). Since a deaerator may be subjected to forces not readily predictable, it is desirable to provide as strong a tray support as is economically possible. It is Altair’s policy to construct its tray supports of heavy gauge (3/16” thick in smaller units to 200,000 pph capacity) and (1/4” thick material in larger units) carbon steel plate. In contrast, tray compartments of stainless steel construction in 1/8” plate for counterflow results in a structure of substantially reduced strength, when compared to Coflow downflow carbon steel supports.

Two final points need to be addressed concerning the content of the new standard - the first concerning performance of deaerators when processing preheated water. In section 5.10 of the new edition entitled “Other Design Considerations”, the HEI members give warning of potential performance problems when the inlet water is preheated prior to introduction into the deaerator, due to a reduction in steam demand within the unit, particularly within the tray section.

Altair is aware of the potential effects on performance resulting from this mode of operation. However, such reductions in performance (dissolved gas removal) are much more common in **counterflow** deaerators. We can only speculate that this is the reason why this “disclaimer” or warning has been included as part of the revised edition.

For someone who understands how both Coflow downflow and Counterflow deaerators operate, this is intuitive. Due to the low steam flow available for scrubbing of the water in the tray section and the large "open area" necessary for steam flow, the water and steam have a tendency to "bypass" one another thereby affecting removal efficiency (aggravated under certain swing load operating conditions). A Coflow downflow design deaerator, on the other hand, is innately suited to accommodate such a condition due to the internal design at previously discussed. Consistent water distribution, less "open area", higher tray loading and steam velocity, and resulting mixing and turbulence prohibits "bypass" in the tray section. In effect, the Coflow downflow design is better suited for applications in which there is a low heating requirement (in addition to being preferred for conditions of high makeup)

The motive behind the statement included in section 5.10 of the Standard is quite evident; a Counterflow deaerator does not perform efficiently under conditions in which the inlet water is substantially preheated and a Coflow downflow design is preferred.

One final point needs to be made concerning the content of the "updated" 5th edition - Namely that regarding the concept of "tray volume". This edition devotes an entire page to defining "tray volume" as the product of length, width and height of the tray enclosure. In addition, the parameter is itemized on the "deaerator specification sheet", which is included at the end of the 5th edition. Based on some of the points indicated above on the differences between a Counterflow and a Coflow downflow tray type deaerator, it is quite evident that a Counterflow unit will require a larger tray volume than a Coflow downflow unit.

Manufacturers involved in developing the new edition know this and are utilizing this parameter with the hope that an inexperienced evaluating engineer will specify a minimum tray volume based on a counterflow design, or select a unit with a larger tray volume thinking (incorrectly) that he is getting "more for his money".

Coflow downflow have been used in boiler houses dating as far back as the 1940's. Many of these units are still in operation. **It is quite accurate to state, that there are more Coflow downflow deaerators in operation today, than the number produced and supplied by the combined total of all the members of the current HEI section.**

In closing, it is our opinion that the latest edition of the HEI Deaerator Standard is unethical in its approach. Originally when the spec was challenged there was no technical committee with the HEI to evaluate counter claims on an unbiased basis. All the members of the committee who reviewed the complaints were those who wrote the standard.

The purposes of the HEI Standard should be to enlighten industry and the public regarding deaerator design and construction, establish minimum design and construction standards consistent with sound engineering practice and experience. Make recommendations to ensure that quality products are supplied. All this while addressing the latest deaerator technologies and applications, **not to write a proprietary Counterflow specification**.

Keeping in mind that the three (3) manufacturers originally involved in "updating" the standard, together represent a relatively small portion of the deaerator market, it certainly seems feasible that they regard the HEI as the vehicle to legitimize themselves as deaerator manufacturers. HEI is recognized as a reputable organization, primarily because of other active sections such as; steam surface condensers, closed feedwater heaters, power plant heat exchangers and vacuum technology.

As stated, the new standard amounts to little more than a specification favoring (thermal) counterflow tray type deaerators, supplemented with recommendations borrowed directly from organizations that had already done extensive research (and had already published their conclusions) into deaerator construction related to material cracking.

We feel that the best approach for the specifying and evaluating engineer is to familiarize himself with the different types of deaerator designs and with the standards being referenced. Make a well informed, responsible, selection of both deaerator types and construction requirements based upon his careful analysis and review.