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The Equity Engineering Group, Inc.

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HOW DOES THIS AFFECT OWNER-OPERATORS?

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→ ABSTRACT

The API STD 2000 *"Venting Atmospheric and Low-Pressure Storage Tanks"* has provided vapor venting and make-up requirements for storage tanks for almost four decades. Released in March 2014, the 7th edition updates the venting and make-up requirements by including new input criteria such as the facility's location in relation to the Earth's equator, as well as the storage liquid's vapor pressure, among other changing assumptions. These changes will, in some applications, result in larger pressure and vacuum relief devices when compared with those selected using the previous version of API 2000. This raises the question of how to maintain adequate protection for tanks in compliance with the new standard. Even though the replacement of existing devices is not proposed or mandatory by the current version, reviewing the needs of most critical service facilities would be of great value to storage tank owner-operators. Changes to the API STD 2000 come from consensus of the API Subcommittee on Pressure Relieving Systems (SPRS). The SPRS is made up of the industry's main practitioners who are considered the subject matter experts in the area of pressure relief. This *Industry Insights* article will provide a summary of the changes to API STD 2000 and will identify where the significant changes in venting requirements occur, in addition to recommendations regarding how to address these changes to meet the standard.

→ INTRODUCTION

Protecting atmospheric and low-pressure storage tanks (ASTs) from overpressure and vacuum scenarios during normal operation and emergency conditions is a major concern for owner-operators. Although failures of ASME Code pressure vessels are not a very common occurrence, failures due to overpressure or buckling due to vacuum conditions occur much more frequently with low-pressure storage tanks.

Routine operations include liquid moving in and out of the tank. This causes the space above the liquid level to change its volume, leading to venting and make-up requirements (called normal venting out-breathing and in-breathing) to maintain relatively constant pressure inside the tank. Additionally, the vapor space might also change its volume because of the vaporization or condensation of lighter compounds caused by temperature changes driven by local weather, creating additional requirements (thermal effects).

In either case, specific pressure relief and vacuum calculations must be conducted to determine how much total gas should flow in or out of the tank to keep the internal pressure within safe operational limits, thereby preserving the tank's mechanical integrity. Pressure relief device (PRD) sizing calculation procedures for ASTs are provided in API STD 2000 *Venting Atmospheric and Low-Pressure Storage Tanks,* 7th edition (2014).

In this latest edition, the methods for normal in-breathing and out-breathing have changed, and in many applications, pressure relief and vacuum capacity requirements have actually increased. The latest procedure, called the General Method (GM), is recommended to use for new tanks; it replaces the previous method, which has been moved to Annex A of the standard for informative purposes; the Annex A method (AAM) also remains applicable for existing ASTs.

This article will provide insights on changes in Calculation of Required Flow Capacity for Normal Out-breathing and In-breathing as outlined in section 3.3.2 of API 2000, guiding readers to a better understanding of how to implement the new standard at their facilities. This article does not discuss emergency venting requirements (e.g., fire case) as covered in section 3.3.3 of API 2000, since these requirements remain unchanged.

WHAT ARE THE CHANGES?

To follow the changes introduced with the new calculation procedure, we will first examine both methods' inputs, assumptions, and equations.

Beginning with the AAM, venting and make-up gas flow are calculated using the following inputs and assumptions:

- Average storage temperature (not directly used, just to limit method to max. 120°F)
- Liquid flash point and boiling point (to select normal and thermal venting in-breathing/out-breathing requirements in table)
- Tank volume (to select thermal in-breathing/out-breathing requirements in table, max. 7,925,000 gal)
- Pumping in and out rates (to select normal venting in-breathing/out-breathing requirements in table)
- Rain is at 60°F
- Tank initial temperature is at 120°F
- Internal convection coefficient is 0.7 $\frac{BTU}{h \cdot ft^2 \cdot °F}$
- Fixed cooling rate for small tanks (<840,000 gal) is 100°F/h, and the estimated cooling rate for larger tanks (>840,000 gal) is 50°F/h

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With the GM, relief requirements will change, given that the calculated venting and make-up gas flow is performed more rigorously than with the AAM; this is taking into consideration tank location, additional fluid properties, and modified heat transfer methodology. Venting and make-up gas flow are calculated using the following inputs and assumptions:

- Average storage temperature (used to select C-factor for thermal in-breathing in equation)
- Tank location latitude (to select C and Y factors for thermal in-breathing/out-breathing in equation)
- Storage liquid vapor pressure compared to n-Hexane (to select C-factor for thermal in-breathing in equation)
- Tank volume (used in thermal in-breathing and out-breathing equation)
- Pumping in and pumping out rates (to calculate normal venting in-breathing and out-breathing requirements)
- % of insulated area and insulated thickness and its thermal conductivity (to correct the in-breathing and out-breathing flows)
- Rain is at 59°F, slightly cooler than AAM
- Tank initial temperature is at 131°F, 9% warmer than AAM
- 25% higher internal convection coefficient, now 0.88 $\frac{BTU}{h \cdot ft^2 \cdot °F}$
- Tank cooling rate is obtained using a continuous thermodynamic model as a function of tank volume

As indicated in the above assumptions, one could anticipate that the tank's higher heat exchange with ambient conditions when cooling will lead mainly to higher in-breathing flows, avoiding vacuum pressures and tank collapse.

The equations that the AAM uses are:

1 OUT-BREATHING

$$V_{op} = k * V_{pf}$$

V_{op} = Out-breathing volume (SCFH)
k = From table A.2 of AAM
V_{pf} = Maximum pumping in rate (BBI/h)

2 IN-BREATHING

$$V_{ip} = 5.6 * V_{pe}$$

V_{ip} = In-breathing volume (SCFH)
V_{pe} = Maximum pumping out rate (BBI/h)

3 THERMAL OUT-BREATHING

$$V_{ot} = F\,(V_{tk}, Stor_{Flash}, Stor_{BP})$$

V_{ot} = Thermal out-breathing (SCFH), from table A.4 of AAM
V_{tk} = Tank volume (BBI or gal)
$Stor_{Flash}$ = Storage product flash point (°F)
$Stor_{BP}$ = Storage product n-boiling point (°F)

4 THERMAL IN-BREATHING

$$V_{it} = F\,(V_{tk})$$

V_{it} = Thermal in-breathing (SCFH) from table A.4 of AAM
V_{tk} = Tank volume (BBI or gal)

Finally, the GM updated equations are:

5 OUT-BREATHING

$$V_{op} = k * V_{pf}$$

V_{op} = Out-breathing volume (ACFH)
k = 8.02 or 16.04 (depending on vapor pressure/no flashing)
V_{pf} = Maximum pumping in rate (gpm)

6 IN-BREATHING

$$V_{ip} = 8.02 * V_{pe}$$

V_{ip} = In-breathing volume (SCFH)
V_{pe} = Maximum discharging rate (gpm)

7 THERMAL OUT-BREATHING

$$V_{ot} = Y * V_{tk}^{0.9} * R_i$$

V_{ot} = Thermal out-breathing (SCFH)
Y = Latitude factor, from table 1 of GM
V_{tk} = Tank volume (m3)
R_i = Reduction factor for insulation

8 THERMAL IN-BREATHING

$$V_{it} = C * V_{tk}^{0.7} * R_i$$

V_{it} = Thermal in-breathing (SCFH)
C = Vapor pressure/latitude/storage temp. factor, from table 2 of GM
V_{tk} = Tank volume (m3)
R_i = Reduction factor for insulation

→ COMMENT ON CHANGES AFFECTING THERMAL IN-BREATHING AND OUT-BREATHING

As shown in GM's equations (7) and (8), the updated method now takes the tank's location (latitude) into consideration when it comes to calculating both thermal in-breathing and out-breathing (Y factor, C factor). Although the out-breathing requirement using the new GM method increases marginally, there are significant increases for all tank in-breathing requirements, with even larger increases for tanks located closer to Earth's equator.

The GM accounts for changes in the tank cooling rate, whereas the original AAM assumes an average cooling rate when determining in-breathing requirements. The GM assumes that in-breathing rate varies with time, with larger in-breathing capacity required when cooling of the tank starts. As the tank cools closer to ambient temperature, the cooling rate diminishes along with the in-breathing requirement. The selected vacuum device must be sized to handle the highest load, which occurs at the start of the cooling process. GM's more sensitive new assumptions and equations are where the two methods differ most, and this is the primary reason why using it results in higher in-breathing loads than those obtained by the AAM.

SAMPLE RESULTS

Figure 1 shows results for a 5 MM gallon tank containing n-Hexane using the GM (blue lines) and the AAM (orange lines). As you can see, relief requirements for thermal out-breathing using the two methods may be more or less the same, depending on the location or latitude of the tanks. For example, at a latitude of 42° away from the equator (e.g., Cleveland, OH), the thermal out-breathing requirements determined by GM could be around 5% lower than when using the AAM method. If that same tank was located in Valencia, Venezuela (Manuel's hometown) at the latitude of 10.2°, the relief requirements for thermal out-breathing would actually be increased by about 25% using the GM.

Note, however, that the thermal in-breathing requirements using the new GM are roughly 2 to 3 times bigger than those obtained using the original AAM. This is a huge difference, which would indicate that many vacuum protection devices installed based on the old AAM of API 2000 might not be large enough.

Figure 2 shows similar results for tanks varying in size between 5 MM to 7.5 MM gallons located at a fixed latitude of 10°(<42°). Again, thermal out-breathing will be 20 to 40% greater at latitude 42°. However, there is a significant increase by a factor of 3 for vacuum requirements for thermal in-breathing.

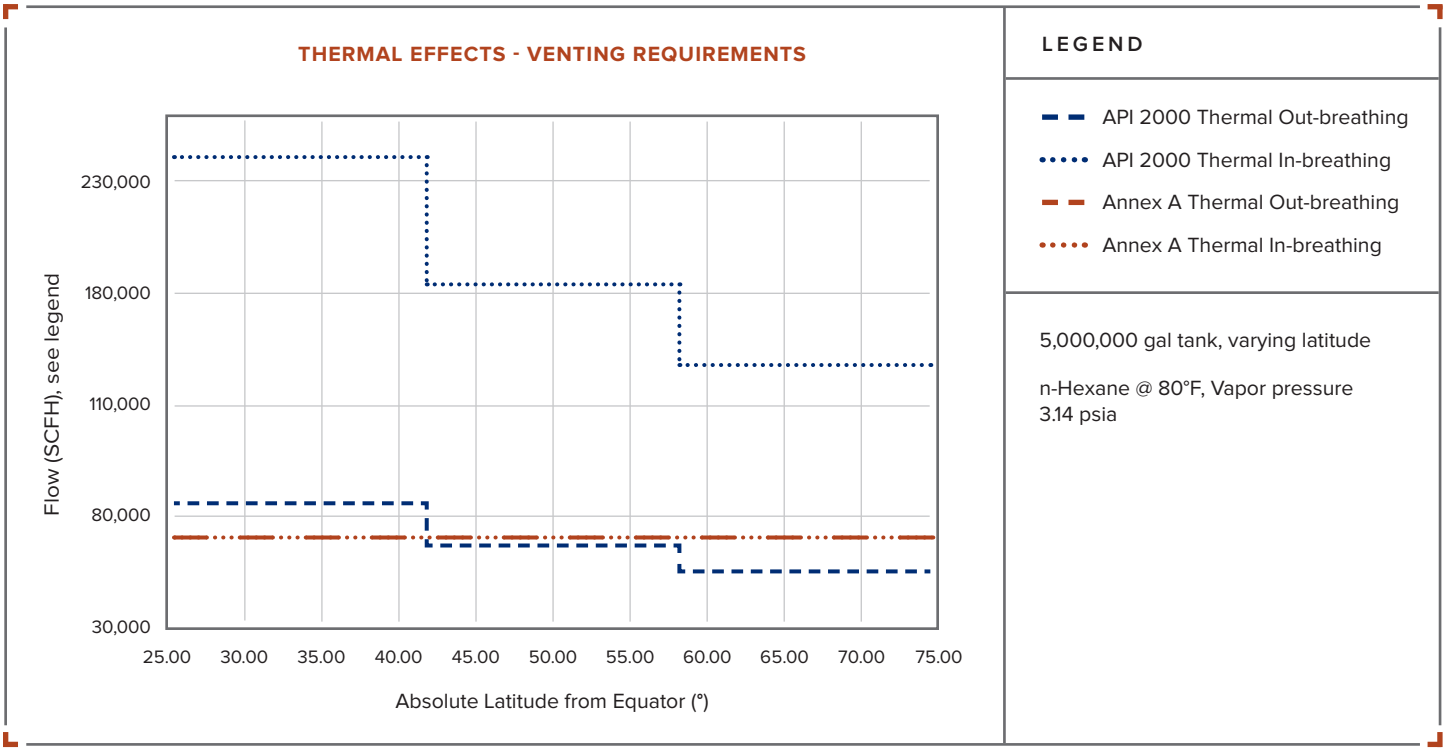

Figure 1. *GM & AAM Thermal Requirements, Changing Latitude*

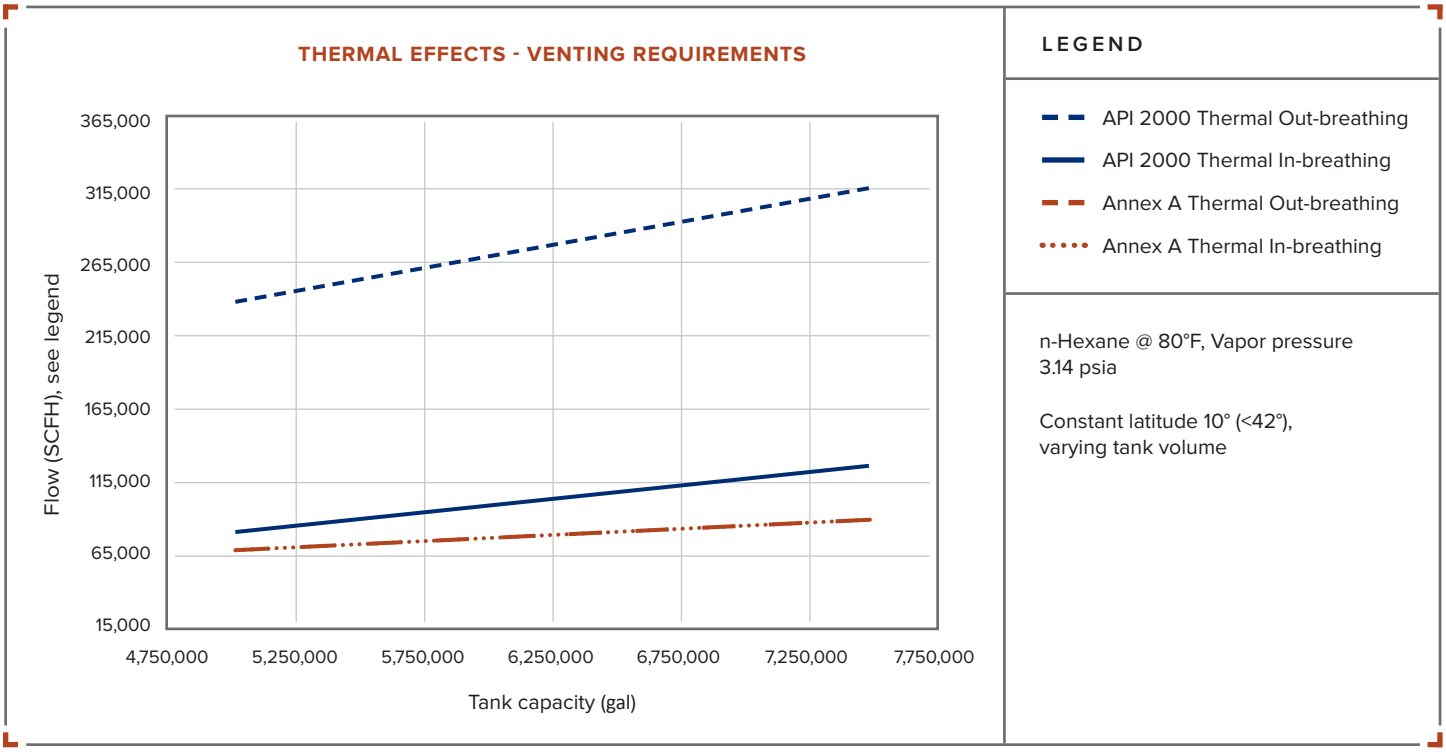

Figure 2. *GM & AA Thermal Requirements, Changing Tank Volume*

HOW DOES THIS AFFECT YOU

AND WHAT SHOULD YOU DO?

The first important takeaway is that API STD 2000 7th Edition does not require that tank owner-operators redo all their calculations and retrofit relief and vacuum devices for existing storage tanks to meet the new requirements. There are no mandatory required upgrades for the existing devices if they were selected following the original AAM. OSHA has weighed in on this when new standards are introduced. Although grandfathering is acceptable, when there are any changes to the tank service or when replacement is required, the design should be based on the new standard.

Adopting the industry's consensus design requirements contained in the newest edition of API 2000 seems valuable, and since compromising the most sensitive tanks could highly affect related units' turndown, operational flexibility, and possibly the business continuity, it is recommended to plan the review of your facility's PRDs to ensure there are no major gaps. After all, the cost involved in identifying and replacing these devices is negligible when compared to the resources and time involved in recommissioning a damaged tank.

E²G can provide support with a risk-based approach to your tanks' PRDs, to show where you are more susceptible and where the higher risks are located within your facilities. With this valuable information at hand, you could properly address any relief requirement and define short-term mitigation actions that could be of financial interest for your business. Do consider that, aside from API STD 2000 changes, any other service change (product, pumps in/out, "to," "from," pipe/valves) could also imply an undetected relief requirement change.

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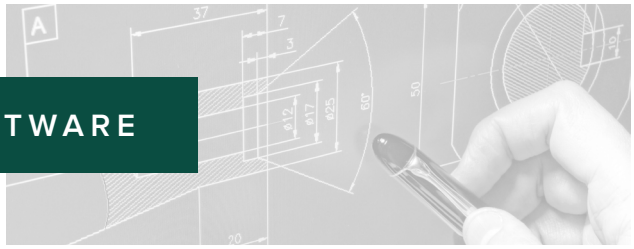

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