ASTM Industry Heat Transfer Program Discrepancies and Path Forward

Cameo Paper

Presented at the Brimstone Sulfur Symposium

September 8-12, 2025 at Vail, Colorado

By

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** Due to significant confusion in the marketplace concerning various "Thorpe" named entities, we are clarifying that Thorpe Specialty Services Corporation (TSSC), headquartered at 6833 Kirbyville, Houston, Texas, 77033 is the parent holding company (in USA) of J T Thorpe Company, Thorpe Plant Services, Inc., Thorpe International Services, Inc., Thorpe Engineered Products Company, and (in Canada) Clayburn Services, Ltd.

These entities can be accessed at www.ThorpePME.com.

ABSTRACT

Thorpe has long been involved in designing, installing and maintaining refractory linings in the industrial sector. Part of this effort involves performing failure studies and providing technical solutions to increase reliability on problematic, severe service lining applications such as Sulfur Recovery Unit (SRU) thermal reactors. The calculation of heat transfer through refractory linings is a critical part of the analysis and design for all kinds of industrial applications involving:

- Potential for low temperature vessel shell corrosion due to acid condensation at steel shell interface
- Potential for high temperature sulfidation corrosion
- Performance and selection of refractory materials at predicted interface temperatures
- Performance of membranes and coatings, some of which have very low allowable service temperatures
- Determination of expansion joint sizing and spacing to prevent mechanical spalling of linings and overstressing of linings and shells
- Economic assessment of lining efficiency to minimize fuel costs

Industry personnel most often utilize refractory manufacturers' heat transfer programs or other commercially available industry programs to perform these calculations. The common standard used to develop these programs is ASTM C680. Over many years and projects, Thorpe has noticed significant differences between our calculations compared to competitor calculations that we could not explain. In performing our initial investigation of commonly used manufacturer heat transfer programs available to refractory designers/users, we found significant differences between calculation outputs while using the exact same data inputs. Our subsequent review of the ASTM C680-19 specification revealed numerous irregularities and discrepancies between equations contained in the standard versus the program source code found in the Appendix. There were also significant confusing issues within the text regarding the proper use of characteristic dimensions in determining overall convection coefficients.

Inconsistencies in output between the various programs on the market are problematic for many reasons, including:

- Potential for unreliable lining design, including potential catastrophic failures.
- Inappropriate technical and commercial decisions resulting from erroneous calculation results.

Our motivation for this internal study was driven by problems experienced in technical review of Thorpe versus competitor designs as shared by prospective purchasers. Some of these recommendations did not make sense to us based upon our internal thermal calculations. Thorpe brought these findings to the attention of the API SCRM (Subcommittee on Refractory

Materials) in Spring 2022. This API Refractory committee agreed in the desire to improve on the guidance and accuracy of these essential refractory calculations. Thus, the process to understand the reasons for variability and to officially rewrite the old C680 standard began in May 2022 with the establishment of an API Task Group. This rewrite effort was only focused on correcting the mistakes and confusing methodology found in ASTM C680-19.

Please note that this effort is not an attempt to validate refractory material thermal conductivity K-values but only to clarify the ASTM C-680 methodology, equations and instructions. Thorpe and the API Refractory Group agree that the variability in the manufacturers' published product K-values is a legitimate and ongoing problem for the industry which has yet to be addressed. Some of this variability is due to the multitude of different test methods used to develop K-values. Individual product K-value determination is a completely different and wider ranging problem than the current re-writing of ASTM C680. Therefore, in order to prevent K-value variability, the API Task Group adopted identical K-value inputs for all the various refractory layers.

In agreement with Thorpe, the group discovered that while the equations of the written portion of the C680-19 version are correct, the suggested programming code detailed in the Appendix has numerous errors. For this reason, the program code has been completely removed. The group also recognized much confusion regarding the use of the characteristic dimension in calculating convective heat transfer coefficients and then appropriately combining the effects of forced and natural convection. While not a focus of the study, it was noted that many of the heat transfer programs commonly used were outdated and not aligned with the with numerous C680 updates and some did not even allow for input of some of the required user data.

While commonly used as the standard for steady state heat transfer calculations for refractory lining design, the C680 standard is governed by ASTM C16 Committee for Thermal Insulation. Several API members made numerous attempts to reach appropriate ASTM C16 committee members but there were no responses received over the period of a year.

In rewriting the text portion of the standard to provide needed clarity, an Annex was also added to illustrate the appropriate characteristic dimensions and convection equations for each of the five surface geometries / orientations.

Upon development and completion of a new draft standard, the Task Group embarked on validating the content, as follows:

- Twenty separate validation cases were developed using the five different equipment configurations discussed in the standard.
- Each configuration has different material inputs and operating inputs.
- The 20 validation cases were completed by two independent companies utilizing different software methods and programming languages. All 20 cases resulted in identical results giving full confidence in the proposed methodology.

- A proposed Annex illustrating these 20 cases will be included in the standard, allowing future programmers to check their work incrementally. This is basically a "Go/No Go" test to confirm accuracy during the development of a user program.
- Currently, there are only two software programs that have been fully validated using the newly proposed standard: Thorpe Specialty Services Corporation's program (currently used only internally) and Simutherm.

As of August 2025, the proposed API Technical Report 985 has been submitted to API staff for review, editing, formatting and preparation for balloting. API balloting is expected in Fall 2025 with publication in 2026.

Simultaneously, ASTM C08.02 Subcommittee on Refractory Thermal Properties has approved the development of a new standard, intended to replace C680 and focused on refractory materials. ASTM will use the proposed API TR 985 in the creation of its own new standard. The new ASTM standard name designation is forthcoming.

It is important to note that historically the C680 programs have often been inappropriately utilized to calculate shrouded heat transfers for equipment such as SRU thermal reactors. This is not recommended as the C680 programs are not intended or developed for such complex calculations. Shrouding changes all of the external convective and radiant calculations which are not included in the C680 programs. To properly calculate thermal behavior for shrouded vessels requires special programs such as Thorpe's proprietary program. This was developed specifically for horizontal cylindrical shrouded units such as thermal reactors. As a single thermal system, critical factors can be entered and manipulated from the internal refractory lining through the External Thermal Protection System (ETPS) which includes all of the convective and radiant heat loss variables involved in order to calculate and determine an optimal thermal design.

The C680 programs are still critical to SRUs due to the high and low temperature corrosion points for unshrouded thermal reactors and other equipment including outlet channels and ducts, catalyst bed reactors, incinerators, etc. It is important to point out that even with correct thermal calculations, heat transfer is never an exact science. Differences between calculated results and field measurements will always exist due to many factors, including assumed surface emissivities, use of incorrect product thermal conductivity K-values (which can also be impacted by material installation methods), the proximity of adjacent equipment affecting ambient conditions, non-uniform or wrongly assumed internal operating temperatures, proximity of heat sinks welded to the vessel shell exterior, etc.,…….and very importantly, the skill and knowledge of the program user in correctly sorting all these variables. Despite all these things, we believe this is a significant step towards improving thermal programs for many industry applications.