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Engineering Notes

ENGINEERING NOTES are short manuscripts describing new developments or important results of a preliminary nature. These Notes should not exceed 2500 words (where a figure or table counts as 200 words). Following informal review by the Editors, they may be published within a few months of the date of receipt. Style requirements are the same as for regular contributions (see inside back cover).

Aerospace Materials Property Database (TPS*X*)

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I. Introduction

RESEARCH toward design of the next generation of crew exploration vehicles, spacecraft, rockets, and aircraft has led to the development of a large array of advanced thermal protection system (TPS) materials. It can be a difficult and time-consuming task to stay informed about new material developments, to keep track of the performance of new materials in comparison with older materials, and to disseminate data on new materials to all interested parties. From a programmatic point of view, it has also become difficult to ensure that researchers and engineers conducting concurrent work at different government, industrial, and academic institutions are all using the same sets of material properties in their analyses.

To address these issues, a Web-based system for storing, organizing, and accessing all pertinent information about TPS materials was developed. This system, called the TPS*X* Material Properties Database [1], was designed to be a high-quality source for TPS material properties, presented in a convenient and easily accessible form for use by engineers and researchers in the field of high-speed-vehicle design. Researchers involved in a wide variety of materials applications also have found the program and data to be useful tools. TPS*X* currently has over 4500 registered users, who represent every NASA center and many aerospace companies, colleges, universities, and U.S. government laboratories.

II. TPS*X* History

The concept for TPS*X* was originally proposed in early 1992. Work began in earnest in 1993 with the development of a Microsoft Windows-based application written in Microsoft Visual Basic [2]. Figure 1 is a screen shot of the program. In 1994, the first version of the TPS*X* application was released. Originally called the Thermal Protection Systems Expert and Material Property Database, abbreviated as TPS*X*, the name was eventually shortened to TPS*X* Material Property Database, as the database expanded to include more than just TPS materials. At the same time, a TPS*X* Web site was created solely for the purpose of distributing the software and providing updates and news.

The initial release of TPS*X* included two material databases. The first database included a limited set of TPS materials used and/or developed by the NASA Ames Research Center [3], and the second database was compiled by the NASA Johnson Space Center (JSC) [4]. A third database [5] was added shortly after that. By 1997, TPS*X* had over 280 registered users and the first Web-based edition of TPS*X* (version 1.0) was online. The online version included a limited set of the features of the Windows-based version. By the year 2000, TPS*X* had over 1000 registered users and version 2.0 of the Web-based edition was online. The Web version included improved functionality and was entirely based on interactive scripts: no static Web pages. A user survey conducted that same year found that most TPS*X* users preferred the (platform-neutral) Web-based version of the database to the standalone Windows application. As a result of the survey, further development of the Windows applications was discontinued, and that application is no longer distributed. In the summer of 2000, a major upgrade to the TPS*X* Web version was undertaken. The purpose of the upgrade was to improve the user interface, to add advanced material search functions, to add the capability to export material data sets in formats suitable for analysis software, to create a database submission process, and to add a new carbon–carbon material database compiled by the NASA Langley Research Center [6]. These upgrades were completed in August 2000 and version 3.0 of the TPS*X* database was online.

A major three-year upgrade project began in 2001. The focus of this upgrade project was to improve the fidelity and accuracy of the existing material property data and to identify potential new materials that could be added to TPS*X*. As a result of this upgrade, many errors were corrected and some questionable data were removed. All of the data are now tied directly to a published reference, and some data include an uncertainty magnitude and a source of the uncertainty. Version 4.0 of TPS*X* was released at the end of the three-year upgrade program in 2003. Incremental improvements continue to be made on the database functionality. TPS*X* now has over 4500 registered users from around the world.

III. TPS*X* Databases

Version 4.2 of the TPS*X* database is now accessible [1] (Fig. 2). TPS*X* includes four individual material databases. The first is the original NASA Ames Thermal Protection Materials database, which contains over 70 TPS materials, including ablators, adhesives, carbon-based ceramic composites, flexible blankets, metals, reusable rigid ceramic insulators, structural organic composites, and ultra-high-temperature ceramics. These data come from various published sources that are listed in the database. This database is by far the most comprehensive of all the databases in TPS*X*. It includes temperature-dependent thermal and mechanical properties of many of the materials. Some of the shuttle-era TPS materials also include some cost-estimation information [3]. The property data are periodically updated and expanded as required to include newly developed materials and refinements to the material property data. A description

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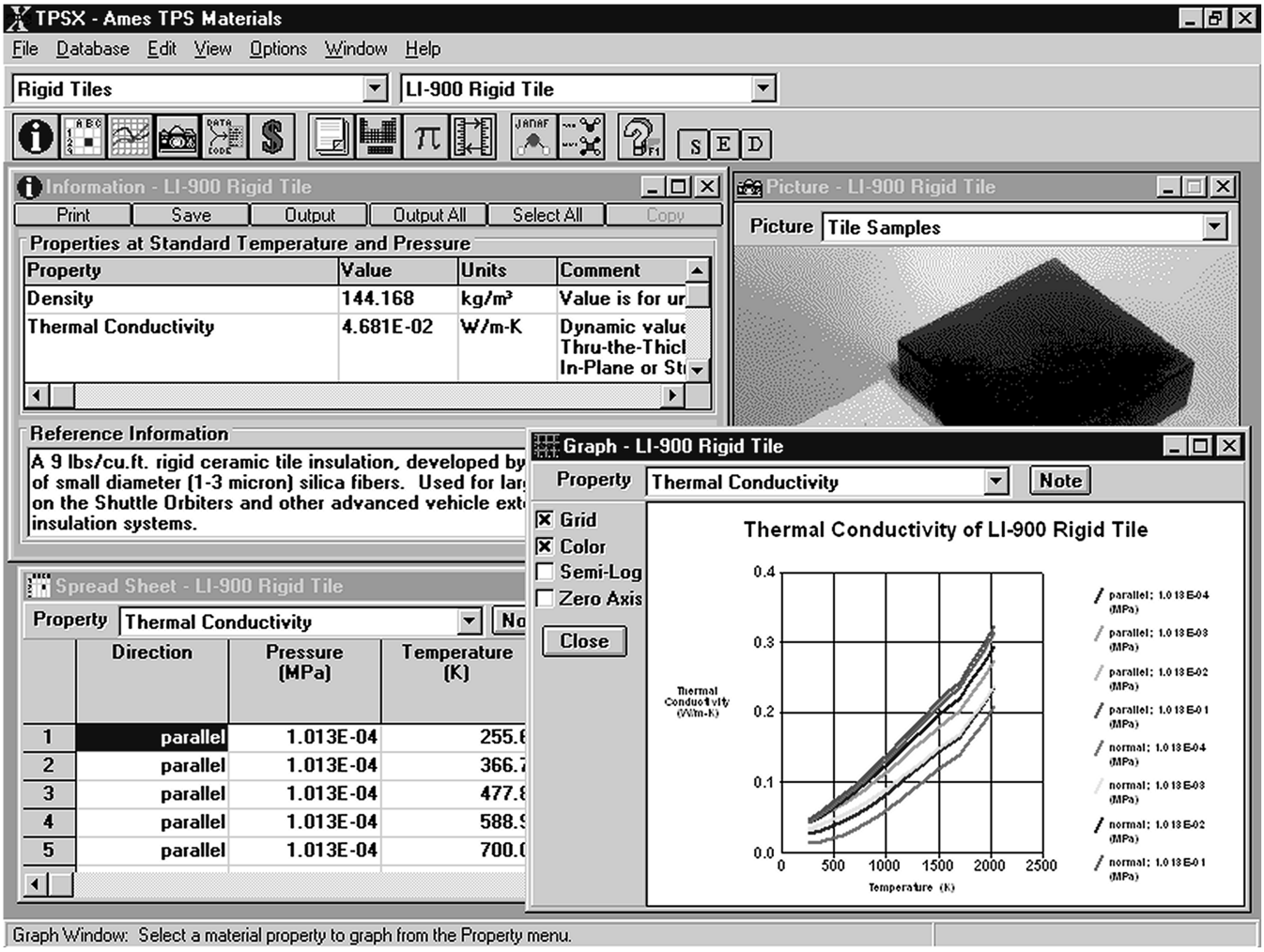

Fig. 1 TPS*X* Windows application.

of each material, including references, common applications, and a responsible point of contact are provided. Photographs and sketches of some materials are also included.

The second database, NASA JSC Pathfinder Materials, consists of materials compiled by the NASA Johnson Space Center [4]. The JSC database contains over 180 TPS materials, including ablators, adhesives, ceramic insulators, metals, pyrolyzers, and structural materials. This database is primarily a historical archive of materials and thermal property data, compiled from journal and conference articles and reports published from 1960 to 1989. It includes many of the materials used on the shuttle system. Some of the materials are no longer manufactured and no points of contact are provided. This database does not include mechanical properties.

The third database is the set of materials provided in [5] that includes limited thermal data on over 1100 materials. The data are limited to room-temperature values of density, thermal conductivity, and specific heat. This database includes many metal alloys, ceramic compounds, glass and quartz, plastics, wood, and even some gases at standard temperature and pressure.

The fourth database includes over 140 materials compiled by the NASA Langley Research Center. This database includes carbon-based reusable materials, adhesives, structural metals, and high-temperature insulators [6,7]. It also includes both thermal and mechanical properties, some as a function of temperature.

IV. TPS*X* Web Site Functionality

The TPS*X* database offers features to make accessing and using the data more convenient for users. Users can access material property data in either SI or engineering English units. Both tabular and graphical displays of data are available for properties that are temperature- and/or pressure-dependent. Examples of the data display options in TPS*X* are shown in Fig. 3.

TPS*X* also allows users to export property data sets to formats that can be imported directly by several commercial thermal and mechanical analysis software packages. The packages include MSC Patran [8], MSC Nastran Heat Transfer [9], I-deas TMG Thermal [10], SINDA/FLUINT [11], Thermal Desktop [12], ANSYS Thermal Analysis System (TAS) [13], and Thermal Synthesizer System (TSS) [14]. Most of the export routines have options for choosing the units and the set of properties to export.

The database also has several search functions that allow users to search based on material name or keyword. An additional search feature will find materials that have a specific set of properties. The user can enter a range of values for up to three properties to match. For instance, a user could search for a material with high strength but low thermal conductivity. The database automatically saves the results of the last search the user performs. Users can also create and save a list of favorite materials.

The TPS*X* home page also features a 1976 U.S. Standard Atmosphere [15] lookup function. By entering an altitude, the page displays Earth atmospheric properties (such as density, pressure, temperature, mole fraction of gas species, and more) in SI units.

V. TPS*X* Access Levels

Each TPS*X* user is required to create an account by completing the online registration form on the Web site. Two levels of access are available. The first level, worldwide access, requires users to provide only a name, e-mail address, and country. This level allows users to see all of the material descriptions and the standard room-temperature and pressure properties. Users with this level of access cannot see the temperature- or pressure-dependent property sets.

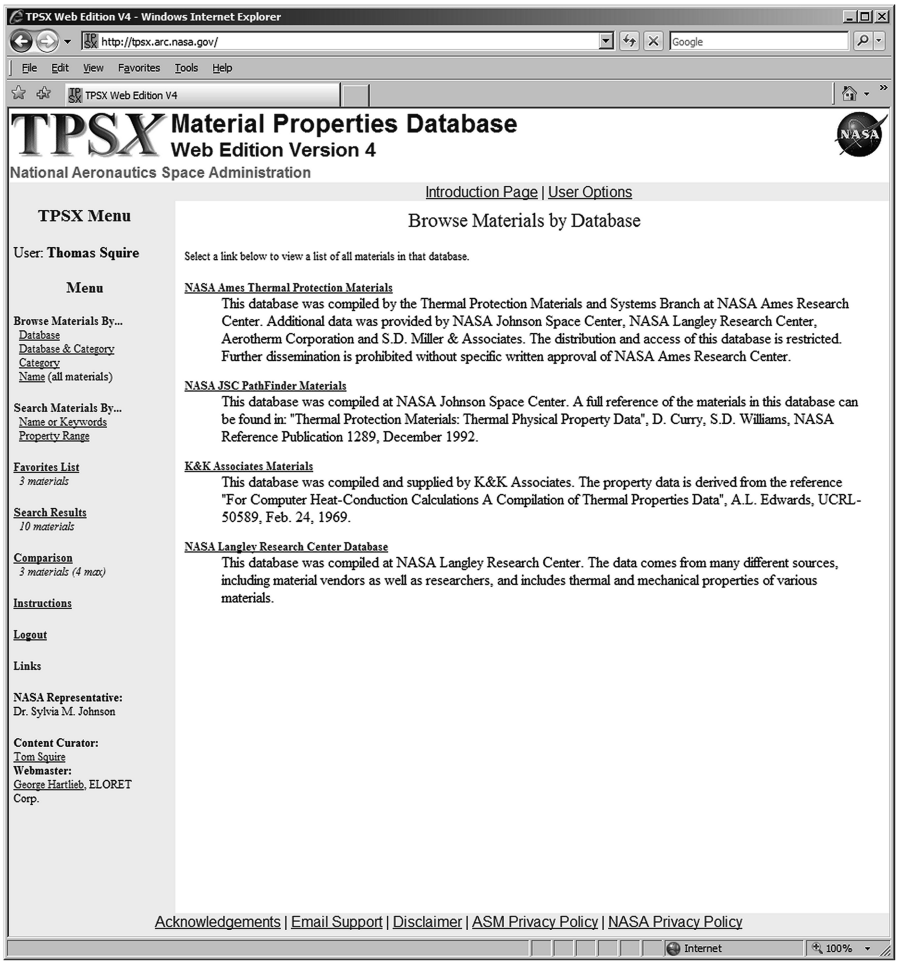

Fig. 2 TPS*X* Web site.

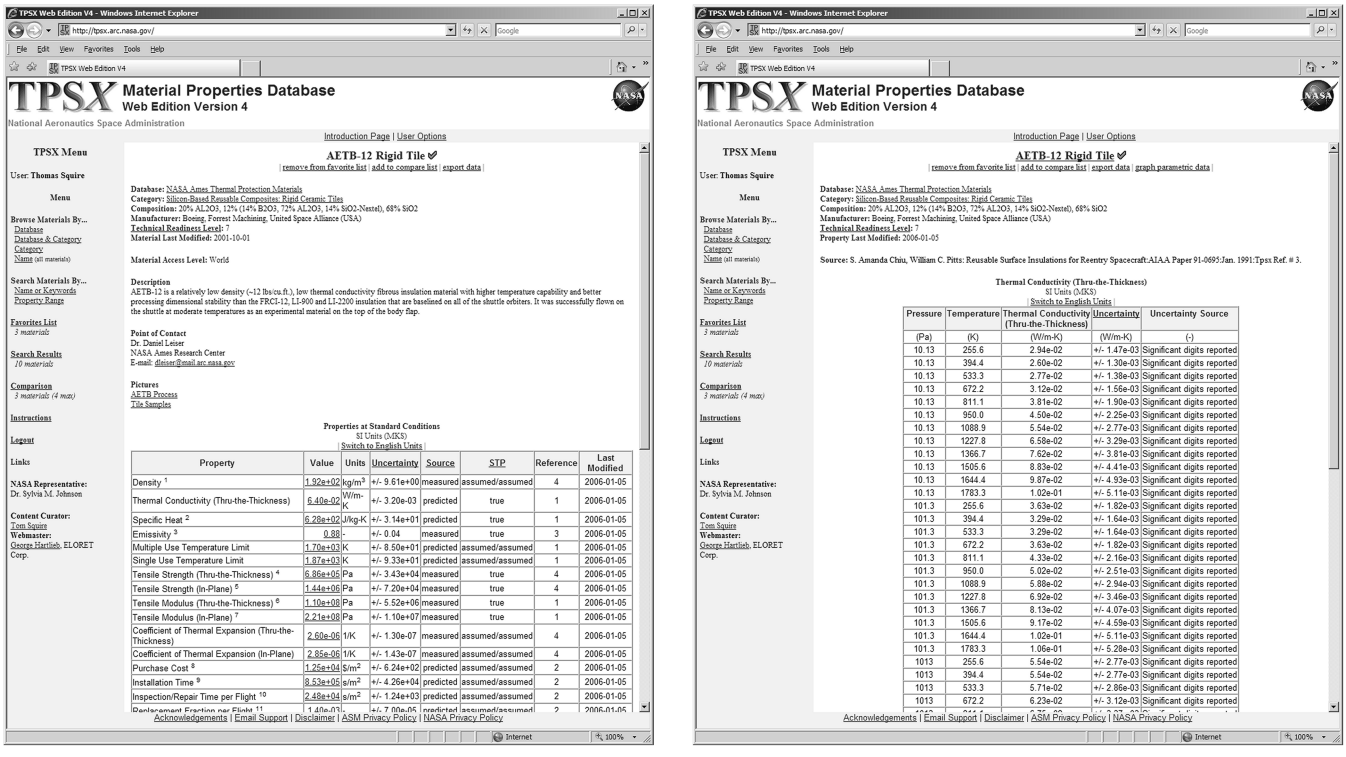

Fig. 3 TPS*X* screen shots.

They also do not have access to some of the advanced search functions and export options.

The second level of access, U.S. restricted, is limited to U.S. citizens and permanent residents. Users requesting this level of access must provide additional information and sign a form affirming their U.S. status. Users must first generate a worldwide-access account before requesting an upgrade to U.S. restricted. This level of access allows users full access to the database and functions.

VI. Conclusions

TPS*X* continues to be maintained by the staff at the NASA Ames Research Center. Most of the effort is focused on improving the performance of the database and updating the server software and hardware. We continue to seek input on possible improvements to the database, new database concepts, and corrections and updates to the existing data.

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