FACILITATING TRU WASTE TRANSPORTATION CERTIFICATION USING THE E-TRAMPAC CODE

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ABSTRACT

The Transuranic Package Transporter-II (TRUPACT-II) is a U.S. Nuclear Regulatory Commission (NRC)-approved Type B packaging for the transport of contact-handled transuranic (CH-TRU) waste. CH-TRU waste may be segregated as either "analytical category waste" or "test category waste" based on the flammable gas and flammable volatile organic compound (VOC) characteristics of the waste. CH-TRU waste containers that exceed the applicable decay heat limits set for the analytical category, and/or have a total concentration of potentially flammable VOCs that exceeds 500 parts per million, or that do not have an established wattage limit, belong in the "test category." A revised methodology for the shipment of test category waste has been developed for submittal to the NRC for approval as part of a TRUPACT-II Safety Analysis Report (SAR) amendment. The methodology provides the technical basis for determining whether a test category payload container demonstrates compliance with the flammable gas generation and concentration requirements and integrates the results of several U.S. Department of Energy initiatives to expand the TRUPACT-II payload. The methodology is comprised of three distinct evaluations: (1) analysis, (2) measurement, and (3) testing of individual containers.

The electronic TRUPACT-II Authorized Methods for Payload Control (e-TRAMPAC) is a Windows-based computer code written in Visual Basic and designed to facilitate compliance evaluations for both individual payload containers and a payload assembly. The software assesses the properties of the container or assembly, calculates necessary parameters, performs the computations of the methodology, and determines the compliance status of a waste container and a payload assembly. The code obtains the necessary data from the e-TRAMPAC database, which is derived from a site's TRU waste database, with a container identification number being the only operator input allowed. The program incorporates the results and methodologies of several payload expansion initiatives, including:

- The Matrix Depletion Program to provide more accurate flammable gas generation potential for different matrices
- The Flammability Assessment Methodology Program to predict lower explosive limits of mixtures of flammable gases and VOCs
- The AltMeth initiative, an alternative method of certifying TRU waste containers based on measuring flammable gas and VOC concentrations
- The MixCat initiative, which provides for mixing of TRUPACT-II shipping categories
- The use of better filters with higher hydrogen diffusivity values.

This paper presents the rationale, structure, methodology, data requirements, and benefits of the e-TRAMPAC code. It is anticipated that the implementation of this code and the revised TRUPACT-II SAR will result in qualification of a large fraction of the CH-TRU waste inventory that cannot currently be shipped. This revised logic will result in cost savings by decreasing the need for repackaging or full-scale drum testing. Additional savings will be realized by the improved efficiencies provided by the e-TRAMPAC. In addition, use of the e-TRAMPAC minimizes the potential for operator error in evaluating compliance.

BACKGROUND

The Transuranic Package Transporter-II (TRUPACT-II) is a Type B shipping package designed primarily for transporting contact-handled transuranic (CH-TRU) waste containers from various U.S. Department of Energy from (DOE) sites to the Waste Isolation Pilot Plant (WIPP) for permanent disposal. A detailed Safety Analysis Report (SAR) for the TRUPACT-II was submitted to the U.S. Nuclear Regulatory Commission (NRC), in response to which the NRC issued a Certificate of Compliance (C of C) for the TRUPACT-II in 1989 (1). The C of C defines the authorized payloads that can be safely transported in the TRUPACT-II and lists the requirements that need to be met by the payloads. The key factors determining CH-TRU waste shippability in the TRUPACT-II are as follows:

- Size and shape limits on the payload containers
- Weight limits on the payload containers and the package
- Fissile gram equivalent (FGE) limits on the payload containers and the package
- Flammable gas generation and decay heat limits on the payload containers and the package
- Authorized content limits based on descriptions in the TRUPACT-II Content Codes (TRUCON) document (2).

Since its initial issuance in 1989, the TRUPACT-II C of C has been revised ten times, primarily to expand the shippable payload envelope based on additional test data and analysis addressing some of the above factors. This payload expansion, as summarized in the TRUPACT-II Payload Expansion Plan (3), is an important factor in filling the WIPP pipeline in a timely manner and ensuring shippability of all CH-TRU waste to the WIPP. The C of C revisions are based on SAR amendments that have been approved by the NRC. The application for Revision 18 of the TRUPACT-II SAR is currently being reviewed by the NRC.

PROBLEM STATEMENT

A primary transportation requirement for the TRUPACT-II is that the concentration of potentially flammable gases (primarily hydrogen) must not exceed 5 percent by volume within the waste and within the TRUPACT-II package during a maximum 60-day period during which the TRUPACT-II is assumed to be sealed (4). Decomposition of waste materials by radiation is the predominant mechanism of hydrogen gas generation during transport. The gas generation potential of a target waste material is characterized by a G value, which is the number of molecules of gas generated per 100 electron volts of ionizing radiation absorbed.

To demonstrate compliance with the flammable gas concentration requirement, theoretical worst-case calculations were performed to establish allowable flammable gas generation rates for each waste container of CH-TRU waste. Allowable decay heat (wattage) limits were then calculated for each container by combining the allowable flammable gas generation rates with the G value for the waste material having the highest potential for flammable gas generation. Containers that meet the decay heat limits fall into the "analytical category." Containers that exceed the decay heat limits, or that do not have a bounding G value, fall into the "test category" and can be shipped only if tested individually for their gas generation potential. In addition, containers that have flammable VOC concentrations greater than 500 parts per million (ppm) in the headspace cannot be shipped in the TRUPACT-II (4).

Based on these allowable wattage limits, it is estimated that a large portion (~35%) of the existing CH-TRU waste containers belong to the test category and cannot be shipped. These include waste containers with high levels of Pu-239 (e.g., residue waste forms), wastes contaminated with Pu-238 (a high-activity isotope), and solidified organic wastes (that do not have an established bounding G value). Several programs and initiatives have been designed in the recent past to improve the percentage of shippable waste by providing alternative methods of determining the gas generation potential of a container. These payload expansion initiatives are expected to constitute the application for Revision 19 of the TRUPACT-II SAR, which will be submitted to the NRC in early 2000, and include the following:

- The TRUPACT-II Matrix Depletion Program (MDP) was established with the objective to investigate the phenomena of matrix depletion to support more realistic, dose-dependent G values (5). The MDP is comprised of experiments designed to examine the behavior of effective G values over time for different waste materials. The experimental data were evaluated in conjunction with waste container headspace gas sampling data and predictive modeling to formulate bounding effective G values for each waste material.

- The objective of the Flammability Assessment Methodology Program (FAMP) is to increase the allowable concentrations of flammable volatile organic compounds (VOCs) by investigating the potential flammability of headspace gases within TRU waste drums (6). The approach includes experimental work to determine mixture lower explosive limits (MLELs) for the types of gas mixtures observed in TRU waste; a model for predicting the MLELs for mixtures of VOCs, hydrogen, and methane; and revised screening limits for flammable headspace gases based on measured drum headspace gas data and model predictions. The FAMP allows shipment of containers with flammable VOC concentrations greater than 500 ppm.

- The AltMeth Program uses container headspace flammable gas sampling data, confinement layer data, and container properties to calculate an initial estimate and a range of flammable gas generation rates by taking the product of the headspace flammable gas concentration and the leakage rate of flammable gas across the container (7). The differential equations describing the unsteady-state mass balances that account for the generation, accumulation, and transport of flammable gas across layers of confinement and flammable gas within each confinement layer are solved iteratively until the predicted flammable gas generation rate provides a headspace flammable gas concentration that matches the sampled headspace gas

concentration. The AltMeth Program provides simple headspace sampling as an alternative to full-scale drum testing over a prolonged time period.

- The Mixing of TRUPACT-II Shipping Categories initiative (MixCat) extends the TRUPACT-II calculational methodology to arrive at a decay heat limit for each payload container, allowing mixing of shipping categories within a payload, with the constraint that each container satisfies the new container-specific wattage limits (8). Individual container decay heat limits are also increased by taking credit for the additional void volumes of dunnage containers, if present.

- The use of improved filters with greater diffusivities allows greater release of flammable gas from the waste containers and could result in increases of the wattage limits depending upon the number of layers of confinement.

- The Flammability Index (FI) is a measure of the flammable gas/VOC generation potential of each container in a selected payload. As long as the FI is below 50,000 (5%) for all containers in a payload, all requirements with flammable gas and VOC limits are met, indicating that no flammable gas/VOC mixtures exist in the payload.

Table I summarizes the major initiatives to be included in the application for Revision 19 of the TRUPACT-II SAR and the benefit from each initiative. Figure 1 presents the logic for evaluating compliance with flammable gas generation limits in CH-TRU waste containers and the options available to demonstrate compliance under the proposed Revision 19 of the SAR. The detailed logic and methodology for integrated application of these initiatives and programs will be described in the application to the NRC.

Table I. Payload Expansion Initiatives Proposed in Revision 19 of the TRUPACT-II SAR

Initiative	Benefit
Matrix Depletion Program	Increases wattage limits by 3 to 5 times
Flammability Assessment Methodology Program	Allows shipment of containers with greater than 500 ppm flammable VOC concentrations
AltMeth Program	Allows waste qualification by simple headspace measurement as opposed to full-scale drum testing
Mixing of Shipping Categories	Allows credit for dunnage containers and allows load management to meet limits
Better Filters	Increases decay heat limits
Flammability Index	Normalizes flammable gas and VOC generation potential in a container and payload

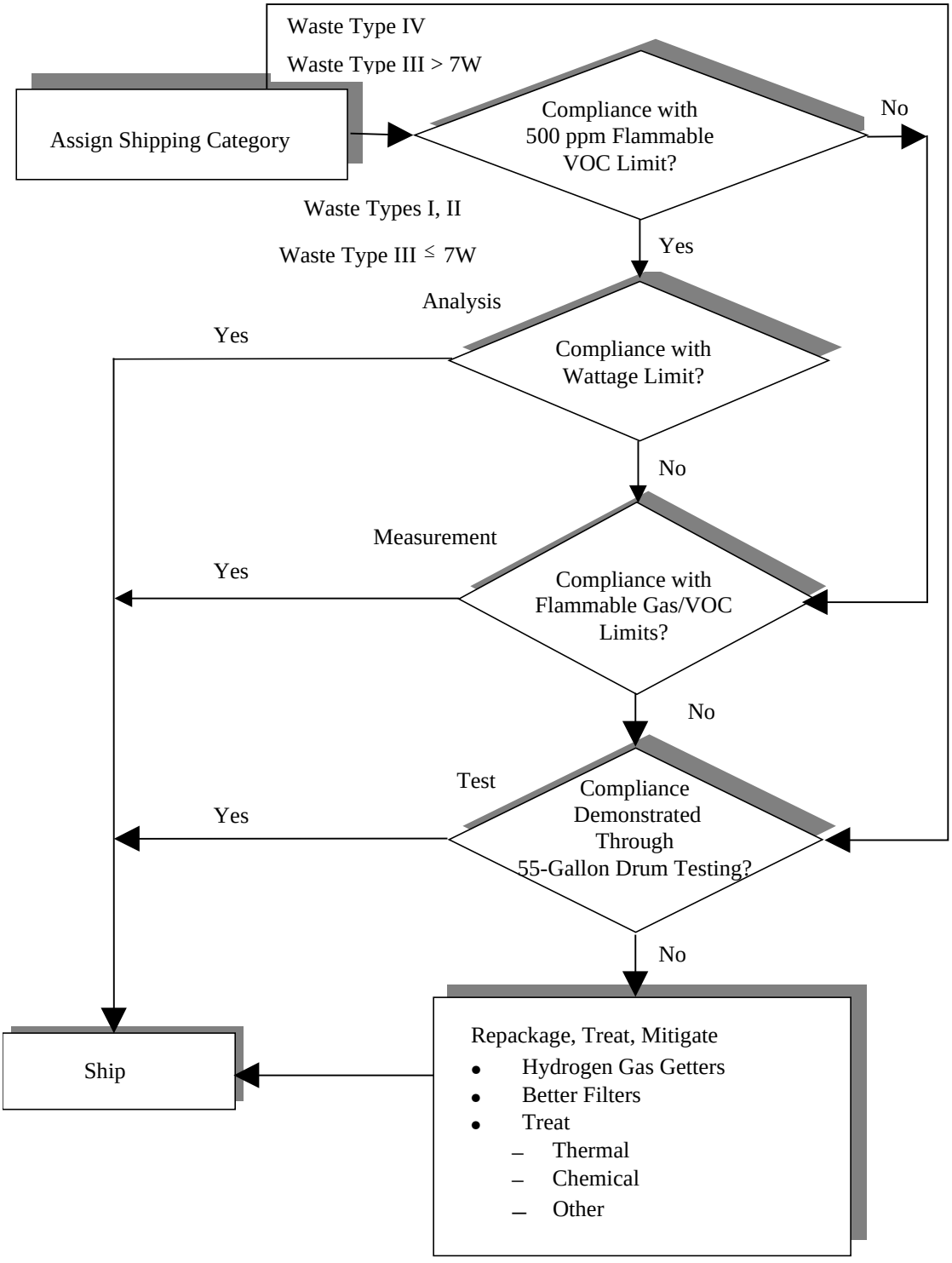


Figure 1. Methodology for Compliance with Flammable Gas/VOC Concentration Limits

Use of the unsteady-state equations in AltMeth, calculation of the MLELs in the FAMP, and application of the MixCat require the use of complex mathematical analysis and numerical solutions that are a function of headspace gas/VOC concentrations and a container packaging history. In the past, sites could determine compliance with flammable gas generation limits by means of simple look-up tables for decay heat limits. This option will still be available to the sites in the proposed Revision 19 of the TRUPACT-II SAR. However, in order to take complete advantage of the payload expansion initiatives being introduced, an automated implementation methodology that will act as a "black-box" will be required to evaluate and ensure compliance based purely on waste container properties.

SOLUTION

The electronic TRUPACT-II Authorized Methods for Payload Control (e-TRAMPAC) is a Windows-based software package that has been designed to facilitate compliance evaluations for both individual payloads and payload assemblies by expediting the various decisions and computations required to correctly implement Revision 19 of the TRUPACT-II SAR. The initiatives and programs integrated in Revision 19 are incorporated into a single code in Visual Basic with solver modules for each initiative that are executed according to the methodology outlined in Figure 1. The software assesses the properties of the container or assembly (contained at each site in a database), calculates necessary parameters, and determines the shippability status of the drum as dictated by Revision 19 logic. As the necessary data for these evaluations is a subset of the information required by the WIPP Waste Information System (WWIS), no new data requirements are imposed on the sites shipping to the WIPP. A logic diagram for the e-TRAMPAC operation is presented in Figure 2, with the logic being dictated completely by Revision 19 of the TRUPACT-II SAR.

The software has two stages of operation. In the first, individual containers are selected from a database and evaluated according to the wattage, gas generation, and transportation criteria of Revision 19. Individual payload container transportation certification documents are printed, if appropriate. In the second stage, containers that are acceptable for shipment individually are combined to create a payload. The payload can then be evaluated using the MixCat methodology. If a container causes the payload to fail shipping requirements, the user can remove it from the payload and replace it with either another waste container or a dunnage container and re-evaluate the payload. When the payload meets all transportation requirements, the payload assembly transportation certification document can be printed for signature.

Access to the e-TRAMPAC is controlled by the use of operator identification numbers and passwords. In addition, the only operator input allowed is a container identification number, with all container properties required for compliance evaluation being electronically accessed from the site database (similar to the WWIS). This ensures integrity of the data input to the e-TRAMPAC.

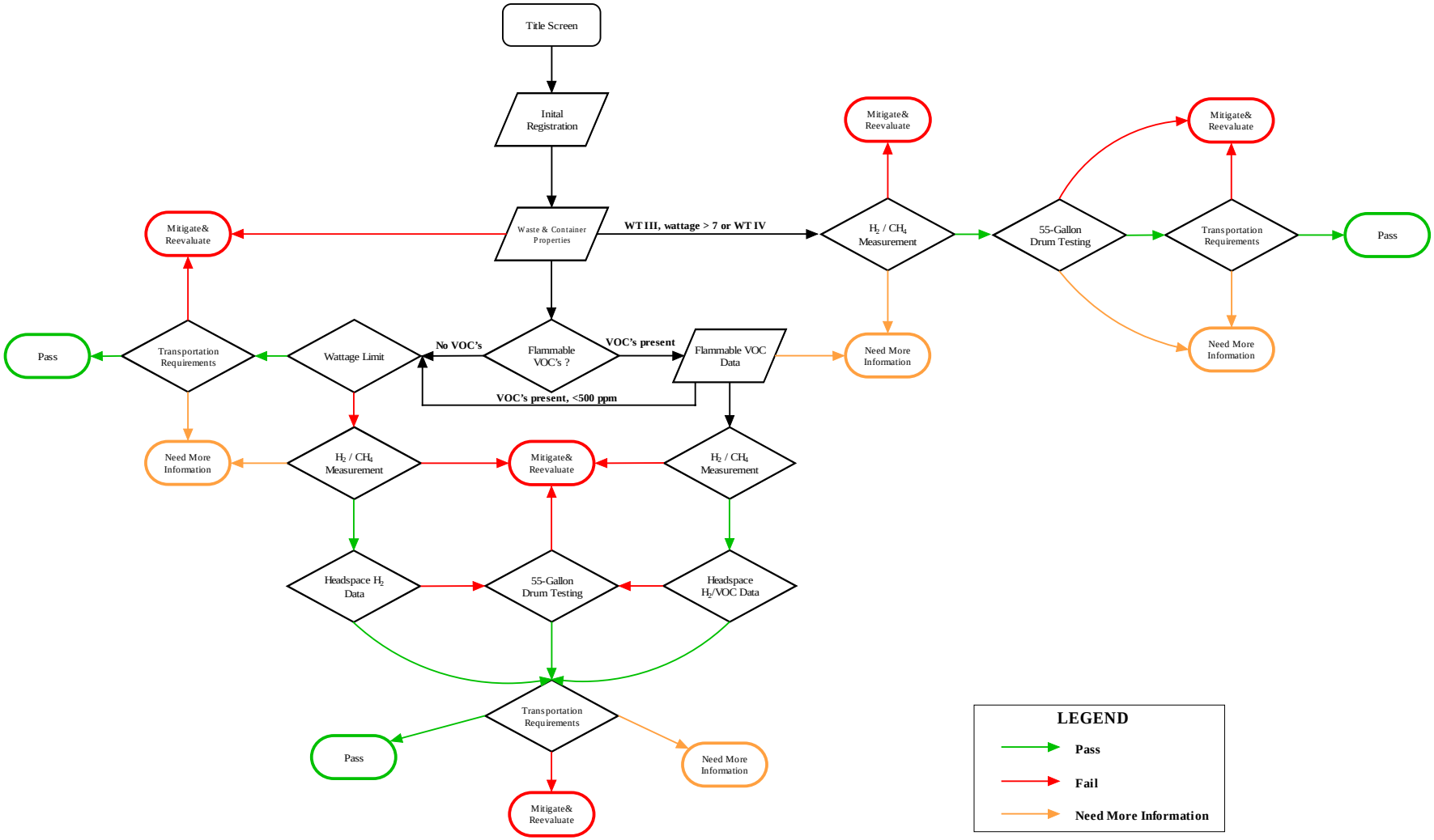


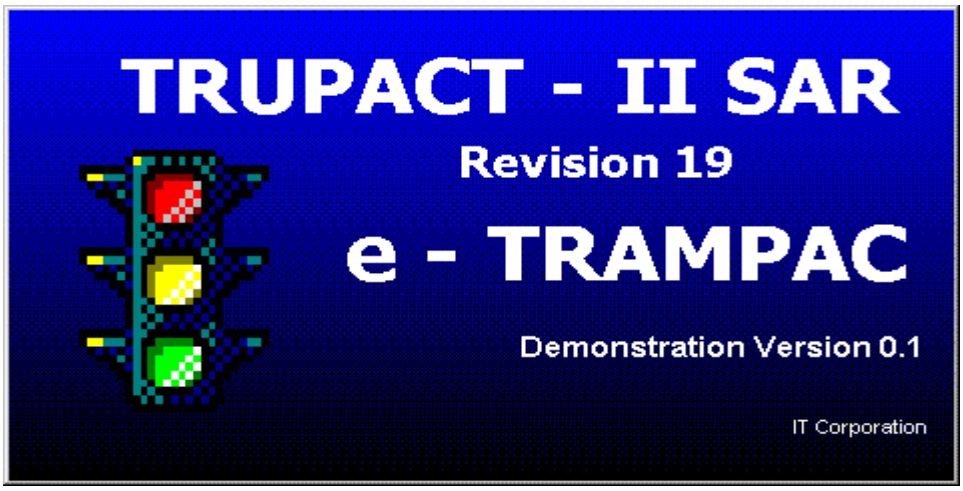
Figure 2: e-TRAMPAC Implementation Logic for Revision 19 of the TRUPACT-II SAR

A demonstration database and step-by-step instructions regarding execution of the software are provided with the application. Documentation showing the purpose and functionality of the interface and instructions for each of the buttons is provided, the decision-relevant information shown, the calculations (if any) explained, and the comparison criteria detailed. The functioning of the e-TRAMPAC is illustrated below using hypothetical drum data.

COMPLIANCE EVALUATION USING e -TRAMPAC

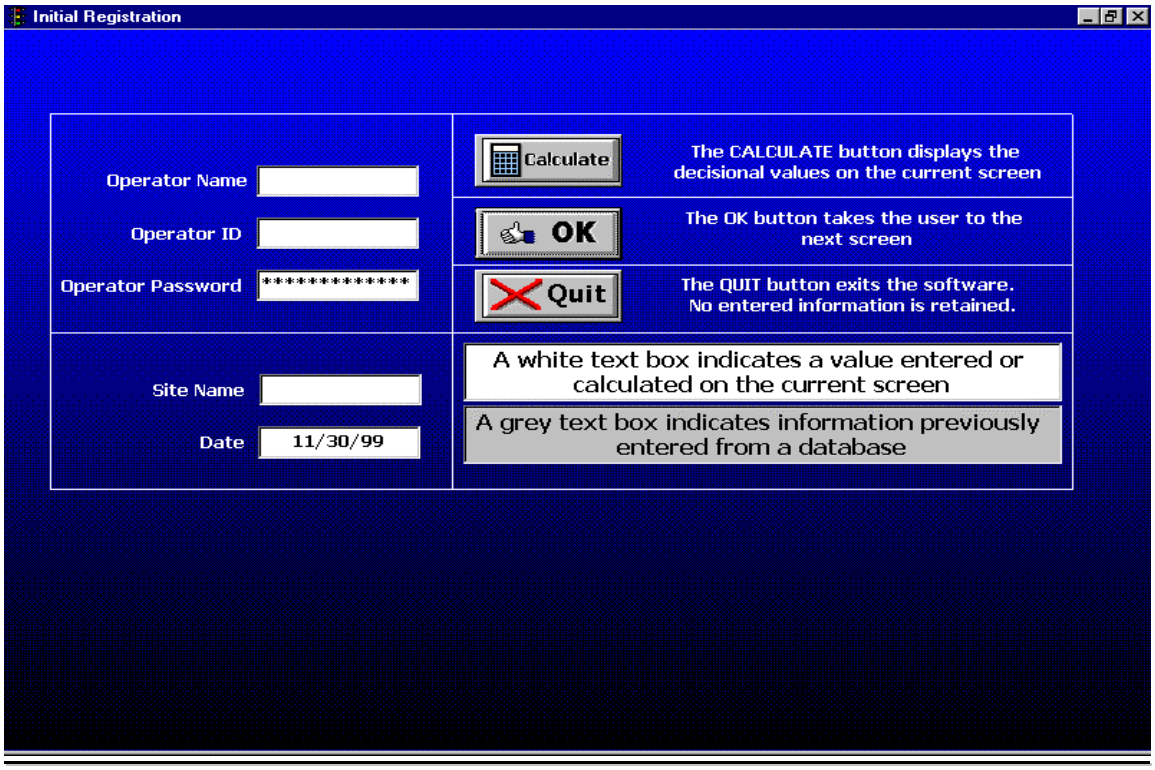
The e-TRAMPAC will be provided to users as software complying with the requirements of the Quality Assurance Program Document (9). It will be configured on a server platform, similar to the WWIS, with access limited to authorized users by means of passwords and identification numbers. Once the e-TRAMPAC is accessed, the initial screen showing the current version of the software is as follows:

Title



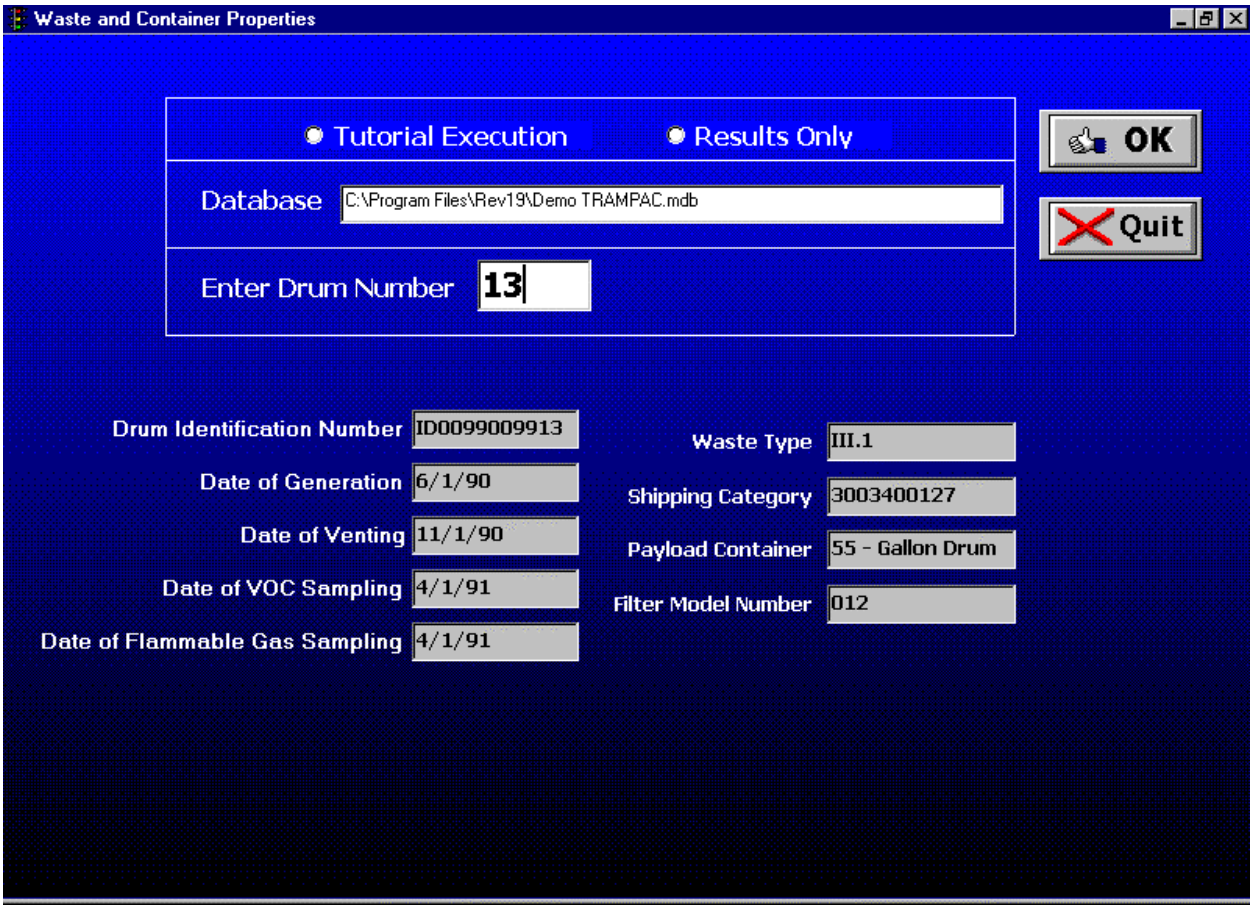
The user can click anywhere on the screen or hit any key to continue to the Initial Registration screen, as follows:

Initial Registration



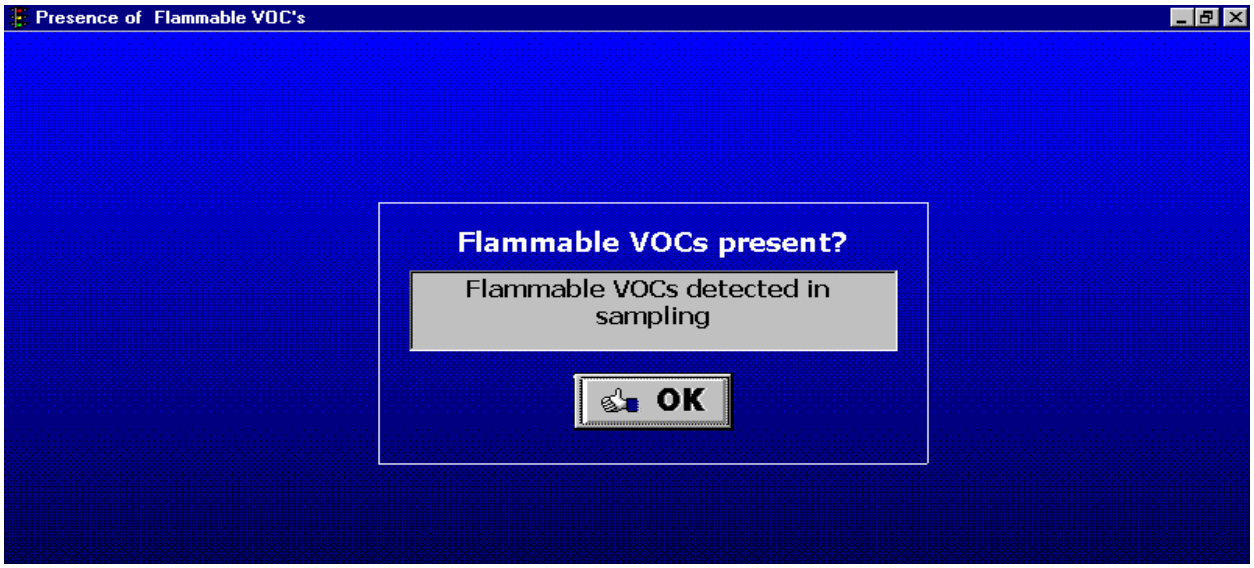
This screen is the user's only opportunity to enter data. The operator's name, identification number, and password are required, after which the OK button will advance the software to the selection of the waste container.

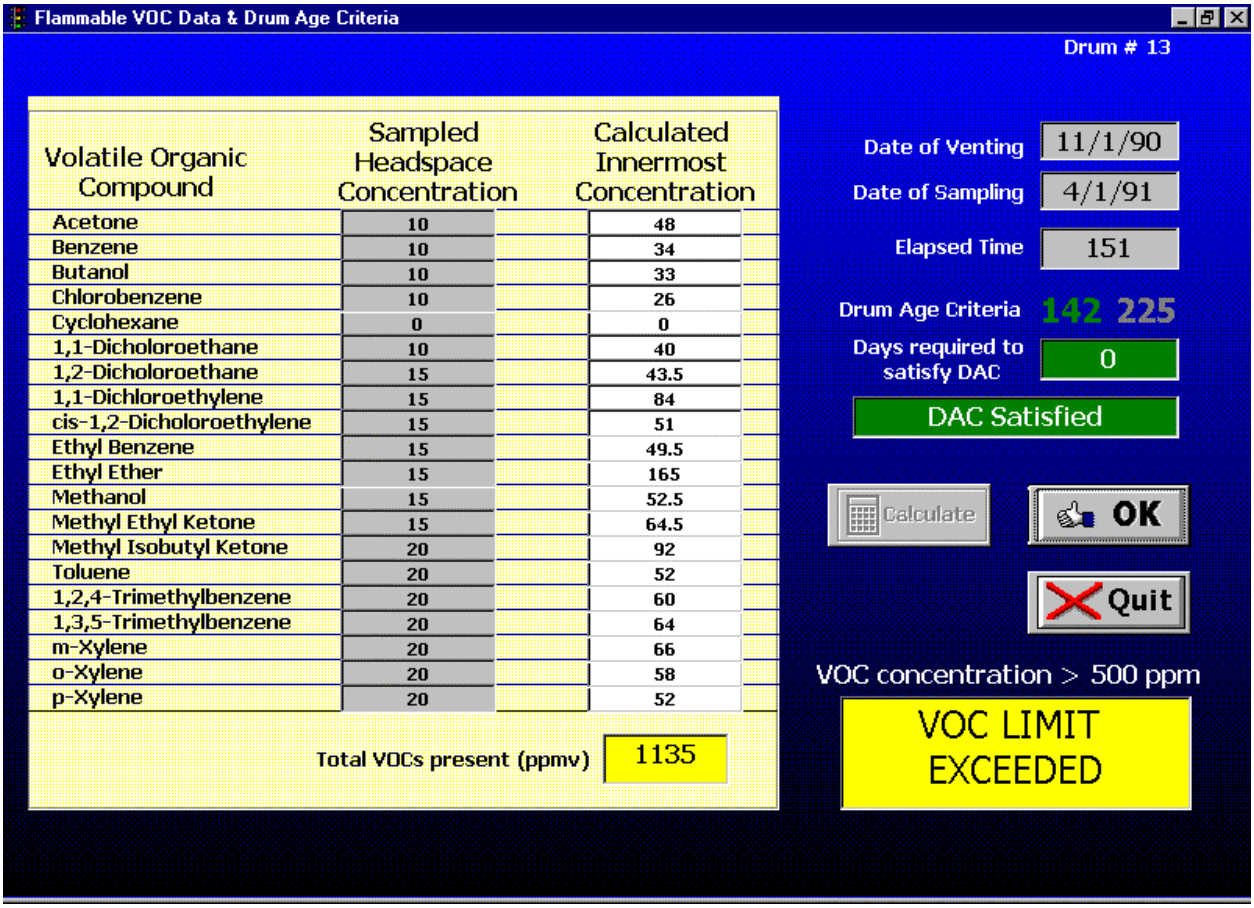
Container Properties



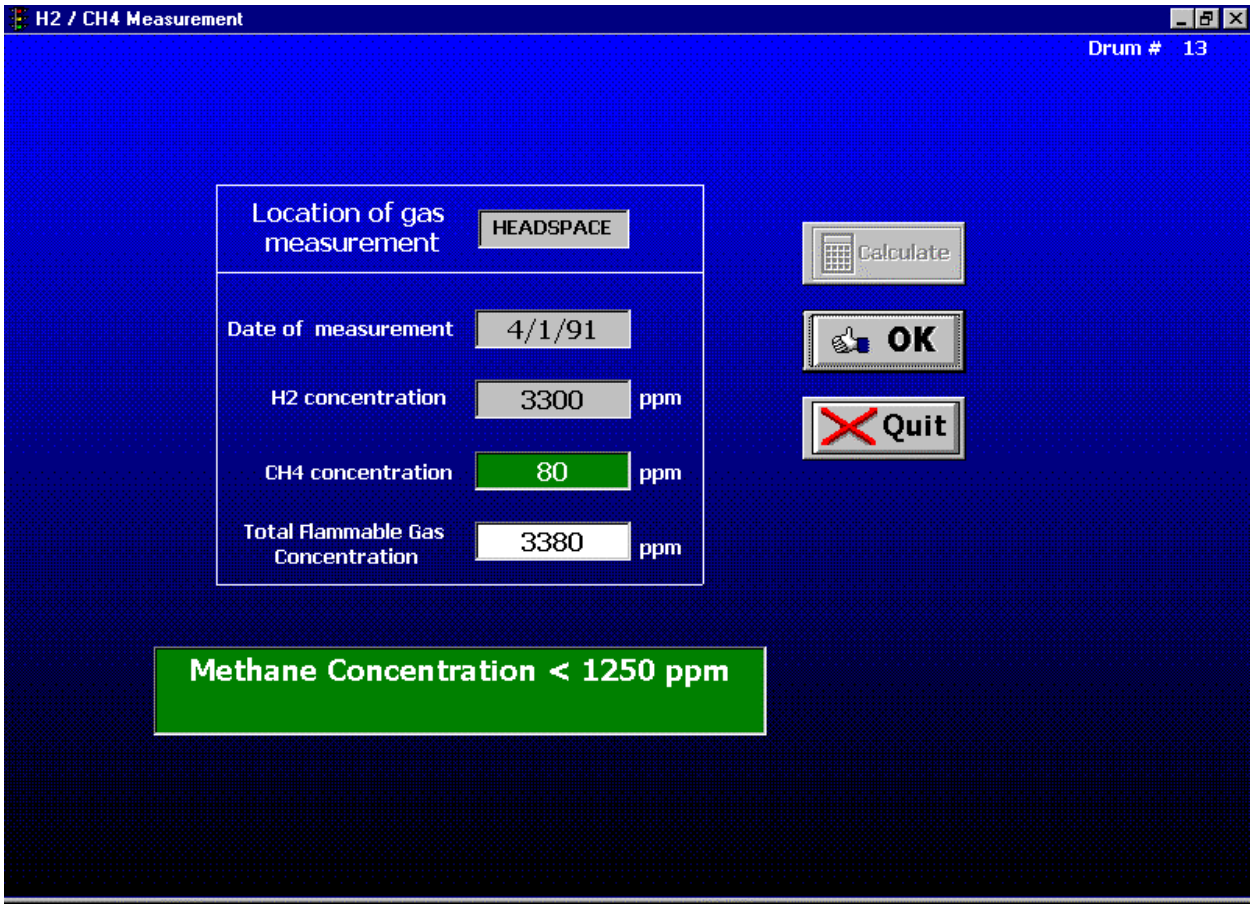
This screen allows the user to select a drum from the demonstration database or a site database linked to the e-TRAMPAC and relays basic information for that drum back to the user. Other container parameters (number of layers of confinement, etc.) are part of the container database and are used in the methodology. The **Tutorial Execution** radio button allows the user to proceed through the software in a step-by-step manner and follow the Revision 19 logic. The **Results Only** radio button takes the user directly to the payload assembly screen, with the program running through all of the compliance evaluations. Drum No. 13 from the demonstration database is selected as an example here.

The  button will advance the software to the next screens, as follows:



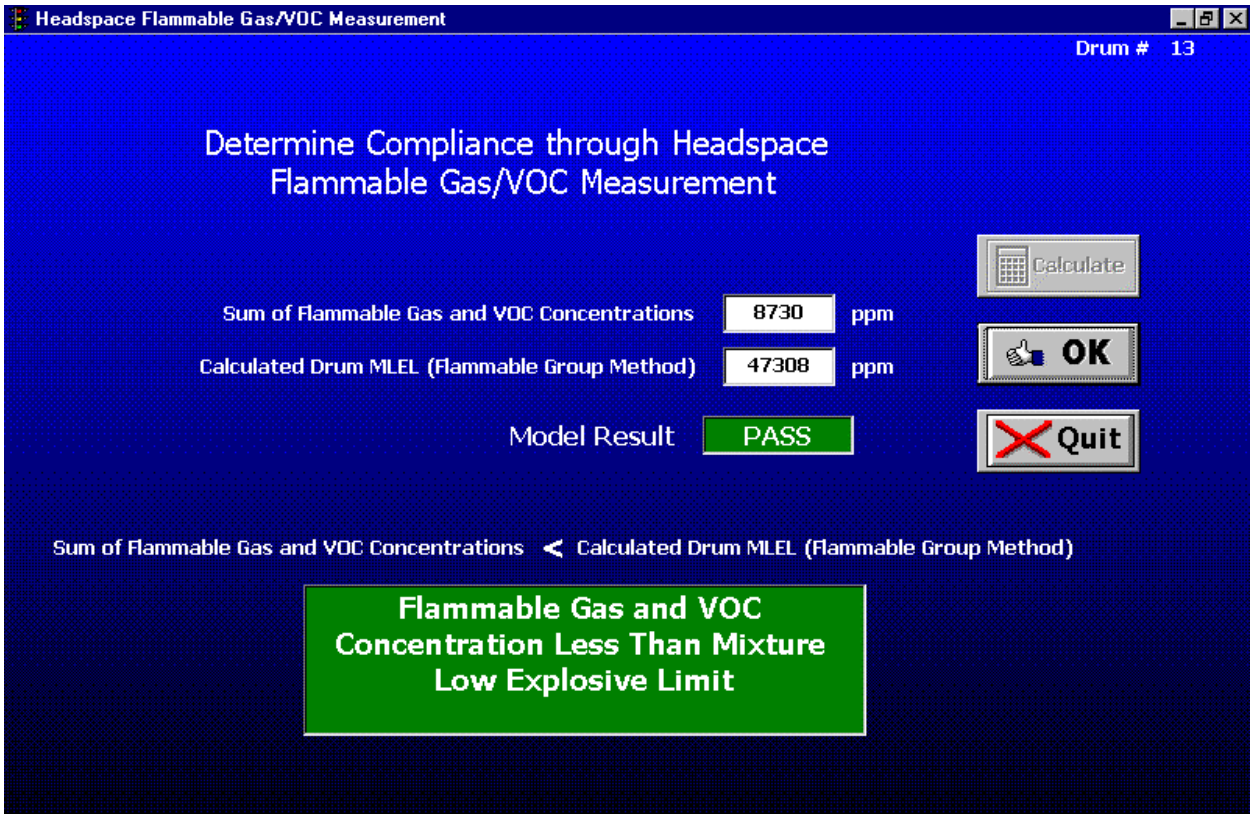


These screens check the container database for the presence of flammable VOCs and, if detected, check to ensure that the sampling has been performed after the drum age criteria has been satisfied. In addition, the code uses prediction factors to predict the total flammable VOC concentration in the innermost confinement layer. As in this case, if this number is greater than 500, the path forward is as follows:



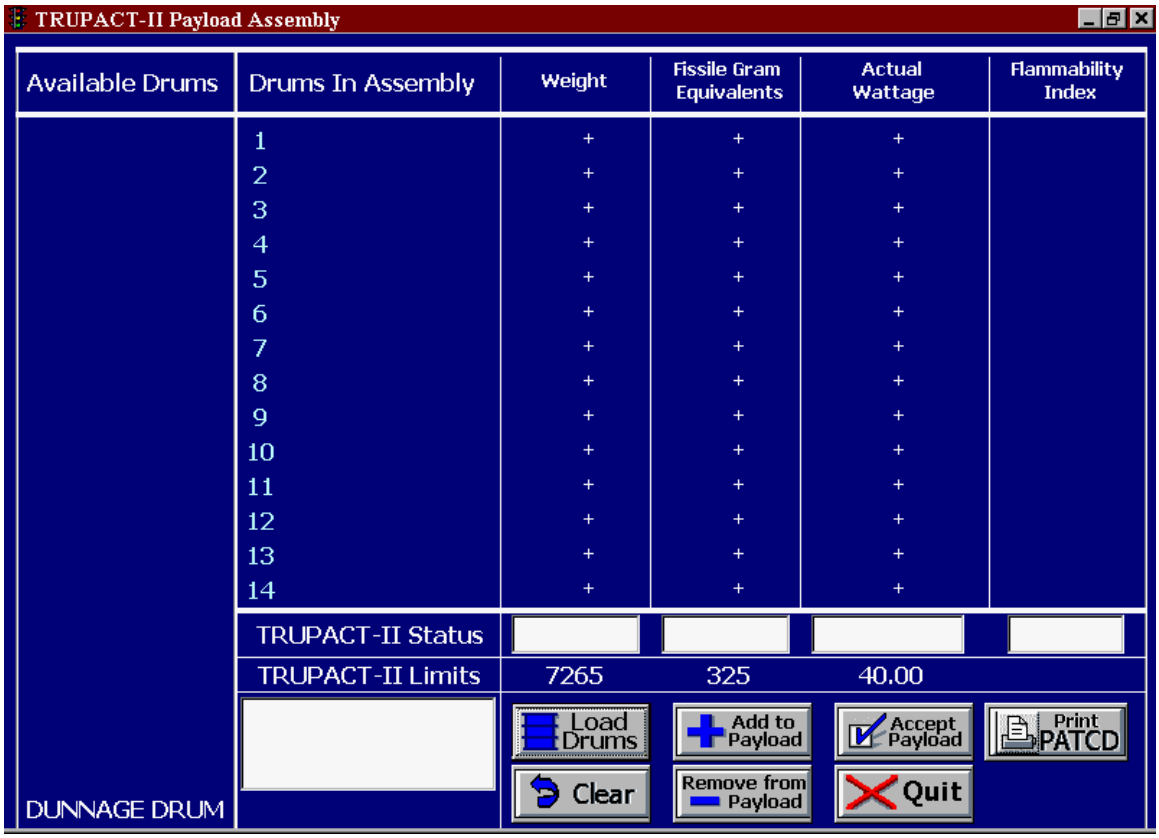
This screen records the hydrogen/methane concentration and checks to ensure that the methane concentration passes a screening limit (high methane concentrations are not expected in TRU waste containers, and methane is limited to 1,250 ppm in the container headspace).

With the sampling data on hydrogen, methane, and flammable VOC concentrations, the code uses the FAMP methodology to determine whether a flammable gas/VOC mixture can exist during shipment of the container. If the sum of the hydrogen and VOC concentrations is less than the MLEL, the drum is eligible for payload assembly consideration, as follows:



The following screen loads drum identification numbers from the database; allows selection of 14 drums to comprise a payload assembly; compares the weight, wattage, and FGE for each drum and the total against TRUPACT-II package limits; and calculates and evaluates the FI for each drum. If any of the limits are exceeded, the noncompliant drums are indicated in red with a message to reconfigure the payload. Drums can be removed from the payload and new drums selected until all limits are met. Once a payload is successfully configured, the e-TRAMPAC also prints out all required payload certification documents for approval by the site transportation certification official prior to TRUPACT-II shipment.

TRUPACT-II Payload Assembly



SUMMARY

The application for Revision 19 of the TRUPACT-II SAR, currently under development for submittal to the NRC, incorporates several payload expansion initiatives to determine more realistic flammable gas generation rates in CH-TRU waste containers and, thereby, increase the shippable portion of TRU waste. The e-TRAMPAC is an implementation tool that allows the sites to take advantage of all proposed payload expansion initiatives by simply linking to the site waste container database. The data required by the e-TRAMPAC are a subset of the data required from the sites by the WWIS. The e-TRAMPAC also provides a printout of the payload certification documents and forms required by the TRUPACT-II SAR. Use of the e-TRAMPAC is an additional option available to the sites that can increase waste shippability and reduce the time and effort required at the sites to determine compliance with the TRUPACT-II SAR. Use of the e-TRAMPAC for compliance evaluations will be authorized after NRC approval of Revision 19 of the TRUPACT-II SAR.

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