Washington
TRU Solutions LLC

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February 17, 2006

Mr. M. Rahimi, Project Manager
NMSS/SFPO, Mail Stop O13D13
U.S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Subject: RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION ON ARROW-PAK EXEMPTION REQUEST (Docket No. 71-9218, TAC No. L23811)

References:
1. Letter from P. C. Gregory to M. Rahimi dated January 31, 2005, subject: Application for Revision of the TRUPACT-II Certificate of Compliance, NRC Docket No. 71-9218
2. Letter from M. Rahimi to P. C. Gregory dated July 8, 2005, subject: Request for Additional Information on ARROW-PAK Exemption Request
3. Letter from P. C. Gregory to M. Rahimi dated December 15, 2005, subject: Reference – Docket No. 71-9218 and TAC No. L23811
4. Letter from P. C. Gregory to M. Rahimi dated January 12, 2006, subject: Reference – Docket No. 71-9218 and TAC No. L23811

Dear Mr. Rahimi:

Washington TRU Solutions LLC, on behalf of the U.S. Department of Energy (DOE), hereby submits an amendment to the application for revision of the TRUPACT-II Certificate of Compliance (Reference 1). The amendment is in response to the Request for Additional Information (RAI) (Reference 2). This letter includes the following attachments:

- Attachment A – Enclosures to Letter
- Attachment B – RAI Responses and Summary of Changes to Revision 0 of the TRUPACT-II Safety Analysis Report (SAR) Addendum for ARROW-PAK
- Attachment C – Application Document.

Technical changes to the TRUPACT-II SAR Addendum for ARROW-PAK necessary to specifically address the RAI are indicated by red-lining in the margin of the document ("|") and are summarized in Attachment B. In response to RAI 2-2, SAR Section 2.6.2, *Cold*, provides the technical basis and justification for an exemption from the requirements of 10 CFR§71.71(c)(2) for the use of the ARROW-PAK at cold temperatures.

As noted in previous application submittals, an NRC/DOE agreement exists to waive applicable review fees.

If you have any questions regarding this submittal, please contact Mr. S. A. Porter at (253) 858-6690 or me at (505) 234-7469.

Sincerely,

Phillip C. Gregory

P. C. Gregory, Manager
Packaging Engineering

:clm

Attachments

cc: M. A. Italiano, CBFO

Attachment A

Enclosures to Letter

Attachment B	RAI Responses and Summary of Changes to Revision 0 of the TRUPACT-II Safety Analysis Report (SAR) Addendum for ARROW-PAK
Attachment C	Application Document

Attachment B

RAI Responses and Summary of Changes to Revision 0 of the TRUPACT-II Safety Analysis Report (SAR) Addendum for ARROW-PAK

Revision 0, February 2006, of the *TRUPACT-II SAR Addendum for ARROW-PAK* is submitted in its entirety with this application as Attachment C and replaces the entire Revision 0, January 2005, application. Changes that affect the safety basis of the package or that constitute content that has not been previously reviewed by the NRC are indicated by redlining ("│") in the margin of the document.

RAI responses and the changes associated with this revision of the *TRUPACT-II SAR Addendum for ARROW-PAK* are described below.

Chapter 1 – Introduction

1-1 Revise Drawing 163-007 to include details for the placement of payload inside the ARROW-PAK container, and the placement of three ARROW-PAK containers in the TRUPACT II, including the pallets, stretch-wrap, etc., which keep the three ARROW-PAKs together during transport.

Details regarding placement of the 55-gallon drum in the ARROW-PAK container, and the placement of the three ARROW-PAK containers and how they are tied together into the TRUPACT II package, are required to evaluate structural performance of the TRUPACT-II package to meet 10 CFR 71.31 and 71.33 requirements.

Drawing 163-007 has been revised to include details for placement of the 55-gallon drum payload inside the ARROW-PAK container, and includes a new view depicting three ARROW-PAK containers on a pallet inside the TRUPACT-II package (see Sheet 3). As shown, corrugated plastic spacers are required at each end of the 55-gallon drum to roughly center it along the length of the ARROW-PAK. Stretch wrap and/or banding may be used to tie the three ARROW-PAK containers together. However, such wrapping or banding is optional since package performance will not be affected by its inclusion or omission. A payload pallet is required at the base of the three ARROW-PAK containers.

1-2 Revise Drawing No. 163-007 as follows:

a. **Show clearly the details of the NPT pipe plug area, including the size of the plug, and how it is connected to the HDPE wall.**

Detail 1 on Drawing 163-007 has been revised to clarify details of the NPT pipe plug area, including the size of the plug and its interfacing configuration.

b. **Sheet 1, Note 3: Refer to the Plastic Pipe Institute's procedures (TR-33 and TR-41) that are recommended to be used for thermal fusion welding of the butt joints and Saddle Seal joints. These procedures are referenced in Section 7.0 Operating Procedures.**

Flag Note 5 on Drawing 163-007 has been revised to reference Plastic Pipe Institute (PPI) procedure TR-33 for thermal fusion welding of butt joints and PPI procedure TR-41 for thermal fusion welding of saddle seal joints.

c. **Specify the material specification and the Fabrication Code for manufacturing the end domed closure devices. The cylindrical portion of the container is certified as being fabricated to F714 specification, as stated in Sheet 1, Note 9. However, the specification for the domed devices is not listed. The ASTM D 3350 specification stated in Note 3 pertains to materials for a pipe, and not to specially molded domed devices.**

The closure devices are manufactured in accordance with the specifications and requirements of ASTM D3261, *Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing*. Per Paragraph 4.1.1 of ASTM D3261, “Fittings covered by this specification are normally molded. Fittings may also be machined from extruded or molded stock.”

Flag Note 14 has been added to Drawing 163-007 to delineate that the closure devices are manufactured in accordance with the specifications of ASTM D3261.

d. **Sheet 2, Pipe Plug Seal: Provide the rationale for using a NPT steel plug for sealing the port on the top domed closure device instead of a double seal threaded NPT plug made of the same material (HDPE) as the container.**

The use of the steel pipe plug is not intended to be the primary sealing device for this ARROW-PAK container penetration. Instead, the steel pipe plug is designed to temporarily confine the inert nitrogen gas until the external saddle seal is heat-fused to the closure device. The saddle seal is designed to reinforce the evacuation port sufficiently to provide the vessel with its full pressure capacity, as demonstrated by hydrostatic burst-pressure testing (see Appendix 2.10.2, *Hydrostatic Validation Testing*); the heat-fused saddle seal joint does not leak. The use of the steel pipe plug and saddle seal provides an easy assembly procedure to provide a fully pressure rated monolithic container.

e. **Sheet 2, Detail 3: Verify if the counter-drilling notation is in accordance with ASME Y14.5M, *Dimensioning and Tolerancing*, and if the depth specified for counter-drilling one-half-inch diameter hole is accurate. It appears that the depth of the one-half-inch diameter hole should be 1.375-inch, instead of 5/8-inch.**

Although the dimensions in Detail 3 on Drawing 163-007 have been slightly changed, the callout for hole depth is consistent with ASME Y14.5M callout convention.

f. Sheet 1, Note 1: Change "ANSI Y14.5M" to "ASME Y14.5M."

Note 1 on Drawing 163-007 has been revised to make the specified change.

g. Sheet 1, Note 5: Verify that the thermal fusion procedures developed for manufacturing the ARROW-PAK containers reflect the material thickness and orientation of the container. Discuss details on the methods for fusion welding, verification of complete fusion, and properties of the as-fused product vis-a-vis the properties of the materials being fusion welded.

This information is required to verify compliance of the application to 10 CFR 71.33 requirements.

Heat-fusion joining of high density polyethylene (HDPE) pipe and components has been effectively accomplished for over 40 years with primary reliance on process controls using qualified procedures and personnel. HDPE pipe and components, with 1-inch to 63-inch pipe diameter and 1/8-inch to 4-inch wall thickness, are joined using the same process. The ARROW-PAK's 30-inch diameter, with a wall thickness of 1.765 inches, is covered by this range of experience.

ARROW-PAK vessel fabrication adopted industry accepted ASTM D2657, *Heat Fusion Joining of Polyolefin Pipe and Fittings*, as elaborated on by the Plastic Pipe Institute in its standards for Generic Butt and Sidewall Heat Fusion Procedures, detailed in Technical Reports TR-33[1] and TR-41[2]. As noted in the response to RAI 1-2(b), drawing flag note 5 now specifies these procedures.

The qualified butt-joining procedure consists of 1) clean, position, and secure; 2) face the pipe; 3) align and tighten; 4) heat and melt; 5) join; 6) hold and cool; 7) visually inspect.

The qualified sidewall-joining procedure consists of 1) clean, position, and prepare; 2) heat and melt; 3) join; 4) hold and cool; 5) visually inspect.

ARROW-PAK also adopted the heat-fusion and inspection procedures from the polyethylene natural-gas pipeline joining standards and requirements, as

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[1] TR-33/2005, *Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe*, Plastics Pipe Institute, Washington, D.C (http://www.plasticpipe.org/pdf/pubs/reports/TR-33-2005.pdf).

[2] TR-41-2002, *Generic Saddle Fusion Joining Procedure for Polyethylene Gas Piping*, Plastics Pipe Institute, Washington, D.C (http://www.plasticpipe.org/pdf/pubs/reports/TR-41-2002.pdf).

regulated by the US-DOT in 49 CFR §192.281 through §192.287 (Plastic Pipe and Plastic Pipe joining). 49 CFR §192.283 and §192.285 are specifically identified in drawing flag note 5 to ensure proper qualification of procedures and personnel.

The butt heat-fusion temperature is “low” at a nominal 400 °F. When the HDPE is heated, the joint does not have a heat affected zone (HAZ) like metal pipes. The joint efficiency of heat-fused and saddle-fused polyethylene is considered to be 1.0 (i.e., 100%; refer to TR-33[1]). The fusion joint has the same physical properties as the parent pipe material itself. The greater mass at the fusion joint makes it stronger than the pressure-pipe itself.

Additionally, effectiveness of the ARROW-PAK heat-fusion processes (procedures and machinery) have been qualified by deflagration testing, hydrostatic rupture testing, and pressure tests.

1-3 Revise Drawing No. 163-007 to provide Codes for Design and Inspection of the ARROW-PAK container, and to provide the basis for ignoring local stresses in the ARROW-PAK container, which are close to yield strength of the material.

The ARROW-PAK container is analyzed for an internal pressure of 100 psig to demonstrate that the primary stress intensity is less than 1000 psi, derived using a factor of 0.667 to assumed yield strength of 1500 psi. However, design and inspection codes required by 10 CFR 71.31(c) and 10 CFR 71.33 are not specified. Additionally, the design criteria for the localized stresses are not specified and are ignored without providing a basis.

Drawing 163-007 has been revised to delineate the codes for Design and Inspection of the ARROW-PAK container.

The ARROW-PAK’s ductile, pressure-vessel cylinder design is calculated in accordance with the formula for primary stresses given by ASME B&PV Code, Section VIII, Division 1, Section UG-27, of the ASME B&PV Code for thick wall pressure vessels, as noted in SAR Section 2.6.1. The design is validated by analysis, using the finite element analysis program ANSYS®, release 8.0A1. The pipe cylinder is also in dimensional compliance with ASTM F714.

The ARROW-PAK’s ductile pressure-vessel closure device (CD) is custom designed and modified using the guidance of the formulae for torispherical flanged and dished (F&D) heads given in ASME B&PV Code, Section VIII, Division 1, Section UG-32.

The 30-inch diameter F&D torispherical head is a modified 93/23 design in which the 28-inch inside spherical radius is 93% of the cylinder’s outside diameter, and the 7-inch inside knuckle radius is 23% of the cylinder’s outside diameter. The flange wall thickness is 2.125 inches to compensate for potential pipe-cylinder outof-round, wall thickness variation, and residual strain toe-in in order to assure 100% pipe-to-head fusion-joint contact area. The vertical skirt is forge-molded with the CD head such that there are no concerns about the skirt-to-CD head juncture.

Because the CD is essentially low-pressure, low temperature, and pressurized only once with no cyclic pressurization, this torispherical flanged and dished CD qualifies for ASME B&PV Code, Section VIII, Division 1, Code Case 2260/2261, with higher acceptable fiber stresses and higher pressure-rating at the same dimensions as given in Drawing 163-007.

ARROW-PAK's saddle seal is a code-compliant, non-intrusive seal for permanent restoration of the pressure boundary. It is a customized, saddle-fused plate-component that is welded to the outside surface of the ductile HDPE pressure-vessel using a full penetration weld to encapsulate the evacuation-port ("defect" opening) in accordance with the pressure design guidance of ASME B&PV Code, Section VIII, Division 1, Section UG-34.

The ANSYS® FEA program that was used to model the ductile ARROW-PAK vessel used an elastic model. HDPE is a visco-elastic material exhibiting creep (strain) and stress-relaxation in the presence of locally intensified stress. Hence, the program conservatively overstates the intensity of localized stresses at discontinuities, specifically at the fusion joint and in the vessel inner surface at the 1/4-inch diameter evacuation port penetration. Because there is no cyclic pressure loading of the pressure vessel, the localized stress intensification cannot lead to fatigue induced crack initiation and a linear static analysis is appropriately conservative.

As specified in SAR Section 2.10.2, one of the purposes of the hydrostatic validation testing was to confirm that peak stresses in the saddle seal can be dismissed in lieu of the dominating sidewall hoop stress. The ARROW-PAK hydrostatic burst tests did confirm that the failure location was not in the area of locally high stress predicted by ANSYS. In reality, the localized stresses in the saddle seal penetration are substantially reduced by the viscoelastic nature of the HDPE material and can be ignored.

1-4 Revise Drawing No. 163-007 to state that the hydrostatic design basis for the material is 800 psi (tested in accordance with ASTM D 2837) at 140 ºF.

Sheet 1, Note 3, shows the cell classification for the HDPE material in accordance with ASTM D 3350, which implies a hydrostatic design basis of 1600 psi. However, the design basis is 800 psi because the design temperature is 140 ºF. This information is required to verify compliance to 10 CFR 71.33 requirements.

The Hydrostatic Design Basis (HDB) is typically assigned using a temperature of 23 ºC (73.4 ºF). The HDB is a variable, based on time, temperature, and stress intensity. The principle of design is to determine the statistical stress intensity that will provide longevity with acceptable strain such that the possibility of a creep pressure-rupture during its service life is virtually zero.

Testing at other temperatures enables the assignment of a HDB for that temperature. ASTM D3350 specifies the 23 ºC HDB as its cell classification system. However, the industry has established a temperature re-rating factor to the HDB to convert the 23 ºC HDB to a HDB at another temperature. It is commonly called the Temperature Rating Factor (TRF). As discussed in SAR Section 2.3.2, the TRF is 0.50 at 140 ºF, 1.00 at 73 ºF, and 1.99 at -40 ºF.

For completeness, Note 3 on Drawing 163-007 state all three conditions of design, i.e., the standardized HDB, the maximum use-temperature HDB at 140 ºF, and the minimum use-temperature HDB at -40 ºF.

Note 3 on Drawing 163-007 has been revised to specify a HDB for the EHMW-HDPE material of 800 psi at 140 ºF, 1,600 psi at 73 ºF, and 3,180 psi at -40 ºF, when tested in accordance with ASTM D2837[3].

1-5 Add the list provided in the TRUPACT-II SAR, Section 1.3.2, "Glossary of Terms and Acronyms," and include it in this document. The following are among the terms to be considered for addition to the list: EHMW-HDPE, ESCR, NCT, HAC, and ATU.

The suggested change will shorten review-times as it aids readability. This information is required to verify compliance to 10 CFR 71.33 requirements.

Appendix 1.3.2 has been added to provide a glossary of terms and acronyms. Terms and acronyms from the TRUPACT-II SAR that are associated with payload containers other than the ARROW-PAK are not included.

1-6 Drawing No. 163-007 references (in Detail 2) the plastic institute's recommended procedures for butt and side-wall fusion. Furnish these procedures and properties of fusion weldment that result from use of these procedures. Describe the differences between thermal fusion joining process (item 5) and heat fusion seal (Item 6).

The requested information is required to evaluate the efficacy of weldments and the properties of fused components, and compliance with 10 CFR 71.71 and 10 CFR 71.73 requirements.

The Plastic Pipe Institute's standards for Generic Butt and Sidewall Heat Fusion Procedures are detailed in Technical Reports TR-33[1] and TR-41[2].

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[3] ASTM D2837-04, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*, Volume 08.04, 2004, American Society for Testing and Materials, Philadelphia, PA.

As discussed in the response to RAI 1-2(b), these recommended procedures are now imposed via drawing flag note 5. The properties of fusion weldments that result from use of these procedures are discussed in the response to RAI 1-2(g).

The term "heat-fuse" was intended to be equivalent to "thermal fusion joining". For clarity and to avoid confusion, Note 6 on Drawing 163-007 has been revised as follows: "THERMAL FUSION JOIN SIDEWALL SADDLE-SEAL COMPONENT OVER PORT OPENING TO FORM A MONOLITHIC VESSEL."

Procedures and properties of fusion weldments are further discussed in the response to RAI 1-2(g).

Chapter 2 – Structural

2-1 Justify that the assumption of zero decay heat, assumed for complying with the 10 CFR 71.71(c)(2) requirements, is conservative (Ref. SAR Section 2.6.2).

This information is required to verify compliance with 10 CFR 71.71(c)(2) requirements.

Two bounding cases are possible when evaluating the ARROW-PAK container for the regulatory cold condition: with and without decay heat. Since the TRUPACT-II packaging provides significant thermal insulation, the temperature gradient between the ARROW-PAK containers and the ICV surface is small (<2 ºF), regardless of the internal decay heat load, as shown in SAR Tables 3-1 and 3-2. Thus, the temperature gradient within the ARROW-PAK container sidewall is negligibly small and may be ignored.

2-2 Provide data to demonstrate that the EHMW-HDPE material has sufficient fracture toughness to preclude brittle fracture. Specify the size of the largest flaws in the EHMW-HDPE material including any that may be present in weldments (base material and material near the fused zone). Include data on fracture toughness measurements as a function of temperature of this material. Include your understanding of the highest local stress-intensity factors that you used to compute the likelihood of propagation of flaws.

Section 2.6.2 of the SAR states that EHMW-HDPE has a brittleness temperature below -40 ºF. However, the data supporting this statement are not provided. Also, the Material Data Sheets, *Marlex HHM TR-480X High Density Polyethylene*, cited as Reference 12 in Section 2.3 of the SAR (page 2-2) states the Brittleness Temperature as 103 ºF. This information is required to meet 10 CFR 71.71(c)(2).

SAR Section 2.6.2 has been revised to more thoroughly address the brittle fracture characteristics of the EHMW-HDPE material and provide calculations for the critical flaw sizes and associated maximum stress intensities to preclude the propagation of flaws.

There is no single, universal definition of the Ductile-Brittle (D-B) Transition Temperature for HDPE; thus, different test methods yield different results. The tests for Charpy Impact and Izod Impact tests give different D-B temperatures, and there is no direct correlation between the two temperatures. All impact test results are dependent upon the test specimen and its impact loading.

ASTM D746 test data support a D-B Transition Temperature of less than -75 ºC (-103 ºF) that is based on a cantilever beam flexural impact of an unnotched specimen that predicts a transition temperature at which 50% of the specimens are expected to fail. The information cited in Reference 13 in SAR Section 2.3 was incorrectly shown; the minus "-" sign from the data sheet was inadvertently omitted. When brought to Chevron Phillips Chemical Company's attention, corrective action was taken and the corrected data sheet is now available at:

http://www.cpchem.com/tds_unsecured/4C08B2B4D889430C98CE3BC6C8370CE1.pdf

ISO 179 Charpy test data support a D-B Transition Temperature of less than 0 ºC (32 ºF) that are based on a simply-supported beam flexural impacts of both unnotched and machine notched specimens. The test data provided in Attachment B of Figure 5 in the response to RAI 2-9 indicates no breaks for unnotched samples down to a temperature of -40 ºC (-40 ºF). The test data provided in Attachment A of Figure 5 in the response to RAI 2-9 indicates ductile partial and/or hinged breaks for machine notched samples at all temperatures greater than or equal to -17.8 ºC (0 ºF).

ASTM F2231 test data also support a D-B Transition Temperature of less than 0 ºC (32 ºF) that is based on a simply supported beam flexural impact of a razor notched specimen. The test data provided in Attachment C of Figure 5 in the response to RAI 2-9 provides the energy vs. temperature plot for a modified ASTM F2231 test. The ASTM F2231 test specifies a room temperature test condition and is designed to determine the Charpy impact energy that is related to the ultimate critical temperature of the rapid crack propagation behavior, as measured by the ISO 13477, S4 test. The results provided in Attachment C of Figure 5 in the response to RAI 2-9 were obtained at temperatures between -30 ºC and 80 ºC as an additional indicator of the D-B Transition Temperature when large flaws are present in the material.

It is therefore concluded that in the absence of flaws EHMW-HDPE demonstrates ductile failure behavior below -40 ºF, but exhibits brittle failure modes at that temperature when significant flaws are present. Consistently ductile behavior is exhibited by EHMW-HDPE at temperatures above 32 ºF, even when significant flaws are present. In lieu of applying restrictive scratch and gouge or internal defect requirements to preclude brittle failure concerns below 32 ºF, it is proposed to apply administrative controls to ensure that ARROW-PAK shipments shall not initiate at any time when the upcoming weekly forecast, or historical trends for the subsequent month, identify the likelihood of a 24-hour averaged temperature occurring at any time during the period that is below 32 °F (0 °C) at any location along the transportation route. This administrative restriction has been added to SAR Section 10.6.3. In addition, when qualifying fusion joint procedures and personnel, the maximum flaw size allowed shall be equivalent to a 3/16-inch diameter flat-bottom hole (e.g., see 49 CFR §192.285(b)(2)(ii)), as established in SAR Section 2.6.2. Finally, the maximum depth of internal or external surface scratches or gouges shall be 3/16 inch, as established in SAR Section 2.6.2. These requirements are specified in SAR Sections 7.1.1, 7.1.2, and 7.1.4.

2-3 Evaluate the degree of uncertainty in the calculation of the maximum pressure (99.66 psig) in the ARROW-PAK container (SAR Section 10.5.3.2.2) and its effect on the selected Maximum Normal Operating Pressure of 100 psig, and the hydrostatic design basis (HDB of 800 psi for HDPE material at design temperature of 140 ºF.

Section 2.6 of the SAR shows the calculated hoop stress as 803 psi, which could increase to 818 psi, when tolerances in thickness of the shell (1.765-inch) are considered. The stress of 818 psi is very close to the HDB of 800 psi. Also, as shown in Table 1 of ASTM D 2837-04, the Long-term hydrostatic strength (LTHS) corresponding to the HDB of 800 psi varies from 760 to 960 psi, which may result in potential cracking in the ARROW-PAK container during Normal Conditions of Transport. This information is required to verify that the ARROW-PAK container meets the requirements of 10 CFR 71.71(b).

As discussed in revised SAR Section 10.5.3, MNOP has been conservatively set at 100 psig to allow a 20% margin (20 psig) for *incidental* aerosol cans. With a contribution of 1.89 psig per aerosol can (see SAR Section 10.7.2), the 20 psig margin is sufficiently high to accommodate other minor uncertainties in the pressure calculations.

With reference to Table 9 of ASTM F714, the 1.765 inch wall thickness is already a specified minimum. Thus, the 803 psig hoop stress calculated in SAR Section 2.6 already accounts for worst-case wall thickness tolerances. Pipe OD tolerances are also negligible (<0.5% for the 30-inch OD ARROW-PAK) based on Table 6 of ASTM F714,

Per Section 3.1.5 of ASTM D 2837, the long-term hydrostatic strength (LTHS) is the estimated hoop stress in the pipe that if applied continuously would cause failure at 100,000 hours (11.4 years). At reduced times, the LTHS will increase. Per Figure 4 of the response to RAI 2-9, at 140 ºF, a LTHS of 750 psi at 100,000 hours will increase to 820 psi at 35,040 hours (4 years). Since the ARROW-PAK container will be sealed and transportation completed within 70 days (1,680 hours) of loading, or less, a shorter term, LTHS value can be considered. Conservative use of the 4-year LTHS value of 820 psig ensures that the design will be acceptable for NCT.

2-4 Provide the basis for testing the ARROW-PAK containers with ambient internal pressure instead of the Maximum Normal Operating Pressure of 100 psig, and at ambient temperatures (73°F and 93°F), instead of at the value most unfavorable condition which may be anywhere in the range of between -20°F and 100°F and above, as appropriate. This information is required to verify compliance of the ARROW-PAK container to 10 CFR 71.73(b) requirements.

Discussions within SAR Section 2.7.1.2, as provided in the original application and retained in this current revision, address the significance of performing the HAC free drop tests at ambient temperature and with the ARROW-PAKs unpressurized. As stated therein, testing without internal pressure minimized the ability of the ARROW-PAK vessel to resist impact induced deformations, thus conservatively allowing worst-case deformations to occur. In addition, the absence of internal pressure is conservative when it comes to maximizing vessel wall compressive stresses (in both an end drop and due to bending in a side drop) and, hence, in addressing potential buckling modes of failure. Had the ARROW-PAKs been pressurized to 100 psig during the drop testing, modest pressure variations could have occurred due to the impact induced deformations that resulted, but the demonstrated ability of the ARROW-PAK to withstand much higher magnitude deflagration related pressure pulses is more than sufficient to accommodate the relatively small pressure variations that could have occurred due to the observed elastic deformations of the ARROW-PAKs.

Relative to performing the drop testing at prevailing ambient condition temperatures instead of at temperature extremes, a consideration of conservatisms inherent in the test set-up coupled with the observed elastic response of the ARROW-PAKs to the free drop tests is considered sufficient to justify the use of ambient temperature drops. In particular, the absence of the energy absorbing polyurethane foam filled OCA during testing and the stiffening of the ICV head used for testing generally led to conservative impact load magnitudes. Since post-drop inspections of the ARROW-PAKs indicated no detectable permanent deformations, it is conservative to assume that deformations just reached the yield point during impact. The ability of the highly ductile HDPE to absorb significant amounts of energy when loaded beyond its yield point and prior to failure (e.g., 12% yield strain and 800% ultimate elongation at room temperature) ensures that the worst consequence of dropping at 140 ºF would be modest permanent deformations of the ARROW-PAK vessel. A more detailed discussion of the above is provided in SAR Section 2.7.1.2.

2-5 Provide the basis for placing the payload at the center of the ARROW-PAK test units 1 and 2 by the use of the corrugated spacers for the 3-foot end and side drop tests, and explain how these test units simulate the actual payload placement of the 55 gallon drum at the base of the ARROW-PAK.

The actual placement of the 55-gallon drum at the base would travel a greater distance during a 30-foot end drop, and impact the lid with much greater force than during the tests, and may adversely impact the structural integrity of the ARROW-PAK container. Also, the drum at the end of the container during a side drop may be more damaging to the domed device, instead of the drum placed at the center. This information is required to verify compliance to 10 CFR 71.73(c)(1) requirements.

Drawing No. 163-007 has been revised to show corrugated plastic spacers at each end of the 55-gallon drum within the ARROW-PAK container. Thus, the prototypic configuration used for testing simulates the actual configuration for transport.

2-6 Provide the basis for the assumption that the horizontal and vertical drop tests performed to meet 10 CFR 71.73(c)(1) hypothetical accident conditions (HAC) Free Drop requirements represent the orientations for which maximum damage is expected.

The 30-foot drop tests are performed for two orientations of the test assemblies, one horizontal, the other vertical. The basis for selecting these two orientations as the most damaging to the ARROW-PAK container is not provided. This information is required to verify compliance to 10 CFR 71.71(c)(1).

SAR Section 2.7.1.2 has been revised to provide the basis for the assumption that the end and side drop tests performed to meet 10 CFR §71.73(c)(1) HAC free drop requirements represent the orientations for which maximum damage is expected.

As stated therein, these orientations impose the maximum axial and lateral loads on the ARROW-PAK container. Impact magnitudes for other orientations, such as center-of-gravity-over-corner, are significantly reduced and although of interest relative to deformation of the TRUPACT-II package, will not govern the design of the ARROW-PAK container.

2-7 Describe the results of the horizontal drop test clearly by showing the location and the extent of broken and cracked welds in the ICV lid to body weld connection, and the significance of the broken and the cracked welds on the structural integrity of the ICV during a HAC drop event (Ref. Test Report for the ARROW-PAK, TR-014).

It is stated in the drop tests report, TR-014, that four welds were broken on one side and at least one weld was cracked in the ICV as a result of the horizontal 30 foot drop. It is not clear which welds between the lid and the body of the ICV are referred to, and whether it is significant in maintaining structural integrity of the ICV during a HAC drop event. This information is required to verify compliance to 10 CFR 71.73(c) requirements.

The test ICV was taken from a training unit, and did not include the locking ring. Instead, to secure the ICV lid to the ICV body, a fillet weld was installed at each ICV body lug location. As shown in Figure 1, below, the welds within the side drop impact zone were broken. In addition, one weld opposite the impact point on the ICV was cracked. However, because of the large number of lid-to-body welds (18 places), lid separation did not occur and the ARROW-PAKs remained confined within the ICV in their original configuration as per the test requirements.

In summary, the broken welds were not part of the original ICV design, nor were the broken welds of any consequence to ARROW-PAK free drop testing since sufficient ICV lid-to-body welds were present to maintain confinement of the ARROW-PAK containers during testing.

2-8 Provide the rationale for testing the ARROW-PAK container at 78°F instead of 140°F, and explain the reason for failure of ARROW-PAK test unit during a pressure drop at 820 psig, instead of during the earlier pressure rise to 1000 psig (Ref. SAR Section 2.10.2, page 2-26). Also, explain the relationship of the test to the hydrostatic design basis (HDB) of 800 psi, which corresponds to 100 psig internal pressure, including the differences in failure criterion, if any. Include appropriate data, showing the relationships between measured properties and test temperature, as indicated in RAI 2-9.

This information is required to verify compliance to 10 CFR 71.71(c)(1).

As stated in SAR Section 2.10.2, the purpose of the hydrostatic validation test was “to determine the maximum short-duration internal pressure capacity of the ARROW-PAK design as well as the rupture location to demonstrate that peak stresses in the saddle seal can be dismissed in lieu of the dominating sidewall hoop stress”. Given the short duration of this test, longer term creep effects are rendered unimportant and general behavior and failure location for the ductile HDPE ARROW-PAK structure would be the same for testing at either 78°F or 140°F. (See the response to RAI 1-3 for a discussion of how the results of the hydrostatic validation test were used as the basis for ignoring highly localized stresses.) If one were interested in the short duration burst test capability at 140°F, a temperature rating factor (TRF) of 0.50, as discussed within the response to RAI 1-4, could be applied to the 78°F burst test results.

The reason for the failure at 820 psig instead of at 1,000 psig was due to the particular test set-up and test equipment capabilities. Ideally, for this test, pressure would be continually increased up to the point of vessel rupture, with no drop in pressure prior to rupture. However, the accumulator system used for testing could not keep up with the rapidly expanding ARROW-PAK sidewall at the high stress and strain magnitudes immediately preceding rupture. Thus, the drop in pressure observed prior to rupture.

Figure 1 – Test ICV Showing Cracked Lid-to-Body Welds

Notably, both 1,000 and 820 psig internal pressures result in sidewall stresses of well over the room temperature material yield strength of 3,000 to 3,500 psi (see SAR Section 2.3). For instance, at 820 psig, using the initial geometry of the cylinder sidewall results in a hoop stress of 6,560 psi. This ignores the fact that post-yield, large displacement affects would increase the effective radius and reduce the wall thickness, thus leading to even higher stress states for the sidewall. Had the pressurization system been able to keep up with the rapidly expanding vessel wall, the 60 second hydrostatic burst pressure would actually have exceeded 820 psig and possibly approached 1,000 psig, the only question being whether the structure would have withstood the applied pressure for a full 60 seconds. In any event, use of 820 psig as a room temperature, 60 second rapid burst pressure is conservative.

There is no direct relationship between the short duration hydrostatic validation test and the hydrostatic design basis (HDB), which takes into consideration the longer duration stress rupture performance capability of the HDPE material (see ASTM D2837, as discussed in the response to RAI 1-4).

2-9 Provide stress-strain curves (engineering and true) for the EHMW-HDPE material in tension and compression at various temperatures (70°F to 200°F), various strain rates, and subjected to stresses for short (<10 hours) to long durations (10,000 hours). Include data that covers all strain rates that may occur in all service in which the ARROW-PAK may be used.

This information is required to determine the structural behavior of the HDPE material to NCT and HAC (10 CFR 71.71 and 71.73) demands, and to evaluate the margins of safety for uncertainties in demands and capacities.

Figure 2 presents the chart and hard-data of multiple tensile-tests at “high-speed”. The standard ASTM D638 tensile test is 2 inches per minute (0.0333 inches per second). The Figure 2 data, at 1 inch per second, is 30 times faster than the standard test velocity. The tensile yield stress at 1 inch per second is approximately 30% higher than at 0.0333 inches per second (see subsequent Figure 7). The hydrogen deflagration velocity is approximately 279 feet per second (3,350 inches per second) within an ARROW-PAK container, which is over 3,000 times faster still.

Even at this very high deflagration velocity, the HDPE material remains ductile, and exhibits strain-rate hardening such that the HDPE yield stress is over 5 times the ASTM D638 tensile yield-stress test value at 0.0333 inches per second (see Figure 7). There is no standardized test for “ultra-high” velocity tensile-testing of polymers. (Compare the above strain velocities to a “high-explosive” minimum detonation velocity, which is known to be above 26,000 inches per second.)

Figure 3 through Figure 9 show additional material properties vs. temperature. Figure 10 illustrates the elastic modulus based on test data from tensile tests, and from calculations based on other explosive tests. The rate of strain above three inches per second is so high that there is no standard equipment to give accurate results. Deflagration pressure within mortar tubes gives instant hoop-stress in the range above 15,000 psi at 73 ºF[4,5,6]. HDPE has about 3% void-space (free-volume; freedom to strain) at that temperature. The elastic modulus is the ratio of stress-to-strain, so 15,000 psi/0.03 in/in = 500,000 psi elastic modulus. This is the slope of the stress-strain curve at very low strain within the elastic region, for milliseconds of pressurization.

---

[4] S. Hillmansen, S. Hobeika, R. N. Haward, P. S. Leevers, *The Effect of Strain Rate, Temperature, and Molecular Mass on the Tensile Deformation of Polyethylene*, Polymer Engineering and Science, Volume 40, No. 2, February 2000.

[5] K. L. Kosanke and B. J. Kosanke, *Shimizu Aerial Shell Ballistic Predictions (Part 1 and Part 2)*, Pyrotechnics Guild International Bulletin, Nos. 72 and 73 (1990).

[6] K. L. Kosanke and B. J. Kosanke, *Repeat Firing of 10.2 cm (4 in.), SDR–17, HDPE Mortars*, Proceedings of the First International Fireworks Symposium (1992).

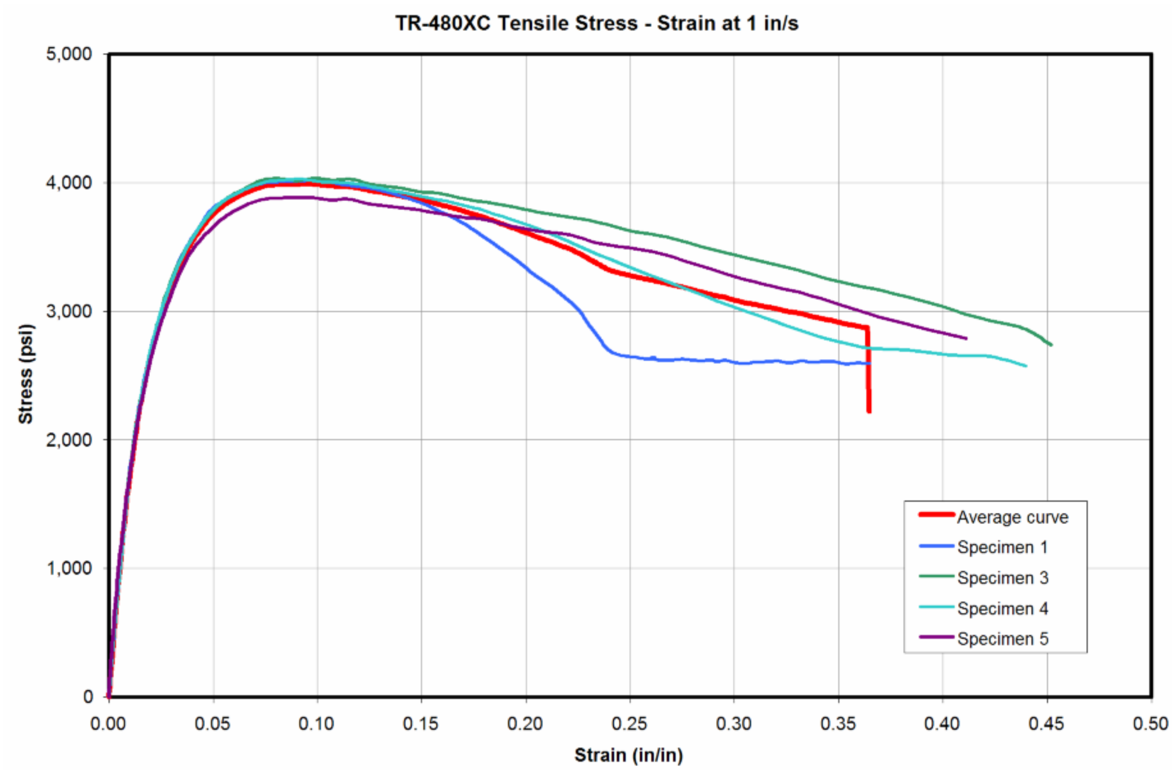

Figure 2 – Tensile Stress vs. Strain at 1 in/s

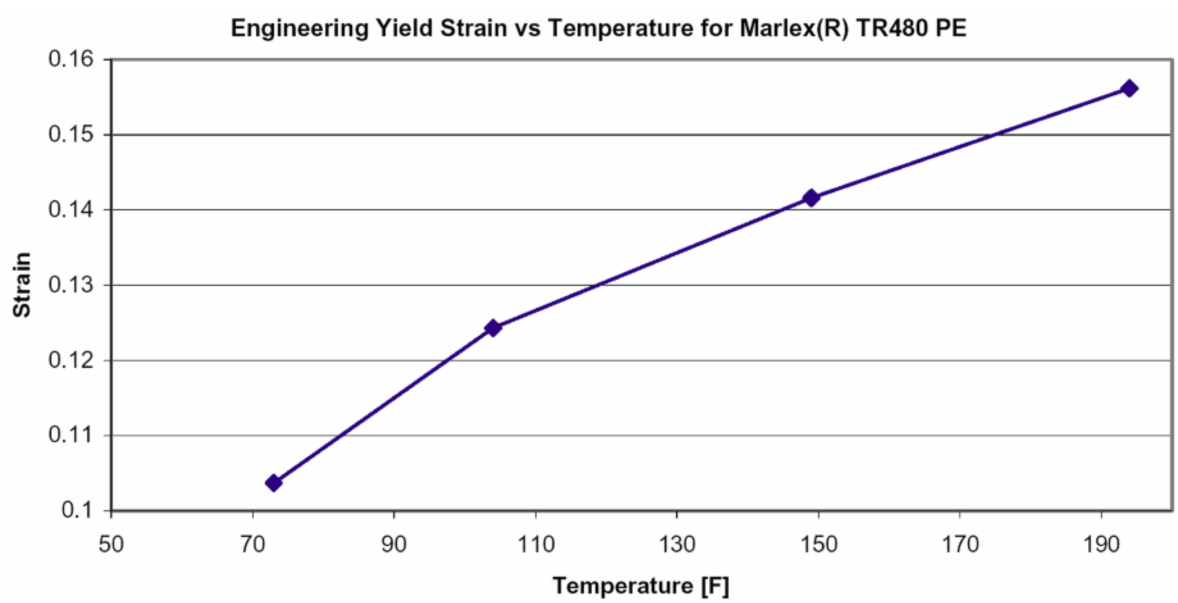

Figure 3 – Engineering Yield Strain vs. Temperature

Chevron Phillips Chemical Company LP

PERFORMANCE PIPE

A DIVISION OF CHEVRON PHILLIPS CHEMICAL COMPANY LP
5085 W. Park Boulevard, Suite 500 (75093)
P. O. Box 269006
Plano, TX 75026-9006

March 4, 2003

Mr. Keith Paxton
Industrial Utility Sales
6265 Benefit Avenue
Baton Rouge, LA 70809-4249

Re: Request for test data

Dear Keith,

The following table contains the information you requested on the Hydrostatic Design Basis at 73°F and 140°F for DriscoPlex™ products produced from Marlex® TR-480 resin. Regrettably, we are not able to provide similar data at 160°F.

Test Method ASTM D2837 'Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials provides the methodology to extrapolate stress rupture data. The method generates a Long Term Hydrostatic Strength (LTHS), which is then categorized into a Hydrostatic Design Basis (HDB). The data are as follows.

Temperature	100,000 hr extrapolation		4 yr extrapolation	
degrees F	LTHS	HDB	LTHS	HDB
73	1610	1600	1630	1600
140	750	800	820	800

Please let us know if there are any questions.

Sincerely,

Karen S. Lively
Associate Technical Manager

cc: Lee Mizell

Figure 4 – Performance Pipe Letter Re: LTHS and HDB vs. Temperature

PERFORMANCE PIPE
A DIVISION OF CHEVRON PHILLIPS CHEMICAL COMPANY LP
5085 W. Park Boulevard, Suite 500 (75093)
P. O. Box 269006
Plano, TX 75026-9006

April 25, 2003

Mr. Keith Paxton
Industrial Utility Supply

Ref: TR 480 Charpy Results

Dear Keith,

Attached are the Charpy results that you requested. We generated Charpy energy values based on the ISO Charpy notched impact values at –40C, 0C, 23C, and 60C. The are shown in table format in Attachment A. All of the failures were hinged breaks except for the tests at –40. We were unable to generate any breaks on the un-notched samples and therefore could not calculate an energy level. These results are documented in Attachment B.

Our testing identified that the ductile – brittle transition would occur between –40 and 0C. I believe that you were particularly interested in the ductile brittle transition. I have also included data from a recently completed impact energy study of Marlex TR-480 resin using test method ASTM F2231. The test method uses a razor notch instead of the more typical machined notch. The razor notch is used to reduce the energy required to break the sample. While the energy values are therefore lower for this test, the data can be used to provide more specific information on the ductile-brittle transition temperature.

I hope this meets your requirements. Please let me know if anything further is required.

Best regards,

Karen S. Lively, P.E.

cc: Lee Mizell

Figure 5 – Performance Pipe Letter Re: Charpy Results

Performance Pipe Page 2 4/25/2003

Attachment A

Charpy Iso Notched

1	**Charpy Iso Notched**						
	Test Temperature =	**22.8**	deg C	73	deg F		
Break Type							
53350	MJL-03-002-001	9 Partial	1 Hinged				
Charpy Value							
53350	MJL-03-002-001	22.50	KJ/M^2	10.71	ft-lb/in^2	0.720 Joule	4.74 % RSD (10)
2	**Charpy Iso Notched**						
	Test Temperature =	**60.0**	deg C	140	deg F		
Break Type							
53350	MJL-03-002-001	9 Partial	1 Hinged				
Charpy Value							
53350	MJL-03-002-001	19.50	KJ/M^2	9.28	ft-lb/in^2	0.624 Joule	3.88 % RSD (10)
3	**Charpy Iso Notched**						
	Test Temperature =	**-17.8**	deg C	0	deg F		
Break Type							
53350	MJL-03-002-001	9 Partial	1 Hinged				
Charpy Value							
53350	MJL-03-002-001	12.71	KJ/M^2	6.05	ft-lb/in^2	0.407 Joule	4.36 % RSD (10)
4	**Charpy Iso Notched**						
	Test Temperature =	**-40.0**	deg C	-40	deg F		
Break Type							
53350	MJL-03-002-001	10 Complete					
Charpy Value							
53350	MJL-03-002-001	5.735	KJ/M^2	2.729	ft-lb/in^2	0.184 Joule	9.44 % RSD (10)

area 8mm x 4mm

Figure 5 – *Continued, Letter Page 2*

Attachment B

RAI Responses and Summary of Changes to Revision 0 of the TRUPACT-II Safety Analysis Report (SAR) Addendum for ARROW-PAK
(continued)

Performance Pipe   Page 3   4/25/2003

Attachment B

	Charpy Iso Unnotched				
1	**Charpy Iso Unnotched**				
	Test Temperature =	**22.8**	deg C	73	deg F
Break Type					
53350	MJL-03-002-001				10 Non-Break
2	**Charpy Iso Unnotched**				
	Test Temperature =	**60.0**	deg C	140	deg F
Break Type					
53350	MJL-03-002-001				10 Non-Break
3	**Charpy Iso Unnotched**				
	Test Temperature =	**-17.8**	deg C	0	deg F
Break Type					
53350	MJL-03-002-001				10 Non-Break
4	**Charpy Iso Unnotched**				
	Test Temperature =	**-40.0**	deg C	-40	deg F
Break Type					
53350	MJL-03-002-001				10 Non-Break

Figure 5 – *Continued, Letter Page 3*

Performance Pipe   Page 4   4/25/2003

Attachment C

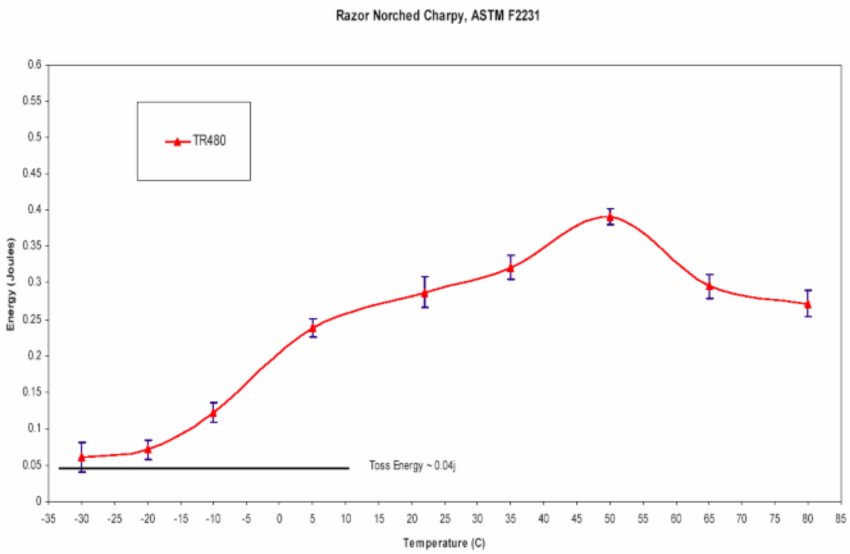

Figure 5 – *Continued, Letter Page 4*

Chevron Phillips Chemical Company LP

***Bryan Hauger**, Pipe Material and Applications Development Specialist*
105 Plastics Technical Center • Highway 60 & 123 • Bartlesville, OK 74004-0001
Telephone: (918) 661-9420 • Fax: (918) 662-2550• haugebe@cpchem.com

August 23, 2005

Larry J. Petroff
Technical Service Manager -- M&I
Performance Pipe
5085 W Park Blvd, Ste 500
Plano, TX 75093

RE: Marlex® HHM TR-480X and HHM TR-480XC polyethylene

I am writing to discuss the information requested by Harvey Svetlik of IPPI on Marlex® HHM TR-480X and HHM TR-480XC engineering and true stress-strain curves in tension and compression at various temperatures, strain rates and including long-term stresses. This request is substantial and we have tried to respond as well as we can under the time constraints.

We are pleased to provide figures of engineering and true stress-strain at four temperatures at the ASTM standard of 2 inches / minute. Please see figures 1 and 2.

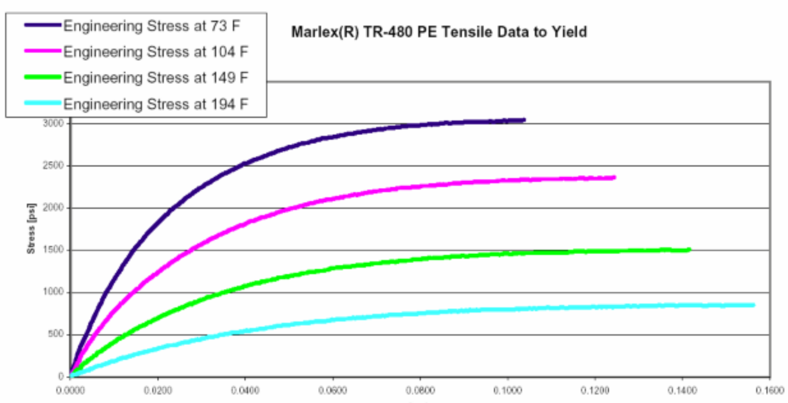

Figure 1. Engineering stress – strain curves for Marlex® HHM TR-480 at 73ºF, 104ºF, 149ºF and 194ºF.

Figure 6 – Chevron Phillips Letter Re: Polyethylene True Stress-Strain Curves

Attachment B

RAI Responses and Summary of Changes to Revision 0 of the TRUPACT-II Safety Analysis Report (SAR) Addendum for ARROW-PAK
(continued)

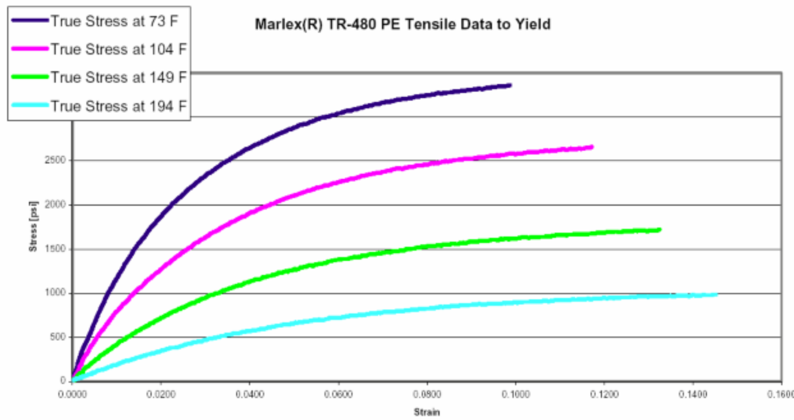

Figure 2. True stress – strain curves for Marlex® HHM TR-480 at 73ºF, 104ºF, 149ºF and 194ºF.

We are also pleased to provide a figure that also includes of Marlex® HHM TR-480 stress – strain at 73ºF at a strain rate of 1 inch / second. Please see figure 3.

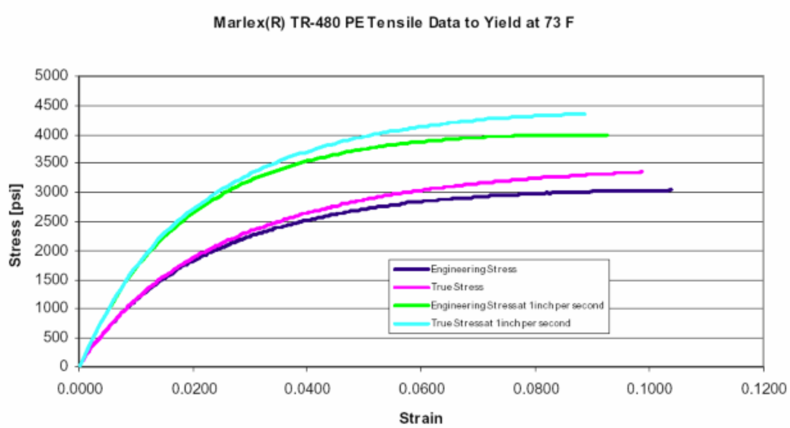

Figure 3. Engineering stress and true stress compared at 1 inch / second and 2 inches / minute.

Figure 6 – *Continued Letter, Page 2*

We have not yet measured a curve for stress – strain for HHM TR-480 in compression. We are currently assessing our capability for making this measurement. It is possible that data will be available prior to September 6th.

In terms of long-term stress – strain curves, we do not have any direct measurements of creep for HHM TR-480 nor do we have any internal capability to make these measurements. However, we have long-term hydrostatic curves for pipes constructed from HHM TR-480 that could provide an indirect and conservative approach to estimating the creep to rupture time at different stresses.

Please let me know if I can provide you any more information on this subject.

Yours truly,

B. E. Hauger

cc: Casey Cords
File

Technical Advice - *Any technical advice, recommendations, results, or analysis ("Information") contained herein, including, without limitation, Information as it may relate to the selection of a specific product ("Product") for your use and application, is given without warranty or guarantee and is accepted at your sole risk. It is imperative that you test the Information (and Product, if applicable) to determine to your own satisfaction whether the Information (and Product, if applicable) is suitable for your intended use and application. You expressly assume, and release Chevron Phillips Chemical Company from, all risk and liability, whether based in contract, tort or otherwise, in connection with the use of, or results obtained from, such Information (and Product, if applicable). Further, Information contained herein is given without reference to any intellectual property issues, as well as federal, state or local laws which may be encountered in the use thereof.*

Figure 6 – *Continued Letter, Page 3*

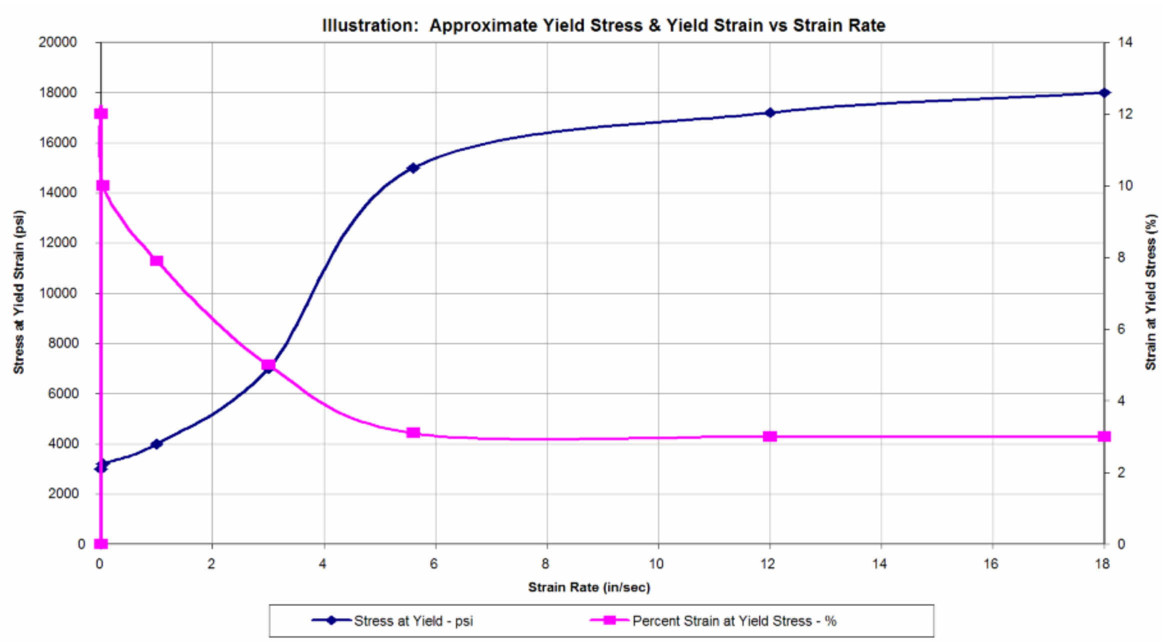

Figure 7 – Approximate Yield Stress and Yield Strain vs. Strain Rate

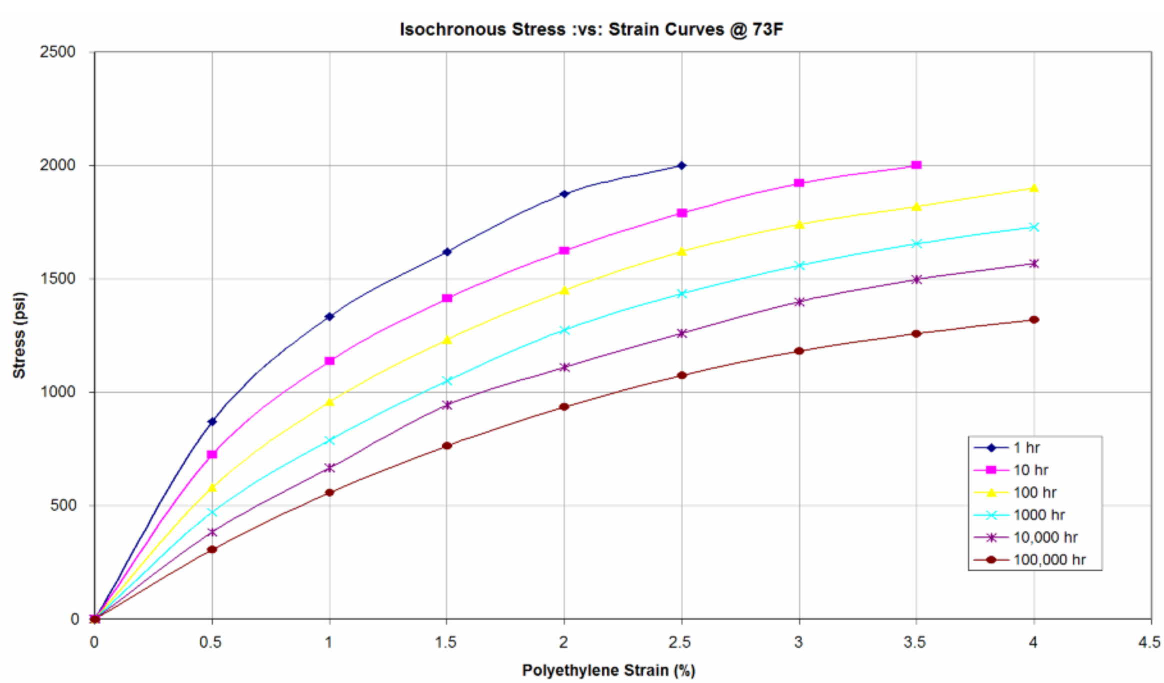

Figure 8 – Isochronous Stress vs. Strain Curves at 73 ºF

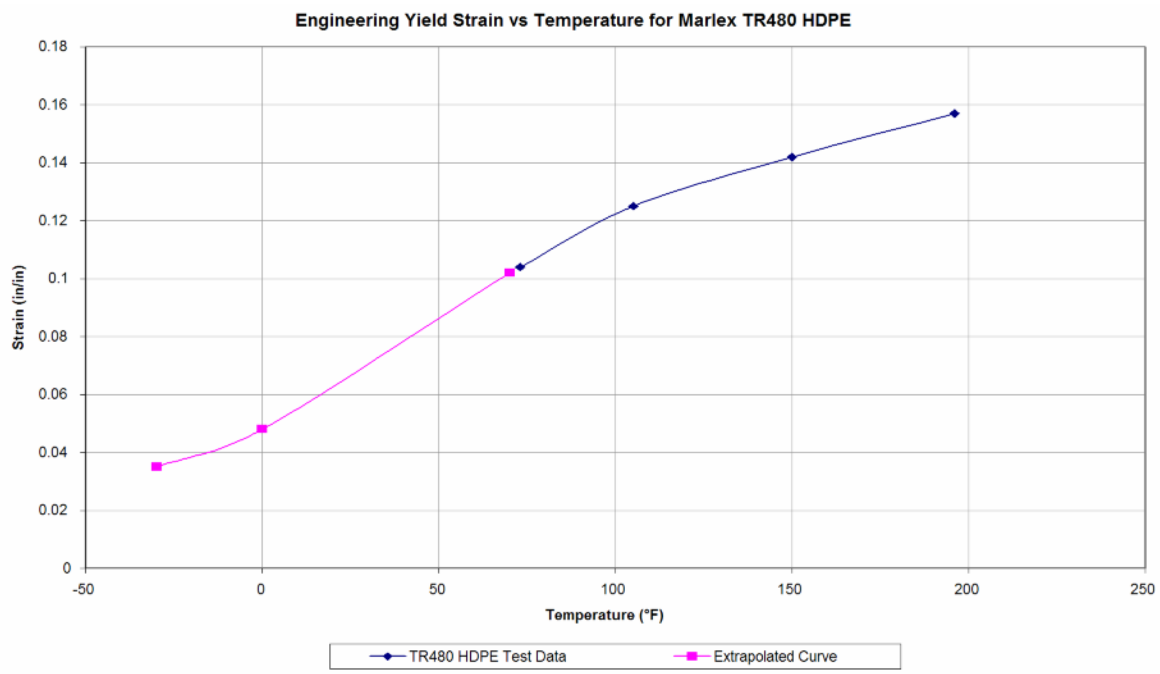

Figure 9 – Engineering Yield Strain vs. Temperature

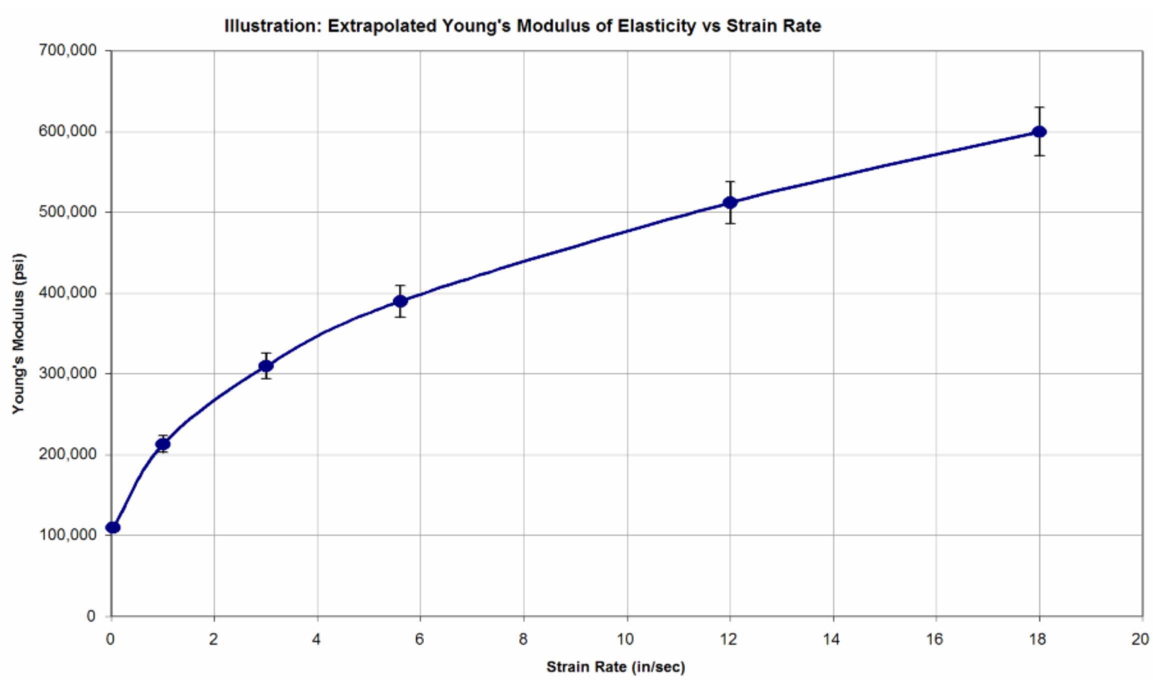

Figure 10 – Young's Modulus vs. Strain Rate

2-10 Provide information on the expected amount of radiation the ARROW-PAK container may be subjected to and its effects (if any) on the structural behavior of the EHMW-HDPE material.

This information is required to verify compliance to 10 CFR 71.71 and 71.73 regulatory requirements.

High-Density Polyethylene (HDPE) is a very efficient neutron moderator and has been used in the shielding of nuclear reactors and other sources of radiation for decades. For this reason, much research and testing has been done to determine the effects of high doses of radiation on HDPE. As a result of this research, HDPE has been approved as a disposal method for low-level radioactive waste in the form of High Integrity Containers (HICs) in lieu of final waste form treatment.

Government sponsored tests performed by Chevron–Phillips on HDPE indicate that material properties are not adversely effected for radiation doses up to 2×10^7 rads[7]. This dose rate is equivalent to 11,400 years of exposure for CH-TRU waste. Between 2×10^7 and 9×10^7 rad, tensile and shear strength actually increase. Above 9×10^7 rad (>51,000 years), physical properties begin to gradually degrade.

Radiation tests were performed at the Department of Energy's Idaho National Engineering Laboratory (INEL) in 1994 on actual ARROW-PAK HDPE material. The ARROW-PAK HDPE was tested to 700,000 rad and found to have no measurable degradation in physical properties. This dose rate is equivalent to over 399 years of continuous exposure to CH-TRU waste. Therefore, radiation will have no adverse impact on the structural integrity of the ARROW-PAK for CH-TRU waste during transport, as discussed at the end of SAR Section 1.2.

2-11 Provide environmental conditions (time, temperature, other) of service expected for the foam of Drawing 2077-500 SNP.

Information is required to ensure that the service conditions imposed upon the use of ARROW-PAK are bounded by previous analyses of the requirements imposed on this polyurethane foam material. This information is required to verify compliance to 10 CFR 71.71 and 71.73 regulatory requirements.

The 25.2-watt decay heat limitation (based on limiting the ARROW-PAK sidewall temperature to 140 ºF; MNOP calculations actually determine a lower decay heat limit) for three ARROW-PAKs within a TRUPACT-II package is bounded by the 40-watt internal decay heat limitation for other payloads within a TRUPACT-II

[7] C. R. Tipton, Jr., *Reactor Handbook*, 2nd Edition, Volume 1 – *Materials*, Interscience Publishers, New York, 1960, Chapter 52, Section 52.4(3)(b), *Polyethylene*, shows little change in properties for doses up to 2×10^7 rads.

package. Therefore, the service conditions imposed upon the use of ARROW-PAK are bounded by the previous analyses of the requirements imposed on the TRUPACT-II package's polyurethane foam.

Chapter 3 – Thermal

3-1 Address the consequences of a hydrogen deflagration on the ARROW-PAK container at MNOP conditions and with its high-density polyethylene walls at the allowable limit of 140°F. Also, evaluate the effects of the strain rate, to which parts of the ARROW-PAK will be subjected, on the calculations and the deflagration testing.

From Table 10-6, the applicant predicts an MNOP of 99.66 psig for an ARROW PAK payload container with an uneven decay heat distribution (15.5 watts in one single container). This value is essentially equal to the design pressure limit of 100 psig. Table B2 from NASA's Safety Standard for Hydrogen and Hydrogen System, as mentioned in Section 3.6.1.4 of the application, indicates a pressure ratio of 3.7 for a 75% hydrogen mixture in air. The combination of the pressure spike and the internal release of energy may damage the container at these extreme, but still possible, conditions. The deflagration testing (SAR Section 3.6 Appendix) was performed at ambient pressure (approx. 12.4 psia) and temperature (approx. 70°F), and at a low strain rate. Also, the hydrostatic validation testing (SAR Section 2.10.2) was performed at 70°F.

This information is required to verify that the package is safe and that there is adequate technical basis to grant an exemption from the requirements of 10 CFR 71.43(d).

SAR Section 2.3.1 (long-term strength) and SAR Section 2.3.2 (instantaneous strength) have been added to SAR Section 2.3 to provide derivation of allowable limits for these two loading conditions. For example, MNOP pressure capacity, as determined in SAR Section 2.6.1, is based on the long-term strength, whereas deflagration testing, as determined in SAR Section 3.6.1, is based on the instantaneous strength.

SAR Section 3.6.1 has been revised to evaluate the ARROW-PAK container for a deflagration event occurring at a MNOP pressure of 100 psig at 140 ºF. The resulting margin of safety is shown to be positive.

Hydrostatic validation testing is discussed in the response to RAI 2-8.

3-2 Justify that the thermal finite-element analysis assuming the 55-gallon drum placed at the center of the ARROW-PAK container length, instead of at the bottom, is conservative for all parts of the container, including the side wall and top and bottom domed closure devices.

During the transport, the 55-gallon drum is placed in the ARROW-PAK container at the bottom, and may result in temperature distribution worse than the assumption of the drum being placed at the center of the container. This information is required to verify compliance with 10 CFR 71.71(c)(1).

The SAR drawing has been revised (see the "Payload Placement" view on new drawing Sheet 3) to include the corrugated plastic end spacers used in free drop testing. Use of these spacers will roughly center the 55-gallon drum along the length of the ARROW-PAK container and will result in temperatures as predicted by the current thermal analyses.

3-3 Revise Tables 3-1 and 3-2 to include temperatures in the top and bottom domed devices to support the statement in SAR Section 2.6.1, 2nd paragraph that the differential thermal stresses are negligible in the ARROW-PAK because the temperature distribution throughout the ARROW-PAK is relatively uniform. Also, include plots of maximum steady-state temperatures in the ARROW-PAK for both even and uneven decay heat scenarios.

The non-uniform distribution at the junction between the domed device and the shell may result in thermal stresses which may not be negligible. This information is required to verify compliance to 10 CFR 71.71(c)(1).

SAR Table 3-1, Table 3-2, and Table 3-3 have been revised to include average temperatures in the top and bottom domed closure devices for NCT maximum temperatures. As shown, average ARROW-PAK sidewall and closure device temperatures are generally within 1 ºF of each other which will result in negligible thermal stresses. In addition, plots of maximum NCT steady-state temperatures for the ARROW-PAK for both even and uneven decay heat limits have been provided.

3-4 Justify the inclusion of convection, besides conduction and radiation, when modeling the heat transfer between the ARROW-PAKs and the inner surfaces of the TRUPACT II package, as suggested in Section 3.4.1.2 of the application. Provide all the details about modeling convection with SINDA/FLUINT, including any correlation and assumption that may have been used. Describe the flow pattern that may be developed in the inner space between ARROW-PAKs and TRUPACT-II, and how buoyancy will help move heat from the hot to the cold bodies. Discuss validation/benchmarking efforts that support the use of the SINDA/FLUINT convection option for such unusually shaped inner space. Indicate the percentage of the total heat the SINDA/FLUINT predicts to be attributed to convection, conduction and radiation. Indicate what the ARROW-PAK sidewall temperature would be if convection were not taken into consideration.

The staff does not agree that convection is a valid way of removing heat from the ARROW-PAKs to the inner surface of the TRUPACT-II due to the oddly shaped geometry of the inner space. The inclusion of convection in the SINDA/FLUINT model may be supporting a non-conservative approach to heat transfer which, in turn, leads to underpredicted sidewall surface temperatures and consequently overpredicted decay heat limits.

10 CFR 71.33 states that the application must include a description of the proposed package in sufficient detail to identify the package accurately and provide a sufficient basis for evaluation of the package.

The inclusion of convection with conduction and radiation was done on the basis that all three modes of heat transfer could exist on some level within the TRUPACT-II cavity. To that end, the specific modeling approach used in the SINDA/FLUINT model was to let the program decide if convection existed based on the computed Rayleigh number for the affected spaces. Generally, if a Rayleigh number is $\leq 10^3$, the buoyancy forces will be too weak to overcome the viscous forces and heat transfer will be primarily by conduction across the fluid. It should be further noted that the “oddly shaped geometry” of the payload will not in and of itself prevent convection from occurring if both the Rayleigh number is sufficiently high and if the boundary layers between ascending and descending buoyancy driven flows do not intersect.

The SINDA/FLUINT model used the thermo-physical properties of air, the computed temperature differences, and the characteristic lengths of the void space between the ARROW-PAKs, between the ARROW-PAKs and the stretch-wrap, and between the stretch-wrap and the inner surfaces of the TRUPACT-II cavity to determine the associated Rayleigh numbers. The results for this application showed that the Rayleigh numbers are too low for convection to occur to any significant degree and the model-returned computed heat transfer coefficients are based on conduction only.

To validate that the SAR model was conservatively computing the thermal linkage between the ARROW-PAKs and the ICV, the SAR thermal modeling was modified to remove the convection/conduction based links and to substitute solid elements instead to represent the void air spaces. Figure 11 presents the modeling of the ARROW-PAKs and a portion of the ICV sidewall as used in the SAR modeling, while Figure 12 provides a graphic representation of some of the convection/conduction based links between the ARROW-PAKs and the ICV. Figure 13 presents the combined solids representation of the ARROW-PAKs, the ICV sidewall, and the void air spaces used for the sensitivity modeling. Figure 14 illustrates the solids modeling for the void air spaces which replace the convection/conduction based links illustrated in Figure 12. Under the solids modeling approach, the void air spaces assume homogenous conduction in all directions based on the thermal conductivity of air as a function of temperature. Heat transfer via radiation was computed in the same manner as with the SAR analysis.

The sensitivity model was exercised for NCT hot condition at the SAR identified limiting decay heat loadings of 25.2 watts for evenly distributed loading and 22.7 watts for unevenly distributed loading. Table 1 presents a comparison of the predicted temperatures using the SAR thermal model and the results from the sensitivity model. The SAR results are taken from Table 3-3 of the SAR. As can be seen from Table 1, the results from the SAR model equal or bound those obtained from the sensitivity thermal model for the evaluated cases for all but one temperature point (i.e., the centerline of the 55-gallon drum in ARROW-PAK No. 1) and in that case, the difference is only a few tenths of a degree – sufficient enough to round the temperature up instead of down. The biggest difference between the analysis methodologies occurs in the computed bulk average air temperature within the ICV cavity where the SAR model methodology uses a higher temperature resulting from arithmetic averaging, while the sensitivity model uses a volumetric averaging approach to estimate the bulk average air temperature. The higher bulk air temperatures are conservative for the purposes of computing the operating pressure within the ICV.

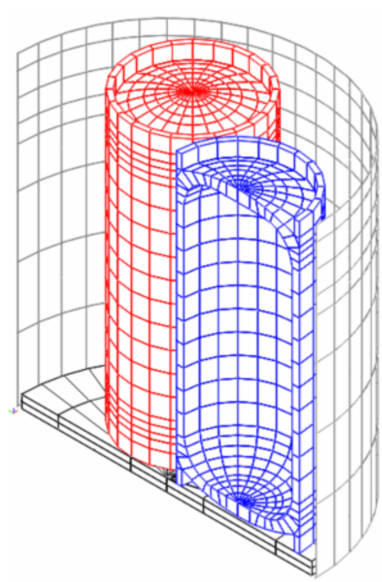

Figure 11 – ARROW-PAK/ICV Modeling Used for the SAR

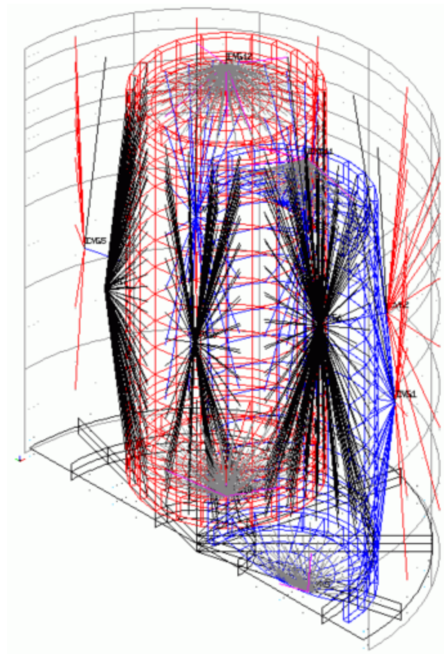

Figure 12 – ARROW-PAK/ICV Modeling Showing Convection/Conduction Links Used for the SAR

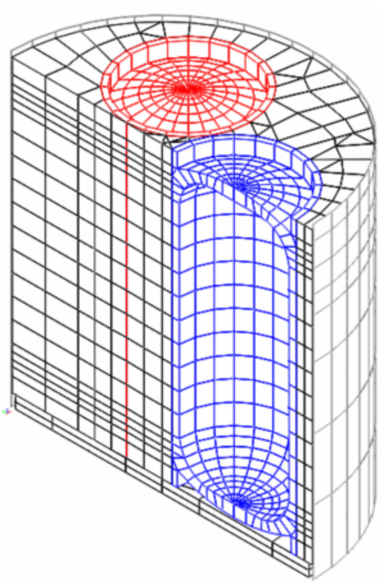

Figure 13 – ARROW-PAK/ICV Sensitivity Model Using Solid Elements for Void Spaces

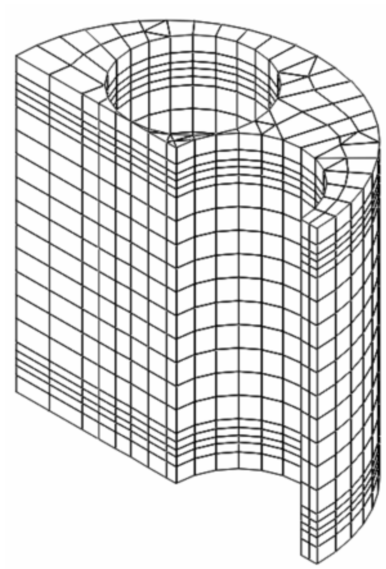

Figure 14 – New 'Solids' Modeling of Air within the ICV Cavity

Table 1 – Comparison of NCT Temperatures for Even and Uneven Decay Heat Distribution Resulting in a 140 ºF Average ARROW-PAK Sidewall Temperature

Location	Temperature (ºF) with Decay Heat			
	Even (25.2 W)		Uneven (22.7 W)	
	SAR Analysis	Sensitivity Analysis	SAR Analysis	Sensitivity Analysis
ARROW-PAK No. 1				
• 55-Gallon Drum Centerline	188	**187**	262	**263**
• 55-Gallon Drum Sidewall	143	**142**	146	**145**
• Maximum ARROW-PAK Sidewall	142	**141**	141	**141**
• Average ARROW-PAK Sidewall	140	**139**	140	**139**
ARROW-PAK Nos. 2 & 3				
• 55-Gallon Drum Centerline	188	**187**	139	**138**
• 55-Gallon Drum Sidewall	143	**143**	139	**138**
• Maximum ARROW-PAK Sidewall	142	**141**	139	**139**
• Average ARROW-PAK② Sidewall	140	**139**	137	**135**
ICV Wall				
• Maximum	137	**137**	136	**135**
• Average	137	**136**	135	**134**
• Minimum	135	**135**	134	**133**
ICV Air (Average)	139	**136**	137	**134**
ICV Main O-ring Seal (Maximum)	137	**136**	135	**134**
OV Wall (Maximum)	137	**137**	135	**135**
OCV Main O-ring Seal (Maximum)	135	**135**	134	**134**
Polyurethane Foam③ (Maximum)	151	**151**	151	**151**
OCA Outer Shell③ (Maximum)	151	**151**	151	**151**

The remaining reason the sensitivity model yields slightly lower temperatures is that the convection/conduction links in the SAR model conservatively ignored surface areas on the ARROW-PAKs in regions were the separating gaps between adjacent ARROW-PAKs and the ARROW-PAKs and the stretch-wrap were small.

These results confirm that the results presented in the SAR are conservatively estimated based on the use of conduction only type of linkages between the ARROW-PAKs and the ICV surfaces. SAR Section 3.4.1.2 has been modified to state this point and to clarify that the convection/conduction links used in the SAR model effectively degrade to conduction only for the temperature differences and geometries involved.

Chapter 10 – Authorized Payload Contents

10-1 Provide information on the standard deviation allowed in the weight of the shipping package (Ref. SAR section 10.2.3.1.1, page 10-2).

The applicant states in SAR Section 10.2.3.1.1 that "ARROW-PAK payload containers and TRUPCT II payloads shall be acceptable for shipment only if the weight plus the measurement error (i.e., one standard deviation) is less than or equal to the maximum gross weight specified in Table 10-1." However, the measurement error is not defined. This information is required to verify structural integrity of the TRUPACT II package and ARROW-PAK containers, in accordance with 10 CFR 71.71 and 10 CFR 71.73.

As noted under SAR Section 10.2.3.2.1, weight must be measured using a scale that is calibrated in accordance with the National Institute of Standards and Technology Handbook 44, or an equivalent standard. The measurement error, as determined from the scale calibration, is required to be added to the measured value before comparison to the applicable limit. Therefore, the maximum gross weight limits specified in SAR Table 10-1 will always be met. This approach is the same as that used for other payload containers authorized for transport in the TRUPACT-II.

10-2 Revise Section 10 of the SAR Addendum for ARROW-PAK, "Authorized Payload Contents," to require blocking, bracing, or specialized packaging for sharp or heavy objects inside the 55-gallon drum in the ARROW-PAK payload container. In addition, explain how the drop tests performed using concrete disks (Ref. SAR Section 2.7.1) simulate the exclusion of blocking, bracing, and specialized packaging of sharp or heavy objects.

The SAR does not adequately demonstrate that unrestrained sharp or heavy objects could not damage the ARROW-PAK payload container during normal conditions of transport so as to degrade its ability to withstand deflagration. This information is needed to ensure that the ARROW-PAK payload

container provides equivalent safety in order to be exempt from the requirements of 10 CFR 71.43(d).

Comment incorporated. SAR Section 10.2.7.1 has been revised to state that "Sharp or heavy objects inside the 55-gallon drum in the ARROW-PAK shall be blocked, braced, or suitably packaged, as necessary, to provide puncture protection for the payload container." SAR Section 10.2.7.2 has been revised to specify that "Compliance shall be by one, or a combination, of the following methods:

- Review of records and database information, which may include knowledge of process
- Radiography
- Visual examination
- Sampling program."

10-3 Revise the analyses in the SAR to use the total gas G value of 8.2 molecules/100ev.

Based on the discussions regarding another amendment related to Revision 21 of the TRUPACT II SAR, the G value cited in the "Shaw Environmental, Inc., High-Dose Criterion for Flammable Gas G Values and Dose-Dependent Net Gas G Values for Contact-Handled Transuranic Wastes, Shaw Environmental, Inc., Albuquerque, New Mexico," is no longer valid. Therefore, the value 3.47 can not be used.

Comment incorporated. The analyses in the SAR have been revised to use a total gas G value of 8.4 molecules/100eV. Resulting changes in the pressure analysis, aerosol can evaluation, and decay heat limits have been incorporated throughout the document.

Attachment C

Application Document

(Two hard copies and seven CDs in Adobe PDF format)

- *TRUPACT-II Safety Analysis Report* (SAR) Addendum for ARROW-PAK, *Revision 0, February 2006*