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DESIGN CALCULATION OR ANALYSIS COVER SHEET

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T	F	
☒	☐	1. This product contains no potentially sensitive information.
☐	☒	2. This product contains information that could define a target.
☐	☒	3. This product contains information that could define a specific location.
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CONTENTS

FIGURES

TABLES

1. PURPOSE

The objective of this calculation was to determine the structural responses of the Emplacement Pallet and Naval Long Waste Package (WP) to drops from their highest possible lift heights. The scope of this document was limited to reporting the calculation results in terms of maximum stress intensities. The Naval Long WP is classified as Quality Level 1 (Ref 12, page 7, Table 1). The Emplacement Pallet is classified as Quality Level 2 (Ref. 19, page 7, Table 1). Therefore, this calculation is subject to the requirements of the Quality Assurance Requirements and Description (Ref. 11). AP-3.12Q, Calculations, was used to perform the calculation and develop the document (Ref. 3).

2. METHOD

The finite element calculation was performed using the commercially available LS DYNA V950 (Ref. 7). The results of this calculation were provided in terms of maximum stress intensities. The control of the electronic management of data was accomplished in accordance with AP-3.13Q, *Design Control* (Ref. 4).

3. ASSUMPTIONS

In the course of developing this document, the following assumptions were made regarding the WP structural calculations. These assumptions do not require confirmation.

3.1 The Poisson's ratio of Alloy C-22 was not available in literature. Therefore, the Poisson's ratio of Alloy 625 (SB-443 N06625) was assumed for Alloy C-22. The impact of this assumption was anticipated to be negligible. The rationale for this assumption was that the chemical compositions of Alloy C-22 and Alloy 625 are similar (see Ref. 2, SB-575 Table 1 and Ref. 1, p. 143, respectively). This assumption was used in Section 5.1 and corresponds to paragraph 5.2.8.2 of Reference 14.

3.2 The geometry of the Naval Long WP was simplified for the purpose of this calculation. A simplified outer shell and inner shell represent the WP and all of its associated parts as it rests on the emplacement pallet while being carried by the Waste Emplacement Gantry. A cylinder of shell elements was created to represent the naval canister. The density of the shell-elements was increased to account for the remaining mass of the loaded Naval Long Waste Package (Ref. 10). The rationale for using this approach was to reduce the computer execution time while preserving all features relevant to the structural calculation. This assumption was used in Section 5.4.

3.3 The drop height for the Emplacement Pallet for this calculation will be $0.9m - 0.118m = 0.782m$. This height is taken from *the Gantry Structural/Control System Analysis* as the highest point that a loaded WP on an Emplacement Pallet will be lifted (Reference 6, page 55, Figure 13). $0.9m$ is the Maximum Lift Travel that the Gantry is capable of, and the $0.118m$ is the clearance below the Emplacement Pallet that the Gantry has. The rationale for this assumption is that it gives a conservative bounding answer for drop height in this configuration of WP and Emplacement Pallet. This assumption is used in Section 5.3.

3.4 Some of the temperature-dependent material properties were not available for Alloy C-22 and 316 SS. Therefore, room-temperature material properties (20 °C) are assumed for these materials when temperature-dependent materials are unavailable. The impact of using room-temperature material properties is anticipated to be small. The rationale for this assumption is that undetermined mechanical properties of said materials would not significantly impact the results (Ref. 14 Section 5.2.8.4). This assumption is used in Section 5.1.

3.5 The elongations of Alloy C-22 and 316 SS at elevated temperatures are not available from traditional sources. However, vendor data are available (Ref. 8, page 15 and Ref. 16, page 3). The percent difference between elongations at RT and elevated temperatures can be normalized and applied to the data available from accepted codes. The rationale for this assumption is that the relative change of typical elongations should be bounding for the relative change of minimum elongation. Even though the values are not from traditional sources, the values are conservative and create higher stress intensities for the same temperature. This assumption is used in Section 5.1.1 and corresponds to paragraph 5.2.8.5 of Ref. 14.

3.6 Three-stage deformation characteristics are not observed in the stress-strain curves for Alloy C-22 or 316 SS (Ref. 18 and Ref. 9). However, in order to capture the uniform strain of the material from the curves, the total elongation should be conservatively reduced by 10%. The rationale for this assumption is to truncate the last portion of the curve that has decreasing slope. This assumption is used in Section 5.1.2 and corresponds to paragraph 5.2.8.6 of Ref. 14.

3.7 The drop height for the Naval Long drop onto the Emplacement Pallet is $2.4m$ from the bottom of the WP to the floor. The Naval Long WP makes contact with Plate 6 of the Emplacement Pallet at $0.250m$ above the ground. That distance will be removed from the initial velocity calculation in Section 5.3 (see Attachment II). The rationale for this assumption is that this is the highest height for horizontal lifts and should give a bounding result for a horizontal drop onto the Emplacement Pallet. This assumption is used in Section 5.3 and corresponds to the horizontal lift height requirement in the System Design Description Document (Ref. 20, Section 1.2.2.1.4).

3.8 The impact surface that the WP is to be dropped on is conservatively assumed to be unyielding. Such a material does not exist. LS-DYNA V950 (Ref. 7) is able to simulate such a surface. The result will be that the stresses produced by this calculation will be a small percentage higher than those that would result if a realistic surface were used. The rationale is that this maximizes the stresses on the falling WP. This assumption is used in Section 5.1 and Section 5.4 and corresponds to paragraph 5.2.8.1 of Ref. 14.

3.9 Strain-rate hardening material properties are not available for Alloy C-22, 316 SS, and A36 CS. The effect of this phenomena is neglected. The impact of ignoring these properties is anticipated to be conservative. The rationale for this assumption is that strain rate hardening would make the material stronger. This assumption is used in Section 5.1 and corresponds to paragraph 5.2.5 in Ref. 14.

4. USE OF COMPUTER SOFTWARE

The qualified Finite Element Analysis (FEA) code used for this calculation is Livermore Software Technology Corporation (LSTC) LS-DYNA V950 (Ref. 7). LS-DYNA V950 was obtained from the Software Configuration Secretariat in accordance with the appropriate procedures and is identified by STN 10300-950-00. LS-DYNA V950 is appropriate for its intended use as a structural FEA solver. The LS-DYNA evaluation performed for this calculation is fully within the range of the validation performed for the LS-DYNA V950 code. The calculations were executed on the Hewlett-Packard (HP) 9000 series UNIX workstations (Operating System HP-UX B.10.20) identified with YMP tag numbers 117161 and 117162 located in Las Vegas, NV.

TrueGrid, Version 2.1 was used in this calculation solely to mesh geometric representations of the domain. The suitability and adequacy of this mesh is based on visual examination, engineering judgment, and the results of mesh verification in Section 6 (see Table 5-1). The mesh has been evaluated in accordance with AP-3.12Q, and determined to be suitable and adequate for use as input to LS-DYNA V950. Therefore, the use of TrueGrid Version 2.1 is exempt from the requirements of AP-SI.1Q, Software Management (Ref. 13) as stated in Section 2.1.2 of this procedure.

The input and output files are defined in Section 8 of this document. They are located in Attachment III (compact disc) to this document. The input files are identified by .k and .inc file extensions for LS-DYNA V950 and .tg for TrueGrid Version 2.1. The output files (d3hsp and output) from LS-DYNA V950 are also provided in Attachment III.

5. CALCULATION

5.1 MATERIAL PROPERTIES

Material properties used in this calculation are listed in this section. All available material properties at 212 *°F* are used to give a bounding result. Some of the temperature-dependent and rate-dependent material properties were not available for Alloy C-22 and 316 SS. Therefore, room-temperature (RT) material properties were used for those unavailable properties (Assumption 3.4 and 3.9).

SB-575 N06022 (Alloy C-22) (Outer shell, outer shell lids, and almost all of the Emplacement Pallet):

- Density = 8690 kg/m^3 (0.314 lb/in^3) (at RT) (Ref. 2, Section II, SB-575 Section 7.1)

- Yield strength = 310 *MPa* (45.0 *ksi*) (at RT) (Ref. 2, Section II, Table Y-1)
- Yield strength = 276 *MPa* (40.1 *ksi*) (at 200 *°F* = 93 *°C*) (Ref. 2, Section II, Table Y-1)
- Yield strength = 265 *MPa* (38.4 *ksi*) (at 250 *°F* = 121 *°C*) (Ref. 2, Section II, Table Y-1)

Linear interpolation of Yield Strength at 212 *°F* (100 *°C*):

Using the point slope equation

$$y - y_1 = m(x - x_1) \qquad \text{Equation 5.1}$$

$$y - 276MPa = \left(\frac{265MPa - 276MPa}{121\deg C - 93\deg C}\right) * (100\deg C - 93\deg C) \qquad \text{using Equation 5.1}$$

$y = 273MPa$ at 100 *°C*

- Tensile strength = 689 *MPa* (100 *ksi*) (at RT) (Ref. 2, Section II, Table U)
- Tensile strength = 689 *MPa* (100 *ksi*) (at 200 *°F* = 93 *°C*) (Ref. 2, Section II, Table U)
- Tensile strength = 679 *MPa* (98.5 *ksi*) (at 300 *°F* = 149 *°C*) (Ref. 2, Section II, Table U)
- Tensile strength = 688 *MPa* (at 212 *°F* =100 *°C*) (using Equation 5.1)

- Elongation = 0.45 (at RT) (Ref. 2, Section II, SB-575 Table 3)

- Poisson's ratio = 0.278 (at RT) (Ref. 1, p. 143; see Assumption 3.1)

- Modulus of elasticity = 206 *GPa* (at RT) (Ref. 8, p. 14)
- Modulus of elasticity = 203 *GPa* (at 200 *°F* = 93 *°C*) (Ref. 8, p. 14)
- Modulus of elasticity = 196 *GPa* (at 400 *°F* = 204 *°C*) (Ref. 8, p. 14)

- Modulus of elasticity = 203 *GPa* (at 212 °*F* =100 °*C*) (using Equation 5.1)

SA-240 S31600 (316 SS) (Inner shell, inner shell lids, naval canister shell, and Emplacement Pallet - Tube 1):

- Density = 7980 kg/m^3 (Ref. 5, Table XI.1, p. 7)

- Yield strength = 207 *MPa* (30 *ksi*) (at RT) (Ref. 2, Section II, Table Y-1)
- Yield strength = 179 *MPa* (25.9 *ksi*) (at 200 °*F* = 93 °*C*) (Ref. 2, Section II, Table Y-1)
- Yield strength = 170 *MPa* (24.6 *ksi*) (at 250 °*F* = 121 °*C*) (Ref. 2, Section II, Table Y-1)
- Yield strength = 177 *MPa* (at 212 °*F* =100 °*C*) (using Equation 5.1)

- Tensile strength = 517 *MPa* (75.0 *ksi*) (at RT) (Ref. 2, Section II, Table U)
- Tensile strength = 517 *MPa* (75.0 *ksi*) (at 200 °*F* = 93 °*C*) (Ref. 2, Section II, Table U)
- Tensile strength = 503 *MPa* (72.9 *ksi*) (at 300 °*F* = 149 °*C*) (Ref. 2, Section II, Table U)
- Tensile strength = 515 *MPa* (at 212 °*F* =100 °*C*) (using Equation 5.1)

- Elongation = 0.40 (at RT) (Ref. 2, Section II, SA-240 Table 2)

- Poisson's ratio = 0.30 (at RT) (Ref. 1, Figure 15, p. 755)

- Modulus of elasticity= 195 *GPa* (28.3 *ksi*) (RT) (Ref. 2, Section II, Table TM-1)
- Modulus of elasticity= 190 *GPa* (27.6 *ksi*) (200 °*F* = 93 °*C*) (Ref. 2, Section II, Table TM-1)
- Modulus of elasticity= 186 *GPa* (27.0 *ksi*) (300 °*F* = 149 °*C*) (Ref. 2, Section II, Table TM-1)
- Modulus of elasticity = 190 *GPa* (at 212 °*F* =100 °*C*) (using Equation 5.1)

SA-36/36M K02600 (A36 CS, see Assumption 3.8 (Unyielding Surface)):

- Density = 7860 kg/m^3 (at RT) (Ref. 5 Table X1, p. 7)
- Poisson's ratio = 0.30 (at RT) (Ref. 21, p. 374)
- Modulus of elasticity = 203 *GPa* ($29.5 \cdot 10^6$ *psi*) (at RT) (Ref. 2 Section II, Table TM-1)

5.1.1 Calculations for Elevated-Temperature Material Properties

The values for elongation at elevated temperatures are not listed in conventional listings such as American Society for Testing and Materials (ASTM) Standards or American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. However, the elongation values at elevated temperatures are available from vendor data. This vendor data will be used to estimate elevated temperature elongation normalized to the RT values from accepted codes (see Assumption 3.5).

For Alloy C-22, the vendor data shows an approximate 5% relative increase between RT and 212 °*F* (Ref. 8, page 15). Therefore, the elongation values for Alloy C-22 at elevated temperatures will be as follows:

Elongation = $0.45 \cdot 1.05 = 0.47$ (at $212\ ^{\circ}F = 100\ ^{\circ}C$)

For 316 SS, the vendor data shows an approximate 20% decrease between RT and 212 °*F* (Ref. 16, page 8). Therefore, the elongation values for 316 SS at elevated temperatures will be as follows:

Elongation = $0.40 \cdot (1 - 0.20) = 0.32$ (at $212\ ^{\circ}F = 100\ ^{\circ}C$)

5.1.2 Calculations for True Measures of Ductility

The material properties in Section 5.1 refer to engineering stress and strain definitions (see Ref. 17, Chapter 9):

$$s = \frac{P}{A_0} \text{ and } e = \frac{L - L_0}{L_0}$$

Where P stands for the force applied during static tensile test, L is the deformed-specimen length, and L_0 and A_0 are original length and cross-sectional area of specimen, respectively. It is generally accepted that the engineering stress-strain curve does not give a true indication of the deformation characteristics of a material during the plastic deformation since it is based entirely on the original dimensions of the specimen. Therefore, the LS-DYNA V950 finite element code requires input in terms of true stress and strain definitions:

$$\sigma = \frac{P}{A} \text{ and } \varepsilon = \ln\left(\frac{L}{L_0}\right)$$

The relationships between the true stress and strain definitions and engineering stress and strain definitions can be readily derived based on constancy of volume ($A_0 \cdot L_0 = A \cdot L$) and strain homogeneity during plastic deformation:

$$\sigma = s \cdot (1 + e)$$ Equation 5.1.2a

$$\varepsilon = \ln(1 + e)$$ Equation 5.1.2b

These expressions are applicable only in the hardening region of stress-strain curve that is limited by the onset of necking.

The following parameters are used in the subsequent calculations:

$s_y \approx \sigma_y$ = yield strength

s_u = engineering tensile strength

σ_u = true tensile strength

$e_y \approx \varepsilon_y$ = strain corresponding to yield strength

e_u = engineering strain corresponding to tensile strength (engineering uniform strain)

ε_u = true strain corresponding to tensile strength (true uniform strain)

In absence of the uniform strain data in available literature, it needs to be estimated based on stress-strains curves and elongation (strain corresponding to rupture of the tensile specimen).

The stress-strain curves for Alloy C-22 and 316 SS do not manifest three-stage deformation character (see Ref. 18 and Ref. 9). Therefore, the elongation, reduced by 10% for the sake of conservativism can be used in place of uniform strain (see Assumption 3.6).

In the case of Alloy C-22 the true measures of ductility are:

$e_u = 0.9 \cdot elongation = 0.41$ (at RT)

$e_u = 0.9 \cdot 0.47 = 0.42$ (at $212\ ^oF = 100\ ^oC$, vendor data)

$\varepsilon_u = \ln(1+e_u) = \ln(1+0.41) = 0.34$ (at RT) (using Equation 5.1.2b)

$\varepsilon_u = \ln(1+e_u) = \ln(1+0.42) = 0.35$ (at $212\ ^oF = 100\ ^oC$, vendor data) (using Equation 5.1.2b)

$\sigma_u = s_u \cdot (1+e_u) = 689 \cdot (1+0.41) = 971\ MPa$ (at RT) (using Equation 5.1.2a)

$\sigma_u = s_u \cdot (1+e_u) = 688 \cdot (1+0.42) = 977\ MPa$ (at $212\ ^oF = 100\ ^oC$, vendor data) (using Equation 5.1.2a)

For 316 SS:

$e_u = 0.9 \cdot elongation = 0.36$ (at RT)

$e_u = 0.9 \cdot 0.32 = 0.29$ (at $212\ ^oF = 100\ ^oC$, vendor data)

$\varepsilon_u = \ln(1+e_u) = \ln(1+0.36) = 0.31$ (at RT) (using Equation 5.1.2b)

$\varepsilon_u = \ln(1+e_u) = \ln(1+0.29) = 0.25$ (at $212\ ^oF = 100\ ^oC$, vendor data) (using Equation 5.1.2b)

$\sigma_u = s_u \cdot (1+e_u) = 517 \cdot (1+0.36) = 703\ MPa$ (at RT) (using Equation 5.1.2a)

$\sigma_u = s_u \cdot (1+e_u) = 515 \cdot (1+0.29) = 664\ MPa$ (at $212\ ^oF = 100\ ^oC$, vendor data) (using Equation 5.1.2a)

5.2 CALCULATIONS FOR TANGENT MODULI

The results of this simulation were required to include elastic and plastic deformations for Alloy C-22 and 316 SS. When the materials are driven into the plastic range, the slope of stress-strain curve continuously changes. Thus, a simplification for this curve was needed to incorporate plasticity into the FER. A standard approximation commonly used in engineering is to use a straight line that connects the yield point and the ultimate tensile strength point of the material. The parameters used in the subsequent calculations in addition to those defined in Section 5.1.2 are modulus of elasticity (E) and tangent modulus (E_1). The tangent (hardening) modulus represents the slope of the stress-strain curve in the plastic region.

In the case of Alloy C-22, the strain corresponding to the yield strength is:
$\varepsilon_y = \sigma_y / E = 310 \cdot 10^6 / 206 \cdot 10^9 = 1.50 \cdot 10^{-3}$ (at RT) (see Section 5.1 and Section 5.1.1)

Hence, the tangent modulus is:

$E_1 = (\sigma_u - \sigma_y)/(\varepsilon_u - \varepsilon_y) = (0.971 - 0.310)/(0.34 - 1.50 \cdot 10^{-3}) = 2.0\ GPa$ (at RT) (see Section 5.1, 5.1.1, and 5.1.2)
$E_1 = (\sigma_u - \sigma_y)/(\varepsilon_u - \varepsilon_y) = (0.977 - 0.273)/(0.35 - 0.273/203) = 2.0\ GPa$ (at $212\ ^\circ F = 100\ ^\circ C$, with vendor data) (see Section 5.1, 5.1.1, and 5.1.2)

Similarly, for 316 SS:

$E_1 = (\sigma_u - \sigma_y)/(\varepsilon_u - \varepsilon_y) = (0.703 - 0.207)/(0.31 - 0.207/195) = 1.6\ GPa$ (at RT) (see Section 5.1, 5.1.1, and 5.1.2)
$E_1 = (\sigma_u - \sigma_y)/(\varepsilon_u - \varepsilon_y) = (0.664 - 0.177)/(0.25 - 0.167/190) = 2.0\ GPa$ (at $212\ ^\circ F = 100\ ^\circ C$, vendor data) (see Section 5.1, 5.1.1, and 5.1.2)

5.3 INITIAL VELOCITY

To reduce the computer execution time while preserving all features of the problem relevant to the structural calculation, the WP is set in a position just before impact and given an appropriate initial velocity.

Using the following parameters:

g = acceleration due to gravity = 9.81 m/s^2
h = drop height

and Newton's equation of motion:

$$V^2 = V_o^2 + 2gh$$

where V and V_o are the final and initial velocity, respectively.

For the WP on the Emplacement Pallet while being lifted by the Emplacement Gantry substituting values in yields:

h = 0.782 *m* (Assumption 3.3)

$V^2 = 0^2 + 2*(9.81m/s^2)*(0.782m)$, which reduces to

$V = 3.92m/s$.

For the WP dropped onto the Emplacement Pallet from 2.4*m* substituting values in yields:

h = 2.4-0.250 *m* = 2.15 *m* (Assumption 3.7)

$V^2 = 0^2 + 2*(9.81m/s^2)*(2.15m)$, which reduces to

$V = 6.49m/s$.

5.4 FINITE ELEMENT REPRESENTATION

A quarter-symmetry Finite Element Representation (FER) was created in TrueGrid for this calculation (see Figure 5-1). Only brick elements were used with the exception of the innermost cylinder that represents the naval canister (see Assumption 3.2). The Emplacement Pallet was represented like the sketch in Attachment II. The Naval Long WP (Ref. 10) was represented simplified, such that a simplified inner and outer shell represent the entire WP and a cylinder of shell elements represents the naval canister (Assumption 3.2). The density of the naval canister is adjusted to account for the weight of the non-represented parts and canister mass (Assumption 3.2). An unyielding surface was also constructed below the Emplacement Pallet to represent the ground (Assumption 3.8).

This calculation was done in two parts. The first part is a representation of the Emplacement Pallet holding the Naval Long WP at its highest possible lift height (0.782*m*) and then dropping it from that height. The initial velocity of 3.92 *m/s*, as calculated in Section 5.3, was applied to all parts except for the unyielding surface. All associated parts are set right before the moment of impact.

The second part is a representation of the Naval Long WP at its highest possible lift height of 2.4*m* being dropped onto the Emplacement Pallet, which is resting on the ground. The initial velocity of 6.49*m/s*, as calculated in Section 5.3, was applied to the inner shell, outer shell, and naval canister and set right before the moment of impact.

The solution was obtained by finding the element with the most stress within the WP inner shell and outer shell during the impact.

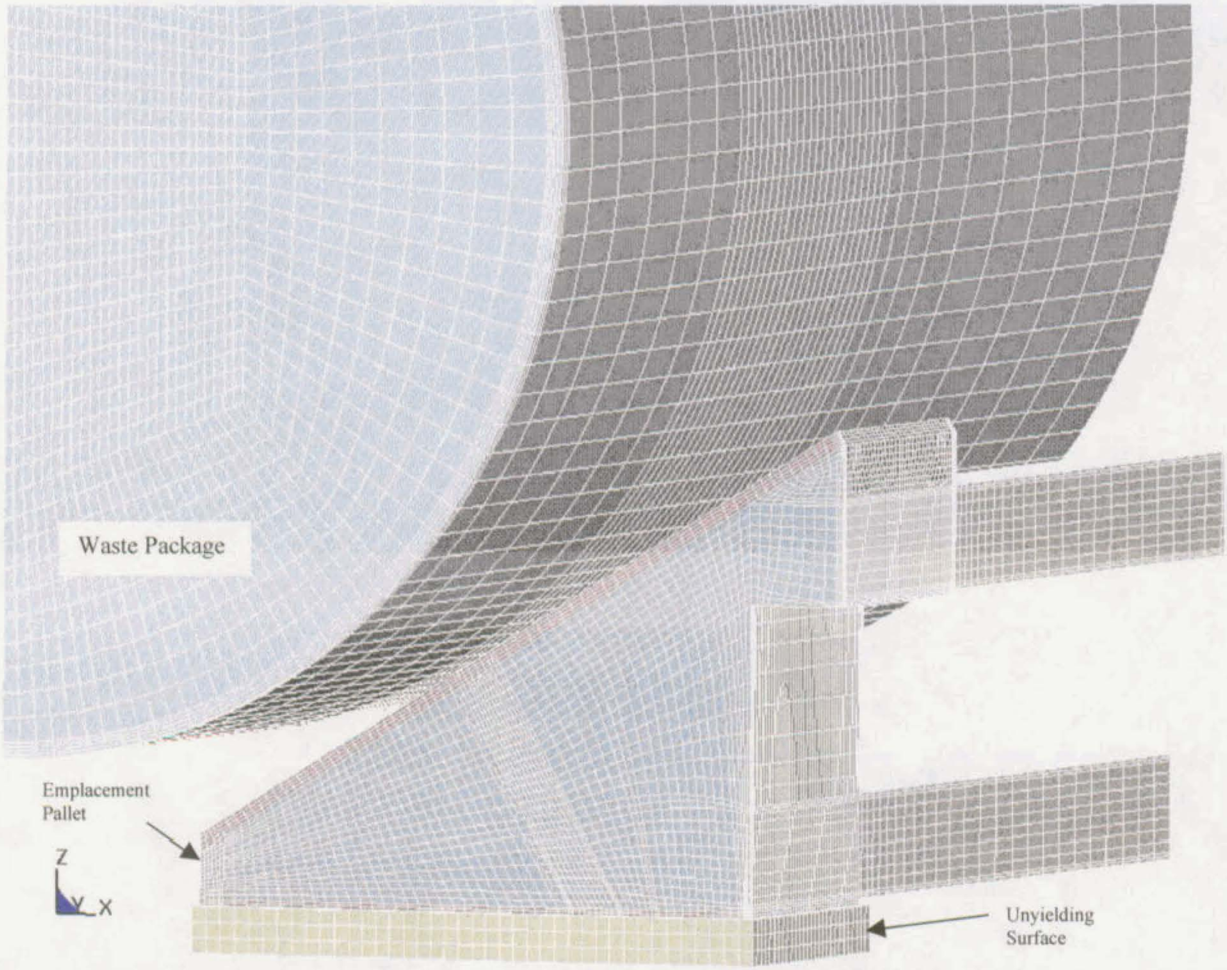

Figure 5-1. Naval Long and Emplacement Pallet Mesh Prior to Contact – Both Scenarios

The mesh refinement for this finite-element calculation was checked on the elements that contained the most stress to be reported out of the all of the representations. That area was on the WP's outer shell in the 2.4*m* Naval WP drop onto the Emplacement Pallet at RT. Specifically where the Emplacement Pallet and the WP outer shell make contact. The outer shell's refinement was checked by increasing the number of elements across the thickness of the outer shell from 3 to 5 and comparing the stresses and element volumes at the element with the highest stress. Table 5-1 shows the critical element volume reduction and change in result. The stresses were taken from Figures I-5 and I-6.

Table 5-1. Mesh Refinement

	Refined Mesh	Un-Refined Mesh
Critical Element Volume	4.6976E-06	7.7337E-06
Maximum Shear Stress on WP Outer Shell	EL# 56380 172 *MPa*	EL# 58759 170 *MPa*
Volume Refinement	64.6 %	
Change in Result	1.2 %	

As the percent change between the volume refinement and the result are within one order of magnitude the mesh is deemed acceptable.

6. RESULTS

Table 6-1 shows the maximum shear stress in the WP outer shell and inner shell for each of the Emplacement Pallet drop while loaded with the Naval Long WP (0.782*m*) (see Attachment I, Figure I-3 and I-4). Table 6-2 shows the maximum shear stress in the WP outer shell and inner shell for each of the 2.4*m* drop of the Naval Long WP onto the Emplacement Pallet (see Attachment I, Figure I-5 and I-7).

Table 6-1. Maximum Shear Stresses (*MPa*) for Emplacement Pallet drop (0.782*m*) while loaded with Naval Long WP (see Figures I-3 and I-4)

Temperature	Part	Stress (*MPa*)
Room Temperature	Inner Shell	122
	Outer Shell	154
212 °F (100 °C)	Inner Shell	106
	Outer Shell	151

Table 6-2. Maximum Shear Stresses (*MPa*) for Naval Long WP drop (2.4*m*) onto Emplacement Pallet (see Figures I-5 and I-7)

Temperature	Part	Stress (*MPa*)
Room Temperature	Inner Shell	117
	Outer Shell	170
212 °F (100 °C)	Inner Shell	101
	Outer Shell	151

The results obtained from LS-DYNA V950 are reported in terms of maximum shear stress. Since the maximum stress intensities are desired, the results must be translated. The maximum shear stress is defined as one half the difference between principal stresses one and three. Maximum stress intensity is defined as simply the difference between principal stresses one and three. Therefore, the results obtained from LS-DYNA will be multiplied by two to obtain the maximum stress intensities. Table 6-3 and Table 6-4 show the maximum stress intensities.

Table 6-3. Maximum Stress Intensities (*MPa*) for Emplacement Pallet drop (0.782*m*) while loaded with Naval Long WP

Temperature	Part	Stress (*MPa*)
Room Temperature	Inner Shell	244
	Outer Shell	308
212 °F (100° C)	Inner Shell	212
	Outer Shell	302

Table 6-4. Maximum Stress Intensities (*MPa*) for Naval Long WP drop (2.4*m*) onto Emplacement Pallet

Temperature	Part	Stress (*MPa*)
Room Temperature	Inner Shell	234
	Outer Shell	340
212° F (100° C)	Inner Shell	202
	Outer Shell	302

As a result of the two drop scenarios the Emplacement Pallet experiences stresses over yielding in all cases. These stresses range from 692 *MPa* (0.782*m* @ 212 *°F*) to 934 *MPa* (2.4*m* @ RT). This yielding is unimportant, as it does not cause breaching in the WP and the damaged Emplacement Pallet would be replaced before emplacement in the drift.

The output values are reasonable for the given inputs in this calculation. The uncertainties are taken into account by consistently using the most conservative approach; the calculations, therefore, yield a conservatively bounding set of results. The results are suitable for assessing the stress state of the Inner Shell and Outer Shell during these events.

7. CONCLUSION

In this calculation the Emplacement Pallet absorbs most of the kinetic energy from both of the two drop scenarios. That energy absorption is shown in Attachment I, Figures I-1 and I-2. The deformation of the Emplacement Pallet takes a tremendous amount of energy and lowers the stresses in the WP considerably by yielding during the impact. This lowering of stresses in the WP is easily demonstrated by comparing the results of this calculation to the results of *Horizontal Drop of the Naval SNF Long Waste Package on Unyielding Surface* (Ref. 22). In Reference 22 the Naval Long WP is dropped horizontally 2.4*m* onto an unyielding surface resulting in a maximum stress intensity in the outer shell of 694 *MPa* (Page 10). Compare that 694 *MPa* with 340 *MPa*, the maximum stress intensity in the outer shell from this calculation. This shows that Reference 22 is a more conservative horizontal drop scenario and should be used instead of this scenario as the basis for design. This calculation should not need to be done again unless drastic changes in design take place in either the Emplacement Pallet or the Naval Long WP.

8. REFERENCES

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9. ATTACHMENTS

Attachment I (4 pages): Figures obtained from LS-DYNA V950

Attachment II (15 pages): Emplacement Pallet Sketch

Attachment III (Compact Disc):

Table 9-1 includes the name, date, time, and size for each electronic file.

Table 9-1. File Names, Dates, Times, and Sizes

File #	Name	Date	Time	Size
1	\pd212\d3hsp	10/14/2002	01:14p	29,911,423
2	\pd212\out	10/14/2002	01:14p	8,192
3	\pd212\pallet_drop.tg	10/14/2002	01:14p	27,227
4	\pd212\pd212.k	10/14/2002	01:14p	3,285
5	\pd212\trugrdo.inc	10/14/2002	01:14p	10,406,916
6	\pd212_2m\d3hsp	10/14/2002	01:15p	29,719,358
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9	\pd212_2m\pd212_2m.k	10/14/2002	01:15p	3,275
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12	\pdroom\out	10/14/2002	01:15p	8,192
13	\pdroom\pallet_drop.tg	10/14/2002	01:15p	27,227
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19	\pdroomref_2m\pdroomref_2m.k	10/14/2002	01:15p	3,282
20	\pdroomref_2m\trugrdoref.inc	10/14/2002	01:15p	11,129,531
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23	\pdroom_2m\pallet_drop.tg	10/14/2002	01:15p	27,227
24	\pdroom_2m\pd_room_2m.k	10/14/2002	01:15p	3,273
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NOTE: The file sizes may vary with operating system.

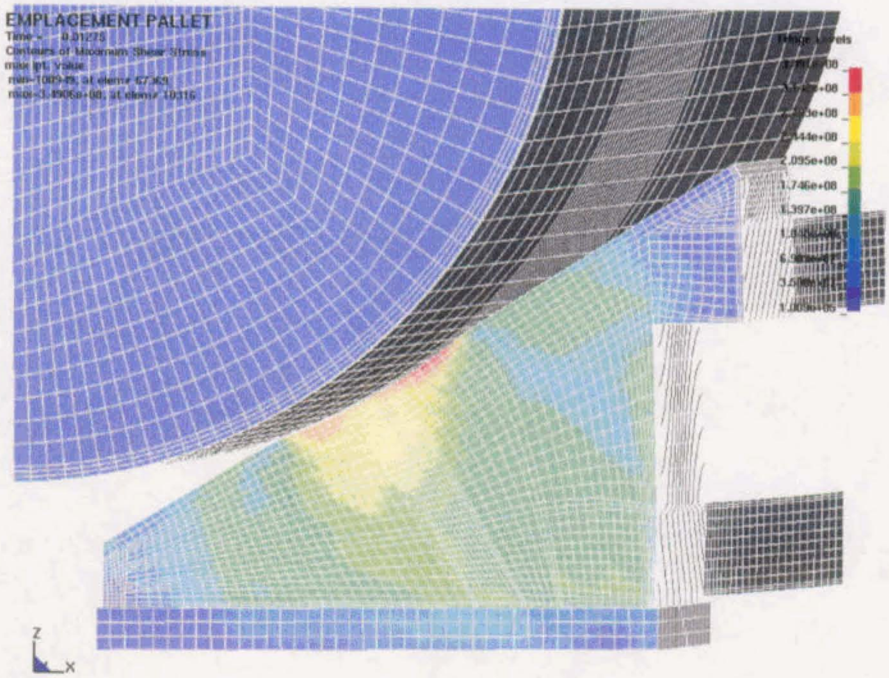


Figure I-1. Emplacement Pallet drop (0.782*m*) while loaded with Naval Long WP Stress Contours (*MPa*) at moment of highest deformation in the Emplacement Pallet

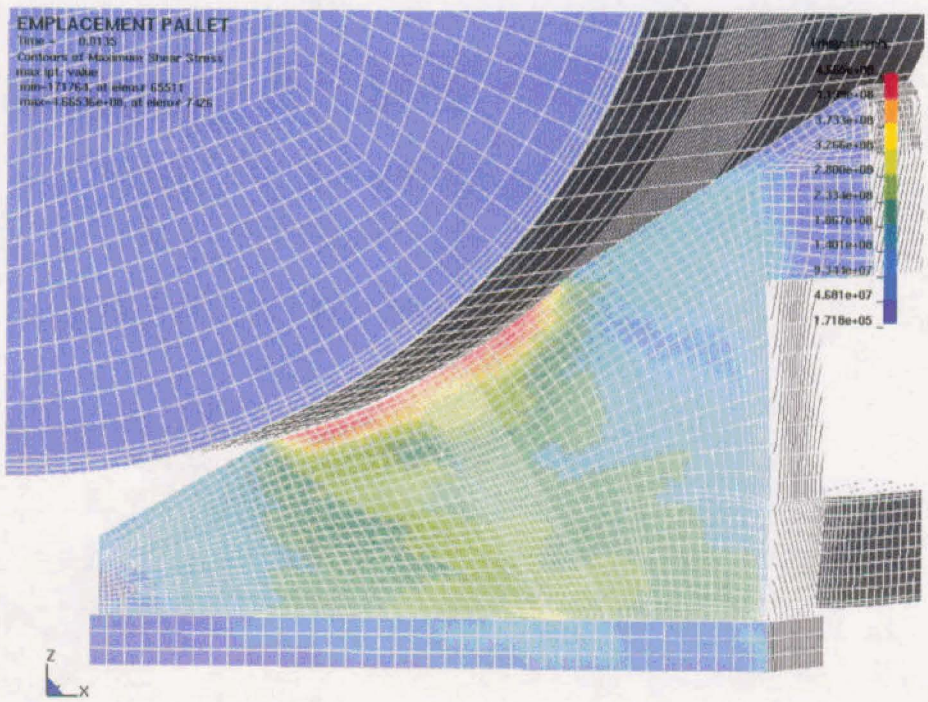


Figure I-2. Naval Long WP drop (2.4*m*) onto Emplacement Pallet Stress Contours (*MPa*) at moment of highest deformation in the Emplacement Pallet

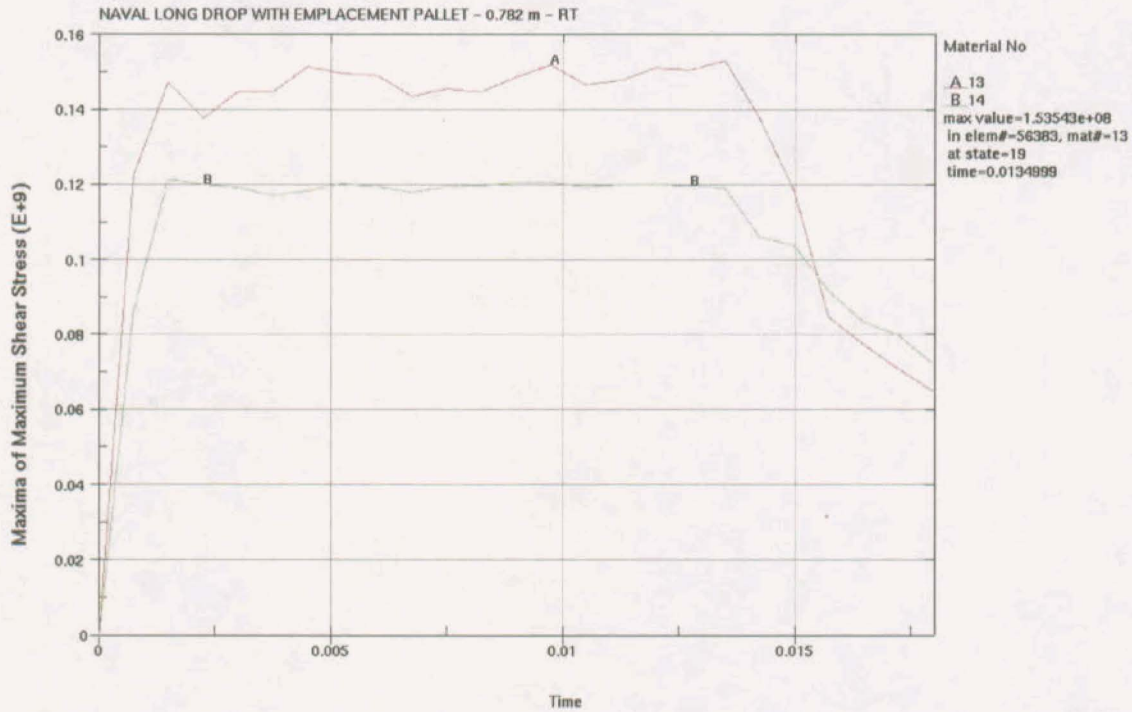


Figure I-3. Emplacement Pallet drop (0.782*m*) while loaded with Naval Long WP Maximum Shear Stress (*MPa*) of Outer Shell (13) and Inner Shell (14) @ RT

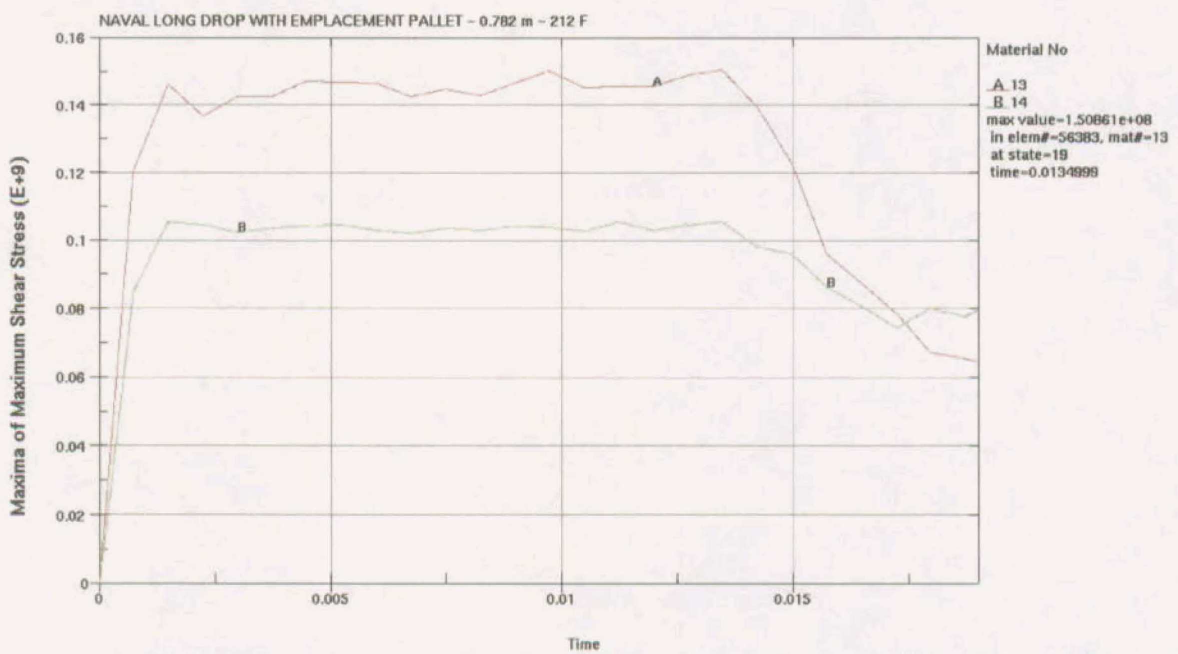


Figure I-4. Emplacement Pallet drop (0.782*m*) while loaded with Naval Long WP Maximum Shear Stress (*MPa*) of Outer Shell (13) and Inner Shell (14) @ 212 °F

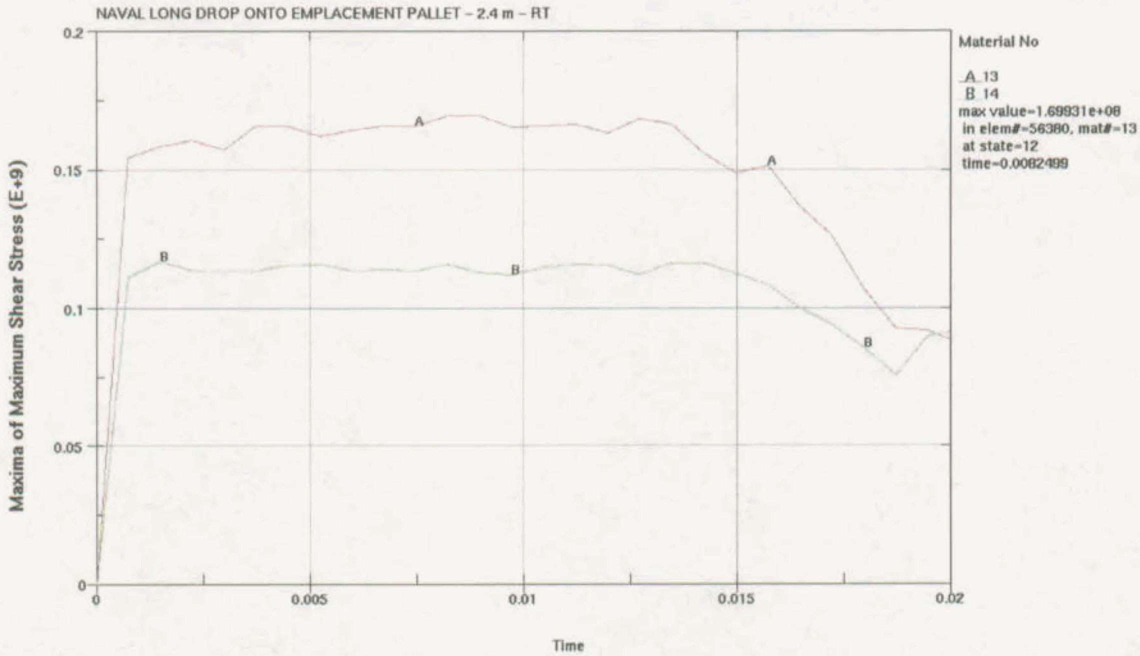


Figure I-5. Naval Long WP drop (2.4*m*) onto Emplacement Pallet Maximum Shear Stress (*MPa*) of Outer Shell (13) and Inner Shell (14) @ RT

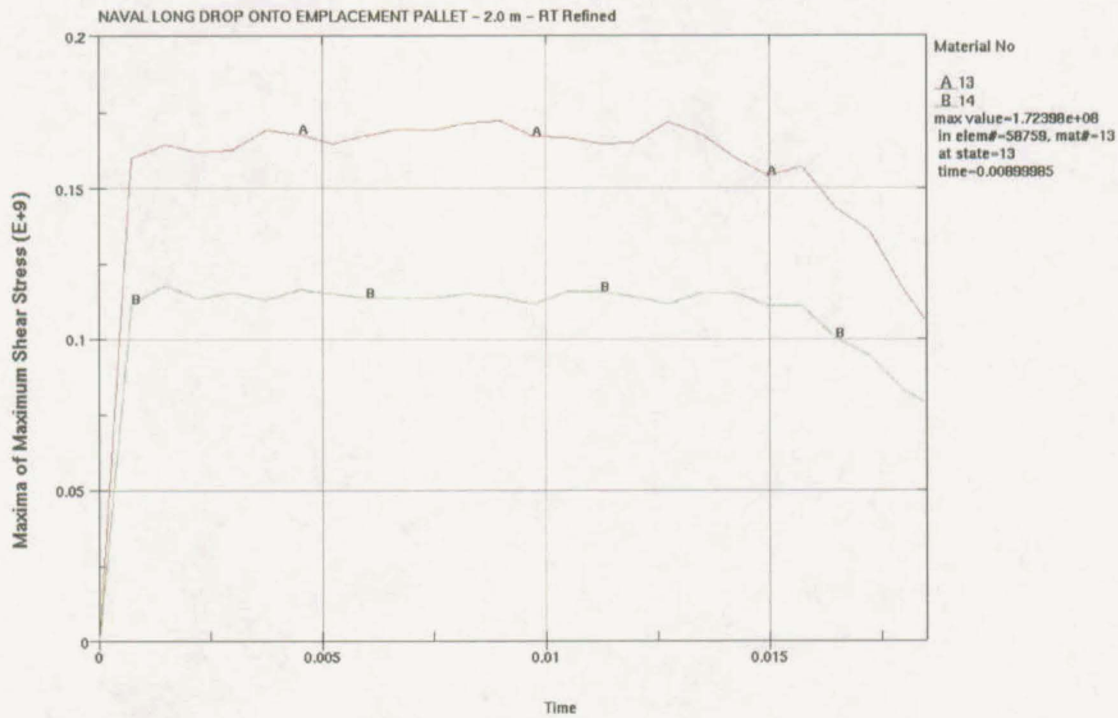


Figure I-6. Naval Long WP drop (2.4*m*) onto Emplacement Pallet Maximum Shear Stress (*MPa*) of Outer Shell (13) and Inner Shell (14) @ RT – Refined Mesh

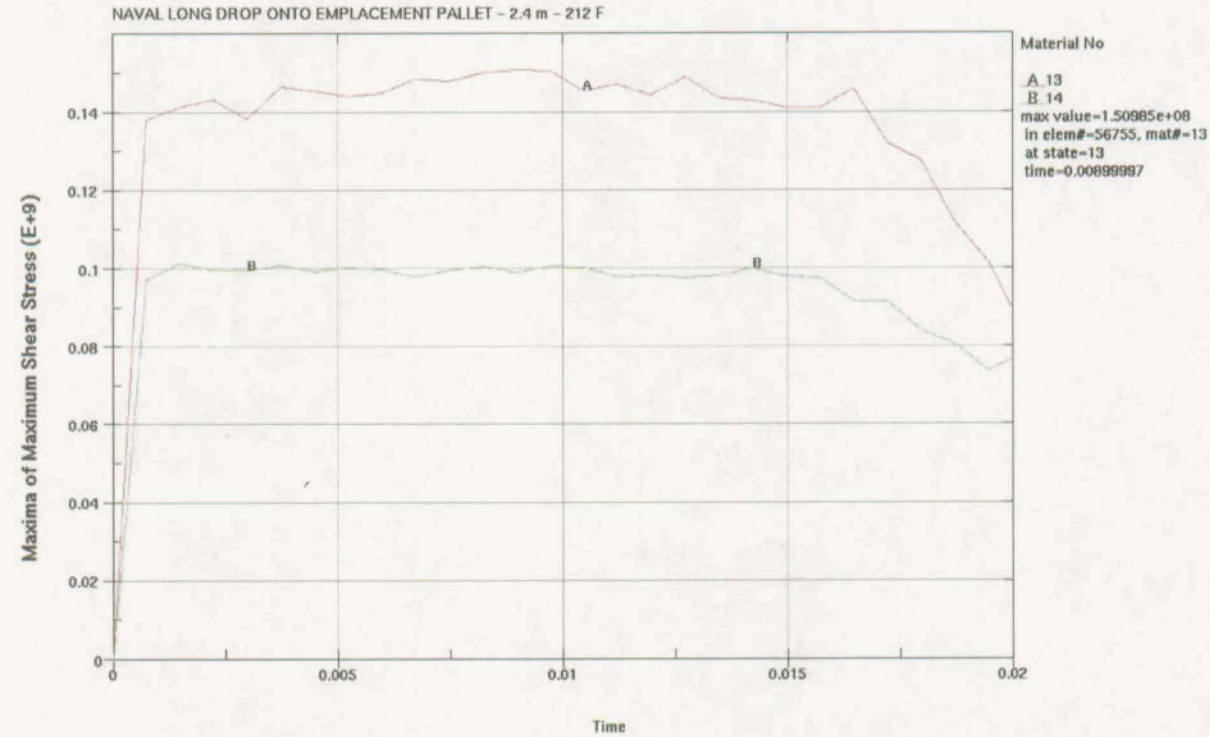
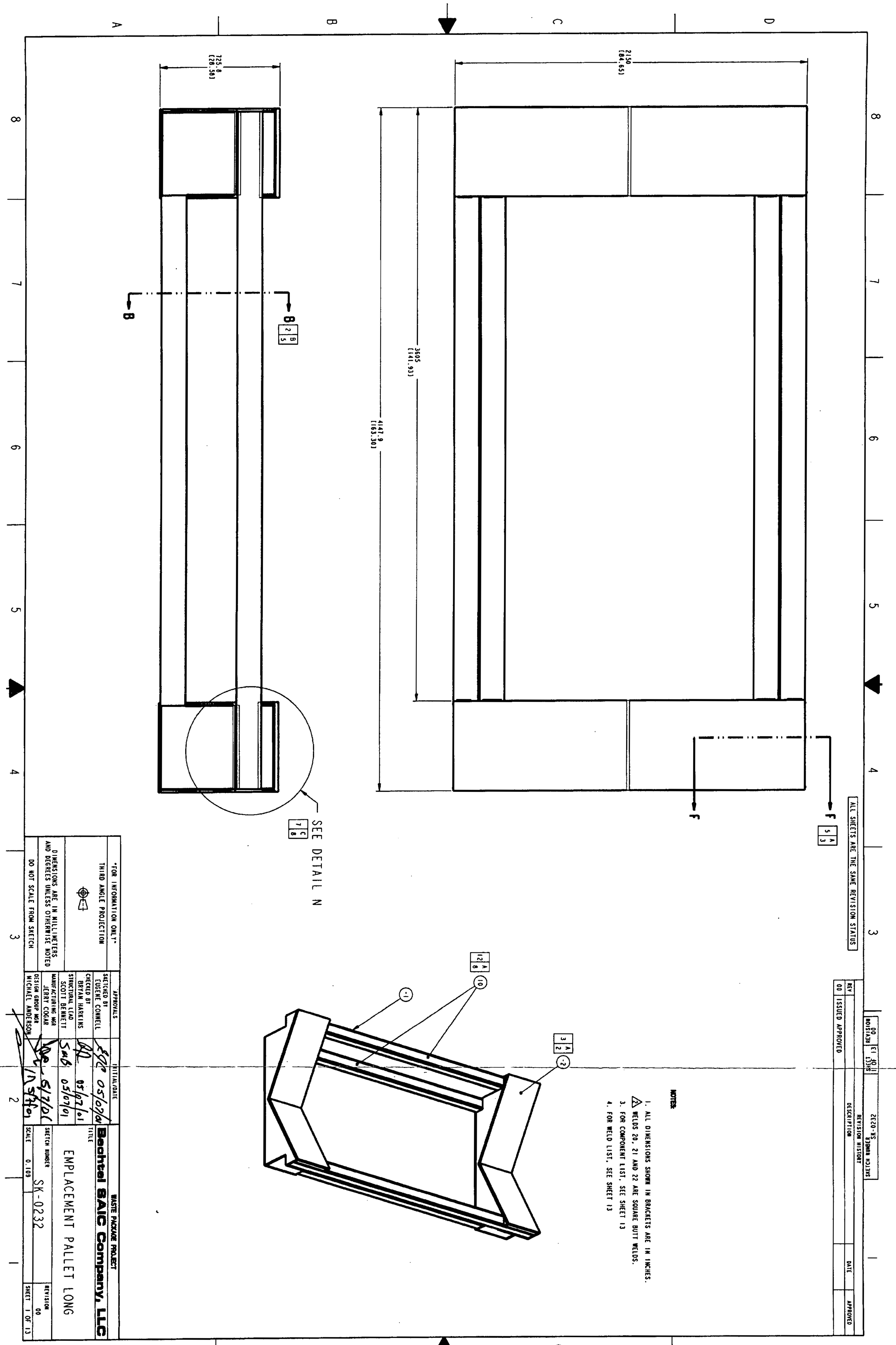


Figure I-7. Naval Long WP drop (2.4*m*) onto Emplacement Pallet Maximum Shear Stress (*MPa*) of Outer Shell (13) and Inner Shell (14) @ 212 °F



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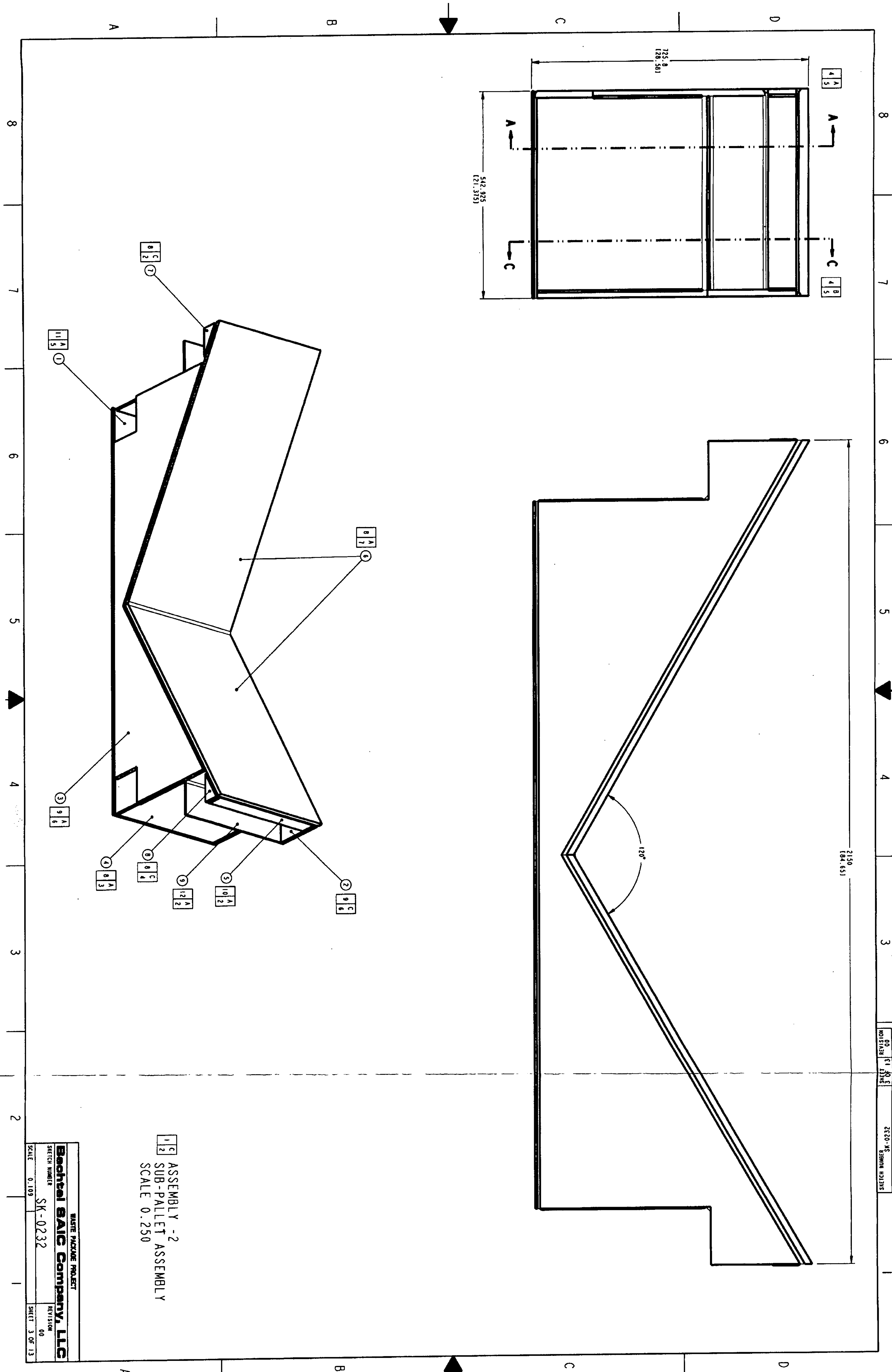

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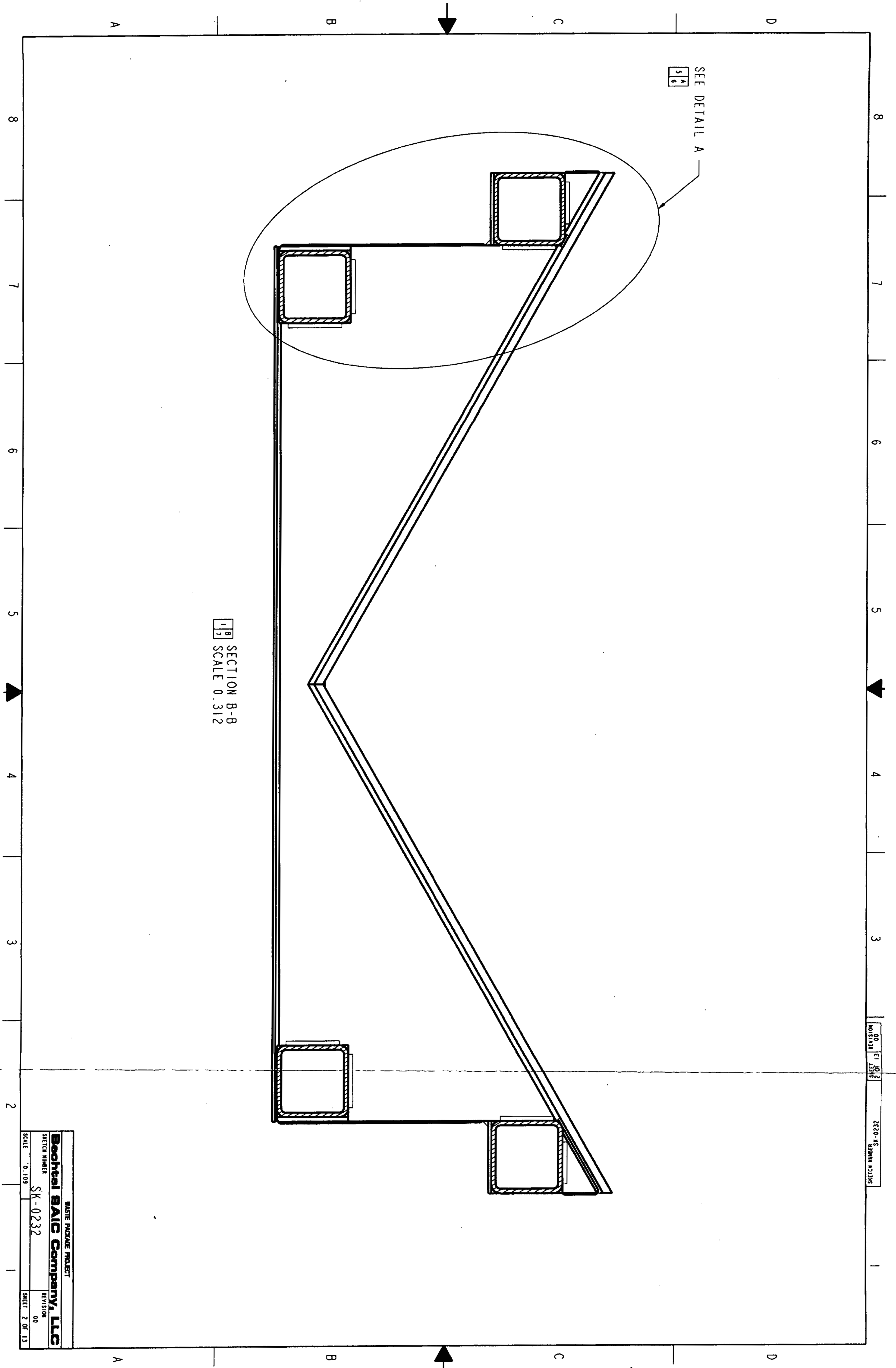

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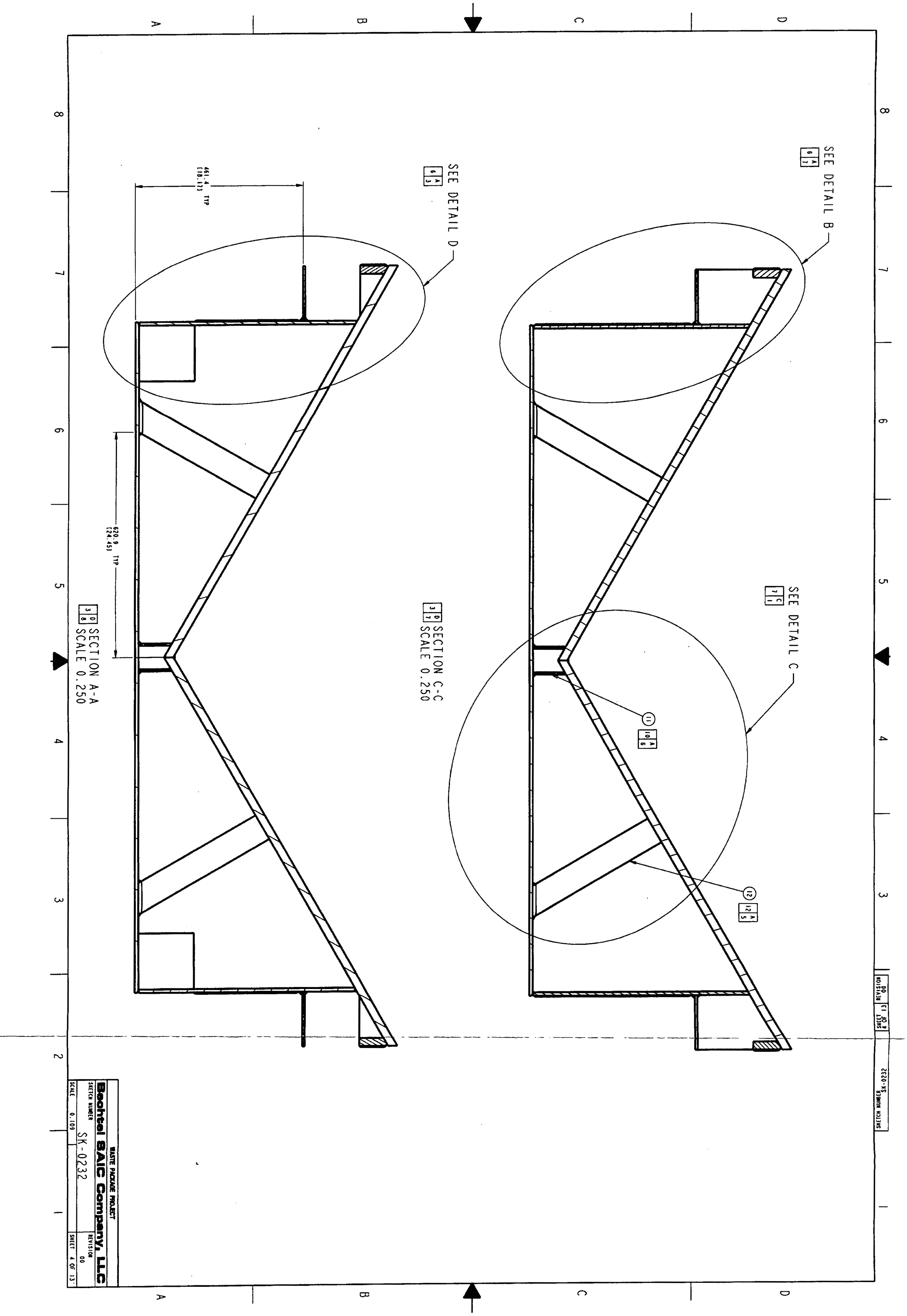

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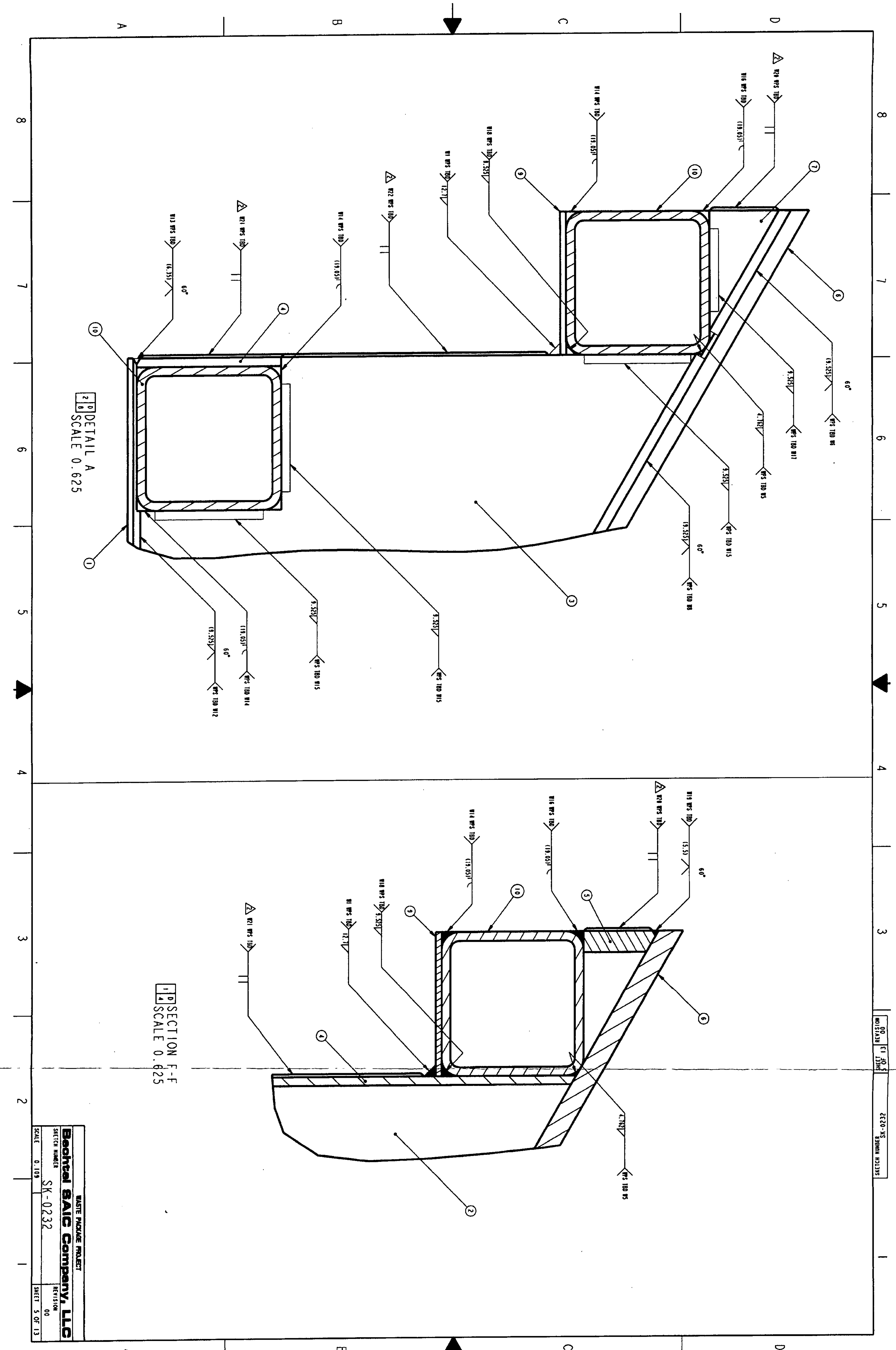

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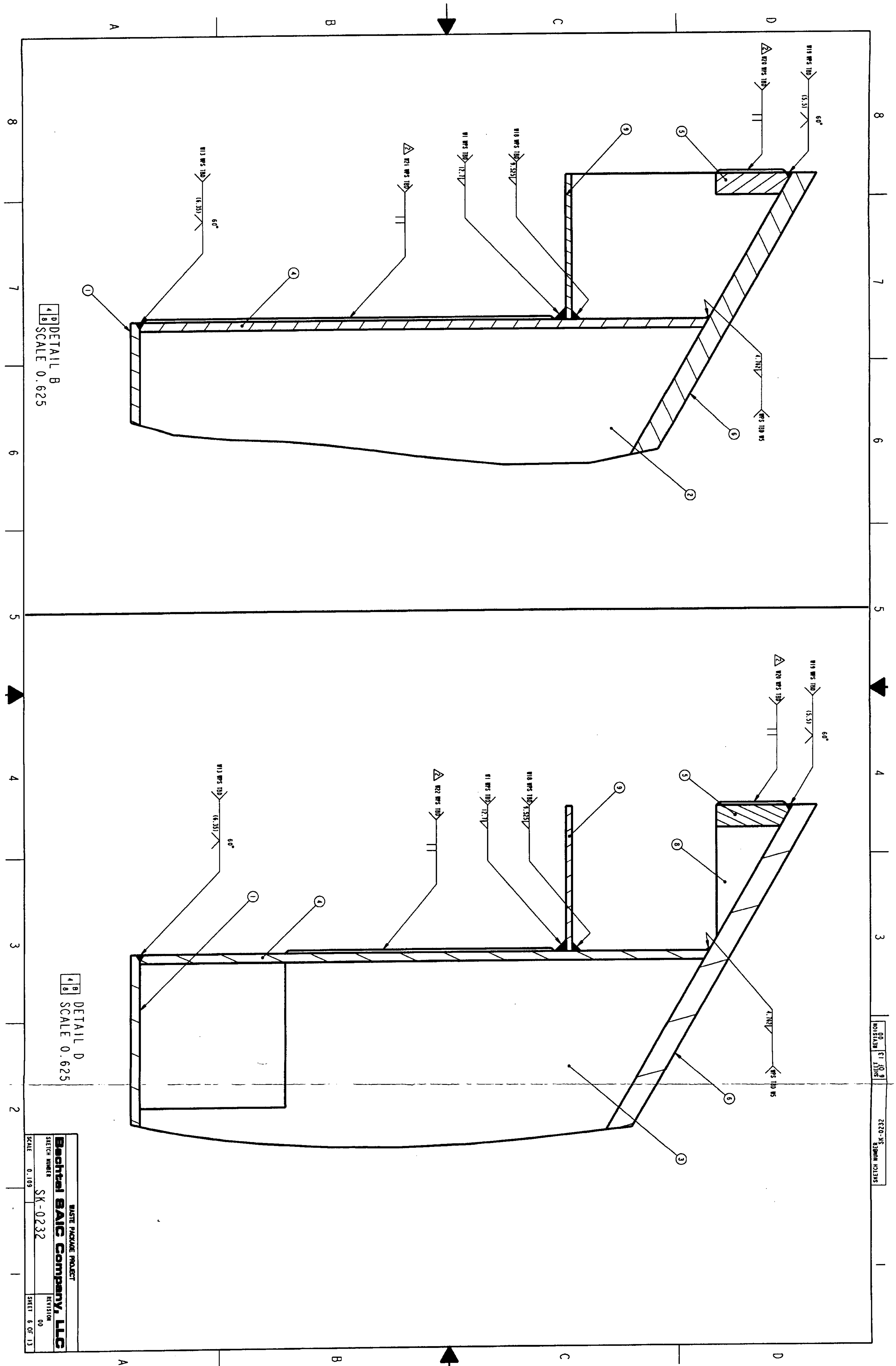

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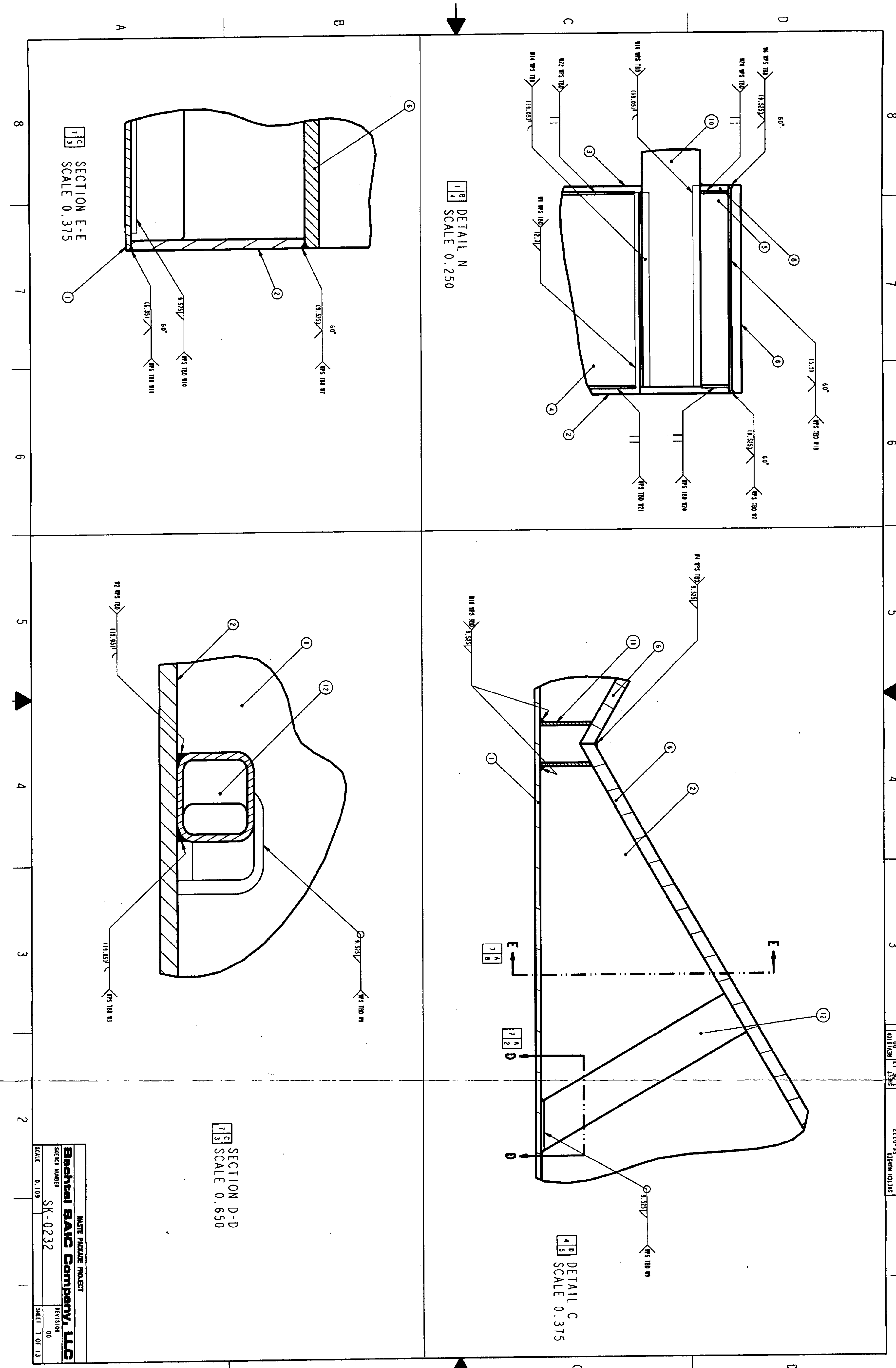

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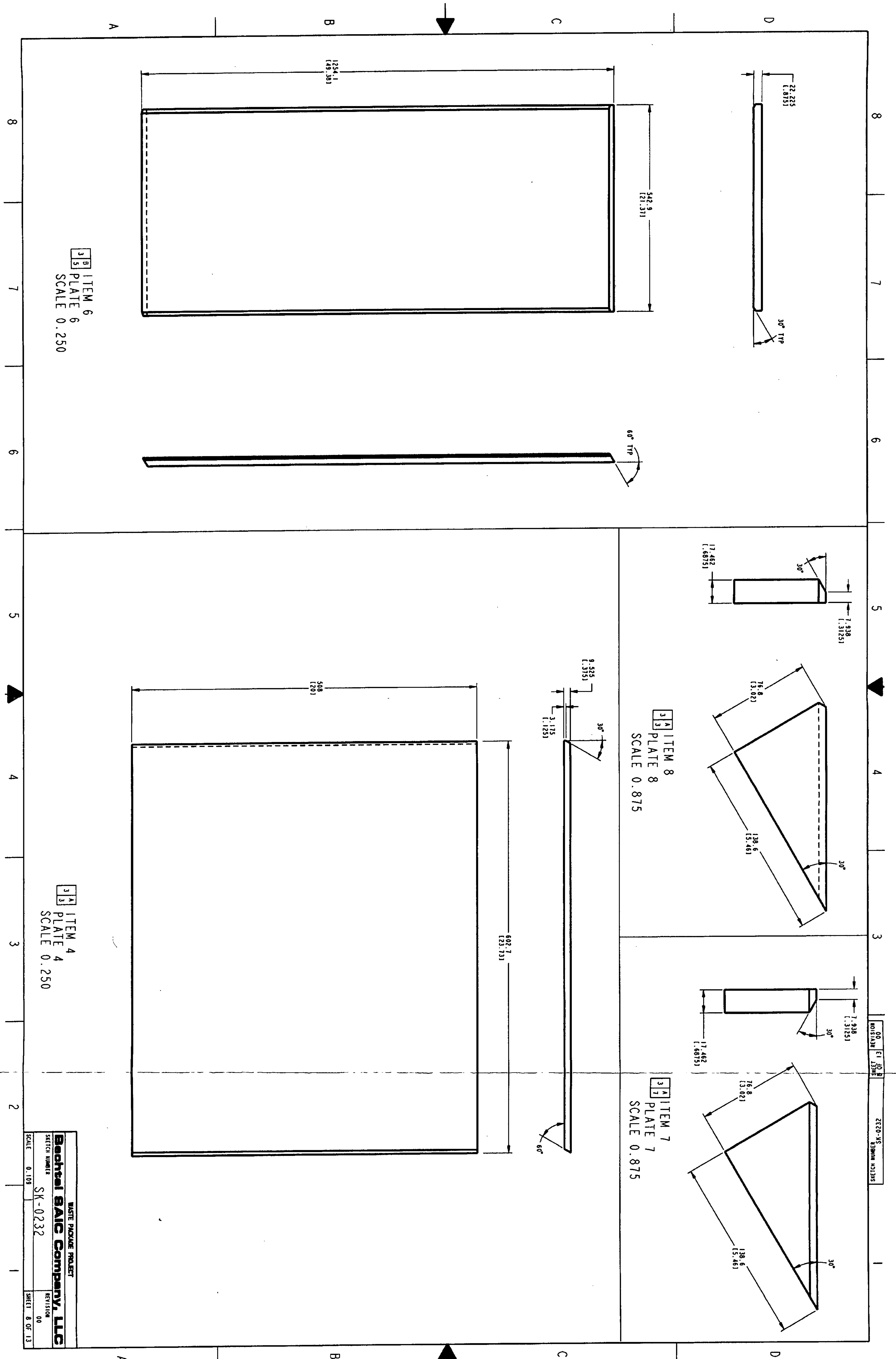

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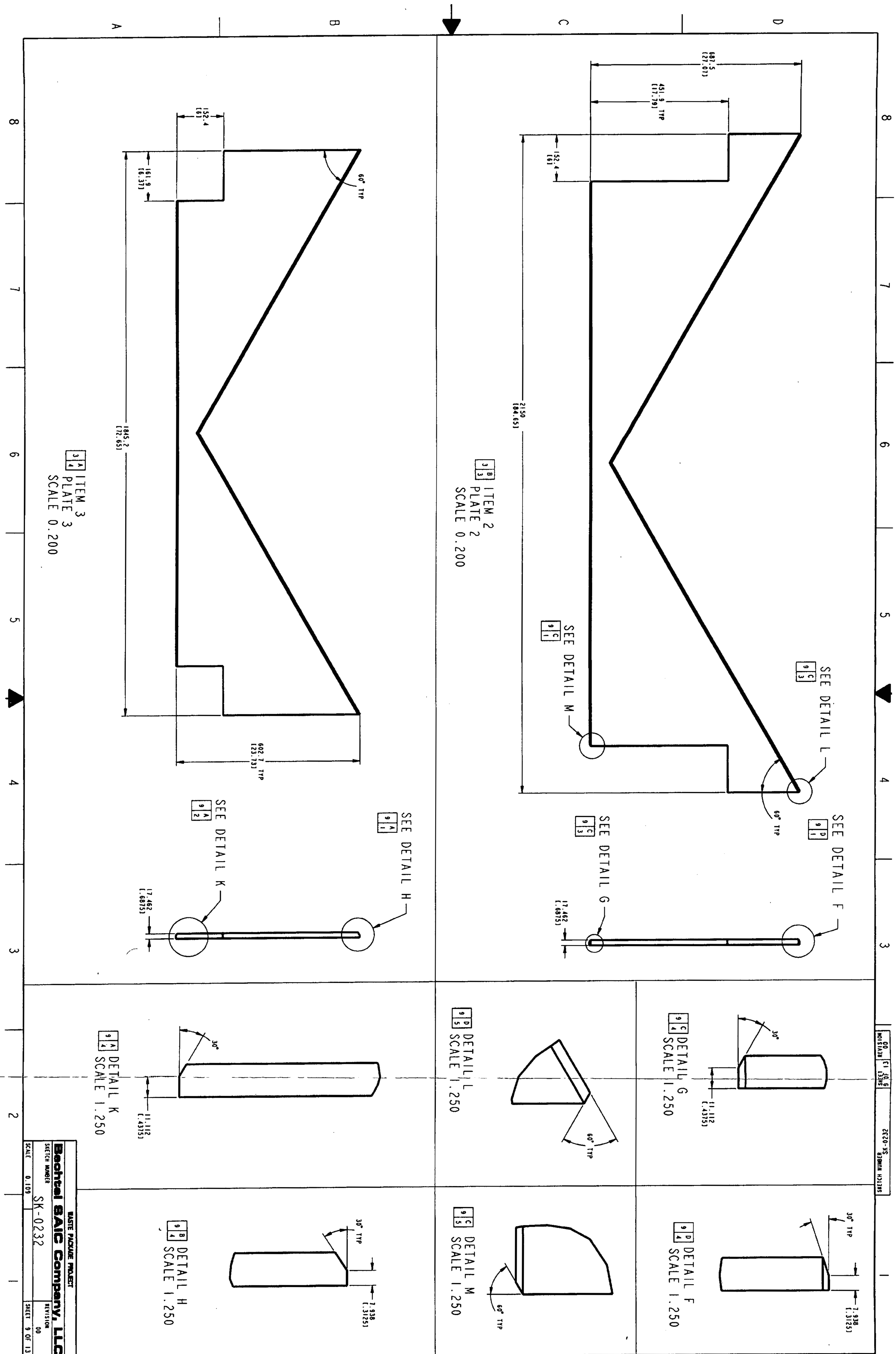

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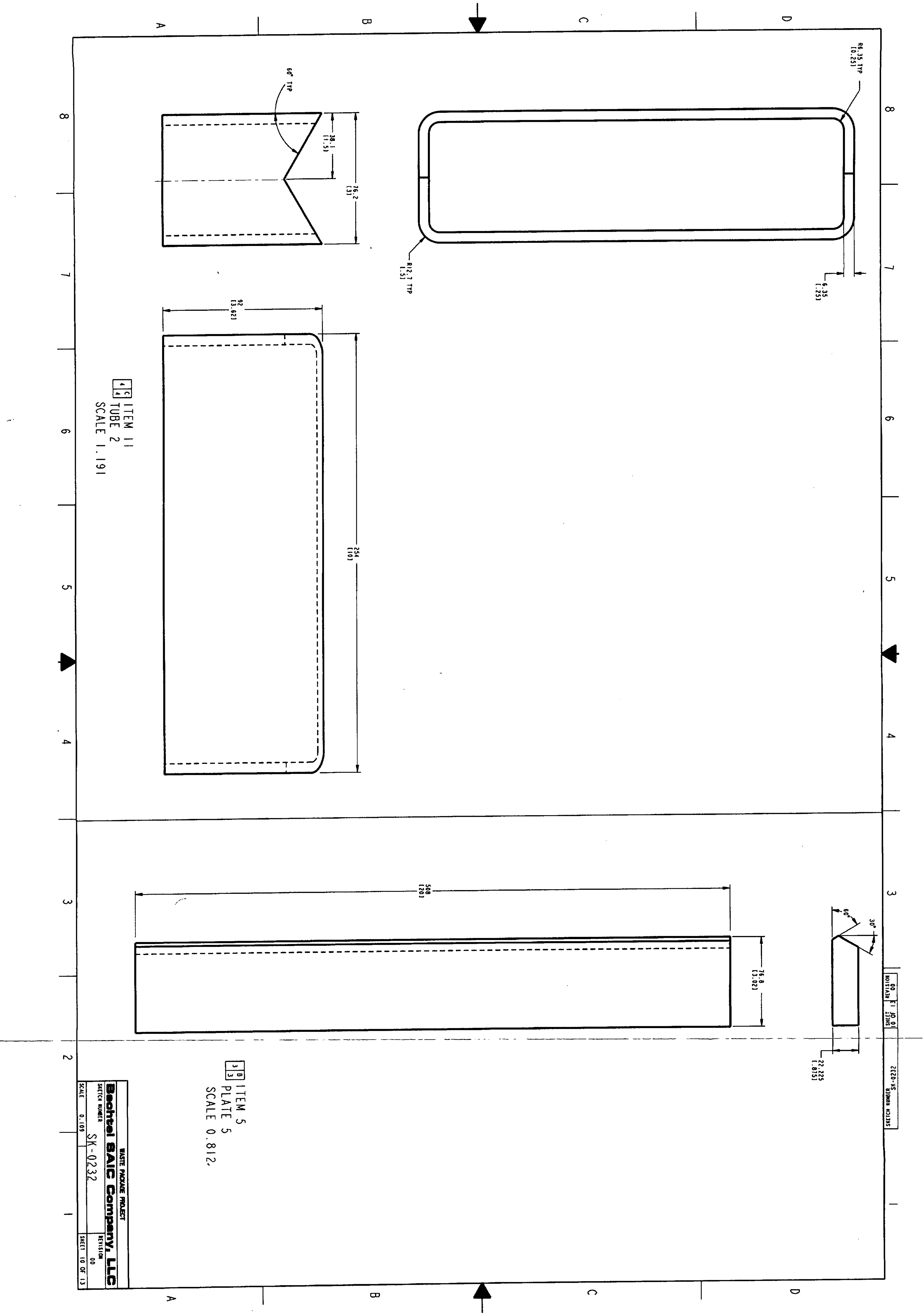

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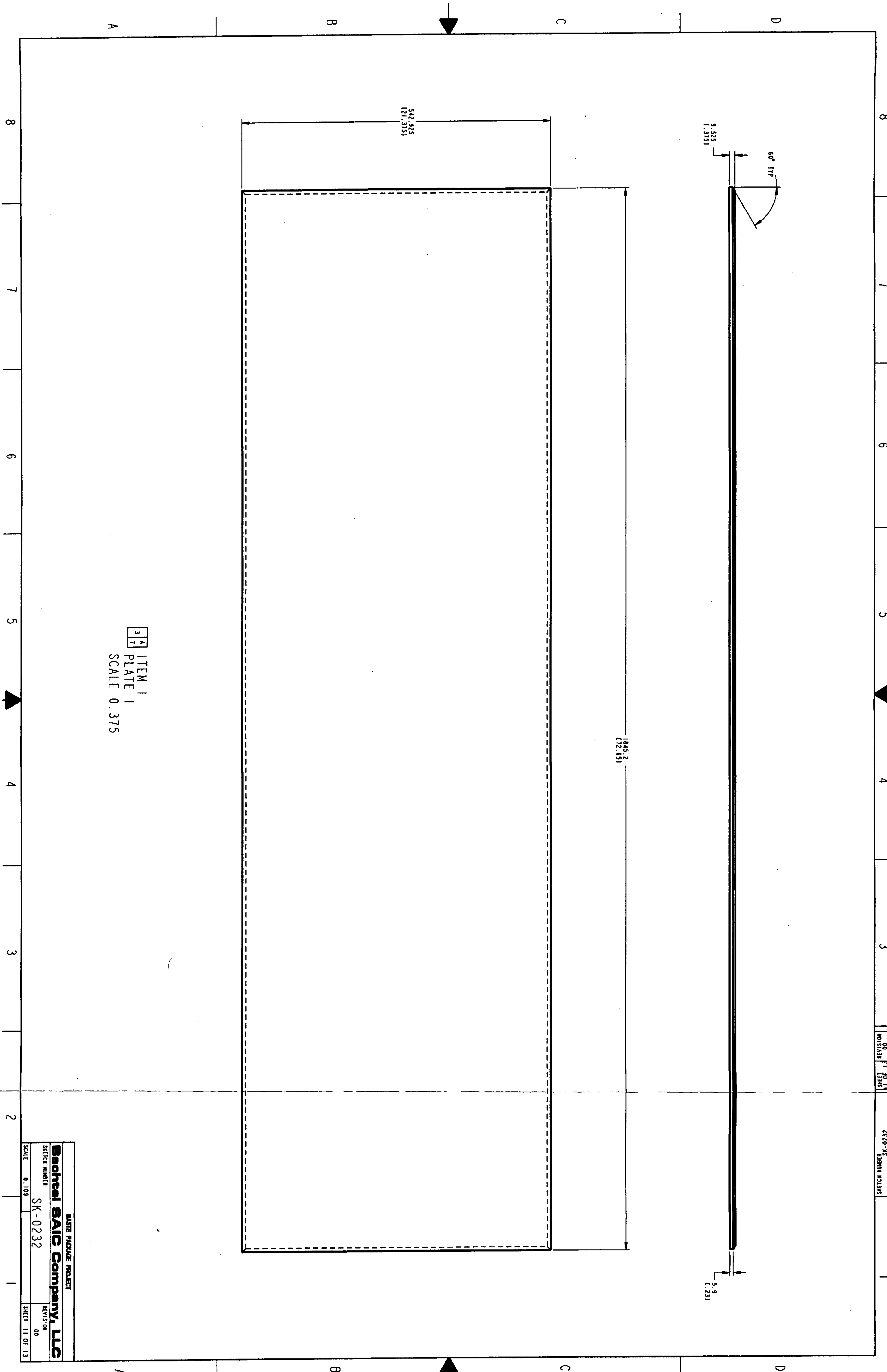

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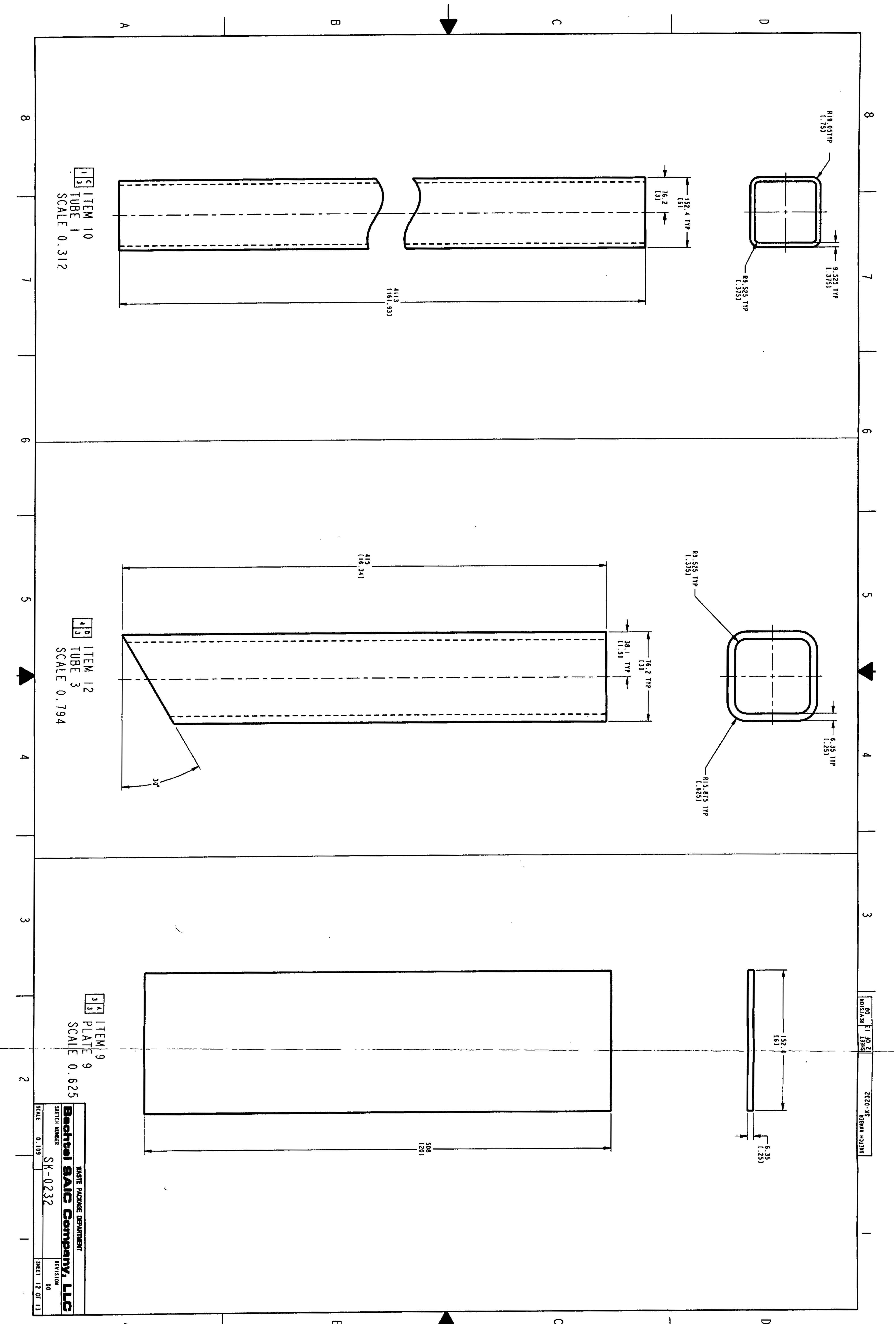

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COMPONENT LIST							
ITEM NUMBER	ASSEMBLY	SUBASSEMBLY	COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY RQD
-1	EMPLACEMENT PALLET LONG	-	-	-	-	1971	1
10	-	-	TUBE 1	SA-240 S31600	9.525	171	4
-2	-	SUB-PALLET ASSEMBLY	-	-	-	640	2
1	-	-	PLATE 1	SB-575 N06022	9.525	82	2
2	-	-	PLATE 2	SB-575 N06022	17.462	102	2
3	-	-	PLATE 3	SB-575 N06022	17.462	86	2
4	-	-	PLATE 4	SB-575 N06022	9.525	25	4
5	-	-	PLATE 5	SB-575 N06022	22.225	7.1	4
6	-	-	PLATE 6	SB-575 N06022	22.225	130	4
7	-	-	PLATE 7	SB-575 N06022	17.462	0.80	2
8	-	-	PLATE 8	SB-575 N06022	17.462	0.80	2
9	-	-	PLATE 9	SB-575 N06022	6.35	4.3	4
11	-	-	TUBE 2	SB-575 N06022	6.35	3.0	4
12	-	-	TUBE 3	SB-575 N06022	6.35	5.5	8
-	-	-	TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	-	21	-

WELD LIST				
WELD NUMBER	WELD	MATERIAL	MASS (KG)	QTY RQD
1	FILLET	SFA-5.14 N06022	0.36	4
2	GROOVE	SFA-5.14 N06022	0.17	8
3	GROOVE	SFA-5.14 N06022	0.20	8
4	FILLET	SFA-5.14 N06022	0.19	2
5	FILLET	SFA-5.14 N06022	0.23	4
6	GROOVE	SFA-5.14 N06022	0.07	4
7	GROOVE	SFA-5.14 N06022	0.57	4
8	GROOVE	SFA-5.14 N06022	0.48	4
9	FILLET	SFA-5.14 N06022	0.08	8
10	FILLET	SFA-5.14 N06022	0.09	8
11	GROOVE	SFA-5.14 N06022	0.37	2
12	GROOVE	SFA-5.14 N06022	0.31	2
13	GROOVE	SFA-5.14 N06022	0.11	4
14	GROOVE	SFA-5.14 N06022	0.34	12
15	FILLET	SFA-5.14 N06022	0.05	12
16	GROOVE	SFA-5.14 N06022	0.35	4
17	FILLET	SFA-5.14 N06022	0.03	4
18	FILLET	SFA-5.14 N06022	0.20	4
19	GROOVE	SFA-5.14 N06022	0.08	4
20	SQUARE	SFA-5.14 N06022	0.01	8
21	SQUARE	SFA-5.14 N06022	0.04	4
22	SQUARE	SFA-5.14 N06022	0.06	4
TOTAL ALLOY 22 WELDS	-	-	21	-

WASTE PACKAGE DEPARTMENT

Bechtel SAIC Company, LLC

SKETCH NUMBER SK-0232 REVISION 00

SCALE 0.109 SHEET 13 OF 13

Originator's Initials: DM Date: 6Nov02 Checker's Initials: AKS Date: NOV 6, 2002

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SPECIAL INSTRUCTION SHEET

1. QA: QA

Page: 1 of: 1

Complete Only Applicable Items

√ file list ok DE 11/18/02

This is a placeholder page for records that cannot be scanned.

2. Record Date 11/06/2002	3. Accession Number Att. To: MOL.20021118.0098
4. Author Name(s) DANIEL MCKENZIE	5. Author Organization

6. Title/Description
NAVAL WASTE PACKAGE WITH EMPLACEMENT PALLET

7. Document Number(s) 000-00C-DNF0-00100-000-00A	8. Version Designator N/A
9. Document Type DATA	10. Medium CD-ROM

11. Access Control Code
PUB

12. Traceability Designator
DC#33779

13. Comments
THIS IS A SPECIAL PROCESS CD-ROM AS PART OF ATTACHMENT III

Text Files

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AN ELECTRONIC ATTACHMENT