Holtec's Position and Proposed Path Forward to Address SFST's Concerns with Respect to The HI-STAR 180 Fuel Basket Material

(USNRC Docket No. 71-9325)

A Presentation to the SFST

by

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Background

- Holtec's initial application, submitted on January 10, 2007, was recalled by Holtec on March 20, 2007 to improve the safety case and format compliance of the submittal.
- On July 5th, 2007, Holtec made a presentation on the *critical characteristics* of Metamic-HT to the SFST in a public meeting under the heading "On the Fitness of Metamic-HT for Fuel Basket Material in HI-STAR 180".
- In that presentation, Holtec provided the following property data on Metamic-HT abstracted from the report "High Temperature Metamic Metal Matrix Composite for Structural Applications and Criticality Control". (The "HT" test report, provided to SFST, contains only controlled tests, no exploratory tests, carried out on Metamic-HT.)
  - ➢ Yield strength, ultimate strength, Young's Modulus, creep rate, and elongation in the temperature range of interest, based on test data, collectively referred to as "*Critical Characteristics*" for structural evaluation.
  - ➢ Test data on other critical characteristics such as impact strength, thermal conductivity, emissivity, thermal expansion coefficient, corrosion resistance, and neutron attenuation characteristics.

Background (continued)

- Minimum guaranteed values (MGVs) of the *Critical Characteristics* are those that are *lower than the lowest strength data* obtained from testing. *The MGVs are guaranteed by the Supplier and will be confirmed, during production, by testing of coupons drawn from each lot.*
- The MGVs were used in the analyses reported in the SAR.
- An equation for correlating the cumulative creep with the stresses and metal temperature was presented along with test data, which showed that the proposed creep equation overpredicted creep for every test specimen (both irradiated and unirradiated); creep tests were done on seven coupons in accordance with ASTM E139-06.

Background (continued)

- In a letter dated March 13, 2008, Holtec informed SFST that the creep test duration had exceeded 10,000 hours and all of the test results continue to corroborate Holtec’s prior representation that the creep equation is conservative.
- A QA-validated update of the March 2008 issue of the test report was offered to SFST (but not delivered, at SFST’s request) to aid in their review.
- Creep tests continue, the duration of testing now exceeds 14,000 hours on some coupons.
  - All creep tests conducted by the Westmoreland Laboratory in Youngstown, PA, renowned for its creep testing facilities.

Background (continued)

- Examples from Europe and Japan, cited in the July 2007 meeting and recapped below, speak to the widespread use of aluminum alloy baskets:
  - TN-12/2 and TN-13/3 are workhorses of France's transport fleet; both use Borated Aluminum.
  - The storage and transport casks used in Belgium (confirmed to Holtec by SYNATOM) also use Borated Aluminum baskets.
  - According to our client, NOK, all casks deployed in Switzerland (TN-97L, TN-24BH, and TN-24G) since 2001 use Borated Aluminum as the structural and neutron absorber material.

Background (continued)

- According to a PATRAM paper by Japanese designers[†],"…most of current designs proposed for transport/storage packaging in Japan adopt aluminum alloy or borated aluminum alloy as a material of the basket…". "…the Design rules limit the creep strain during a design life up to 60 years not to exceed 0.4%, though they allow to use the material in a temperature range of creep growth…The design code for baskets made of aluminum alloys and borated alloys is expected to be the basis for the transport/storage packaging for the Mutsu Recyclable Fuel Storage Facility in 2010…"

[†] "Development and Discussion of Design Code for Baskets made of Aluminum Alloys and Borated Aluminum Alloys for Transport/Storage Packagings", by M. Hirose et al., PATRAM 2007.

Background (continued)

- Using the creep equation, the maximum lateral deflection of the "HT" panels during one year of continuous transport at maximum heat load was shown to be less than the flatness tolerance for ASME plate stock!
- Responding positively to the information provided in the "HT" report, SFST indicated its willingness to accept the modified application. Holtec submitted the upgraded application on August 17, 2007, which the SFST accepted for formal review on October 11, 2007, but asked Holtec to continue the creep tests to complete 1 year of testing.
- By way of clarification, it should be stated that the duration of the initial license per 10CFR71 is limited to 5 years. Hence, all regulatory evaluations relative to aging of the package at this time *should be limited to 5 years*, even though Holtec has engineered the equipment for a "design life" of 40 years.

COLLECTION OF TEST DATA

- To ensure conservative (low) value of strength test data, all coupons were *heated to 545°C, held for 3 hours* and then air cooled prior to testing.
- All tests, except neutron attenuation and emissivity, were conducted by the Westmoreland Lab, which is an accredited laboratory using applicable ASTM procedures:

Property	ASTM Procedure
Tensile Strength Testing	**E8-04** **E21-05**
Impact Testing	**E23-07**
Precision Young's Modulus	**E111-04**
Dynamic Young's Modulus	**E1876-07**
Creep	**E139-06**
Thermal Expansion Coefficient	**E228-06**
Thermal Conductivity	**E1225-04** **E457 (reapproved 2002)**
Specific Heat	**E1269-05**

Minimum Guaranteed Values of Metamic-HT Structural Properties		
	Item	**Value**[†]
1.	**Minimum yield strength, σ_y (ksi)** **at 37ºC, 200ºC, 300ºC**	**26, 21, 15**
2.	**Minimum tensile strength, σ_u (ksi)** **at 37ºC, 200ºC, 300ºC**	**30, 22.5, 17**
3.	**Minimum Young's Modulus (elastic), Y (ksi)** **at 37ºC, 400ºC**	**12, 8**
4.	**Minimum elongation, e (in %)** **at 37º C, 200º C, 300º C**	**8, 7, 7**
5.	**Impact resistance at ambient temperature** **Mils lateral exp. At 37ºC, 400ºC**	**6, 19**

[†] Linear interpolation allowed.

Coupons from a manufactured lot of Metamic-HT must meet the above MGVs; otherwise, the whole lot will be rejected.

Understanding Metamic-HT

1. **Pure Aluminum!**

- Metamic-HT is made of pure aluminum strengthened by nano-particles of alumina (and to a lesser extent, superfine boron carbide powder), providing grain-to-grain connectivity. As a product form, *it is not new at all*: its characteristics are well documented on the Web and in the published literature. The extract from a 2007 Ph.D. dissertation by Jacques Mouton, Durban University of Technology", (in Chapter 1, p. 4) provides a concise description:

  "… we can consider a special group of dispersion-strengthened materials containing particles 10nm to 20nm in diameter as particulate composites. These dispersoids, usually a metallic oxide, are introduced into the matrix *by means other than traditional phase transformations*. Even though the small particles are not coherent with the matrix, they block the movement of dislocations and produce a pronounced strengthening effect.

Understanding Metamic-HT (continued)

Quotation Continued

At room temperature, the dispersion-strengthened composites may be weaker than traditional age-hardened alloys, which contain a coherent precipitate. However, because the composites do not catastrophically soften by over-aging, over-tempering, grain growth, or coarsening of the dispersed phase, *the strength of the composite decreases only gradually with increasing temperature. Furthermore, their creep resistance is superior to that of metals and alloys*.

The dispersant must have a low solubility in the matrix and must not chemically react with the matrix, but a small amount of solubility may help improve the bonding between the dispersant and the matrix. Copper oxide (Cu_2O) dissolves in copper at high temperatures, thus, the CU_2O-Cu system would not be effective. However, *Al_2O_3 does not dissolve in aluminum; the Al_2O_3-Al system does give an effective dispersion-strengthened material.*

Understanding Metamic-HT (continued)

Quotation Continued

Examples of Dispersion-Strengthened Composites. … Perhaps the classic example is the sintered aluminum powder (SAP) composite. SAP has an aluminum matrix strengthened by up to 14% Al_2O_3. The composite is formed by powder metallurgy. In one method, aluminum and alumina powders are blended, compacted at high pressures, and sintered. *In a second technique, the aluminum powder is treated to add a continuous oxide film on each particle. When the powder is compacted, the oxide film fractures into tiny flakes that are surrounded by the aluminum metal during sintering.”*

(Italics added herein for emphasis)

Understanding Metamic-HT (continued)

2. The properties of Metamic-HT are discussed in classical references on aluminum: The quote below is from the "Handbook of Aluminum".

"The main advantage of dispersion-strengthened composites is not their ability to improve the room-temperature yield strength or work-hardening rate, but more the ability to maintain this yield-strength increase and attendant creep resistance increase over a wide temperature range, up to $T \approx 0.8T_m$ of the melting point of the metallic matrix, see e.g. [2]. The effectiveness of the dispersion and dispersoids is determined by their insensitivity to high temperatures. This distinguishes dispersion-hardened composites from precipitation-hardened alloys, which soften with increasing temperature. The dispersoids in aluminum-based composites may be oxides (Al_2O_3), carbides (SiC, Al_4C_3), silicides (VSi_2), borides (TiB_2) or refractory metal particles (Cr, W, etc.), which are insoluble or incoherent with the matrix." †

† "Handbook of Aluminum", Vol. 2, and cited Ref. [2], "Oxide Dispersion Strengthening", by Ansell et al., AIME Conference, Vol. 47, 1966, Gordon & Breach, NY, London, Paris.

Understanding Metamic-HT (continued)

3. The only form of "HT" used is "extruded": Metamic-HT is produced by isostatic compaction, dewatering and degassing of oxidized superfine particles of pure aluminum with spatially homogenized inclusions of fine boron carbide powder in cylindrical "billets". These billets are heated to a specific temperature and extruded through a die of rectangular opening to produce the final "HT" product.

4. Number of variables that affect structural properties: The structural properties of Metamic-HT depend on *only* three variables, namely:
   - i. Surface area to mass ratio of the powder, σ
   - ii. Particle size of aluminum powder, δ
   - iii. Temperature of extrusion, T

Understanding Metamic-HT (continued)

5. Control range of manufacturing variables
    5. σ must be greater than 1 sq. meter per gram of powder
    6. δ D90 must be < 6 microns
    7. T must be between 460 and 520°C

In addition, the extrusion ratio is maintained by the supplier to be in the range of 15 to 20 (the low threshold, based on testing, is 7).

Understanding Metamic-HT (continued)

6. Manufacturing control to improve property control: Because σ, δ, and T can be precisely controlled using proven commercial equipment, the strength properties are *definitively predictable*. Therefore, the material can be made with minimal scatter in strength data and the minimum guaranteed values (presented earlier) are guaranteed to be met.

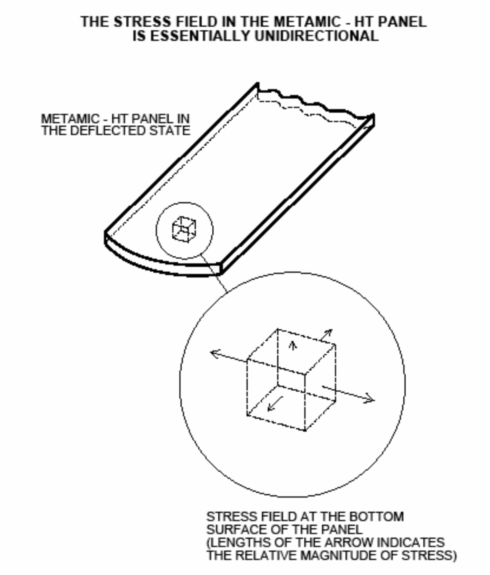
    - Because the “HT” for HI-STAR 180 will be manufactured in one factory (with full QA pedigree), the manufacturing parameters will be much more controllable than an ASTM material such as stainless steel.
    - Because the license application involves only one composition (9% min. B_4C), the production processes will be standardized with one set of parameters.

Understanding Metamic-HT (continued)

7. Predictability of Properties: The strength properties of the “HT” material correlate extremely well by the so-called *Hall-Petch* relationship (ca. 1950 work), which holds that the change in the yield strength of the MMC is inversely proportional to the square root of the size of the aluminum particle. Thus, by using a finer aluminum powder, greater strength can be realized.
8. Isotropic or Anisotropic: There is no evidence in the literature that spheroid reinforced metal matrix composites (in contrast to fiber-reinforced MMCs) exhibit anisotropic structural properties.
   - Scientific literature *as well as test data* corroborate Holtec’s position that Metamic-HT extrusions will be essentially isotropic.
9. Metamic-HT is closely related to the widely used Metamic (classic) material: both are discontinuously reinforced aluminum composites made using identical manufacturing processes such as isostatic compression, sintering, and extrusion.

Demands on Metamic-HT in HI-STAR 180 During Storage and Transport

- Metamic-HT panels are subject to minimal stress during the storage mode when the cask baskets are vertical.
- In the transport mode, when the cask is horizontal, the Metamic-HT panels will experience flexural stress in the (transverse) planar direction, i.e., the state of stress is essentially unidirectional.
- The planar direction (flexural) stresses in the Metamic-HT panels – even during transport – are non-trivial *only* during the hypothetical accident conditions.
- Stresses in the thru-thickness direction are insignificant under all storage and transport modes.



Summary of the "HT's" Temperature State In HI-STAR 180†

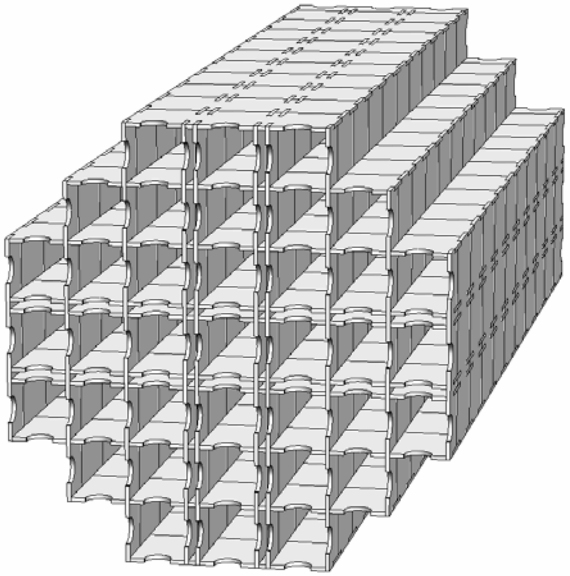
Condition	Maximax Temperature, °C	
	Panel Closest to the Basket Centerline	Weld Line (At the Basket Periphery)
Normal condition of transport if transport occurred *on the first day* permitted by the CoC †	**292**	**234**
10CFR71 Fire Event †	**332**	**275**
Normal condition of storage (on the first day of storage)**	**287**	**236**
† Source: HI-STAR 180 SAR, Table 3.1.3. ** HI-STAR 180 FSAR for action by the Swiss Regulatory Authority (HSK)		

The maximum temperatures in the HI-STAR 180 fuel basket are quite modest and well below the material recrystallization temperature (530°C).

Compare the Demands on Metamic-HT Panels in HI-STAR 180 to Those on the (Licensed) MPC-32 Fuel Basket Panels

Acceptance Criteria

- Maximum permanent strain from creep for 60 years of service life = 0.4%. Criterion taken from the Japanese standard on aluminum fuel baskets.
- Primary stresses must *remain below yield* under the hypothetical accident (9-meter drop) scenario.
- *The F-37 basket has higher stress levels than F-32; hence, the statements on F-37 also apply to F-32.*



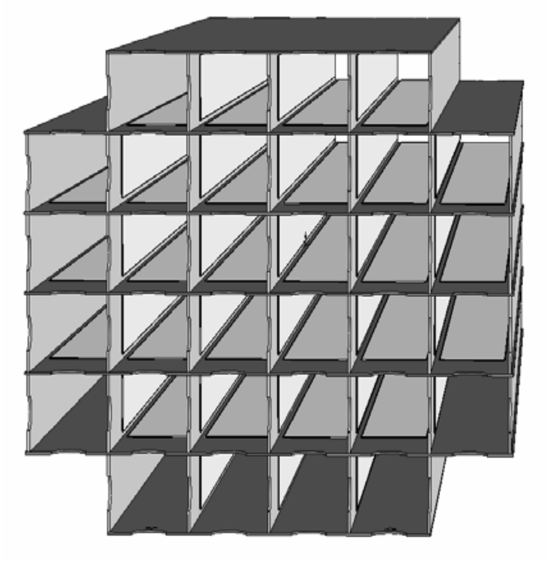
F-37: Metamic-HT Basket

MPC-32 Uses 304S/S Basket in a Honeycomb Construction Similar to F-37 and F-32 “HT” Basket

Acceptance Criteria

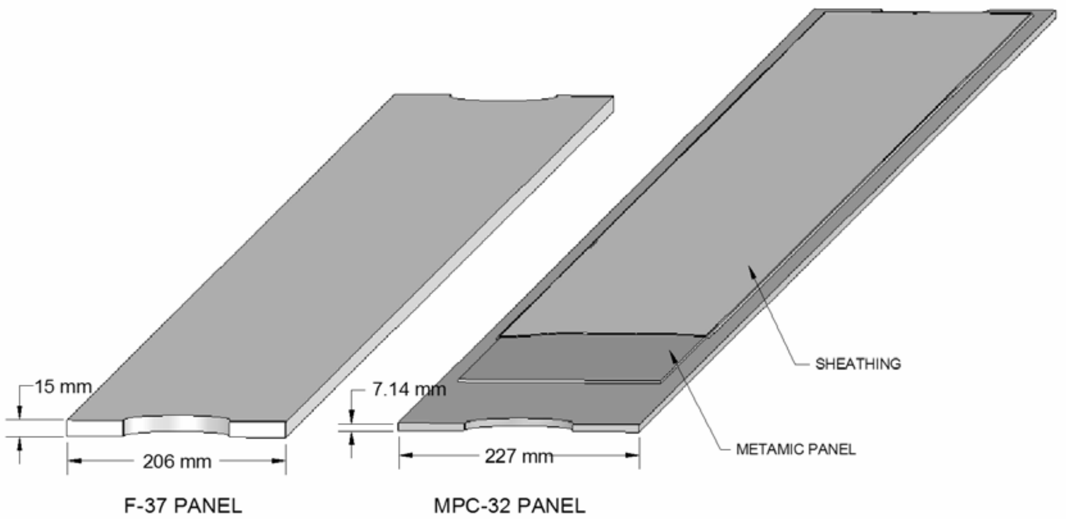
- No criterion on creep.
- Maximum permitted primary bending stress must remain below the *ultimate strength* (not the yield strength) of the material.

Conclusion: F-37 and F-32 are designed to much more stringent stress limits than MPC-32.



MPC-32 in Perspective View; Stainless Steel Basket – Licensed in Docket Nos. 72-1014 and 71-9261

Compare the Inertial Properties of “HT” in F-37 and “304S/S” in MPC-32 Basket Sections



The Metamic-HT Basket panel is 2.1 times as thick as MPC-32 panel and has:

- 9.27 times the section moment of inertia; and
- 4.41 times the section modulus

The result is a substantially reduced stress level in the “HT” basket panels.

Compare Vital Performance Data for Both Baskets Under 60g Inertial Load Condition

Item	MPC-32	F-37
Lateral pressure (psi)	64.92	61.5
Maximum deflection (inch)	0.12†	0.02304††
Maximum bending stress (psi)	52,290†	8,880 ††

Note the maximum primary stress (based on the simple beam theory) in the F-37 basket remains well below the material yield point under the Hypothetical Drop Event. In MPC-32, the stress in the stainless steel basket is almost 3 times that of the material yield strength!

† The yield strength @300ºC – 18,500 psi; therefore, the deformation goes plastic.

†† The maximum bending stress remains well below the minimum Guaranteed Yield Strength of the “HT” material at 300ºC (15,000 psi)

Compare Deflection and Maximum Stress in the MPC-32 and F-37 Basket Panels in Horizontal Orientation by Considering a Beam Strip of Unit Width Laterally Loaded by the Weight of the Fuel

Item	MPC-32	F-37
Pressure from the weight of fuel (psi)	1.082	1.025
Maximum deflection (inch)	0.002	0.000384
Maximum bending stress assuming pinned/pinned condition (psi)	871.5 psi	148 psi

Organizational Approach

To evaluate the SFST concerns, Holtec assembled a team of internal and external experts on the characteristics of aluminum-based MMCs, including welding, to address SFST's concerns.

<u>Members of the Task Force</u>

1. Dr. Philip Blue. Semi-retired expert on metal matrix composites with patents dating back to the mid-60s. Among the few men who pioneered nano-particle technology in the 70s and 80s.

2. Mr. Walter Rajner. Founder of NMD New Materials Development GmbH, an MMC technology company in Austria.

Organizational Approach (continued)

3. Dr. Martin Balog. An MMC expert based in the SAS Slovak Academy of Sciences; Institute of Materials and Machine Mechanics. Dr. Balog has conducted the most extensive set of tests on MMCs, including Metamic-HT.

4. Mr. Tom Haynes. Founder and President of Metamic, LLC, co-inventor of "HT"; 25 years of professional immersion in powder metallurgy; a research specialist on powder metallurgy at Reynolds Aluminum Company in the 80s.

5. Mr. Rick Arn. V.P., Holtec Manufacturing Division, a former president of the American Welding Society; over 35 years experience in welding exotic metals.

Organizational Approach (continued)

7. Mr. John Menhart, P.E., Welding Engineer, Holtec Manufacturing Division, responsible for implementing HMD's welding program.

8. Dr. Stanley Turner. Executive Engineer-Emeritus, Holtec International. Principal contributor to the Metamic-HT test program since 2004. Member ASTM Committee on neutron absorbers; active in the nuclear industry since 1952.

SFST Issues – Holtec's Technical Position

The SFST concerns center around the following numbered items:

1. Unrepresentative Test Coupons: Test coupons used to qualify the material (in the "HT" test report) not representative of the product form to be used in the fuel basket [2-38].
2. Possible Anisotropy: Concern that the "HT" is *anisotropic* by virtue of its constitution and/or manufacture. Tests in the "HT" report not enough because anisotropic materials require multi-dimensional tests to quantify behavior, including creep [2-37, 2-38, 2-40, 2-47, and 2-55].
3. Possible damage from irradiation: Material properties, including weld, may degrade under irradiation [2-37, 2-45, 2-46].
4. Possible detrimental effect of temperature: Material properties, including neutron absorption properties, may degrade from thermal effects under normal operating conditions [2-39, 2-44].

SFST Issues – Holtec’s Technical Position (continued)

5. Test data anomalies: The elongation and charpy data trends are atypical [2-49] and Young’s Modulus data has substantial scatter [2-50, 2-51].
6. Possible degradation under cold conditions: Metamic-HT under cold condition (-40°F ambient is defined as the limiting “cold” condition) may be subject to brittle fracture [2-48].
7. Demonstration of acceptable creep for a 5-year license [1-1, 2-27, 2-36].
8. Weldability and possible loss of strength in the welded region under temperature and/or radiation [2-41, 2-42, 2-43].
9. Need for a Comprehensive Test Plan [2-53, 2-54].

Abstract of Task Force's Position and Proposal

Concern #1: Unrepresentative Coupons

Task Force's Position

1.1 SFST is misinformed regarding the Metamic-HT product form. Metamic-HT will be used in the as-extruded condition (no rolling).

1.2 Metamic-HT coupons were tested in the as-extruded configuration; the product form in the fuel basket will be identical (i.e., extruded only). The test coupons and production product are of *identical genre*.

Proposed Path Forward

The coupons are fully representative of the fuel basket. No additional action is warranted.

Abstract of Task Force's Position and Proposal (continued)

Concern #2: Possible Anisotropy

Task Force's Position

The SFST's concern regarding anisotropy likely derives from the misunderstanding that the panels are "rolled" plate. Furthermore, the loading on the panels, as explained before, is essentially unidirectional.

Proposed Path Forward

Prove isotropic properties by running 3-D tension tests at ambient, -40°C and thermally treated coupons (baked at 440°C for 15 days as discussed later).

Abstract of Task Force's Position and Proposal (continued)

Concern #3: Possible Damage from Radiation

Task Force's Position

Test data on irradiated samples in the "HT" test report shows that fast neutron fluence levels exceeding 10 years of exposure at maximum flux have little effect on the structural properties of the "HT" material.

(Even higher neutron and gamma fluence levels on Metamic-classic coupons had re-confirmed the well-known radiation resistance of aluminum and aluminum alloys).

Proposed Path Forward

Test additional irradiated samples (elaborated in Dr. Blue's presentation).

Abstract of Task Force's Position and Proposal (continued)

Concern #4: Possible Detrimental Effect of Temperature

Task Force's Position

The maximax temperature in the fuel basket panels under normal transport conditions is below 300°C.

4.1 Metamic-HT does not involve elements in solution that precipitate out causing softening and degradation of mechanical properties; it is a *dispersion-reinforced aluminum (*no alloy!) with only alumina nano-particles and boron carbide serving to pin the grain boundaries. As a result, there are no phase transformation issues (like carbide precipitation in stainless steel) that may degrade performance when the “HT” panel is subjected to an extended heated state.

Abstract of Task Force’s Position and Proposal (continued)

Concern #4 (continued)

4.2 Test data on coupons baked at above the “HT’s recrystallization temperature (≈530°C) and then cooled and tested shows a modest loss of strength.

4.3 Annealing at 350°C and 300°C for 120 hours showed virtually no change in mechanical properties.

4.4 Effect of sustained exposure to different elevated temperatures on Metamic-HT can be quantified using the classical Arrhenius Principle, which holds that the rate of reaction, θ, bears an inverse exponential relationship to the absolute temperature of the material.

$$\theta \sim \mathrm{EXP}\,[- e/RT]$$

where R is the universal Gas Constant and e is the activation energy for the metal (for aluminum, e = 28 Kcal/g-mol).

Abstract of Task Force’s Position and Proposal (continued)

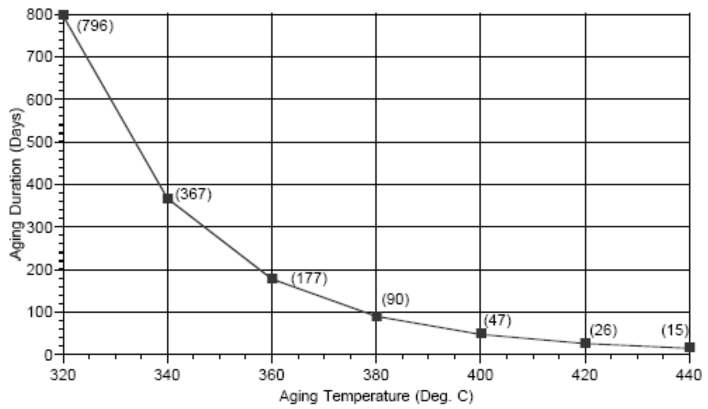
Concern #4 (continued)

4.5 Using the Arrhenius equation, soaking of the coupons for 47 days at 400°C equates to 5 years of soak at 300°C (300°C is the maximax panel temperature under normal condition of transport).

Abstract of Task Force’s Position and Proposal (continued)

Concern #4 (continued)

This figure provides the number of days the “HT” panel must be baked at temperature T (320°C < T < 440°C) to emulate 5 years of constant exposure at 300°C.



This figure can be used to conduct an accelerated test to study the effect of sustained heat state on the “HT” material.

Abstract of Task Force’s Position and Proposal (continued)

Concern #4 (continued)

4.7 Theoretical metallurgy holds that heating of a pure metal with non-soluble inclusions (alumina and B_4C) such as Metamic-HT to a value below its recrystallization temperature (≈530°C for Metamic-HT) will not cause a change in the material’s property). The maximum “HT” temperature under the Part 71 fire event is, per the SAR, only 332°C.

4.8 Heating the coupons to 350°C, holding them at that temperature for 120 hours, and cooling down to ambient caused no loss in strength. The maximum “HT” temperature under the Part 71 fire event is, per the SAR, only 332°C

Abstract of Task Force’s Position and Proposal (continued)

Concern #5: Test Data Anomolies

Task Force's Position

The anomalies stem from the thermal treatment of the specimens at 545°C for 3 hours. 545°C is above the recrystallization temperature of the Metamic-HT material. Hence, an uncertain rate of grain growth can cause uneven decline in the mechanical properties.

Proposed Path Forward

Retest without heating the coupons in the recrystallization range.

Abstract of Task Force's Position and Proposal (continued)

HOLTEC
INTERNATIONAL

Concern #6:
Possible Degradation Under Cold Conditions

Task Force's Position

Aluminum and aluminum alloys are used in cryogenic applications: -40°C service temperature does not pose a challenge to Metamic-HT's fracture toughness properties.

Proposed Path Forward

Run coupon tests at -40°C to show that the charpy strength is essentially unchanged from the ambient state.

Abstract of Task Force's Position and Proposal (continued)

HOLTEC
INTERNATIONAL

Concern #7:
Demonstration of Acceptable Creep for a Five-Year License

Task Force's Position

Creep tests show that "HT" has excellent creep properties in the 300°C-350°C range.

Creep:

- Five virgin and two irradiated coupons tested for creep for durations ranging from approximately 9,000 hours to 14,300 hours, yielded the following creep rate equation:

$$\boxed{\varepsilon = \alpha \exp\left(-\frac{E}{RT}\right) \sinh(\gamma\sigma)\, \tau^{\beta}}$$

where ε is the accumulated creep and α, β, γ and E are creep rate coefficients.

Abstract of Task Force's Position and Proposal (continued)

HOLTEC
INTERNATIONAL

Concern #7 (continued)

- The creep equation uniformly over-predicts creep for all 7 test specimens.
- The total creep strain after a period of horizontal transport can be conservatively computed using the above formula.

Abstract of Task Force's Position and Proposal (continued)

HOLTEC
INTERNATIONAL

Computed Flexural Strain From Creep Using the Bounding Creep Prediction Equation	
Duration of Transport	**Cumulative Flexural Strain, %**
1 Year	**0.046**
5 Years	**0.104**

- The maximum creep is less than the creep to which certain coupons have already been subjected (measured value = 0.1864% in March 2008). Hence, failure from creep in transport during 5 years of transport mode (= licensed life) is ruled out.
- Calculation of projected creep in 60 years of horizontal transport meets the Japanese limit of 0.4%.

<u>Proposed Path Forward</u>

Continue the ongoing creep tests for the duration desired by SFST.

Abstract of Task Force’s Position and Proposal (continued)

Concern #8:

Weldability and Possible Loss of Strength in the Welded Region Under Temperature and/or Radiation

There may be a significant loss of strength in the heat affected zone [2-41] and possible degradation of weld properties under prolonged exposure to the operating temperature [2-42, 2-43].

Task Force's Position

- Weldability: Metamic-HT is amenable to welding by all standard welding methods, viz., MIG and TIG. Laser welding and electron beam welding can also be used.

Abstract of Task Force’s Position and Proposal (continued)

Concern #8 (continued)

Task Force's Position

- Tests indicate that the decline in the strength of the heat affected zone will be less than 25%. Further testing needed to optimize the strength of the heat affected zone (which is much smaller compared to stainless steel).
- For conservatism, Holtec will assume that the tensile strength in the heat affected zone is only 60% of the base metal.

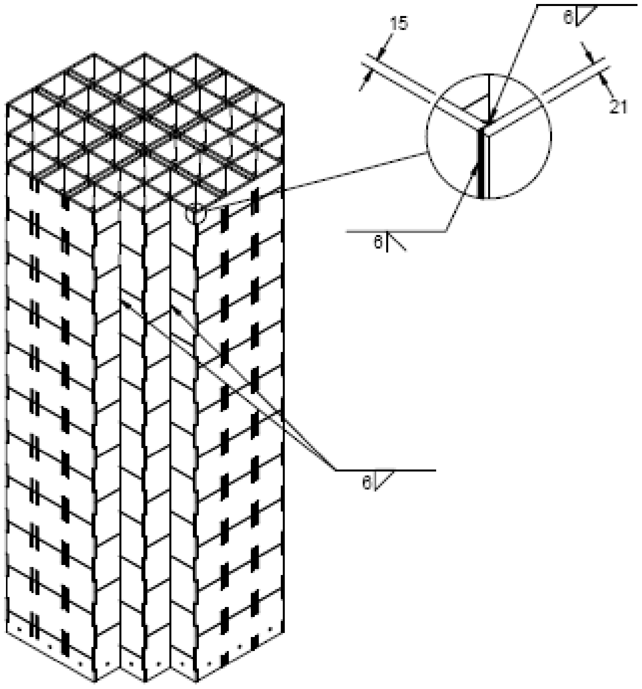
Abstract of Task Force's Position and Proposal (continued)

HOLTEC
INTERNATIONAL

Concern #8 (continued)

The F-37 and F-32 basket designs have been slightly modified to re-locate the number of welds (F-37 shown).

The peripheral flat panels have been thickened to 21mm (all other panels remain at 15mm).



Abstract of Task Force's Position and Proposal (continued)

HOLTEC
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Concern #8 (continued)

<u>Proposed Path Forward</u>

Develop and qualify weld procedures to be used in the project; submit to SFST.

- Irradiate welded coupons and test.
- Thermally treat welded coupons at 440°C for 15 days and test.

Abstract of Task Force's Position and Proposal (continued)

Concern #9: Need for Additional Test Data

Task Force's Position

To answer SFST's concerns fully, Holtec should propose the following test plan:

- The test plan shall parallel the testing that is typically carried out to qualify metals.
- Demonstrate isotropy by testing an appropriate number of coupons.

Abstract of Task Force's Position and Proposal (continued)

Concern #9 (continued)

- The test plan will seek to test a sufficiently large number of coupons to provide supplemental data so that statistically meaningful results for the following properties can be obtained:
  - Yield strength, ultimate strength, Young's Modulus, Charpy value and elongation at -40°F, ambient (37°C) and 350°C.
  - Study the effect of long-term elevated temperature environment by baking at 440°C for 15 days to simulate 5 years at 300°C, and then running all of the above property tests.

Proposed Path Forward

Obtain SFST's concurrence to the Test Plan to be proposed by Dr. Phillip Blue.