T-Flex® Shielding

Specifications Document

MarShield
CUSTOM RADIATION SHIELDING PRODUCTS

T-Flex® products maximize shielding effectiveness while keeping the weight to a minimum. Ideal for applications that require custom moldable shapes along with flexibility, such as small bore pipe, elbows and valves.

SPECIFICATIONS

T-FLEX®

MATERIAL:	METAL IMPREGNATED POLYMER (TUNGSTEN, BISMUTH, IRON)
SAFETY:	REFER TO SDS (SEPARATE DOCUMENT)
SITE PREPARATION:	ENSURE SURFACE IS FREE OF PROTRUSION OR SHARP AREAS. CONSIDER ALL INSTALLATION CONDITIONS
USAGE:	SECURE TO SURFACE VIA MAGNETS, STRAPS, OR OTHER SPECIFIED DEVICES
GENERAL CONDITION:	FLEXIBLE WITH NO SIGNS OF CRACKING OR BRITTLENESS, DARK GREY IN COLOR (OPTIONAL: COLORED OUTER LAYER)
HANDLING:	USING PRIOR TRAINING OR A MOCK UP DEMONSTRATION IS RECCOMMENDED BEFORE INSTALLATION
PHYSICAL PROPERTIES:	TENSILE: 158 psi, ELONGATION: 320%, TEAR: 34.5 lbf/in, DUROMETER: 46
DENSITY:	TUNGSTEN: 0.25 lb/in^3, BISMUTH: 0.167 lb/in^3, IRON: 0.098 lb/in^3
THERMAL PROPERTIES:	CONTINUOUS OPERATING TEMPERATURE[(Fe)]: 350°F MAXIMUM TEMPERATURE[(Fe)]: 450°F THERMAL CONDUCTIVITY: ~24 W/(m x K) HEAT OF COMBUSTION: 2680 BTU/lb FLAME SPREAD INDEX: 55, SMOKE DEVELOPED INDEX: 700 NFPA 701-2010 FIRE TESTS FOR FLAME PROPAGATION[(Fe)] (SEE APPENDIX A)
RAD STABILITY:	INCIPIENT TO MILD DAMAGE (25% DAMAGE) UP TO OVER 10E8 RADS (1000 KGY) (PER NASA SP-8053, SEE APPENDIX B)
ATTENUATION:	SEE APPENDIX C
LEACHABLES:	SEE APPENDIX D

Appendix A

INTRODUCTION

This report is a presentation of results of a flammability test conducted for MarShield Custom Radiation Shielding The test was conducted in accordance with the National Fire Protection Association test method NFPA 701, Standard Methods of Fire Tests for Flame Propagation of Textiles and Films, 2010 Edition, Test Method 2.

The purpose of the test is to assess the propagation of a flame beyond the area exposed to an ignition source. It does not indicate whether the material resists flame propagation under more severe exposure conditions, or where used in a manner that differs substantially from the test conditions.

Test 2 is used for testing materials having weight greater than 700 g/m^2, vinyl coated fabric blackout linings, drapery fabrics with vinyl coated blackout linings, plastic films used for decorative purposes inside a building, and fabrics used in the assembly of awnings, tents, tarps, and similar structures and banners.

For materials that have been treated with fire retardant treatments, the materials are typically exposed to applicable cleaning or weathering treatments prior to testing.

PROCEDURE

Test Method 2 uses five specimens for the folded test, or ten flat specimens measuring 125 mm by 1200 mm that have been conditioned in an oven maintained at 105°C for not less than one hour nor more than three hours. The specimens are tested within two minutes after removal from the oven.

The gas burner, fueled with Technical Grade methane, is ignited and regulated at a flow of 113 L/hr at 17.5 kPa pressure, which gives an igniting flame approximately 280 mm high. The flame is applied for 2 minutes at an angle of 25° and 100 mm from the lower edge of the vertically suspended specimen. The duration of flaming combustion of material that drops to the floor of the test chamber, and the duration of burning of the specimen after the igniting flame has been removed are measured and recorded.

After all flaming has ceased, the length of the char is determined. Length of char is defined as the original length of the specimen minus the distance from the top edge of the specimen to the horizontal line above which all material is intact.

PERFORMANCE CRITERIA

The following criteria determines whether or not the material passes NFPA 701 Test Method 2.

- When any specimen continues flaming for more than 2 seconds after the test flame is removed from contact with the specimen, the material is recorded as failing the test.
- Where the length of char of any individual folded specimen exceeds 1,050 mm, or any single flat specimen exceeds 435 mm, the material is recorded as failing the test.
- Where at any time during or after application of the igniting flame any portions or residues of the material break or drip from the specimen and fall to the floor and continue burning for more than 2 seconds after reaching the floor of the apparatus, the material is recorded as failing the test.

The test method makes provision for retesting materials under the following conditions.

- If only one of the four **folded specimens** fail during the initial test, two new specimens are cut and tested. If both of these specimens pass, the material is recorded as passing the test.
- If only one of the ten **flat specimens** fails during the initial test, five new specimens are cut and tested. If all five of these pass, the material is recorded as passing the test.

MATERIAL TESTED

The client submitted a sample of silicone based shielding product identified as **T–Flex®**.

TEST DATA

Specimen Type: Flat
Cleaning Procedure: None
Weathering Procedure: None

Specimen	Afterflame (sec)	Length of Char (mm)	Flaming Drippings (sec)	Specimen Result
1	0.0	10	0.0	Pass
2	0.0	10	0.0	Pass
3	0.0	15	0.0	Pass
4	0.0	11	0.0	Pass
5	0.0	15	0.0	Pass
6	0.0	20	0.0	Pass
7	0.0	20	0.0	Pass
8	0.0	15	0.0	Pass
9	0.0	24	0.0	Pass
10	0.0	30	0.0	Pass

TEST RESULT

The material tested meets the requirements of NFPA 701 Test Method 2.

Appendix B

RADIOLOGICAL STABILITY OF T-FLEX®

Per Figure 3 of NASA SP-8053, Nuclear and Space Radiation Effects on Materials (see page 2 of this document), mineral filled silicone will experience only incipient to mild damage (25% damage) up to over 10E8 rads (1000 kGy).

Polymers undergo two types of damage when exposed to ionizing radiation:

1) Chain Scission, which leads to
   a. Decreased young's modulus
   b. Reduced Yield Stress
   c. Increased elongation
   d. Decreased Hardness
   e. Decreased Elasticity
2) Cross-linking, which leads to
   a. Increased Young's modulus
   b. Impeded viscous flow
   c. Decreased elongation
   d. Increased Hardness
   e. Embrittlement

Silicone typically undergoes the cross-linking damage, leading to brittleness. The addition of inorganic filler materials (tungsten, bismuth, etc.) can improve radiation stability by acting as a sink for excitation energy and by adding structural strength in degraded silicone. Due to the decreased dose experienced as radiation is attenuated through the material, the most damage would be expected on the surface facing the radiation source.

At 1E6 Rad (10 kGy), which is an equivalent exposure of 10E4 rad/h for 100 hours, we would expect minor loss of elasticity of T-Flex®. At higher doses significant brittleness would be expected.

Research and analysis performed by Daniel R. McAlister, Ph.D.

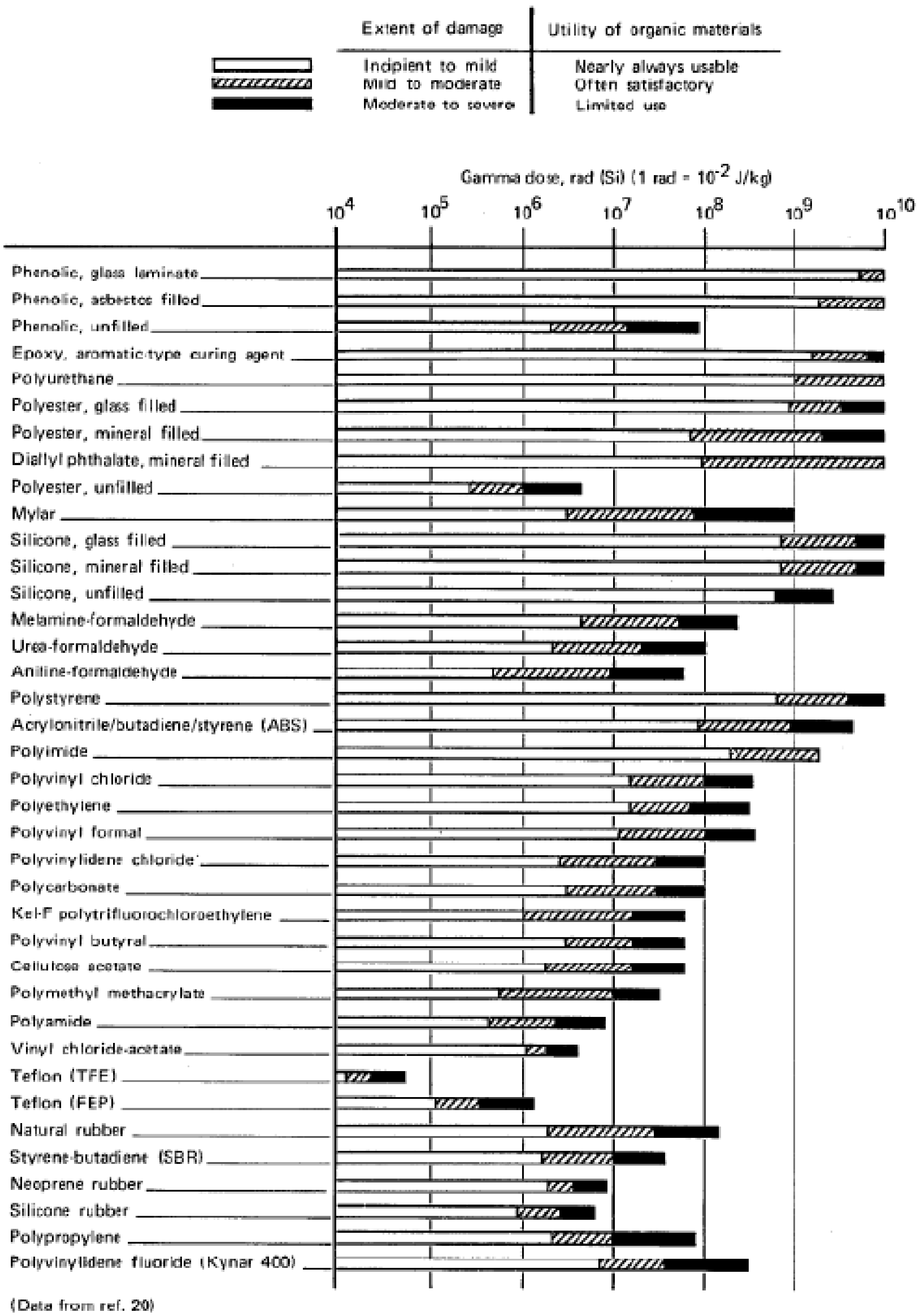


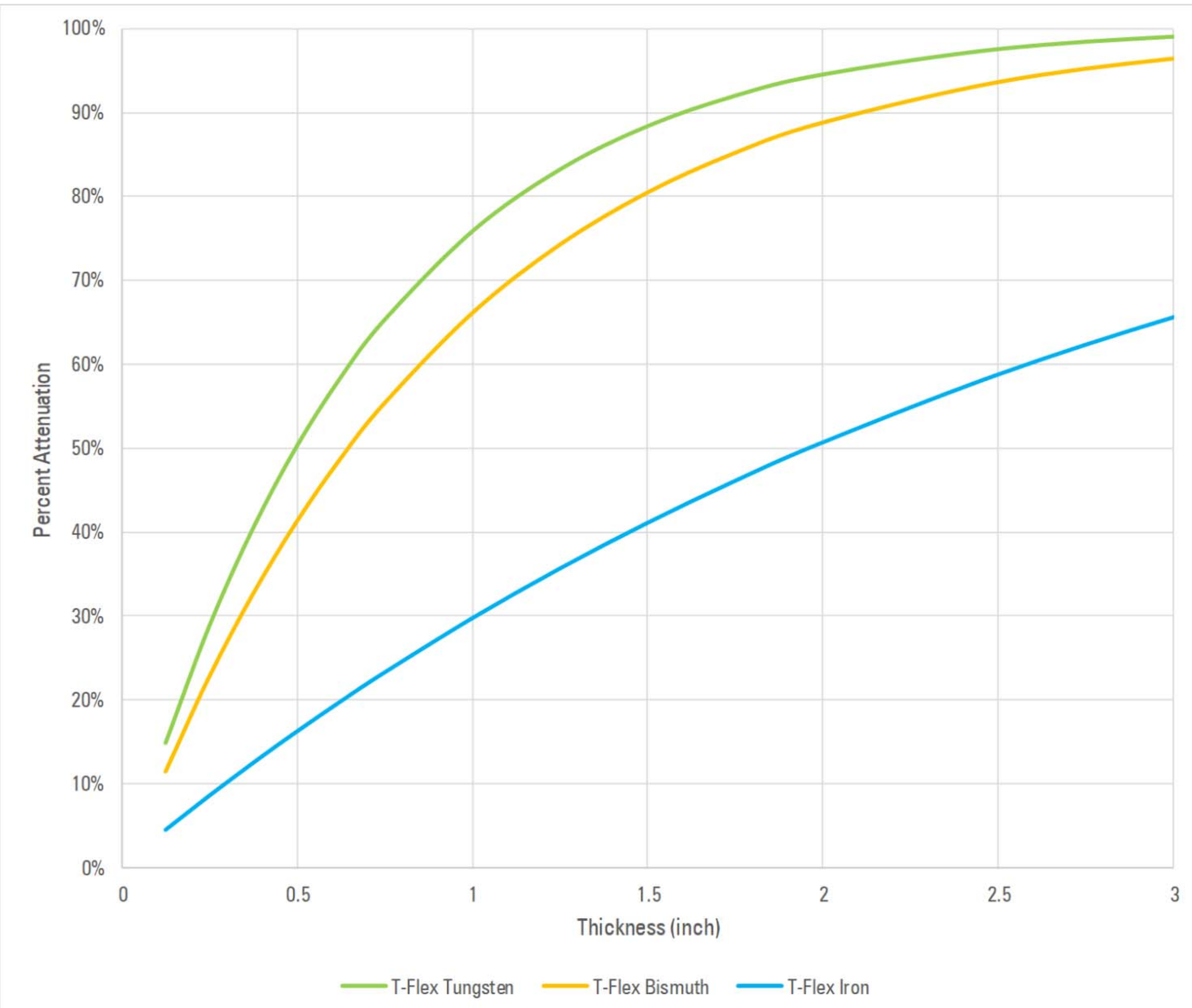
Figure 3. – Relative radiation resistance of organic materials based upon changes in physical properties.

Appendix C

T-Flex® Shielding

Gamma Attenuation - Cs-137 662 keV

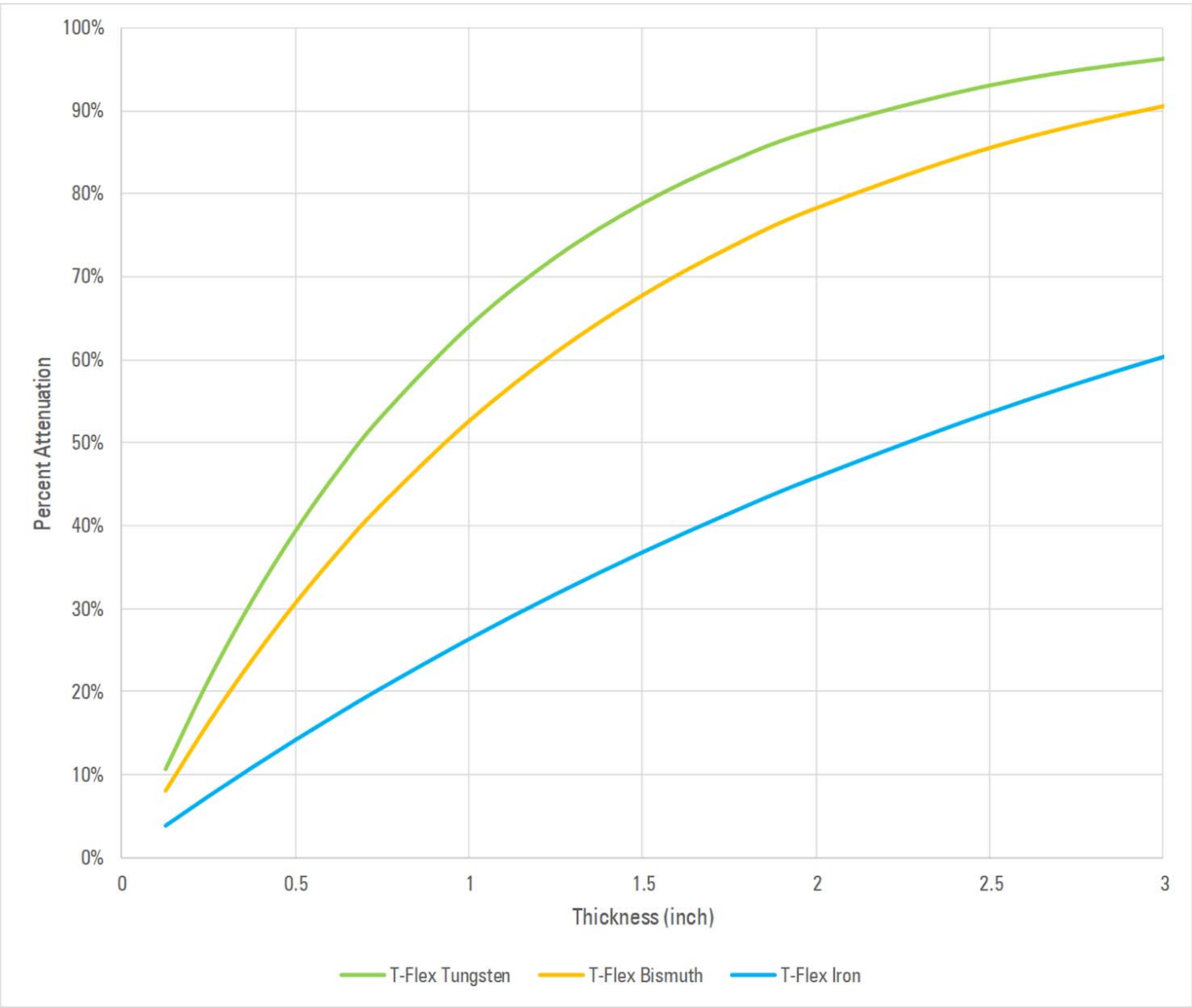
Attenuation for T-Flex® at Cs-137 (≈662 keV)															
Material	Thickness (inch)														
	0.125	0.25	0.375	0.5	0.625	0.75	1	1.25	1.5	1.75	2	2.5	3	3.5	4
T-Flex Tungsten	15%	29%	40%	50%	58%	65%	76%	83%	88%	92%	95%	98%	99%	100%	100%
T-Flex Bismuth	11%	23%	33%	41%	49%	55%	66%	74%	81%	85%	89%	94%	96%	98%	99%
T-Flex Iron	4%	9%	12%	16%	20%	23%	30%	36%	41%	46%	51%	59%	66%	71%	76%



T-Flex® Shielding

Gamma Attenuation - Average Outage Energy 900 keV

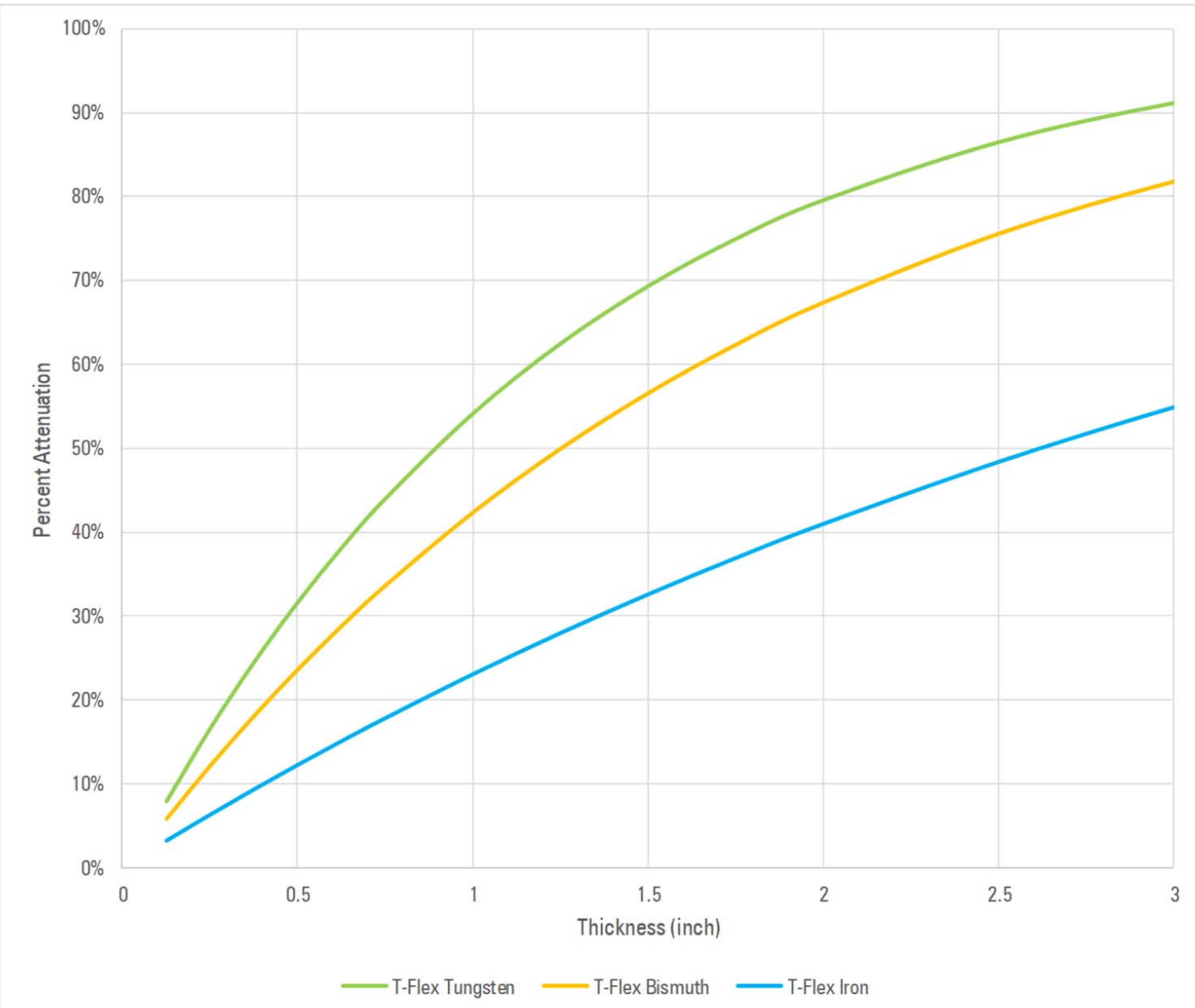
Attenuation for T-Flex® at Average Plant Energy (≈900 keV)															
Material	Thickness (inch)														
	0.125	0.25	0.375	0.5	0.625	0.75	1	1.25	1.5	1.75	2	2.5	3	3.5	4
T-Flex Tungsten	11%	21%	31%	39%	47%	53%	64%	72%	79%	84%	88%	93%	96%	98%	99%
T-Flex Bismuth	8%	16%	24%	31%	37%	43%	53%	61%	68%	74%	78%	86%	91%	94%	96%
T-Flex Iron	4%	7%	11%	14%	17%	20%	26%	32%	37%	42%	46%	54%	60%	66%	71%



T-Flex® Shielding

Gamma Attenuation - Co-60 1253 keV

Attenuation for T-Flex® at Co-60 (≈1250 keV)															
Material	Thickness (inch)														
	0.125	0.25	0.375	0.5	0.625	0.75	1	1.25	1.5	1.75	2	2.5	3	3.5	4
T-Flex Tungsten	8%	17%	25%	32%	38%	44%	54%	62%	69%	75%	80%	86%	91%	94%	96%
T-Flex Bismuth	6%	12%	18%	24%	29%	34%	42%	50%	57%	62%	67%	76%	82%	87%	90%
T-Flex Iron	3%	6%	9%	12%	15%	18%	23%	28%	33%	37%	41%	48%	55%	61%	66%



Appendix D

T-Flex® Shielding

Leachables

A sample of T-Flex® shielding was submitted for analysis to ensure compliance with GE Specification NEDC31735P, rev. December 2000. Duplicate portions of the sample were prepared for analysis by performing a Parr bomb oxidation. The resultant solutions were analyzed by ion chromatography for total halogens and total sulfur and by inductively coupled plasma spectrometry for total embrittling metals. The sample was also prepared for analysis by performing a 48-hour extraction with demineralized water. The resultant solutions were analyzed by ion chromatography for total nitrite and total nitrate.

Parameter	Measured	Acceptance Criteria	Test Method
Total Halogens as Cl, ppm	47	450 max	ASTM D4327-03
Total Nitrite, ppm	<1	10 max	ASTM D4327-03
Total Nitrate, ppm	<1	820 max	ASTM D4327-03
Total Sulfur, ppm	83	630 max	ASTM D4327-03
Total Combined Level	3	13.2 max	CALCULATED
Total Antimony, ppm	16	200 max	ASTM D1976-07
Total Arsenic, ppm	<1	200 max	ASTM D1976-07
Total Bismuth, ppm	<1	200 max	ASTM D1976-07
Total Cadmium, ppm	<1	200 max	ASTM D1976-07
Total Gallium, ppm	<1	200 max	ASTM D1976-07
Total Indium, ppm	<1	200 max	ASTM D1976-07
Total Lead, ppm	<1	200 max	ASTM D1976-07
Total Mercury, ppm	<1	200 max	ASTM D1976-07
Total Silver, ppm	15	200 max	ASTM D1976-07
Total Tin, ppm	<1	200 max	ASTM D1976-07
Total Zinc, ppm	7	200 max	ASTM D1976-07
Total Embrittling Metals, ppm	46	500 max	ASTM D1976-07

MarShield
CUSTOM RADIATION SHIELDING PRODUCTS

Certificate of Analysis
No. CA15151

Product: T-Flex®
Lot #: T6215081908

T-Flex® Lot # T6215081908 has been manufactured according to standard operating procedures. This lot has been tested in accordance with quality assurance policy and procedures. This lot of product meets all quality specifications.

ANALYSIS RESULTS

Analyte	Limit (mg/kg)	Result (mg/kg)
Br^-	450	0.13
Cl^-	450	0.06
F^-	450	0.03
NO_2^-		<2
NO_3^-		<2
Ag	200	<0.2
Sb	200	0.7
Bi	200	<0.2
Cd	200	<0.2
Ga	200	<0.2
Hg	10	<5
In	200	<0.2
Pb	200	<0.2
S	250	35
Sn	200	<0.2
Zn	200	<0.2

Joel Williamson
Director of Operations

October 6, 2015

Test:

- A 485 gram sample of TFlex®-W was placed in 500mL of Boric Acid (2750mg/L B).
- The solution was heated to 60C (140F)
- Aliquots of the liquid were removed every 24 hours for analysis by ICP-OES to determine leached tungsten.

Results:

- After 96 hours, no noticeable degradation of the TFlex®-W was apparent.
- ICP-OES analysis did show measurable amounts of leached tungsten in the boric acid solution:

Time(hrs)	ppm Tungsten (mg/L)	% Mass Lost to Leach
24	75	0.0077
48	158	0.016
72	282	0.029
96	451	0.046

Test Performed by:

Daniel McAlister, Ph.D.
Senior Chemist