Los Alamos
NATIONAL LABORATORY
Est. 1943
The World's Greatest Science Protecting America

Memorandum

Nuclear Nonproliferation Division
International Threat Reduction Group N3
Off-Site Source Recovery (OSR) Project

To/MS: Cristy Abeyta, OSRP TL- Material MGT. and Disposition, MS: J552
Jim Matzke, OSRP TL- Recovery Ops. MS: J552
From/MS: J. Andrew Tompkins, Vance Contractor c/o OSRP
Phone/Fax: 770-517-4320, 505-699-0809

Symbol: N3-2012-057
Date: April. 11, 2012

SUBJECT: MRC Model 24120 and 24112 Special Form Self-Certification

SCOPE

The purpose of this memo is to characterize Monsanto Research Corporation Model 24120 and 24112 sealed sources as US DOT Special Form Radioactive material, with the goal of achieving interim storage at TA-54 and final disposition at WIPP.

BACKGROUND

In 1975 Monsanto Research Corp. was requested to fabricate AmBe neutron sources of 5 and 16 Ci nominal activity for Seismograph Services, Birdwell Div.. The special form character of these sources was analyzed by Dr. Ed Janzow, and USDOT COCA were issued for these models USA/0119/S & USA/0120/S, respectively. Another document we have for the special form analysis used by MRC is the mark up of the Engineered Products Manufacturing Order form No. 3015-9. In this document Dr. Ed Janzow calculated the critical stress in the model 24120 design and calculates the service life of the source using internal pressure and the ASME Pressure Vessel code model with a safety factor of 4.

SPECIAL FORM CHARACTER

In May of 1975 Seismograph Services contracted with MRC to build several Pu8Be model 24120 and 24112 well logging sources. These sources were double encapsulated, stainless steel, neutron sources containing a mixture of beryllium metal and up to 16 Ci of Pu-238 oxide (see attached manufacturing file). Overall design testing at this stage was ANSI classification testing, special form engineering evaluation, and high pressure testing. The source was evaluated under ANSI N542-1968 (sealed Radioactive Source – Classification) standard as meeting a 68E66545. A USDOT Certificate of Competent Authority (COCA) was issued for the model 24120 source, based upon a 20 Ci Pu-238 maximum activity and a 20 year recommended working life. The COCA was allowed to expire in 1983 and MRC was out of business in 1984. The 5 Ci maximum activity MRC model 24112 was identical to the 24120 and all aspects except its external length. The model 24112 was proportionally shorter since it held 25% of the maximum activity of the model 24120. The model 24112 was granted a USDOT COCA as well (USA/0119/S). COCA USA/0119/S expired about the same time as its higher activity and slightly longer cousin the model 24120. A comparison of pertinent all dimensions of the model 24120 and 24112 are in Table 1.

The original sources were tested to 25,000 psi external pressure at room temperature, in-order to establish the robust character of these sources for work in a well logging environment. A single sample of the model 24120 was even tested at 30,000 psi external pressure without any damage or loss of integrity.

The problem is that 40 years later we are still disposing of model 24120 and 24112 sources and need to establish a maximum life-time for shipping these sources as DOT special form radioactive material. The original engineering design calculations for models 24120 and 24112 were extremely conservative. The goal of the original calculations was to insure that the sources greatly exceeded service and transportation requirements. The engineering calculations indicated that the design goal of 20 years of working life would be readily met. However, 40 years after these sources were fabricated the question is now will they meet special form requirements? In particular will they survive an 800 degree C fire for 10 minutes? Since the issue is pressure build up from alpha decay in the source, it is a simple matter to re-examine the pressure build up in the void volume of the source at the highest temperature and duration required to meet special form requirements.

Model 24120

The internal pressure of the model 24120 source containing 16 Ci of Pu8Be powder packed to 36% of theoretical density is 288 psi at 810 degrees C after 40 years of decay. This pressure was based upon the known dimensions of the source model (see Table 1.), The calculated number of helium atoms generated from 40 years of decay, a packing factor of 36% (Dr. Janzows Safety Analsis), and the temperature required for the 10 minute fire simulation of 49CFR173.469 special form testing. These calculations are done separately for 50% PF and 36% PF in order to demonstrate the difference this one element creates in the pressure calculation.

The allowable pressure calculation is done exactly as described by Dr. Janzow in his safety analysis, with one exception. Dr. Janzow derated the 9,900 psi strength of material for 304 SS at 815 degrees C to 7,900 psi for the purpose of MRC corporate risk reduction. This additional risk reduction factor of 20% was not incorporated in these calculations.

Further since the sources made in 1975 will only be at 69% of the allowable internal pressure (288psi/417 psi) and additional 10 years of DOT special form lifetime is possible. However, since the present objective is simply to insure that these sources are transported compliantly and dispositioned safely a date of June 1, 2016 is selected as the arbitrary date for loss of special form character.

Model 24112

The internal pressure of the model 24112 source containing 5 Ci of Pu8Be powder packed to 36% of theoretical density is 367 psi at 810 degrees C after 40 years of decay. This pressure was based upon the known dimensions of the source model (see Table 1.), The calculated number of helium atoms generated from 40 years of decay, a packing factor of 36% (Dr. Janzows Safety Analysis), and the temperature required for the 10 minute fire simulation of 49CFR173.469 special form testing. These calculations are done separately for 50% PF and 36% PF in order to demonstrate the difference this one element creates in the pressure calculation.

The allowable pressure calculation is done exactly as described by Dr. Janzow in his safety analysis, with one exception. Dr. Janzow derated the 9,900 psi strength of material for 304 SS at 815 degrees C to 7,900 psi for the purpose of MRC corporate risk reduction. This additional risk reduction factor of 20% was not incorporated in these calculations.

Further since the sources made in 1975 will only be at 88% of the allowable internal pressure (288psi/417 psi) and additional 4 years of DOT special form lifetime is possible. However, since the present objective is simply to insure that these sources are transported compliantly and dispositioned safely a date of June 1, 2016 is selected as the arbitrary date for loss of special form character.

Differences in the Basis of Calculation
The original pressure calculation for the model 24120 was based upon a maximum activity of 20 Ci of Pu-238 for the model 24120. This model as is presently being considered was only loaded to 16 Ci of Pu-238. A 20% reduction in source activity and of He atoms accumulating from alpha decay.

Additionally, an adhoc 20% decrease in source cladding material strength was rejected. MRC had arbitrarily decreased material strength in order to reduce corporate risk. The allowable stress of 9,900 psi for the 304 SS cladding was originally cited by Dr. Janzow prior to 20% reduction.

Correction of small calculational errors also increased the allowable service life for these sources. This was associated with the inside diameter of the capsule head.

The biggest change in the calculation was the use of a 36% packing factor for internal volume. This data was cited in the safety analysis, although Dr. Janzow chose to use a 50% packing factor in order to make the analysis as much an absolute "worst case" as was possible. The actual packing factor used is much more appropriate since the safety factor of 4 used as the basis of the ASME Pressure Vessel calculation is already very conservative for this calculation.

SUMMARY
Since model 24120 sources were evaluated as special form radioactive material in 1975, leading to the issuance of USA/0120/S, and continue to meet special form requirements over 40 years later, it is my engineering opinion that these radioactive sources containing 16 Ci of radioactive Pu-238, packaged for final disposition, continue to exhibit special form character and may be domestically shipped as USDOT special form material until June 1, 2016.
Model 24112 sources were evaluated as special form radioactive material in 1975, leading to the issuance of COCA USA/0119/S, and continues to meet special form requirements over 40 years later, it is my engineering opinion that these sources 5 Ci of radioactive Pu-238 respectively, packaged for final disposition continue to exhibit special form character and may be domestically shipped as USDOT special form material until June 1, 2016.

JAT

Cy: attach
MRC Manufacture Order 3015-9 (TWCP: 07409)
USA/0119/S
USA/0120/S
Dimension Comparison (Table 1.)
Pressure Calculations

Disttibution:
OSR File, MS: J552
N3 File, MS: E541

DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
WASHINGTON, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY

Special Form Radioactive Material Encapsulation

Certificate Number USA/0120/S

(Revision 1)

This certifies that the encapsulated source, as described, when loaded with the authorized radioactive contents, has been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in IAEA 1/ and USA 2/ regulations for the transport of radioactive materials

I. Source Description - The source described by this certificate is identified as MRC Neutron Source Model Number 24120, which is doubly encapsulated in stainless steel and measures 0.750" in diameter and 2.957" in length.

II. Radioactive Contents - The authorized radioactive contents of this source consist of not more than 20 Curies of Plutonium-238 as oxide.

III. This certificate, unless renewed, expires April 30, 1983.

This certificate is issued in accordance with paragraph 803 of the IAEA Regulations 1/, and in response to the March 7, 1980, petition by the Monsanto Research Corporation, Dayton, Ohio and in consideration of the associated information therein.

Certified by:

R. R. Rawl — June 27, 1980

Richard R. Rawl
Chief, Radioactive Materials Branch
Office of Hazardous Materials Regulation
Materials Transportation Bureau

(Dates)

1/ "Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition", published by the International Atomic Energy (IAEA) Vienna, Austria.

2/ Title 49, Code of Federal Regulations, Part 170-178, USA.

Revision 1 issued to extend expiration date and reflect conformance to the 1973 IAEA regulations.

DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
WASHINGTON, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY

Special Form Radioactive Material Encapsulation

Certificate Number USA/0119/S

(Revision 1)

This certifies that the encapsulated source, as described, when loaded with the authorized radioactive contents, has been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in IAEA[1/] and USA[2/] regulations for the transport of radioactive materials.

I. Source Description - The source described by this certificate is identified as MRC Neutron Source Number 24112 which is doubly encapsulated in stainless steel and measures 0.750" in diameter and 1.400" in length.

II. Radioactive Contents - The authorized radioactive contents of this source consist of not more than 5 curies of Plutonium-238 as oxide.

III. This certificate, unless renewed, expires April 31, 1983.

This certificate is issued in accorance with paragraph 803 of the IAEA Regulations 1/, and in response to the March 7, 1980 petition by the Monsanto Research Corporation, Dayton, Ohio and in consideration of the associated information therein.

Certified by:

R R Rawl

June 27, 1980
(Date)

Richard R. Rawl
Chief, Radioactive Materials Branch
Office of Hazardous Materials Regulation
Materials Transportation Bureau

1/ "Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1979 Revised Edition", published by the International Atomic Energy (IAEA) Vienna, Austria.

2/ Title 49, Code of Federal Regulations, Part 170-178, USA.

Revision 1 issued to extend expiration date and reflect conformance to the 1973 IAEA regulations.

Number of He Atoms Genererated by Alpha Decay **MRC Model 24120**

$N_T = (N_0/Lambda)*(1-e^{-(Lambda*T)})/N_{Avagodro}$

$N_i = ((3.7E10*3600*24*364.25)/(0.69315/87.75)*(1-exp(-0.693/87.75)*Age)))/ 6.023E23$

i = Age (yr)

N_1 =	1.93E-06	mol/Ci
N_5 =	9.48E-06	mol/Ci
N_{10} =	1.86E-05	mol/Ci
N_{20} =	3.58E-05	mol/Ci
N_{30} =	5.16E-05	mol/Ci
N_{40} =	6.63E-05	mol/Ci

MRC 24120 **(16 Ci Pu-238, 40 yr decay, 50% PF)**

Clad Internal Volume	7.37	cc
Void Volume$_{50\%}$	3.725	cc
A_0 =	16	Ci
N_{40} =	6.63E-05	mol/Ci
N_{He} =	1.06E-03	mols gas

$Pressure_{RT} = (N \times R \times T) / V$ $Pressure_{RT}$ 101 psi

N =	1.06E-03	mol
R =	0.08208	Liter-Atm/mol-K
T =	293	degrees K
V =	0.003725	Liters

$Pressure_{800} = (N \times R \times T) / V$ $Pressure_{RT}$ 375 psi

N =	1.06E-03	mol
R =	0.08208	Liter-Atm/mol-K
T =	1093	degrees K
V =	0.003725	Liters

MRC 24120 **(16 Ci Pu-238, 40 yr decay, 34% PF)**

Clad Internal Volume	7.37	cc
Void Volume$_{50\%}$	4.86	cc
A_0 =	16	Ci
N_{40} =	0.00E+00	mol/Ci
N_{He} =	0.00E+00	mols gas

$Pressure_{RT} = (N \times R \times T) / V$ $Pressure_{RT}$ 77 psi

N =	1.06E-03	mol
R =	0.08208	Liter-Atm/mol-K
T =	293	degrees K
V =	0.00486	Liters

$Pressure_{800} = (N \times R \times T) / V$ $Pressure_{Fire}$ 288 psi

N =	1.06E-03	mol
R =	0.08208	Liter-Atm/mol-K
T =	1093	degrees K
V =	0.00486	Liters

Tensile stress in MRC 24120 inner capsule wall 810 degrees C

Inner Capsule Wall thickness	0.120	in.
Wall median Length	1.747	in.
Wall Area	0.210	in^2
Head Area	0.193	in^2
Pressure	288	psi
Force on Head	55.6	lb_F
Wall Stress	265	psi at 810 degrees C

Allowable Stress Accepting limited Deformation

Material Outer Clad	Armco 17-4 PH		
Ultimate yield strength		150,000	psi
Safety Factor: 4		30,000	psi
Further derated[1]	S =	9,900	psi

Allowable Internal Pressure (single cycle not concerned about deformation)

$P_{Allowable} = S^* (t_H \text{^} 2/(d \text{^} 2 * C))$

t_H = 0.090 in.

d = ID= 0.75-(2*0.065)

C = joint configuration factor = 0.5

$P_{Allowable}$ = 417 psi

[1] In his write up Dr. Janzow suggests that we should further derate the strength number to 9,900 psi, a value appropppriate for 304 SS at 1500 degrees F. Dr. Janzow then based upon MRC risk avoidance policy derates the strength another 20%. Since these sources are already packaged in an additional inch of 304 SS (the S-100 POC), I believe it is unnecessary to derate the strength further, therefore 9,900 psi will be used.

Since the calculated actual internal pressure of the MRC model 24120 source is at 69 % of the allowable internal pressure an additional 6 years of aging is reasonable (46 yr total). Therefore, it is reasonable to allow the treatment of MRC model 24120 sources to be treated as special form radioactive material until Jun. 1, 2016, when packaged in an OSR Project S-100 package for final disposition at WIPP.

Number of He Atoms Genererated by Alpha Decay **MRC Model 24112**

$N_T = (N_0/Lambda)*(1-e^{-(Lambda*T)})/N_{Avagodro}$

$N_l = ((3.7E10*3600*24*364.25)/(0.69315/87.75)*(1-exp(-0.693/87.75)*Age)))/ 6.023E23$

l = Age (yr)

N_1 =	1.93E-06	mol/Ci
N_5 =	9.48E-06	mol/Ci
N_{10} =	1.86E-05	mol/Ci
N_{20} =	3.58E-05	mol/Ci
N_{30} =	5.16E-05	mol/Ci
N_{40} =	6.63E-05	mol/Ci

MRC 24112	(5 Ci Pu-238, 40 yr decay, 50% PF)			
Clad Internal Volume	1.80	cc		
Void $Volume_{50\%}$	0.9	cc		
A_0 =	5	Ci		
N_{40} =	6.63E-05	mol/Ci		
N_{He} =	3.32E-04	mols gas		
$Pressure_{RT}$ = (N x R x T) / V			$Pressure_{RT}$	130 psi
N =	3.32E-04	mol		
R =	0.08208	Liter-Atm/mol-K		
T =	293	degrees K		
V =	0.0009	Liters		
$Pressure_{Fire}$ = (N x R x T) / V			$Pressure_{RT}$	486 psi
N =	3.32E-04	mol		
R =	0.08208	Liter-Atm/mol-K		
T =	1093	degrees K		
V =	0.0009	Liters		

MRC 24112	(5 Ci Pu-238, 40 yr decay, 34% PF)			
Clad Internal Volume	1.80	cc		
Void $Volume_{50\%}$	1.19	cc		
A_0 =	5	Ci		
N_{40} =	6.63E-05	mol/Ci		
N_{He} =	3.32E-04	mols gas		
$Pressure_{RT}$ = (N x R x T) / V			$Pressure_{RT}$	99 psi
N =	3.32E-04	mol		
R =	0.08208	Liter-Atm/mol-K		
T =	293	degrees K		
V =	0.00119	Liters		
$Pressure_{Fire}$ = (N x R x T) / V			$Pressure_{Fire}$	367 psi
N =	3.32E-04	mol		
R =	0.08208	Liter-Atm/mol-K		
T =	1093	degrees K		
V =	0.00119	Liters		

Tensile stress in MRC 24112 inner capsule wall 810 degrees C

Inner Capsule Wall thickness	0.120	in.
Wall median Length	1.747	in.
Wall Area	0.210	in^2
Head Area	0.193	in^2
Pressure	367	psi
Force on Head	70.9	lb_F
Wall Stress	338	psi at 810 degrees C

Allowable Stress Accepting limited Deformation

Material Outer Clad Armco 17-4 PH

Ultimate yield strength		150,000	psi
Safety Factor: 4		30,000	psi
Further derated[1]	S =	9,900	psi

Allowable Internal Pressure (single cycle not concerned about deformation)

$P_{Allowable} = S^* (t_H^2/(d^2 * C))$

t_H = 0.090 in.

d = ID= 0.75-(2*0.065)

C = joint configuration factor = 0.5

$P_{Allowable}$ = 417 psi

[1] In his write up Dr. Janzow suggests that we should further derate the strength number to 9,900 psi, a value appropppriate for 304 SS at 1500 degrees F. Dr. Janzow then further derates the material strength another 20%, based upon MRC risk avoidance policy. Since these sources are already packaged in an additional 0.25 inches of 304 SS (the S-100 POC). I believe it is unnecessary to derate the strength further, therefore 9,900 psi will be used.

Since the calculated actual inpressure of the MRC model 24112 source is at 88% of the allowable internal pressure an additional 10% aging is reasonable (44 yr total). Therefore, it is reasonable to allow the treatment of MRC model 24120 sources to be treated as special form radioactive material until June 1, 2014, when packaged in OSR Project S-100 packages for final disposition at WIPP.

TABLE 1., Comparison of MRC model 24120 & 24112 Dimensions to those of Similar MRC Special Form Sealed Sources

			Inner Capsule					Outer Capsule					
Source Model	Capsule Material	Weight (grams)	O.D. (in.)	O.L. (in.)	W_t (in.)	H_t (in.)	B_t (in.)	O.D. (in.)	O.L. (in.)	W_t (in.)	H_t (in.)	B_t (in.)	US DOT COCA
2722-A	304 SS	15	0.402	0.500	0.045	0.100	0.100	0.500	0.700	0.047	0.100	0.100	USA/0043/S
24112	304 SS/17-4	83	0.616	0.800	0.058	0.120	0.095	0.750	1.400	0.065	0.360	0.115	USA/0119/S
24120	304 SS/17-4	137	0.616	2.357	0.048	0.120	0.095	0.750	2.957	0.055	0.360	0.115	USA/0120/S
2724-A	304 SS	71	0.902	0.920	0.045	0.100	0.100	1.000	1.120	0.047	0.100	0.100	USA/0043/S
2728-A	304 SS	365	1.370	3.330	0.060	0.100	0.100	1.500	3.500	0.063	0.100	0.100	USA/0043/S

I.D. = Inner Diameter (in.)
O.D. = Outer diameter (in.)
W_t = Cladding wall thickness
O.L. = Overall Length (in.)

H_t = Head thickness (in.)
B_t = Bottom thickness (in.)

MRC Model	ID Inner (in.)	Inner Length	Vol (in.)
24112	0.5	0.585	0.037
24120	0.52	2.142	0.145

Activity ratio	Vol. Ratio	
0.31	0.25	
1.24		Pressure is 24% higher due to shortened internal volumn