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, MS: J552
From/MS: J. Andrew Tompkins, Vance Contractor c/o OSRP
Phone/Fax: 770-517-4320, 505-699-0809
Symbol: N3-2012-054
Date: *March 5, 2012*

SUBJECT: MRC Model 24110 Special Form Self-Certification

SCOPE

The purpose of this memo is to characterize Monsanto Research Corporation Model 24110 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 1972 Monsanto Research Corp. was requested to fabricate an AmBe neutron source of 5 Ci nominal activity for McCullough Services. Although the special form character of these sources was analyzed by Dr. Ed Janzow, these sources were never intended for export and thus a US DOT COCA was never issued for this model.

SPECIAL FORM DOCUMENTATION

One document we have for the special form analysis used by MRC is the mark up of the MRC order form[1] . In this document Dr. Ed Janzow compares the model 24110 source to 5 other MRC neutron source. Using the method of similarity Dr. Janzow compares the size and weight of the neutron sources. (See Table 1).

MRC models 2722-A, 2724-A, and 2728-A (2720 series) were fully tested and found to be special form radioactive material (COCA USA/0043/S, expires 5/31/2012). Models 24112 and 24120 were analyzed by the method of similarity and found to be special form radioactive material (COCA USA/0119/S & USA/0120/S, exp 1983).

The model 24110 can be compared dimensionally to the other 5 approved special form sources using Table 1. Note that the materials of construction, primarily 304 SS, are identical or of similar strength for all of the sources discussed. The issue is how similar to the other sources is the model 24110? A dimensional analysis of a group of neutron sources, all of which have or had a US DOT COCA for use as special form radioactive material, will allow an unbiased comparison of the attributes of these sealed sources to those of the model 24110 source.

WEIGHT

The weight of the model 24110 is bracketed by that of the models 24112 and 24120, and is lower mid range for the 2720 series sources. This weight is important in quantifying how much energy is dissipated by the 9 m impact test. Lower weight means less energy to be dissipated as the source impacts an immovable object after a 9 m fall.

[1] MRC Engineered Products Division Order no. 1024-5.

OUTSIDE DIAMETER (O.D.)
The OD of the model 24110 inner and outer claddings is identical to that of the models 24112 and 24120. Further the OD is mid range for the 2720 series neutron sources.

OVERALL LENGTH (O.L.)
The OL is bracketed by that of the 2720 series neutron sources. While the OL is not bracketed by the models 24112 and 24120, it is only 0.043 in. greater than the model 24120 source. This difference represents a 1% increase over the model 24120 and does not represent a significant change in this non critical dimension. Recall that the Special Form test requirements for sealed sources have a rule for determining when additional testing is required due to sources being long and slender. The requirement is that if the length to diameter ratio (L/D) is greater than 10, them a bending test is required. The L/D of the model 24110 is 4.0. The L/D of the model 24120 is 3.9, a 1% difference and less than the value of 10 which would require additional testing.

WALL THICKNESS (W_t)
The cladding wall thickness of a neutron source is a key dimension for evaluation of the strength and durability of a sealed source. The greater the wall thickness of the source the greater the source physical integrity. The model 24110 has an inner cladding thickness of 0.067 in., which is 0.007 in. greater than the largest source in this comparison, and 0.019 in. greater than the model 24120. This represents a substantial increase in integrity of the inner cladding of the model 24110.

The outer cladding thickness of the model 24110 is equal to that of the model 24112 (0.065 in.), which is greater than all other outer cladding wall thickness in this group of neutron sources, and thus represents the maximum integrity within this group of sources.

HEAD THICKNESS (H_t)
The model 24110 inner cladding head thickness is identical to that of the model 2720 series sources (0.100 in.) and is 0.020 in. less than that of the models 24112 and 24120. While 0.020 in. is a significant change in this parameter, the 0.100 in inner cladding head thickness is equivalent to that of the model 2720 series which has sources much larger in size and weight than the model 24110.

The model 24110 outer cladding head thickness exceeds that of the other sources in this comparison. This head thickness exceeds that of the models 24112 and 24120 by 0.015 in., which exceeds that of the 2720 series sources by a factor of 3.75. This represents a substantial increase in head integrity.

BOTTOM THICKNESS (B_t)
The model 24110 inner cladding bottom thickness (B_t) substantially exceeds that of any other source in this comparison. The model 24110 source has a bottom head thickness of at least a factor of 1.8 greater than the other sources in this comparison.

The Outer cladding bottom thickness also exceeds all other sources in this comparison. The model 24110 outer clad bottom thickness of 0.375 in. exceeds that of the models 24112 and 24120 by 0.015 in., a slight increase. It exceeds the outer clad bottom thickness of the model 2720 series sources by a factor of 3.75.

40 YEAR OLD SOURCE

Another critical factor in the physical integrity of this almost 40 year old sealed source is self pressurization from the accumulation of ^{4}He atoms from alpha decay within the source. The self pressurization was examined by Dr. Janzow in his original evaluation for a nominal 5 Ci source. Dr. Janzow found that the model 24110 source had a recommended working life of 20 years with a safety factor of 4[2] during the hypothetical fire event (800 degrees C). The recommended working life is influenced by potential transportation events and the working environment of a well logging source, namely a 25,000 psi external pressure, prolonged use at 400 degrees C, and a potentially abusive physical environment. The source being evaluated is in storage at TA-54 packaged in an acceptable WIPP S-100 POC geometry. A decrease of the safety factor to a factor of 2 would increase the recommended working life to 40 years. This would indicate that all MRC model 24110 source being self-certified as special form for OSR Project purposes be repackaged in OSR Special Form capsules after July of 2014.

SUMMARY

The MRC model 24110 sealed source is dimensionally very similar to the models 24112 and 24120 MRC sources. It exceeds their dimensions in the critical area of inner and outer cladding wall thicknesses, inner clad bottom thickness, and outer clad head thickness. The model 24110 is dimensionally equivalent all other significant parameters examined to this set of sealed sources. It is very important in that all other sources in this group were granted a US DOT COCA, and hence the MRC model 24110 meets the requirements for US DOT special form radioactive material, as manufactured in 1974, by the method of similarity.

The age of the MRC model 24110 was also considered with respect to special form character. Using the original very conservative pressurization calculations of Dr. Janzow it was possible to determine that a MRC model 24110, 5 Ci AmBe, with packing factor of 50% is still within a 40 year envelope of time permitting characterization as special form radioactive material.

CONCLUSION

The MRC model 24110 neutron source as documented in MRC Engineered Products Division Order No. 1024-5 can be self-certified as US DOT special form radioactive material by OSR Project, within the limits and scope of this memo until July of 2014. After July of 2014 all MRC model 24110 shipped by OSR Project need to be re-encapsulated in OSR Special Form encapsulations.

Encl.:

A. MRC, Engineered Products Manufacturing Order Form No. 1024-5, 2-19-74
B. Table 1., Dimensional Comparison of MRC Neutron Sources

[2] ASME Boiler and Pressure Vessel Construction Code, 1969 standard

NPD-29, Rev. 1
6-15-73

TO: ANDY T.

ENGINEERED PRODUCTS DEPARTMENT

Contract No. 050-4E0 Manufacturing Order No. 1024-5

Quantity 5 Serial Number(s) AmBe-1827 thru 1831

Customer:

Baroid Division - McCullough Servies
NL Industries, Inc.
P. O. Box 1675
Houston, Texas 77001

Shipping Address:

Baroid Division N L Industries, Inc
McCullough Services Dept.
405 McCarty Drive
Houston, Texas 770

Purchase Order No. H4894

Date Received 2/19/74

Delivery Required 5/11/74

Spec. Form Cert. Req'd. ☐ Yes ☐ No

License No. ☐ Yes ☐ No

Ship: ☐ Prepaid ☒ Collect ☐ Prepaid & Charge

FOB: ☒ Dayton ☐ Destination

Ship Via Motor Freight

Additional Documents Required Cert Issued 2/27/74

Manufacturing Instructions:

5 - AmBe neutron sources - Output 1.0×10^7 n/s ± 10
3" length x 3/4" DD tapped for 10/32 thread 1/4" depth as per drawing A24110-

Sources to be engraved "Radioactive Do Not Handle, Notify Civil Authorities"
Their serial number A-151 thru A-155

HARDWARE - On hand

Engineering Notice/Release: Meets: ☒ Special Form ☐ Normal Form

Construct the sources per MRC DWG. A-24110-AA00/Rev.1 and A-2411-PA01/Rev.2. Mark the Sources per MRC license. The Sources to be engraved: "Radiactive Do not Handle, Notify Civil Autorities".

By: N-R Date 4-2-74

Authorized Time and Material:

Nuclear Mfg. Labor: 24 Isotope (Ci or ~~gms~~): 25

Nuclear Engrg. Labor: — Outside Jobs: —

Shop Labor: — Material: —

Released to: ☐ Engineering ☐ Manufacturing.

Issued by: DR Adams Date 2/28/74

ENGINEERED PRODUCTS MANUFACTURING ORDER FROM

McCullough Service; Houston, Texas

Cnt. No. 050-4E
No. No. 1024-5

4-2-74 MK

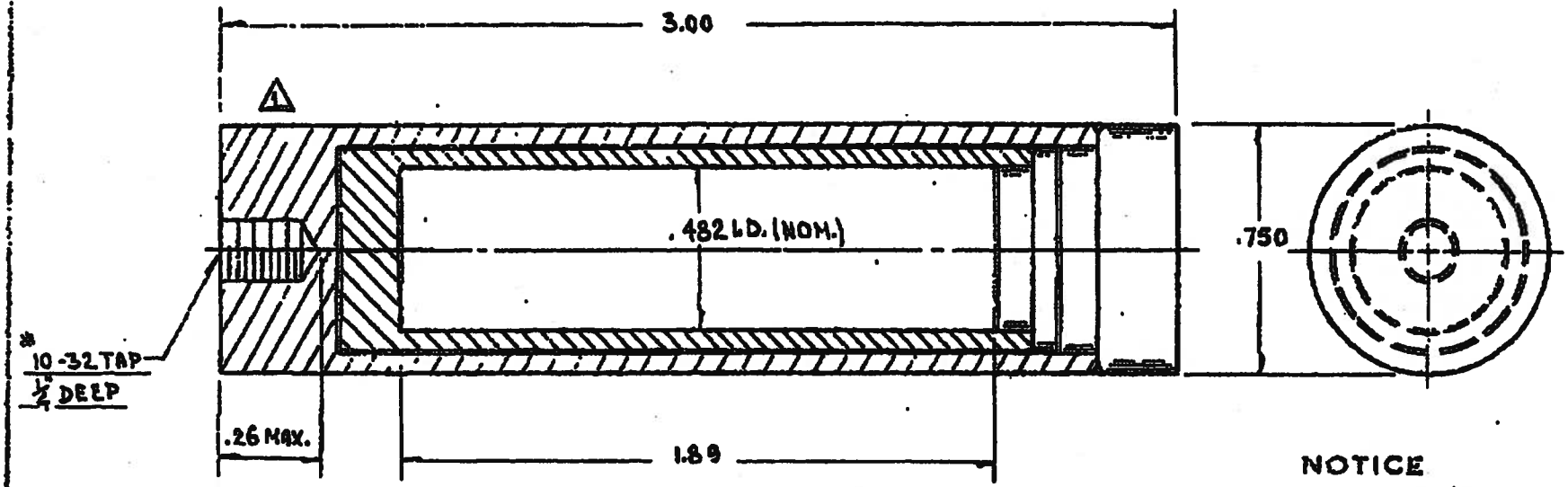
This Contract calls for 5 Am Be - neutron source with nominal output $1.0 \times 10^7 \frac{n}{sec} \pm 10\%$; fabricated to MRC Dwg. A24110-AA00. The Source OD = .750" ; OL = 3" With a 10-3½ tap ¼ deep at one end.

The Source was cheked and found to meet "Special Form" test for Cnt. No. 045-2A0 from 4-20-72. The Check was done on life expectation for Source to be fabricated per MRC Dwg. A24110-AA0(containig 5 ci. Am Be & Be to fill 50% compaction.

The Internal pressure due to gas build up @ fire test condition for 20 years was 165.1 psi. and the Stress - limited allowable internal pressure (here we had observed as most critical - Head stress) at that temperature was 344 psi for inner Container and 233 psi for Outer container; based on full yield strength at temp (1475°F). Downgrading Outer Containers internal pressure as smaller by 20% as it is our new standard practice, the limited allowable internal pressure @ 1475°F is 186 psi for 5 ci. Am Be.

By the comparision to the above, our Source-design meets Costomers Request in Contract No. 050-4E0 (2-28-74).

REVISIONS				
ZONE	SYM	DESCRIPTION	DATE	APPROVAL
	1	CHANGED TO SOLID BOTTOM	9-20-72	EJQ



NOTICE

This drawing is the property of Monsanto Research Corporation and must be returned, without reproduction or duplication, at any time upon request, but in any event at completion of the work or job. While in the possession of the recipient, it must be properly safeguarded against revelation or disclosure to anyone except those employees who require it for the work or job. The recipient must keep confidential, and require his (its) employees to keep confidential, the information contained hereon.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
DECIMALS
.XX = ±.02
.XXX = ±.005
.XXXX BASIC
FRACTIONS ±
ANGLES ± 30'
ALL SURFACES 32

MATERIAL 304 ST. STEEL

FINISH

APPD			
APPD			
APPD	[illegible]	9-20-72	
APPD	EJQ	9-25-72	
CHECKED	EJQ	9-25-72	
DRAWN	[illegible]	9-24-72	
SIGNATURE		DATE	

MONSANTO RESEARCH CORPORATION
DAYTON LABORATORY
DAYTON, OHIO

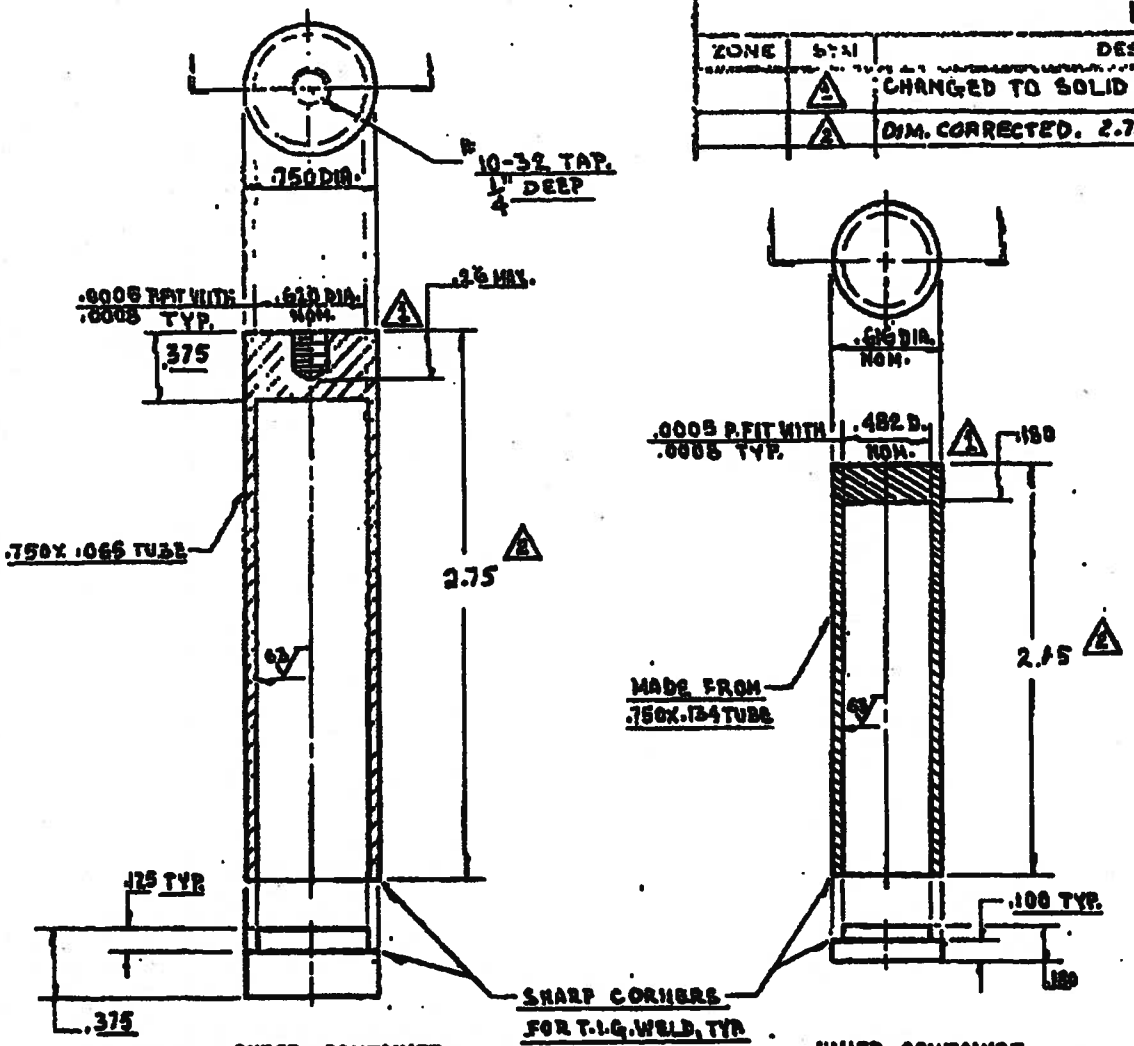
Am Be NEUTRON SOURCE 1.0×10^7 N/sec

DWG NO. A-24110-AA00 REV 1

SCALE DOUBLE WT CALC ACT. CODE IDENT NO.

SHEET 1 OF 2

REVISIONS				
ZONE	STAT	DESCRIPTION	DATE	APPROVAL
	1	CHANGED TO SOLID BOTTOM	9-20-72	[illegible]
	2	DIM. CORRECTED. 2.75 WAS 2.50, 2.15 WAS 2.05	10-13-72	EPG



NOTES:

1. DIA. CLEARANCE BETWEEN INNER AND OUTER CONTAINER IS .004 NOMINAL, .002, MINIMUM.
2. BREAK ALL CORNERS .030 UNLESS OTHERWISE SPECIFIED.

NOTICE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES:
DECIMALS: .XX = ±.02, .XXX = ±.005, .XXXX BASIC
FRACTIONS: ±
ANGLES: ± 30'
ALL SURFACES 32

MATERIAL 304 ST. STEEL

FINISH

APPD			
APPD			
APPD	R.H.M.	9-30-72	
APPD	EPG	9-26-72	
CHECKED	EPG	9-26-72	
DRAWN	N.R.	4-25-72	
SIGNATURE		DATE	

MONSANTO RESEARCH CORPORATION
DAYTON LABORATORY
DAYTON, OHIO

OUTER AND INNER CONTAINER
Am Be NEUTRON SOURCE 1.0×10^7 N/SEC.

USED ON A24110-AA00

DWG NO. A 24110 - PA01 REV 2

SCALE FULL | WT CALC ACT. | CODE IDENT NO.

SHEET 2 OF 2

7/9 [illegible]

Based on the attached analysis, the 2.110 MeV emitter source has been shown by comparison to HRC source to have an incl classification of 66525 based upon the 1969 publication "Classification of Sealed Radioactive Sources", USAEC standard N.E.10-1969, published by American Institute of Chemical Engineers.

It assumes 5Ci mat Am, 30% by volume loading of Am.

~~APPENDIX C~~

ANSI CLASSIFICATION, MODEL~~S~~ ~~24112 AND 24120~~ 24112 24110 NEUTRON SOURCE~~S~~

1. ANSI Classification

The sealed classification recommended by the American National Standards Institute for oil-well logging sources is ANSI 46515*. It was shown in Appendix A that three sources of the MRC 2720 Neutron Source series have been found by test to meet ANSI Classification 64525. The Model~~s~~ ~~24112 and 24120~~ 24110 neutron source~~s~~ ~~are~~ is shown herein to meet the above classification by comparison to the models tested. External pressure tests on typical production sources of Model 24120 are employed to show that the ~~Models 24112 and 24120~~ 24110 neutron source~~s~~ meet ANSI Pressure Classification 6. The resulting ANSI classification of 66525 for the Models ~~24112 and 24120~~ 24110 exceeds the minimum recommended classification for oil-well logging sources.

2. ANSI Qualification

a. Temperature Class 6

Elevated temperature test at 1010°C for one hour in air, reduced temperature test at -57°C for one hour, and thermal shock 1010°C to 15°C.

It was shown in Appendix A that dummy Models 2722-A, 2724-A, and 2728-A sources were sucessfully tested to Temperature Class 6, and in Appendix B that the Models 24112 and 24120 and 24110 sources are intermediate in size between the three test models, and stronger than the test models. [Note: 24110 has shield with other than lead & shield bottom. Thus, more stronger in that region than listed source.

* Classification of Sealed Radioactive Sources, USASI standard N5.10-1968, published by the American Institute of Chemical Engineeres, New York, c. 1968.

Since the Models 2722-A, 2724-A, and 2728-A each passed the test for ANSI Temperature Class 6, the Model ~~s 24112 and 24~~ 24110 will also pass the Temperature Class 6 test.

b. External Pressure Class 6

3.4 to 25,000 psi absolute external pressure.

Appendix A shows that dummy Models 2722-A, 2724-A, and 2728-A sources were successfully tested to ANSI Pressure Class 4, and Appendix B shows that the Models 24112 and 24120, & 24110 are intermediate in size between the three models tested, and stronger than the test models. The test for ANSI Pressure Class 4 includes a reduced pressure test at 3.4 psia. Since the Models 2722-A, 2724-A, and 2728-A passed the reduced pressure test, the Models 24112 and 24120, & 24110 will also pass the 3.4 psia test.

Four typical production sources of the Model 24120 neutron source were tested to an external hydrostatic pressure of 25,000 psi on 7-17-75. Source serial numbers were Pu8Be-384, 385, 386, and 387. One of these sources, Pu8Be-387, was also tested to an external hydrostatic pressure of 30,000 psi on the same date. All tests were in water, and leak testing was performed by ANSI method B2.5. No visible damage was evident on any of the test sources, and all sources remained sealed after the tests. Test reports are on file at Monsanto Research Corporation, Dayton, Ohio. [illegible]

~~It is evident from the above that the Model 24120 neutron source meets ANSI Pressure Class 6. The Model 24112 neutron source is identical in dimensions and materials to the 24120, except that the Model 24112 is shorter than the Model 24120 and the Model 24112 lacks the 0.010 mid deep weld reliefs present in the welded ends of the Model 24120 capsules. The Model 24112 source is therefore somewhat stronger than the Model 24120, and will also meet ANSI Pressure Class 6.~~

The 24110 is slightly longer than the 24120, has a smaller [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] than the [illegible] [illegible] [illegible] and [illegible] [illegible] [illegible] on the inner capsule. The [illegible] [illegible] 24110 [illegible] [illegible] wall, slightly longer length (4.3 in) [illegible] [illegible] [illegible] [illegible] [illegible]), than the [illegible] 24120 [illegible] [illegible] [illegible] [illegible] [illegible]

c. Impact Class 5

Drop 20 pound weight onto source from 10 feet.

It was shown in Appendix A that the Models 2722-A, 2724-A, and 2728-A were each qualified to ANSI Impact Class 5 by testing, and in Appendix B that the Models 24112 and 24120 are intermediate in size between the sources tested and stronger than the sources tested.

The Models ~~24112 and 24120~~ neutron sources therefore will pass the ANSI Impact Class 5 test.

d. Vibration Class 2

Vibration for 30 minutes, 25-500 cycles/sec. at 56 peak amplitude. It was shown in Appendix A that the Models 2722-A, 2724-A, and 2728-A were each sucesssfully tested to ANSI Vibration Class 2, and in Appendix B that the Models 24112 and 24120 are intermediate in size between the sources tested and stronger than the sources tested.

The Model ~~24112 and 24120~~ neutron sources therefore will pass the ANSI Vibration Class 2 tests.

e. Puncture Class 5

Drop source 15 feet onto a 1/8-inch diameter pin.

It was shown in Appendix A that the Model 2722-A, 2724-A, and 2728-A were each sucessfully tested to ANSI Puncture Class 5, and in Appendix B that the Models 24112 and 24120 are intermediate in size between the sources tested, and stronger than the sources tested.

The Models ~~24112 and 24120~~ neutron sources therefore will pass the ANSI Puncture Class 5 tests.

APPENDIX B
SPECIAL FORM ANALYSIS, MODELS 24112 AND 24120 NEUTRON SOURCES

1. Special Form Criteria

It was shown in Appendix A that three sources of the MRC 2720 Neutron source series have been found by test to meet ANSI Classification 64525. The Models 24112 and 24120 are intermediate in dimensions between two of the models tested, the Models 2722-A and 2728-A (See Table 1). The discussion which follows employs the data from the ANSI tests to show that the Models 24112 and 24120 meet "special form" criteria.

a. Free Drop

A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal surface, striking the surface in such a position as to suffer maximum damage.

The weight of a neutron source is the summation of the weights of the outer capsule, inner capsule and the isotope - target mixture.

The weights of the outer and inner capsules can be calculated with the following general formula:

$$W = [\tfrac{\pi}{4}(d_o^2 - d_i^2)\ell + \tfrac{\pi}{4}(d_i^2)(t + b)]\rho$$

Where d_o and d_i are the outside and inside diameters, respectively, ℓ is the length, t is the thickness of the end plug, b is the thickness of the bottom and ρ is the density of the stainless steel. For the Models 24112 and 24120 the formula must be modified to include the weight of the threaded portion and of the handling device.

As a worst case (maximum weight), the threaded portion may be taken to be solid cylinder at its maximum diameter. Referring ~~drawings A24112-AA00 and A27120-AA-01~~, the weights of the Models ~~24112 and 24120~~ inner and outer capsules are, respectively:

MODEL ~~24112~~

$$W_{(IC)} = \frac{\pi}{4}\{[(0.616")^2-(0.500")^2](0.800")+(0.500")^2(0.186"+0.095")\}(0.29\ lb/in^3)$$

$$= 0.0396\ lb$$

$$W_{(OC)} = \frac{\pi}{4}\{[(0.750")^2-(0.620")^2](1.400")+(0.620")^2(0.485"+0.115")\}(0.29\ lb/in^3)$$

$$+\frac{\pi}{4}\{[(0.498")^2(0.531")(0.29\ lb/in^3)$$

$$= 0.1003\ lb + 0.0300\ lb = 0.1303\ lb$$

The maximum weight of the active compound in the Model ~~24112~~ is, using the maximum loading of 5.0 curies,

$$W_{(Pu\,O_2)} = \frac{(5.0\ Ci)(238+32)}{(17.10\ Ci/g)(238)(0.80g\ Pu\text{-}238/gPu)}$$

$$= 0.413g = \frac{0.413g}{454.5g/lb} = 0.0009\ lb$$

The maximum volume of PuO_2 at its theoretical density of ~~11.46~~ g/cm³ is just $V_{(PuO_2)}$ = (~~0.413~~ g) ÷ (~~11.46~~ g/cm³) = ~~0.036~~ cm³. Since the maximum inner capsule volume $V_{(i)}$ is $(\pi/4)(0.505")^2$ x (~~0.665"-0.090"-0.061"~~) = 0.102 in³ or (~~6.167~~ in³)(16.39 cm³/in³) = ~~1.75~~ cm³, and the maximum fuel/target packing fraction is 50%, the maximum volume of beryllium at its theoretical density of 1.848 g/cm³ is:

$$V_{(Be)} = (0.50)(\text{~~1.754~~ cm}^3 - \text{~~0.036~~ cm}^3)$$

$$= \text{~~0.859~~ cm}^3$$

Whence, the maximum weight of beryllium is:

$$W(Be) = \frac{(3.052\ cm^3)(1.848\ g/cm^3)}{454\ g/lb} = .0124\ lbs$$

Total core mass = .0901 + .1974 + .0039 + .0124 lbs =

= .2937 lbs

TABLE 1., Comparison of MRC model 24110 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
24110	304 SS	133	0.616	2.250	0.067	0.100	0.180	0.750	3.000	0.065	0.375	0.115	self-certified
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.)