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DRYBOX GLOVES:
EVALUATION AND PROCUREMENT

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THE DOW CHEMICAL COMPANY
ROCKY FLATS DIVISION
P. O. BOX 888
GOLDEN, COLORADO 80401

U.S. ATOMIC ENERGY COMMISSION
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A C K N O W L E D G M E N T S

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DRYBOX GLOVES: EVALUATION AND PROCUREMENT

Ray E. Giebel and Robert L. Riegel

Abstract. A comprehensive testing program for drybox gloves is described. Criteria are outlined for selecting the proper glove for a given application. Desirable qualities of gloves such as protection of the worker or glovebox contents, longevity, comfort, dexterity, reasonable cost, and adaptability to the operation, are discussed. Appendices include a data sheet for glove tests, specifications for seven types of gloves, and inspection acceptance procedures.

SUMMARY

The contractors of the U. S. Atomic Energy Commission (USAEC) should have methods to evaluate gloves which may be used in contractor operations. Desirable glove qualities include protection of the operator or the glovebox contents, longevity, reasonable cost, comfort, dexterity, and adaptability to the operation. After gloves are evaluated, desirable properties must be specified so the consumer can procure a consistently satisfactory product, the supplier can deliver products meeting the specifications, and competitive suppliers can bid on the requirements.

This report describes:

1. Methods for evaluating and selecting drybox gloves.
2. Testing procedures developed for determining properties of gloves in current use or new glove types submitted by commercial sources. These tests determine mechanical properties, dimensions, chemical resistance, permeability, flammability, and lead equivalence.

Glove types tested include:

- 15-mil neoprene
- 30-mil neoprene
- 30-mil butyl
- 30-mil Hypalon-coated neoprene
- 30-mil leaded neoprene
- 30-mil leaded Hypalon-coated neoprene
- 80-mil multilayered leaded Hypalon-coated neoprene

3. Purchasing specifications developed from the results of testing and evaluation.
4. Plant acceptance and quality assurance procedures used to ensure compliance with the purchasing specifications.
5. Applications, limitations, and problems associated with various types of drybox gloves used in the plutonium plant.

INTRODUCTION

Some personnel at Rocky Flats (The Dow Chemical Company) perform a variety of operations within gloveboxes. These operations include chemical, metallurgical, and mechanical functions. Rubber drybox gloves* are used primarily in a plutonium plant to provide a flexible working barrier between the operator and the radioactive material inside the glovebox. Various types of gloves are required with procurement costs ranging from \$9.00 to \$72.00 per pair. When considering overall costs, an approximate additional \$8.00 per pair (\$4.00 per glove) must be included for installing new gloves and disposing of worn out gloves. Plutonium removal is considered a part of the disposal costs.

The qualities desired in a drybox glove are: (1) protection of the operator from toxic glovebox atmospheres and/or excessive radiation, (2) longevity and reasonable cost, (3) comfort and dexterity, and (4) adaptability to the operation. Gloves usually fail from chemical attack (by acids, solvents, and oils), cuts, abrasions, punctures, or degradation by ozone. Most gloves used at Rocky Flats contain lead oxide to provide gamma radiation shielding.

Initial standards for glove procurement were developed by Argonne National Laboratory.¹ A specification, revised numerous times, became an accepted guide

*Arm length gloves used on gloveboxes are generally referred to as "drybox gloves" by glove manufacturers and users. Gloveboxes in use at the Rocky Flats facility are not dryboxes.

within the Atomic Energy Commission for the purchase of drybox gloves.² However, this specification was inadequate for the various types of gloves and service requirements needed at Rocky Flats.

There were also needs for improved methods to aid in the selection, procurement, and quality acceptance testing of the various types of required gloves. A procedure was needed to test and evaluate new and different glove types submitted by commercial sources to Rocky Flats for evaluation.[†] These needs were met by:

1. Reviewing testing procedures of the American Society for Testing Materials (ASTM).
2. Contacting rubber companies and glove manufacturers.
3. Initiating an experimental program to develop adequate testing procedures to fulfill Rocky Flats service requirements.
4. Establishing a procedure to evaluate gloves.
5. Writing procurement specifications for seven types of gloves.
6. Establishing a quality acceptance program.

EXPERIMENTAL

Testing and Evaluation:

Procedures have been developed for testing and evaluating drybox gloves. These include determination of permeability (water vapor transmission), fire resistance, lead equivalency, mechanical properties, physical (dimensional) properties, and chemical properties. Workmanship criteria, packing, marking, and economics were also evaluated. A data sheet is used to report the test results and recommendations for the glove being evaluated (Appendix A). If test results are favorable, additional gloves are procured for in-plant evaluation.

[†]Gloves formulated from neoprene, neoprene containing lead oxide, polyvinyl chloride (PVC), PVC containing lead powder, butyl, Buna N, natural latex, Nordel[®], Hypalon[®], and Viton[®] have been submitted for evaluation. These gloves varied in dimensions and hand designs.

[®] Trade names of E. I. DuPont de Nemours and Company, Inc., Wilmington, Delaware.

Permeability:

Low vapor and gas permeability is desirable because the glove is either protecting the contents of the glovebox from the outside atmosphere (usually water vapor or oxygen), or protecting the operator from the contents in the glovebox (in our case, plutonium, nitric acid, and/or carbon tetrachloride). Permeability is determined by measurement of water vapor transmission as outlined in ASTM E96, "Method of Test for Water Vapor Transmission of Materials in Sheet Form," Procedure "A." This test consists of sealing a glove sample (the membrane) over an aluminum cup. Molecular Sieve (Linde-4A) contained in the cup maintains a zero percent relative humidity on the inside of the membrane. The sealed cup is then placed in an atmosphere of 50% relative humidity maintained by a sodium dichromate saturated salt solution. The humidity is checked with a Hygro-dynamics (product of American Instrument Company, Inc., 8050 Georgia Avenue, Silver Springs, Maryland) humidity sensing element. The weight gain of the cup (containing the desiccant) for the last 10 days of a 30-day period becomes a measure of the water vapor permeability of the glove material.

Flammability:

A flame from a Bunsen burner is applied to the bottom of a hanging strip of glove material. After the material is ignited and a good flame is established, the burner is removed. The burning properties of the sample are compared to the burning properties of 30-mil neoprene.

Lead Equivalence:

Drybox gloves impregnated with red lead oxide (Pb_3O_4) are used to protect personnel from soft gamma radiation (~60 keV). "Lead equivalence" is the expression used to measure the shielding power of a lead-loaded material. It is used in this report as the shielding capability or attenuating property of glove material to soft gamma radiation; equivalent to the same shielding capability of pure metallic lead foil.

Lead equivalence and uniformity of lead dispersion (usually as red lead oxide) are determined by a nondestructive x-ray technique. Kodak Type-M Ready Pack film is placed inside the glove. A number made of lead is positioned above the glove for identification. Another film of the same type and emulsion number is placed directly beside the glove along with a calibrated lead step-wedge. This procedure is followed to ensure identical exposure parameters for both the

glove being tested and for the step-wedge standard. The glove and the step-wedge are exposed to an approximate tube-voltage energy of 50 kilovolts, 4 milliamperes, for 3½ minutes (30-mil samples), or 125 kilovolts, 4 milliamperes for 5 minutes (80-mil samples).

After exposure, the films are developed and examined on a densitometer. The density readings from the step-wedge are used to construct a curve of density units versus lead thickness in millimeters. Density units from selected random areas of the sample are then read with the densitometer. Approximate lead equivalency values are determined from the curve. Prior to the x-ray film technique, gamma-radiation attenuation properties were determined at Rocky Flats by using an americium-241 source (60 keV) and standard gamma-survey detector, or a pulse height analyzer and scaler. A copper shield was used to absorb radiation below 30 keV, thereby providing monoenergetic radiation. Sixty keV gamma from americium contained in the plutonium is the major source of gamma radiation at Rocky Flats. The source-detector method was abandoned because glove manufacturers and glove testing laboratories did not have radioactive sources available, but did have x-ray capabilities. Often, results from the two methods did not agree. Exact conditions of source location, distance, and meter calibration were difficult to duplicate and control; therefore results from the source detector were more variable than x-ray results. The x-ray method is superior because it provides a better coverage of the total glove area, uses an absolute comparison with lead, is direct, and is reproducible.

Mechanical Properties:

Rocky Flats has established the capability to test drybox gloves for tensile strength, tensile stress, and puncture resistance. Tear strength and abrasion resistance are also important, but Rocky Flats has not established a capability to determine these properties. Tensile testing is performed according to ASTM D412, "Method of Tension Testing of Vulcanized Rubber," except that five measurements are taken instead of three, and most gloves tested are less than the ASTM thickness recommendation of not less than 1.5 mm nor more than 3 mm. Tensile strength is determined using 0.250-inch-wide dumbbell-shaped specimens cut with a standard "C" die. It is

extremely important to have the tensile cutter free of minute nicks and scratches on the cutting edge, and to have a proper cutting base so that a nick-free

dumbbell specimen can be cleanly cut from a glove sample in one blow. Otherwise, a tear break rather than a true tension break occurs.†

For multilayer glove types composed of more than one homogeneous material (i.e., lead oxide loaded neoprene, neoprene plus Hypalon coating, etc.) the *force to break* the 0.250-inch-wide specimen, in pounds, is a more practical value than *tensile strength*, in pounds per square inch (psi). The true tensile strength of the multicomponent material cannot readily be determined because the weaker material affects the breaking property of the stronger, and vice versa. Also, for thicker gloves, the utility strength of the glove is better reflected in pounds-force necessary to break rather than tensile strength, which discounts the additional thickness.

Modulus of elasticity or tensile stress is generally determined at 100% elongation. During use, gloves will not ordinarily be stretched more than 100%. Occasional puncture tests are performed by mounting a needle with a one-quarter-inch-radius tip on a tensile testing machine and drawing the needle through a mounted rubber specimen. Travel of the needle from first point of contact, and pounds to penetrate, are recorded. No puncture tests have been performed on the 80-mil-thick gloves. These gloves are quite puncture resistant because they are very thick.

Accelerated Aging:

Two aging tests are conducted involving tensile properties: (1) tensile strength and ultimate elongation are determined after exposure to air for seven days at 158°F (70°C) (see ASTM 573); and (2) tensile strength is determined after immersion in 3M nitric acid for 24 hours.

Dimensions:

Linear measurements are taken, and include (see Figure 1):

Diameter at the cuff

Circumference at the wrist

Diameter of the bead

†Rocky Flats capability for testing rubber (tensile strength and modulus of elasticity) results from the cooperation of, and a sample exchange program with, The Charleston Rubber Company, Stark Industrial Park, Charleston, South Carolina.

Figure 1. Arm Length Glove.

Rate of taper (in/in) from the shoulder area to the wrist area overall length

Length of the third finger, and length of the straight section of glove from the cuff to the beginning of the taper

Hand size is expressed as the circumference (in inches) at the palm. Thickness is measured (using a 0 to 1-inch outside micrometer) at the palm, finger, wrist, arm, and shoulder.

Chemical Resistance:

Chemical resistance of glove materials is determined by controlled contact of coupons with selected chemicals. (The Data Sheet for Glove Tests, Appendix A, lists the chemicals used.) If the glove being tested is constructed of homogeneous material, the entire coupon may be immersed in the chemical.

If the glove possesses a special outer layer to provide added chemical and physical resistance, only the outside surface of the glove test specimen is exposed to the chemical. Discoloration of the chemical, and softening, swelling, tackiness, weakening, and liquid permeation of the elastomer are observed. Also, weight changes are recorded after immersion of sample disks for 24 hours and drying for 10 minutes, and again after drying for 48 hours. The weight difference observed between the 10-minute and 48-hour weighings is a measure of the amount of volatile liquid absorbed in the material. The 48-hour weight compared to the original weight shows the weight change resulting from the solvent contact. In some cases, there is evidence that the solvent has leached a component from the elastomer. A coupon removed from an organic solvent is blotted dry on the surface and is allowed to air dry (22 to 25% relative humidity). A coupon removed from an aqueous solution is rinsed with water to remove the acid, base, or salt from the surface, then blotted dry, and air dried.

RESULTS AND DISCUSSION

Permeability:

Water vapor transmission is expressed in gram per day per square meter (g/day m^2). For neoprene, 1.5 g/day m^2 is an accepted standard value for 30-mil-thick material. Butyl rubber is about one-tenth as permeable to water vapor as neoprene. Table 1 shows selected results of water vapor transmission determinations for various drybox gloves tested. These gloves were sufficiently impermeable for Rocky Flats requirements.

Table 1. Typical Water Vapor Transmission of Various Gloves.

Glove Description	Water Vapor Transmission (Permeability) (g/day m^2)
30-mil neoprene	1.2
30-mil neoprene (different manufacturer)	0.6
30-mil butyl	0.15
30-mil leaded neoprene	1.5
30-mil Hypalon neoprene	1.3
30-mil lead Hypalon neoprene	1.5
80-mil lead Hypalon neoprene	1.5

Flammability:

The flammability results of other materials, compared to the burning properties of neoprene, are as follows:

NEOPRENE – Neoprene material is difficult to ignite. The flame needs to be applied for several seconds to accomplish ignition. After the neoprene ignites and a good flame is established, the burner is removed. The neoprene material continues to burn slowly. No observable differences were found among neoprene materials from different manufacturers.

LEADED NEOPRENE – If the lead oxide impregnated layer is not exposed, the ignition properties are essentially the same as those of the unleaded neoprene. The leaded neoprene material is slightly easier to ignite when the inner, lead oxide-impregnated layer has been exposed to the flame.

POLYVINYL CHLORIDE – Generally, polyvinyl chloride (PVC) materials are self-extinguishing. They will ignite, but will not continue to burn after the ignition source is withdrawn. However, for reasons unknown, the PVC glove materials tested are easy to ignite and continue to burn after the flame is removed.

HYPALON-NEOPRENE – The Hypalon-coated neoprene is more difficult to ignite than plain neoprene. The Bunsen burner flame must be held to the material for a longer period of time. After the test strip is ignited, it will continue to burn slowly.

Lead Equivalence:

Densitometric examination of exposed x-ray film reveals that the lead content varies from point-to-point in a given glove. Not only is there a point-to-point variation in lead content, but a uniform gradient is also in evidence. More lead is seen in the hand area and the lead content progressively decreases from the forearm to the middle arm to the upper arm. Small areas of high lead content are seen in unique places such as finger crotches and finger ends. This distribution of material is characteristic of a solvent dipped product. Gravity causes flow of the dipping material before the solvent evaporates. The variance in lead content causes no special concern or problem in glove utilization. It is taken into consideration in the purchase specifications.

The specification for a nominal 30-mil leaded glove (nominal 0.1 mm lead equivalency) calls for uniformity such that lead equivalence will be not less than 0.08 mm or more than 0.14 mm over a 4-square-inch area. A typical glove would exhibit the following lead equivalency: Hand and forearm – 0.1 to 0.13 mm;

middle arm – 0.095 to 0.12 mm; and upper arm – 0.085 to 0.090 mm. Very small areas of high lead content might measure 0.16 mm. A minimum spot measurement might be 0.08 mm, and a maximum spot measurement might be 0.16 mm on a given glove.

Typical lead equivalency results from the source-detector method and the x-ray method are summarized in Table 2. At the time of these measurements, the lead equivalence of a nominal 0.36-mm lead glove was significantly above the specification requirements of 0.32 to 0.40-mm lead. The manufacturer has reduced the lead content to meet specification.

Table 2. Summary of Typical Lead Equivalence Results.

	Source-Detector Method		X-Ray Method	
	Nominal 30-mil Lead Glove (mm)	Nominal 80-mil Lead Glove (mm)	Nominal 30-mil Lead Glove (mm)	Nominal 80-mil Lead Glove (mm)
Regions of low lead equivalency	0.08	0.38	0.08	0.43
Regions of average lead equivalency	0.11	0.42	0.11	0.47
Regions of high lead equivalency	0.13	0.47	0.14	0.53

Mechanical Properties:

Typical values from mechanical tests are presented in Table 3. Tensile strength test results for 30-mil neoprene gloves range from 2500 to 3300 psi with values occasionally falling outside these limits. Most of the results are grouped around 2800 to 3100 psi.

A series of five dumbbells is pulled for each determination and the median value selected. The median value is considered a better selection than the mean value because the mean is affected by frequent low values and infrequent high values. The dissident low values are usually from causes other than variations in true tensile strength. Invalid low values can be caused by improper cutting of the dumbbell specimen (a dull cutting die, a faulty die, an improper cutting surface, or an improper blow while cutting) or improper mounting and holding of the specimen in the jaws of the tensile machine. These errors will cause premature tearing of the tensile specimen. Failure of the material will not be caused by tensile failure, but will be the result of tear failure.

Table 3. Mechanical Test Results (typical).

Glove Description	Tensile (lb/in ²)	100% Modulus (lb/in ²)	Ultimate Elongation (%)	Permanent Set (% at % elongation)	Puncture	
					Travel (inches)	Force (pounds)
30-mil neoprene	2900-3040	315	725	13 at 487	0.9	10.5
30-mil neoprene (different manufacturer)	2900	670	675	29 at 450	0.6	10.4
30-mil neoprene (different manufacturer)	3190	520	715	27.5 at 450	not determined	
15-mil neoprene	2940-3370	400	725	14 at 512	not determined	
30-mil butyl	2500	140	720	20 at 575	1.2	9.0
30-mil lead neoprene	17.5 ^a	425	700	13 at 400	0.5	7.2
30-mil lead Hypalon neoprene	15 ^a	415	550	15 at 430	0.5	7.5
30-mil Hypalon neoprene	22 ^a	306	680	20 at 460	0.7	9.9
80-mil lead Hypalon neoprene	22 ^a	500	500	17 at 400	not determined	

^aForce to break, in pounds.**Accelerated Aging:**

After neoprene is aged in air for 7 days at 158°F, tensile strength and ultimate elongation range from about the same, to 10% lower, as compared to the values observed before accelerated aging. After immersion in 3M nitric acid for 24 hours, tensile strength is unchanged or slightly higher.

Aging tests have not been conducted at Rocky Flats with materials other than neoprene. The Charleston Rubber Company has conducted extensive accelerated aging tests with various elastomers in high concentrations of ozone.

Dimensions:

The gloves used at Rocky Flats have 8-inch-diameter cuffs. (The gloves are used on 8¼-inch-o.d. glove rings). A glove length of 32 inches is preferred for most applications. Typical dimensions of some of the gloves tested are listed in Tables 4 and 5.

Chemical Resistance:

The effects of chemicals on neoprene and Hypalon-coated neoprene materials are compared in Table 6. The Hypalon coating has much more resistance to nitric acid but has no apparent advantage when used with hydrochloric acid, hydrofluoric acid, potassium hydroxide, benzene, carbon tetrachloride, or trichloroethylene.

Purchase Specifications:

Suggested specifications are included in Appendix B for seven types of drybox gloves. The specifications have

Table 4. Typical Glove Dimensions.

Glove Type	Thickness (mils)				Diameter (inches)		
	Minimum		Maximum*		Cuff	Wrist	Bead
	Finger Crotch	Else- where	Hand	Other			
30-mil neoprene	30	27	36	32	8	3.1	7/32
15-mil neoprene	14	12	21	20	8	3.0	—
30-mil butyl	33	30	33	32	8	3.2	7/32
30-mil lead neoprene	30	27	43	44	8	3.2	7/32
30-mil lead Hypalon neoprene	31	30	36	35	8	3.2	3/16
30-mil Hypalon neoprene	31	30	36	35	8	3.2	3/16
30-mil neoprene (different manufacturer)	34	30	37	36	8	2.9	1/4
30-mil neoprene (different manufacturer)	35	30	45	47	8	3.2	7/32

*Within 1-sq. in. or greater.

Table 5. Typical Glove Dimensions.

Glove Type	Rate of Taper (inches)	Length (inches)			Hand Size (inches)
		Over All	Third Finger	Cuff to Taper	
30-mil neoprene	0.1	32 ± ½	3.0	4	9%
15-mil neoprene	0.1	32 ± ½	3.0	4	9%
30-mil butyl	—	32 ± ½	3.0	4	9%
30-mil lead neoprene	0.15	32 ± ½	3.1	4	9%
30-mil lead Hypalon neoprene	0.15	32 ± ½	3.1	4	—
30-mil Hypalon neoprene	—	29 ¾	3.0	3	9%
30-mil neoprene (different manufacturer)	—	31	3.2	—	9%
30-mil neoprene (different manufacturer)	—	31	3.2	—	9%

Table 6. Effects of Chemicals on Drybox Glove Materials.

Chemical	Exposure Time (hr)	Neoprene	Hypalon-Coated Neoprene (11 mils Hypalon)
14M HNO ₃	1	Loss of gloss, some bleaching	No change
	4	No observation	No change
	24	Rubber tacky, cracking solution discolored	Slight surface discoloration
	72	Rubber tacky, much cracking	Slight softening
	24 + 48 drying	Rubber crumbly	No change
3M HNO ₃	4	No change	No change
	24	Slightly sticky	No change
	72	Slightly sticky	Slight surface discoloration
	72 + 48 drying	No change	No change
12M HCl	72	Loss of gloss, some bleaching	Slight softening
48% HF	1	No change	Slight surface discoloration
	24	Loss of gloss	Surface discoloration
	72	Loss of gloss, some bleaching	Slight softening
10M KOH	72	Loss of gloss, some bleaching	No change
Benzene and CCl ₄	1	Swelling, weakening solution discoloration	Swelling, solution discoloration
	24	Completely penetrated	No additional change
	24 + 48 drying	Swelling gone, strength regained	Swelling gone, strength regained
Trichloroethylene	1	Swelling, weakening solution discoloration	Swelling, solution discoloration
	24	Completely penetrated	Tacky and weakened
	24 + 48 drying	Swelling gone, strength regained	Swelling gone, strength regained, no tackiness

been organized similar to ASTM D120. "Standard Specifications for Rubber Insulating Gloves." The seven specifications were developed to define minimum standards for quality gloves used at the Rocky Flats facility. All requirements included are related to logical and practical glove applications.

Acceptance and Quality Assurance Testing:

A suggested procedure has been developed for "acceptance inspection testing" of incoming glove shipments. A copy of this procedure has been included in Appendix C. In addition, "terms of rejection" have been included with each Purchase Specification.

The qualities desired in a drybox glove are: (1) protection of an operator from toxic glovebox atmospheres and excessive radiation, and/or protection of the glovebox contents from the outside environment, (2) longevity and low cost, (3) comfort and dexterity, and (4) adaptability to the operation. Testing and evaluation which has been described reflect these qualities, as do the subsequent purchasing specifications. Seven different types of drybox gloves are used at Rocky Flats. Typical applications for each type of glove are summarized in Table 7.

Table 7. Drybox Glove Applications.

15-mil neoprene	Use where optimum touch and flexibility are needed and lead protection is not needed, such as in the analytical laboratories.
30-mil neoprene	Use for general application where no lead protection is needed. Use with oils, solvents, non-oxidizing atmospheres, elevated temperature atmospheres, hydrochloric acid, and chlorides when failure is generally from wear, puncture, or tear rather than aging (ozone cracking).
30-mil leaded neoprene	Use where lead protection is needed in addition satisfying the other conditions discussed above.
30-mil leaded Hypalon neoprene	Use where lead protection is needed and the Hypalon coating offers advantages. Use with oxidizing acids, such as nitric acid, or in areas where failure is generally the result of aging and stress cracking (ozone attack).
30-mil Hypalon-neoprene	Use with HNO ₃ and HF and where failure results from aging or stress cracking (ozone attack) and no lead protection is needed.
30-mil butyl	Use where extremely low permeability to water and oxygen or solvents is necessary, and for certain chemical environments such as bromobenzenes and methylene bromide.
80-mil leaded Hypalon-neoprene multilayered	A heavy, flexible glove of 0.36 mm lead equivalency used in areas of high or penetrating radiation such as in americium processing.

Special Glove Types:

HYPALON-COATED GLOVES – Hypalon-coated gloves are higher priced than uncoated neoprene gloves. But, because they last longer in certain applications, they can demonstrate a significant savings. A hypothetical savings is illustrated in the Economics section of this report. Hypalon-coated gloves are superior if neoprene gloves fail either from aging (ozone degradation), or chemical attack by oxidizing acids and acid vapors. Hypalon-coated gloves generally show no advantage where chlorinated solvents and other organic fluids are used. Also, they show no superiority over neoprene gloves in puncture or cut resistance. Therefore, care should be taken that higher priced gloves are not used in applications where they demonstrate no advantage.

BUTYL GLOVES – Butyl gloves are recommended for maximum impermeability to water vapor, oxygen, and most gases. They are also superior for use with some organic solvents. They have been used with bromobenzene and methylene bromide at Rocky Flats.

Economics:

The determination of a glove's value results from in-plant evaluation. If a glove provides comfort, workability, and protection from the glovebox contents, then economics becomes the deciding factor as to whether or not a glove is utilized. As a glove is evaluated in-plant, its longevity is compared to the glove currently in use for a particular operation. An example of the proper method for comparing economics is as follows:

Typical Operation Using Nitric Acid

30-mil leaded neoprene

Approximate initial cost	\$10.00
Changing, removal of plutonium, and disposal	4.00
Total cost expended per glove	\$14.00
Longevity 7 days,	
Cost per glove per day	\$ 2.00

30-mil Leaded neoprene Hypalon-coated glove

Approximate initial cost	\$14.00
Changing, removal of plutonium, and disposal	4.00
Total cost expended per glove	\$18.00
Longevity 18 days,	
Cost per glove per day	\$ 1.00

In this example, use of the more expensive glove results in a savings of \$1.00 per day per glove in use.

Suggestions and Problems:

Each glovebox port (on which a glove is mounted) can be labeled as to the best glove type for that

port. This precludes putting a more expensive or less efficient glove on this port.

Gloves are often turned inside out, before being installed, for two reasons: (1) a glove of the proper hand (left hand or right hand) is sometimes not readily available, and (2) the outside of the glove is smoother than the inside (the operator prefers to have the smooth side "in" for improved arm entry and exit, and the rough side "out" for a better gripping surface). Turning gloves inside out before installation is not recommended because it places addition stress on the hand areas. This can cause stress cracking and weakening. Also if the Hypalon coating is on the wrong side, its benefits are lost.

Inherent problems with drybox gloves include limited glove life, problems in changing gloves, recovery of radioactive material from the glove, and glove disposal. Improved polymers and elastomers such as polyvinyl chloride, polyvinyl alcohol, ethylene copolymers and terpolymers, urethanes, polyepichlorohydrin, and fluorinated elastomers (Viton) should continue to be developed and eventually incorporated into drybox gloves. As new glove types become available, they should be evaluated by industrial users.

Close communication with the glove manufacturer is desirable. The manufacturer should include data and test results with gloves submitted for evaluation. A comparison of test data can then be made at the users laboratory. The data and in-plant evaluations can be communicated back to the manufacturer. Differences in results can be resolved. The manufacturer will gain a better awareness and appreciation of the needs of the user.

REFERENCES

1. J. E. Ayer and R. M. Mayfield, "Gloves for Protective Enclosures," ANL-5743, Argonne National Laboratory, Argonne, Illinois, May 1957.
2. "Specifications for Arm Length Gloves; Production Type Synthetic Rubber," PF-1-b (Rev.7), Argonne National Laboratory, Argonne, Illinois, April 2, 1962.

APPENDIX A

DATA SHEET FOR GLOVE TESTS

Glove Description:

Cost —

Sp gr —

_____ g/cc

Water Vapor Transmission (Permeability):

0 percent to 50 percent Relative Humidity

_____ g/24 hr/M²

Differential:

Fire Resistance:Lead Equivalence: _____ mm (X-Ray tube source)

Energy _____ kv; Current _____ Ma: Time _____ minutes;

Distance _____ inches

Mechanical Properties:

Tensile Strength:

_____ psi

Force to Break:

_____ lb.

Ultimate Elongation:

_____ %

Modulus at _____ % Elongation:

_____ psi

Permanent set at 70% U. E.

_____ %

Puncture:

_____ lb, _____ inches travel

Accelerated Aging:HeatNitric Acid

Tensile Strength:

_____ psi

_____ psi

Force to Break:

_____ lb.

_____ lb.

Ultimate Elongation:

_____ %

_____ %

Dimensional Properties:

Diameters: _____ in. at cuff

Hand Size: _____

_____ in. at wrist

Thickness: _____ in. palm

Bead: _____ in.

_____ in. finger

Taper _____ in./in.

_____ in. wrist

Length _____ in. overall

_____ in. arm

_____ in. third finger

_____ in. shoulder

_____ in. cuff to taper

Workmanship:Packing:Marking:Economics:

Other observations, opinions, and recommendations:

APPENDIX A (continued)

<u>Chemical Resistance:</u>	<u>Observations</u>			
	<u>1 hour</u>	<u>4 hours</u>	<u>24 hours</u>	<u>72 hours</u>
<u>Chemical</u>				
14 M HNO ₃				
Red Fuming Nitric Acid				
3 M HNO ₃				
12 M HCl				
48 percent HF				
10 M KOH				
10 M NaOH				
Acetone				
Benzene				
CCl ₄				
Trichloroethylene				
Freon TF				
Hydraulic Oil				
KW Decontamination Solution				

	<u>Weight Change^a</u>		<u>Observations After Drying^b</u>	
	<u>Dry for 10 minutes</u>	<u>Dry for 48 hours</u>	<u>Dry for 10 minutes</u>	<u>Dry for 48 hours</u>
14 M HNO ₃				
3 M HNO ₃				
Red Fuming Nitric Acid				
12 M HCl				
48 percent HF				
10 M KOH				
10 M NaOH				
Acetone				
Benzene				
CCl ₄				
Trichloroethylene				
Freon TF				
Hydraulic Oil				
KW Decontaminating Solution				

^aWeight change in milligrams per square centimeter from original after immersion for 24 hours and drying for time indicated. Percent of original weight is also given where sample was completely penetrated

^bAfter immersion for 24 hours and drying for time indicated.

APPENDIX B

Drybox Glove Specifications

Note: All specifications, except RF30N have been abbreviated to reduce repetition in this report.

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Golden, Colorado

SPECIFICATION FOR ARM LENGTH GLOVES – MILLED NEOPRENE NOMINAL 30 MIL THICKNESS – RF 30N

I. SCOPE

- A. This specification covers arm-length gloves used for the protection of workers handling radioactive materials. The gloves will be used on safety cabinets, dryboxes or other hood type structures to provide an air tight seal to the structure and to protect the hands and arms of personnel from harmful materials while permitting suitable dexterity for required manipulations.
- B. The glove described herein refers to a polychloroprene synthetic rubber compound (neoprene) arm length glove, having a nominal thickness of 30 mils, a nominal inside shoulder cuff diameter of 8 in., a tapering sleeve and an overall conformity to the attached drawing (Rocky Flats Dwg. 940511-7).
- C. The gloves will be made on manufacturer's forms of approved design.
- D. The "proof test" voltage referred to in this specification should in no sense be construed to mean that these gloves are approved or recommended for electrical work of any kind. The electrical properties outlined in Section III are primarily intended to indicate glove soundness. Gloves of this type are used for personnel protection and a fatal or serious injury may result through the installation of defective gloves.

II. MANUFACTURE

- A. Material and Process – The gloves shall be of a polychloroprene synthetic rubber compound using neoprene, or its equal, as the base. The virgin raw material (no reprocessed material) may be suitably milled or otherwise compounded, mixed, the forms dipped and the dipped product cured to provide a light-heat-chemical-oil and ozone resistant material that will meet or exceed the requirements of this specification.
- B. Cuff Finish – Shoulder cuff ends shall be finished with a neat and uniform roll approximately $\frac{3}{16}$ in. in diameter unless otherwise specified.

III. FILM CONTINUITY BY ELECTRICAL TEST – PROOF VOLTAGE TEST

- A. This test shall be made at room temperature by filling the glove with fresh tap water and immersing it in water to within approximately 1 in. of the edge of the cuff. The glove shall be tested with the right side out. (Additional information on electrical testing procedures may be obtained from the specification listed in Section XIV.)
- B. Each glove shall withstand a direct current potential of 10,000 volts.
- C. Method of Testing – The proof test voltage shall be applied at a low value and gradually and steadily raised at a rate of approximately 500 volts per second until the prescribed proof testing voltage is reached (or failure occurs). The glove shall be subjected to the proof test voltage for a period of *not less* than fifteen (15) seconds. The test period shall be counted from the instant when the prescribed testing voltage is reached. After the test period, the voltage will be immediately returned to zero.

IV. PHYSICAL AND CHEMICAL PROPERTIES

- A. Tensile Strength – The tensile strength shall be not less than 2500 psi.
- B. Ultimate Elongation – Elongation at rupture shall be not less than 600% (1 in. stretched to 7 in.).
- C. Permanent Set or Tension Set – The set, after pulling at a constant rate to 450% elongation, holding for ten minutes, releasing without snapping, and allowing to set for ten minutes, shall not exceed 20% (1 in. returned to 1.2 in.).
- D. Modulus or Tensile Stress – The tensile stress shall be no more than to 450% elongation, holding for ten

- E. Accelerated Aging — In Air — After being subjected to a temperature of $158 \pm 2^\circ\text{F}$ ($70 \pm 1^\circ\text{C}$) in circulating air for seven days, the tensile strength and elongation shall be not less than 85% of the original values.
- F. Permeability to Water Vapor — Water vapor permeability shall not exceed 1.5 g per day per m^2 for a random sample taken from the arm of the glove. (Test run at 70°F and 50% relative humidity differential for 30 days.) See Section XIV. The permeability report shall be for the last ten days of the thirty day test.
- G. Resistance to Nitric Acid — The glove must be resistant to nitric acid — (1) as determined by surface exposure to $3M \text{ HNO}_3$ for 24 hours, (2) as determined by tensile strength after immersion in $3M \text{ HNO}_3$ for 24 hours.
1. The outside glove surface shall be in contact with $3M \text{ HNO}_3$ (liquid) for 24 hours. The effect shall be no more severe than slight tackiness at the surface.
 2. Tensile specimens shall be immersed in $3M \text{ HNO}_3$ for 24 hours, removed and immediately rinsed in water, blotted lightly on a paper towel to dry, and pulled within an hour. Tensile strength shall be no less than 90% of the original.

V. STYLE AND SIZE

Style and size shall be in general conformance with the attached drawing (Rocky Flats Dwg. 940511-7) and in accordance with the approved form design. The beaded shoulder cuff must be capable of being stretched by hand over a ten-inch-diameter metal ring.

VI. THICKNESS

The thickness shall fall within the minimum and maximum limiting values specified below when thickness measurements are made in accordance with applicable specifications listed in Section XIV.

Thickness Limits				
Min. in Finger Crotches (mils)	Min. Other Than Crotch (mils)	Max. Across One Sq. In. Area on Hand (mils)	Max. Across One Sq. In. Area Other Than Hand (mils)	Max. at Any Point (mils)
22	30	40	35	50

VII. SURFACE

- A. Neither the inner nor outer glove surface shall be tacky, gummy, or sticky. The inside surface of the glove shall be such that (1) the hand and arm can be

easily inserted and removed, (2) the rubber can be slipped over itself (film to film surface contact) to facilitate glove changing.

- B. Gloves may be designated "roughened surface" in which case the outer palm and finger surface areas shall be spray or dip roughened to provide a glove with better gripping properties.

VIII. WORKMANSHIP

Finished gloves shall be free of patches, blisters, pinholes, cracks, protuberances, indentations, surface breaks, imbedded foreign matter, or other harmful physical defects which can be detected by thorough test or inspection. A "roughened surface" hand is not a defect when so designated.

IX. MARKING

Each glove shall be marked to include: (1) the name of the manufacturer (or brand name), (2) a symbol to indicate that it has passed an approved electrical test, (3) glove type, and (4) nominal gage. All required markings can be included as part of approved manufacturer's code designation. All such markings shall be confined to the back of the glove and shall be of a permanent nature and so applied as to not injure the glove.

X. PACKING

Packing cartons shall contain only right hand gloves or only left hand gloves packed fully extended (without folding). The cartons shall be of stiff paper board of sufficient strength to protect the gloves properly. Each glove shall have a cardboard insert to cause retention of full open position during shipping. The end of the carton shall be marked with a description of the included glove, including number contained, right or left hand, and gage and polymer type (coding acceptable). Maximum gross weight per packing carton shall be twelve pounds.

XI. CONDITIONS OF INSPECTION AND TEST

The manufacturer shall thoroughly inspect and test the finished gloves for compliance with the specifications prior to shipment. Inspection and test by the purchaser for initial acceptance purposes shall be made within one month after receipt of the material. Determination of permeability to water vapor may require two months.

XII. REJECTION

- A. The term "shipment" as used in this section is defined as all gloves of one type that are received under one purchase order within a two-week period.
- B. Individual gloves may be rejected if they fail to meet the requirements of any of the following sections: II-Manufacture; III-Film Continuity; V-Style and Size; VII-Surface; VIII-Workmanship; IX-Marking; and X-Packing. The purchaser reserves the right

to return the entire shipment if purchaser sampling reveals that there is more than one chance in twenty (95% confidence) that more than 2% of the shipment is defective in any one of the above items.

- C. The purchaser reserves the right to return the entire shipment if it fails to meet the requirements of IV-Physical and Chemical Properties, and VI-Thickness.

To determine shipment quality a sample representing 1% of the shipment will be taken and tested. If one or more gloves of the sample do not meet the requirements of Sections IV and VI, a second 1% sample will be taken and tested. If one glove of the second sample fails to meet the requirement not met by the first sample, the entire shipment shall be considered as not meeting the specification and subject to rejection. In this event the manufacturer's test results will also be evaluated in an effort to resolve differences in results before rejection is stipulated.

- D. Rejected material shall be returned as directed by the manufacturer and at his expense, without being defaced by rubber stamp or other permanent markings.

XIII. STORAGE

- A. Concerning a delivery accepted under Section XI, the manufacturer shall replace, without charge to the purchaser, gloves which, at any time within a period of eight months from the date of receipt, fail to pass the tests prescribed in these specifications, provided the gloves have been properly stored in their original boxes.
- B. Proper storage of gloves is construed as:
1. Storage in original boxes, right side out and not folded.
 2. Storage in a cool area away from direct sunlight, steam pipes, radiators, or other heat sources.

3. Storage in a location where ozone is at a minimum. (Ozone is likely to be more prevalent in a room where high-voltage testing is conducted, or energized high-voltage is located.) It is desirable that the ambient temperature shall not exceed 90°F (32°C).

XIV. APPLICABLE SPECIFICATIONS

Property Tests – Tests necessary to determine specific properties required in this specification may be made as indicated, or the following applicable specifications may be utilized.

- A. Electrical Testing – The general procedure for electrical testing is described in ASTM D120.
- B. Physical Tests – Method of tension testing of vulcanized rubber ASTM D412 for tensile strength, elongation, tensile stress or modulus, and tension set.
- C. Accelerated Aging – Accelerated aging of vulcanized rubber by the oven method – ASTM D573.
- D. Water Permeability – The permeability of glove materials shall be determined by ASTM E96. Procedure "A" shall be employed using a test dish similar to Thwing-Albert Cat. No. 68-1.
- The calculations of water vapor transmission shall be made according to the method suggested in ASTM E96, expressed in grams per day per square meter.
- E. Chemical Tests – Resistance of plastics to chemical reagents – ASTM – D543 is a helpful reference for chemical testing.
- F. Thickness Measurements – Thickness measurements shall be made as indicated or in accordance with specification ASTM D120 – Rubber Insulating Gloves.

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Golden, Colorado

SPECIFICATION FOR
ARM LENGTH GLOVES – MILLED NEOPRENE
NOMINAL 15 MIL THICKNESS – RF 15N

(This specification has been abbreviated to reduce repetition.)

I. SCOPE

A. Same as RF 30N.

B. The glove described herein refers to a polychloroprene synthetic rubber compound (neoprene) arm length glove, having a nominal thickness of 15 mils, a nominal inside shoulder cuff diameter of 8 in., a tapering sleeve and an overall conformity to the attached drawing (Rocky Flats Dwg. 940511-7).

C. Same as RF 30N.

D. Same as RF 30N.

II. MANUFACTURE

Same as RF 30N.

III. FILM CONTINUITY BY ELECTRICAL TEST – PROOF VOLTAGE TEST

A. Same as RF 30N.

B. Each glove shall withstand a direct current potential of 5,000 volts.

C. Method of Testing – Same as RF 30N.

IV. PHYSICAL AND CHEMICAL PROPERTIES

Same as RF 30N.

V. STYLE AND SIZE

Same as RF 30N.

VI. THICKNESS

The thickness shall fall within the minimum and maximum limiting values specified below when thickness measurements are made in accordance with applicable specifications listed in Section XIV.

Thickness Limits

Min. in Finger Crotches (mils)	Min. Other Than Crotch (mils)	Max. Across One Sq. In. Area on Hand (mils)	Max. Across One Sq. In. Area Other Than Hand (mils)	Max. at Any Point (mils)
11	14	23	18	25

VII. SURFACE

Same as RF 30N.

VIII. WORKMANSHIP

Same as RF 30N.

IX. MARKING

Same as RF 30N.

X. PACKING

Same as RF 30N.

XI. CONDITIONS OF INSPECTION AND TEST

Same as RF 30N.

XII. REJECTION

Same as RF 30N.

XIII. STORAGE

Same as RF 30N.

XIV. APPLICABLE SPECIFICATIONS

Same as RF 30N.

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Golden, Colorado

SPECIFICATION FOR
ARM LENGTH GLOVES – BUTYL RUBBER
NOMINAL 30 MIL THICKNESS – RF 30B

(This specification has been abbreviated to reduce repetition.)

I. SCOPE

- A. Same as RF 30N.
- B. The glove described herein refers to a polyisobutylene (butyl) synthetic rubber compound arm length glove, having a nominal thickness of 30 mils, a nominal inside shoulder cuff diameter of 8 in., a tapering sleeve and an overall conformity to the attached drawing (Rocky Flats Dwg. 940511-7).
- C. Same as RF 30N.

II. MANUFACTURE

- A. Material and Process – The gloves shall be of a polyisobutylene synthetic rubber compound using butyl rubber, or its equal, as the base. The virgin raw material (no reprocessed material) shall be suitably milled, mixed, the forms dipped and the dipped product cured to provide a light-heat-chemical and ozone resistant material that will meet or exceed the requirements of this specification.

- B. Same as RF 30N.

III. PHYSICAL PROPERTIES

- A. Tensile Strength – The tensile strength shall be not less than 2000 psi.
- B. Ultimate Elongation – Elongation at rupture shall be not less than 550% (1 in. stretched to 6½ in.).
- C. Modulus or Tensile Stress – The tensile stress at 100% elongation shall be no more than 300 psi.
- D. Permanent Set or Tension Set – The set, after pulling at a constant rate to 450% elongation, holding for ten minutes, releasing without snapping, and allowing to set for ten minutes, shall not exceed 25% (1 in. returned to 1.25 in.).
- E. Accelerated Aging – In Air – after being subjected to a temperature of $158 \pm 2^{\circ}\text{F}$ ($70 \pm 1^{\circ}\text{C}$) in circulating air for seven days the tensile strength and elongation shall be not less than 85% of the original values.

- F. Permeability to Water Vapor – Water vapor permeability shall not exceed 0.15 g per day per m² for a random sample taken from the arm of the glove. (Test run at 75°F and 50% relative humidity for 30 days.) See Section XIII. The permeability reported shall be the average permeability for the last ten days of the 30 day test.

IV. STYLE AND SIZE

Same as RF 30N.

V. THICKNESS

The thickness shall fall within the minimum and maximum limiting values specified below when thickness measurements are made in accordance with applicable specifications listed in Section XIII.

Thickness Limits

Min. in Crotch (mils)	Min. Other Than Crotch (mils)	Max. Across One Sq. In. Area (mils)	Max. at Any Point (mils)
22	30	36	50

VI. SURFACE

Neither the inner nor outer glove surface shall be tacky, gummy, or sticky. The inside surface of the glove shall be such that (1) the hand and arm can be easily inserted and removed, (2) the rubber can be slipped over itself (film to film surface contact) to facilitate glove changing.

VII. WORKMANSHIP

Finished gloves shall be free of patches, blisters, pinholes, cracks, protuberances, indentations, surface breaks, imbedded foreign matter or other harmful physical defects which can be detected by thorough test or inspection.

VIII. MARKING

Unless otherwise specified, each glove shall be marked with the name of the manufacturer or brand

name, the nominal gage, and rubber type. Markings may be in the form of an approved manufacturer's code. All such markings shall be confined to the back of the glove and shall be of a permanent nature and so applied as to not injure the glove.

IX. PACKING

Each pair of gloves (right and left hand) shall be packed fully extended (without folding) in an individual, stiff paper-board carton of sufficient strength to protect the gloves properly. The end of the carton shall be marked with a description of the included gloves, including gage and polymer type (coding acceptable).

X. CONDITIONS OF INSPECTION AND TEST

Same as RF 30N.

XI. REJECTION

A. Same as RF 30N.

B. Individual gloves shall be rejected if they fail to meet the requirements of any of the following sections: II – Manufacture; IV – Style and Size; VI – Surface, VII – Workmanship; VIII – Marking; and IX – Packing. The purchaser reserves the right to return the entire shipment if purchaser samplings reveals that there is more than one chance in twenty (95% confidence) that more than 2% of the shipment is defective in any one of the above items.

C. The purchaser reserves the right to return the entire shipment if it fails to meet the requirements of III – Physical and Chemical Properties, and V – Thickness.

To determine shipment quality a sample representing 1% of the shipment will be taken and tested. If one or more gloves of the sample do not meet the requirements of Sections III and V, a second 1% sample will be taken and tested. If one

glove of the second sample fails to meet the requirement not met by the first sample, the entire shipment shall be considered as not meeting the specification and subject to rejection. In this event the manufacturer's test results will also be evaluated in an effort to resolve differences in results before rejection is stipulated.

D. Same as RF 30N.

XII. STORAGE

Same as RF 30N.

XIII. APPLICABLE SPECIFICATIONS

Property Tests – All tests necessary to determine specific properties required in this specification shall be made as indicated or in accordance with one of the following applicable specifications:

A. Physical Tests – Method of tension testing of vulcanized rubber – ASTM D412 for tensile strength, elongation, tensile stress or modulus, and tension set.

B. Accelerated Aging – Accelerated aging of vulcanized rubber by the oven method – ASTM D573

C. Water Permeability – The permeability of glove materials shall be determined by ASTM E96. Procedure "A" shall be employed using a test dish similar to Thwing-Albert Cat. No. 68-1.

The calculations of water vapor transmission shall be made according to the method suggested in ASTM E96, expressed in grams per day per square meter.

D. Thickness Measurements – Thickness measurements shall be made as indicated or in accordance with the following specification: ASTM D120 – Rubber Insulating Gloves.

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Golden, Colorado

SPECIFICATION FOR
ARM LENGTH GLOVES – MILLED NEOPRENE
PLUS SYNTHETIC ELASTOMER OUTER SURFACE
NOMINAL 30 MIL THICKNESS – RF 30NH

(This specification has been abbreviated to reduce repetition.)

I. SCOPE

A. Same as RF 30N.

B. The glove described herein refers to a polychloroprene synthetic rubber compound (neoprene) arm length glove possessing a synthetic elastomer outer surface, having a nominal thickness of 30 mils, a nominal inside shoulder cuff diameter of 8 in., a tapering sleeve and an overall conformity to the attached drawing (Rocky Flats Dwg. 940511-7).

C. Same as RF 30N.

D. Same as RF 30N.

II. MANUFACTURE

A. Material and Process – The gloves shall be of a polychloroprene synthetic rubber compound using neoprene, or its equal, as the base, and Hypalon® (DuPont trademark) or material with similar properties, as the synthetic elastomer for the outer surface. The virgin raw materials (no reprocessed material) may be suitably milled or otherwise compounded, mixed, the forms dipped and dipped product cured to provide a light-heat-chemical-oil and ozone resistant material that will meet or exceed the requirements of this specification.

B. Cuff Finish – Same as RF 30N.

III. FILM CONTINUITY BY ELECTRICAL TEST – PROOF VOLTAGE TEST

Same as RF 30N.

IV. PHYSICAL AND CHEMICAL PROPERTIES

A. Tensile Strength – The force required to break a 0.250-inch-wide tensile specimen shall be not less than 15 pounds.

B. Ultimate Elongation – Elongation at rupture shall be not less than 550% (1 in. stretched to 6½ in.).

C. Permanent Set or Tension Set – The set, after pulling at a constant rate to 400% elongation, holding for ten minutes, releasing without snapping, and allowing to set for ten minutes, shall not exceed 20% (1 in. returned to 1.2 in.).

D. Modulus or Tensile Stress – Same as RF 30N.

E. Accelerated Aging – Same as RF 30N.

F. Permeability to Water Vapor – Water vapor permeability shall not exceed 1.3 g per day per m² for a random sample taken from the arm of the glove. (Test run at 75°F and 50% relative humidity differential for 30 days.) See Section XIV. The permeability reported shall be for the last ten days of the 30 day test.

G. Resistance of Nitric Acid – The glove must be resistant to nitric acid – (1) as determined by surface exposure to 14M HNO₃ for 24 hours, (2) as determined by force required to break a 0.250-inch-wide tensile specimen after immersion in 3M HNO₃ for 24 hours.

1. The outside glove surface shall be in contact with 14M HNO₃ (liquid) for 24 hours. The effect shall be no more severe than loss of gloss or discoloration at the surface.

2. Tensile specimens shall be immersed in 3M HNO₃ for 24 hours, removed and immediately rinsed in water, blotted lightly on a paper towel to dry, and pulled within an hour. Force required to break shall be no less than 90% of original.

H. Synthetic Elastomer Outer Surface – The synthetic elastomer outer layer shall be continuous, free of pinholes, and at least eight mils in thickness in the palm and wrist area, and at least six-mils thick over the rest of the glove.

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V. STYLE AND SIZE

Same as RF 30N.

VI. THICKNESS

Same as RF 30N.

VII. SURFACE

Same as RF 30N.

VIII. WORKMANSHIP

Same as RF 30N.

IX. MARKING

Same as RF 30N.

X. PACKING

Same as RF 30N.

XI. CONDITIONS OF INSPECTION AND TEST

Same as RF 30N.

XII. REJECTION

Same as RF 30N.

XIII. STORAGE

Same as RF 30N.

XIV. APPLICABLE SPECIFICATIONS

Same as RF 30N.

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Golden, Colorado

SPECIFICATION FOR
ARM LENGTH GLOVES – MILLED NEOPRENE – LEAD LOADED
NOMINAL 30 MIL THICKNESS – RF 30NL

(This specification has been abbreviated to reduce repetition.)

I. SCOPE

- A. Same as RF 30N.
- B. The glove described herein refers to a polychloroprene synthetic rubber compound (neoprene) arm length lead loaded glove, having a nominal thickness of 30 mils, a nominal inside shoulder cuff diameter of 8 in., a tapering sleeve and an overall conformity to the attached drawing (Rocky Flats Dwg. 940511-7).
- C. Same as RF 30N.
- D. Same as RF 30N.

II. MANUFACTURE

Same as RF 30N.

III. FILM CONTINUITY BY ELECTRICAL TEST – PROOF VOLTAGE TEST

Same as RF 30N.

IV. PHYSICAL AND CHEMICAL PROPERTIES

- A. Tensile Strength – The force required to break a 0.250-inch-wide tensile specimen shall be not less than 14 pounds.
- B. Ultimate Elongation – Elongation at rupture shall be not less than 550% (1 in. stretched to 6½ in.).
- C. Permanent Set or Tension Set – Same as RF 30N.
- D. Modulus or Tensile Stress – The tensile stress shall be no more than 500 psi at 100% elongation.
- E. Accelerated Aging – In Air – After being subjected to a temperature of 158 ± 2°F (70 ± 1°C) in circulating air for seven days, the force to break and elongation shall be not less than 85% of the original values.
- F. Permeability to Water Vapor – Same as RF 30N.
- G. Resistance to Nitric Acid – Same as RF 30N.

- H. Lead Equivalence – Nominal shielding power to soft gamma shall equal that of 0.10 mm thickness of lead metal foil. Uniformity will be such that there will be no significant areas (four square inches) containing less than 0.08 mm or more than 0.14 mm lead equivalence as determined by a standard x-ray tube source; the glove being compared with a calibrated lead stepwedge. The method may consist of placing an x-ray film inside the glove, placing another film with a lead stepwedge beside the glove for reference, and exposing the films. The film is then developed and the images are evaluated on a densitometer. Recommended exposure conditions are: energy – 50-70 kV, with current, time, and distance such that a readable density is obtained. Lead equivalence will not be determined on last 3 in. of cuff end; lead protection is unnecessary in that area.

V. STYLE AND SIZE

Same as RF 30N.

VI. THICKNESS

Thickness shall fall within the minimum and maximum limiting values specified below when thickness measurements are made in accordance with applicable specifications listed in Section XIV.

Thickness Limits

Min. in Finger Crotches (mils)	Min. Other Than Crotch (mils)	Max. Across One Sq. In. Area on Hand (mils)	Max.	
			Across One Sq. In. Area Other Than Hand (mils)	Max. at Any Point (mils)
22	25	44	36	50

VII. SURFACE

- A. Same as RF 30N.

B. The inner and outer glove surface shall be of the material described in Section II.A., devoid of lead, such that the person wearing the glove, and the materials and chemicals contacting the glove shall receive no lead contamination.

C. Gloves may be designated "roughened surface" in which case the outer palm and finger surface areas shall be spray or dip roughened to provide a glove with better gripping properties.

VIII. WORKMANSHIP

Same as RF 30N.

IX. MARKING

Same as RF 30N.

X. PACKING

Same as RF 30N.

XI. CONDITIONS OF INSPECTION AND TEST

Same as RF 30N.

XII. REJECTION

Same as RF 30N.

XIII. STORAGE

Same as RF 30N.

XIV. APPLICABLE SPECIFICATION

Same as RF 30N.

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Golden, Colorado

SPECIFICATION FOR
ARM LENGTH GLOVES – MILLED NEOPRENE – LEAD LOADED
PLUS SYNTHETIC ELASTOMER OUTER SURFACE
NOMINAL 30 MIL THICKNESS – RF 30NLH

(This specification has been abbreviated to reduce repetition.)

I. SCOPE

Same as RF 30NH.

II. MANUFACTURE

Same as RF 30NH.

III. FILM CONTINUITY BY ELECTRICAL TEST – PROOF
VOLTAGE TEST

Same as RF 30N.

IV. PHYSICAL AND CHEMICAL PROPERTIES

- A. Tensile Strength – The force required to break a 0.250-inch-wide tensile specimen shall be not less than 9 pounds.
- B. Ultimate Elongation – Elongation at rupture shall be not less than 500% (1 in. stretched to 6 in.).
- C. Permanent Set or Tension Set – Same as RF 30NH.
- D. Modulus or Tensile Stress – The tensile stress shall be no more than 500 psi at 100% elongation.
- E. Accelerated Aging – Same as RF 30N.
- F. Permeability to Water Vapor – Same as RF 30N.
- G. Resistance to Nitric Acid – Same as RF 30NH.
- H. Synthetic Elastomer Outer Surface – Same as RF 30NH.
- I. Lead Equivalence – Same as RF 30NL.

V. STYLE AND SIZE

Same as RF 30N.

VI. THICKNESS

Same as RF 30NL.

VII. SURFACE

Same as RF 30NL.

VIII. WORKMANSHIP

Same as RF 30N.

IX. MARKING

Same as RF 30N.

X. PACKING

Same as RF 30N.

XI. CONDITIONS OF INSPECTION AND TEST

Same as RF 30N.

XII. REJECTION

Same as RF 30N.

XIII. STORAGE

Same as RF 30N.

XIV. APPLICABLE SPECIFICATIONS

Same as RF 30N.

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Golden, Colorado

SPECIFICATION FOR
ARM LENGTH GLOVES – MILLED NEOPRENE – LEAD LOADED
PLUS SYNTHETIC ELASTOMER OUTER SURFACE
NOMINAL 80 MIL THICKNESS (MULTILAYERED) – RF 80NLH

(This specification has been abbreviated to reduce repetition.)

I. SCOPE

- A. Same as RF 30N.
- B. The glove described herein refers to a polychloroprene synthetic rubber compound (neoprene) arm length lead loaded glove possessing a synthetic elastomer outer surface, having a nominal thickness of 80 mils, a nominal inside shoulder cuff diameter of 8 in., a tapering sleeve and an overall conformity to the attached drawing (Rocky Flats Dwg. 940511-7).
- C. Same as RF 30N.
- D. Same as RF 30N.

II. MANUFACTURE

Same as RF 30NH.

III. FILM CONTINUITY BY ELECTRICAL TEST – PROOF VOLTAGE TEST

Same as RF 30N.

IV. PHYSICAL AND CHEMICAL PROPERTIES

- A. Tensile Strength – The force required to break a 0.250-inch-wide tensile specimen shall be not less than 18 pounds.
- B. Ultimate Elongation – Elongation at rupture shall be not less than 450% (1 in. stretched to 5½ in.).
- C. Permanent Set or Tension Set – The set, after pulling at a constant rate to 400% elongation, holding for ten minutes, releasing without snapping, and allowing to set for ten minutes, shall not exceed 25% (1 in. returned to 1.25 in.).
- D. Modulus or Tensile Stress – The tensile stress shall be no more than 550 psi at 100% elongation.
- E. Accelerated Aging – Same as RF 30N.
- F. Permeability to Water Vapor – Same as RF 30N.

G. Resistance to Nitric Acid – Same as RF 30NH.

H. Synthetic Elastomer Outer Surface – Same as RF 30NH.

I. Lead Equivalence – Nominal shielding power to soft gamma shall equal that of 0.36 mm thickness of lead metal foil. Uniformity will be such that there will be no significant areas (4 square inches) containing less than 0.32 mm or more than 0.40 mm lead equivalence as determined by a standard x-ray tube source, the glove being compared with a calibrated lead stepwedge. The method may consist of placing an x-ray film inside the glove, placing another film with a lead stepwedge beside the glove for reference, and exposing the films. The film is then developed and the images are evaluated on a densitometer. Recommended exposure conditions are: energy – 100-125 kV, with current, time, and distance such that a readable density is obtained. Lead equivalence will not be determined on last 3 in. of cuff end; lead protection is unnecessary in that area.

V. STYLE AND SIZE

Same as RF 30N.

VI. MULTILAYERED CONSTRUCTION

The hand, wrist, and lower arm portion (first 14 in.) shall be of multilayered construction such that the layers can internally slip on one another resulting in improved hand and wrist flexibility.

VII. SURFACE

Same as RF 30NL.

VIII. WORKMANSHIP

Same as RF 30N.

IX. MARKING

Same as RF 30N.

X. PACKING

Same as RF 30N.

XII. REJECTION

A. Same as RF 30N.

B. Individual gloves may be rejected if they fail to meet the requirements of any of the following sections: II – Manufacture; III – Film Continuity; V – Style and Size; VI – Multilayered Construction; VII – Surface; VIII – Workmanship; IX – Marking; and X – Packing. The purchaser reserves the right to return the entire shipment if purchaser sampling reveals that there is more than one chance in twenty (95% confidence) that more than 2% of the shipment is defective in any one of the above items.

C. The purchaser reserves the right to return the entire shipment if it fails to meet the requirement of IV – Physical and Chemical Properties.

To determine shipment quality a sample representing 1% of the shipment will be taken and tested. If one or more gloves of the sample do not meet the requirements of Sections IV, a

second 1% sample will be taken and tested. If one glove of the second sample fails to meet the requirement not met by the first sample, the entire shipment shall be considered as not meeting the specification and subject to rejection. In this event, the manufacturer's test results will also be evaluated in an effort to resolve differences in results before rejection is stipulated.

D. Same as RF 30N.

XIII. STORAGE

Same as RF 30N.

XIV. APPLICABLE SPECIFICATIONS

Property Tests – Same as RF 30N.

A. Electrical Testing – Same as RF 30N.

B. Physical Tests – Same as RF 30N.

C. Accelerated Aging – Same as RF 30N.

D. Water Permeability – Same as RF 30N.

E. Chemical Tests – Same as RF 30N.

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APPENDIX C

Procedures for Drybox Glove Acceptance Inspection Tests

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Golden, Colorado

PROCEDURES FOR DRYBOX GLOVE ACCEPTANCE
INSPECTION TESTS

I. VISUAL INSPECTIONS

A. Cuff Finish

Inspect to see if shoulder cuff is finished with a neat uniform roll. Measure the roll diameter. The diameter must be $\frac{3}{16}$ in. $\pm \frac{1}{16}$ in. to be acceptable.

B. Surface

Inspect the surface of the glove. It shall not be tacky, gummy, or sticky. The inner and outer surfaces of the glove shall be devoid of lead.

C. Workmanship

The finished glove shall be free of patches, blisters, pinholes, cracks, protuberances, indentations, surface breaks, imbedded foreign matter, or other harmful physical defects.

D. Multilayered Construction

On the 80NLH glove, only the hand, wrist, and lower arm portion (first 14 inches) shall be of multilayered construction such that the layers can internally slip on one another.

E. Marking

Each glove shall be marked with symbols that convey the following information: (1) manufacturer's name or brand name, (2) that the glove has passed an approved electrical test, (3) the glove type, and (4) the nominal gage. All markings shall be confined to the back of the glove and shall be of a permanent nature and so applied as to not injure the glove.

F. Packing

Except for butyl gloves the packing cartons shall contain only right hand gloves or only left hand gloves. All gloves shall be packed fully extended (without folding). The cartons shall be of stiff paper board of sufficient strength to protect the gloves properly. Each glove shall have a card-board insert to cause retention of full open position

during shipping. The end of the carton shall be marked with a description of the included glove, including number contained, right or left hand, and gage and polymer type (coding acceptable). Maximum gross weight per packing carton shall be twelve pounds.

II. SIZE VERIFICATION

A. Thickness

Thickness measurements shall be made in accordance with ASTM D120. The thickness measurements shall fall within limits shown in the table for the appropriate glove. (See Table I-C).

Table 1-C. Thickness Limits (mils).

Rocky Flats Glove Designation	Area of Measurement				
	Min. In Finger Crotch	Min. Other Than Crotch	Max. Across one Sq. In. Area on Hand	Max. Across One. Sq. In. Area Other Than Hand	Max. At Any Point
RF 30NL and RF 30NLH	22	25	44	36	50
RF 30NH and RF 30N	22	30	40	35	50
RF 15N	11	14	23	18	25
RF 30B	22	30	36	36	50
RF 80NLH ^a	—	—	—	—	—

^a No thickness limits on this glove.

On the 30NH, 30NLH, and 80NLH gloves the synthetic elastomer outer surface shall be continuous, free of pinholes, and at least eight mils in thickness in the palm and wrist area, and at least six mils thick over the rest of the glove.

B. Size

The glove dimensions shall be within the tolerances shown in Rocky Flats Drawing 940511-7.

The beaded shoulder cuff should stretch by hand over a ten-inch-diameter metal ring.

III. LEAD EQUIVALENCE

The lead equivalence shall be within the limits specified for each type of glove. No area of 4 square inches can be over or under the following equivalent lead thickness:

	Lead Equivalence (mm lead)	
	Nominal 30 mil ^a	Nominal 80 mil ^b
maximum	0.14	0.40
minimum	0.08	0.32

^aIncludes gloves designated RF 30NE and RF 30NLH.

^bIncludes gloves designated RF 80NLH.

PROCEDURE FOR LEAD EQUIVALENCE DETERMINATION

1. Place the x-ray film under one thickness of the glove. Place a lead stepwedge on the same film adjacent to the glove and expose both portions of the film simultaneously.
2. Expose the films using an x-ray energy of 50-70 kV for 30-mil gloves, and 100-125 kV for 80-mil gloves. Adjust current, time, and distance such that readable density is obtained.
3. Inspect the developed film on a densitometer. Report any area of 4 square inches that is not within the specified limits.

Report any unusual observations that are not covered by other limits. Do not consider that portion of the glove within three inches of the cuff bead.

IV. PHYSICAL PROPERTIES

The physical properties of the drybox glove material as received shall be within the limits shown in Table 2-C.

Table 2-C. Physical Property Specifications of Drybox Glove Materials.

Rocky Flats Glove Designation	Tensile Strength (psi)	Force To Break (lb)	Property Ultimate Elongation (%)	Tension Set (%)	Tensile Stress (psi)
RF 30N	≥2500	—	≥600	≤20	≤450
RF 30NH	—	≥15	≥550	≤20	≤450
RF 30NL	—	≥14	≥550	≤20	≤500
RF 30NLH	—	≥9	≥500	≤20	≤500
RF 80NLH	—	≥18	≥450	≤25	≤550
RF 15N	≥2500	—	≥600	≤20	≤450
RF 30B	≥2000	—	≥550	≤25	≤300

After accelerated aging the tensile strength and elongation of all types of gloves shall not be less than 85% of the original values.

After immersion in nitric acid the tensile strength of all types of gloves shall be no less than 90% of the original values. NOTE: The RF 30B gloves are not tested for nitric acid resistance.

PROCEDURE FOR DETERMINATION OF PHYSICAL PROPERTIES OF DRYBOX GLOVES

- A. Conduct the tests necessary to report the required properties of the drybox glove material as received according to the following methods.
 1. The force required to break a 0.250-inch-wide tensile specimen or the tensile strength according to the procedure in ASTM D412.
 2. The ultimate elongation according to the procedure in ASTM D412
 3. The tension set according to the procedure in ASTM D412. Use 400% elongation for all Hypalon® coated gloves and 450% for all other gloves.
 4. The tensile stress according to the procedure in ASTM D412. Record the stress at 100% elongation.
- B. Conduct the tests necessary to report the following properties of the drybox glove material. Aging by the method described in ASTM D573. Conduct the aging at 158 ±2°F (70 ±1°C) in air for seven days. Record the following:
 1. The force required to break a 0.250-inch-wide tensile specimen, or the tensile strength according to the procedure in ASTM D412.
 2. The ultimate elongation according to the procedure in ASTM D412.
- C. Conduct the tests necessary to report acid resistant properties of the drybox glove material after exposure to nitric acid. Tensile specimens shall be immersed in 3M nitric acid for 24 hours, removed and immediately rinsed in water, blotted lightly on a paper towel to dry, and pulled within an hour. Record the following:
 1. The force required to break a 0.250-inch-wide tensile specimen or the tensile strength according to the procedure in ASTM D412.

V. CHEMICAL PROPERTIES

A. Water Vapor Permeability

The water vapor permeability of the drybox glove material as-received shall be within the limits for the specific glove as shown in Table 3-C.

Table 3-C. Water Vapor Permeability Limits for Dry-box Glove Materials.

Rocky Flats Glove Designation	Maximum Allowable Water Penetration Rate (gm/day m ²)
RF 30N	1.5
RF 30NL	1.5
RF 30NH	1.3
RF 30NLH	1.5
RF 15N	3.2
RF 80NLH	1.5
RF 30B	0.15

PROCEDURE FOR DETERMINATION OF WATER VAPOR PERMEABILITY OF DRYBOX GLOVE MATERIAL

1. The permeability of glove materials shall be determined according to procedure A in ASTM E-96. A test dish similar to Thwing-Albert Catalog No. 68-1 shall be used.
2. The samples to be tested shall be taken at random from the arm of the glove.
3. Run the test at 75°F and 50% relative humidity differential for 30 days. Report the permeability for the last 10 days of the tests.

B. Surface Resistance to Nitric Acid

The outside surface of the glove material after exposure to nitric acid shall show effects no more severe than slight tackiness at the surface for neoprene gloves, and loss of gloss and discoloration at the surface for Hypalon® gloves. Butyl rubber gloves (RF 30B) are not tested for nitric acid resistance.

PROCEDURE FOR DETERMINATION OF SURFACE RESISTANCE TO NITRIC ACID

1. Determine the effect of nitric acid on the outside glove surface by clamping the sample of glove material to a container with nitric acid and inverting so the acid covers the glove surface.
2. Use 3M nitric acid for neoprene glove surfaces (RF 30N, RF 15N, RF 30NL) and 14M nitric acid for Hypalon® gloves surfaces (RF 30NH, RF 30NLH, RF 80NLH), and leave the surfaces exposed for 24 hours.
3. Remove the sample from the acid, rinse in water, and examine visually for the effects of the acid.
4. If samples are not judged to meet the requirements, save the test samples as evidence.

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Arm Length Glove. Rocky Flats (The Dow Chemical Company) Drawing 940511-7.