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INVESTIGATION OF NATURAL LATEX RUBBER GLOVES (U)

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**INVESTIGATION OF NATURAL LATEX RUBBER GLOVES
(U)**

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EXECUTIVE SUMMARY

Seventy five percent of natural latex rubber gloves used in laboratories at the Savannah River Site are not reused. A cost analysis performed by the SRS Procurement Department determined that a net savings of \$1,092,210 could be achieved annually by recycling latex rubber gloves. The Materials Technology Section, at the request of the Procurement Department, examined some mechanical and chemical properties of latex rubber gloves manufactured by Ansell Edmont, which had been purchased by the site specifications for protective clothing. It also examined mechanical properties of re-cycled gloves purchased by specifications and of "off the shelf" gloves manufactured by North Brothers Company. Finally, water vapor transmission studies, simulating tritium permeation, were performed on gloves from both manufacturers. These studies were performed to determine whether latex rubber gloves can be recycled or whether using only new, unwashed gloves is required in areas where tritium exposure is a possibility.

The results of these studies indicate that the acceptable glove characteristics, required in the WSRC Manual 5Q1.11, Protective Clothing Specifications, are not adversely affected after washing and drying the gloves manufactured by Ansell Edmont for seven cycles. Results also indicate that natural latex rubber gloves manufactured by North Brothers comply with most of the acceptable glove characteristics specified in the WSRC Manual 5Q1.11. Statistical analysis of the water vapor permeation data show that there is no correlation between permeation rates and the manufacturer.

INTRODUCTION

Natural latex rubber gloves are used in general laboratory work for protection against various aqueous solutions of acids, alkalies and radioactive contaminants at the Savannah River Site. Gloves must conform to acceptable physical, chemical and mechanical requirements specified in Westinghouse Savannah River Company Manual 5Q1.11, Protective Clothing Specifications (See Tables 1 and 2). Gloves are also required to be capable of withstanding repeated washing and drying.

Rubber and rubber products must withstand tensile forces for adequate performance when used as glove material. Tensile strength in rubber refers to the force per unit of original cross section on elongation to rupture. Tensile characteristics are the most widely reported mechanical properties of any

material.⁽¹⁾ Properties which improve with tensile strength are wear and tear resistance, resilience, cut resistance, stress relaxation and creep. The tensile properties of rubber depend on both material and conditions of test, such as temperature, humidity, environment or mechanical pre-conditioning. ASTM- D412 is used to measure the tensile properties of elastomers. A "dumb-bell" shaped specimen is most often used with pneumatic grips that tighten automatically to prevent slipping as the specimen tabs thin under load. Gage lengths of 1 or 2 inches are defined by inked bench marks on the specimen.

Elongation, tension set and aging effects are also used to measure performance of rubber products. Elongation, the maximum extension of a rubber at the moment of rupture, is determined by measuring the separation of the gage marks with a rule held close to the specimen while loading. Tension set represents residual deformation which is partly recoverable after stretching and retraction. Aging is a deteriorative process which could be caused by sunlight, heat, stress with atmospheric ozone, atmospheric moisture or atmospheric nitrous oxide.

EXPERIMENTAL PROCEDURE

CHEMICAL RESISTANCE

Chemical resistance tests were performed on "as received" samples cut from gloves manufactured by Ansell Edmont with 1990 and 1992 dates stamped on the gloves. Two inch diameter samples were immersed in each of the following chemicals for 8 hours: 48% hydrofluoric acid, 50% nitric acid, 50% sulfuric acid, 37% hydrochloric acid and 50% sodium hydroxide.

MECHANICAL TESTING

Tensile properties were measured on dumb-bell shaped specimens stamped from gloves manufactured by Ansell Edmont and North Brothers Company per ASTM D-412. Minimum thickness measurements were recorded from glove palm, back and finger crotch areas per WSRC 5Q1.11. The North Brothers gloves were tested in the "un-washed" condition. The Ansell Edmont gloves, with both 1990 and 1992 manufacture dates, were tested in the "un-washed" condition and after laundering up to seven times. Tensile strength and ultimate elongation percent were measured on samples in the "as received" condition and after heat aging, immersion in either distilled water, sodium hydroxide, sulfuric acid or nitric acid. Acceptable glove characteristics, listed in the site specifications for protective clothing, are given in Table 2.

PERMEABILITY

The transmission of molecules through polymer films is named "permeability". The process of permeation in elastomers generally is one of solution of the gas molecules on one surface of the material, followed by diffusion through the elastomer to the other side. The amount of permeating species existing on the

reverse side of the membrane per unit time can be described by the steady state permeation of gases through polymers.⁽³⁾

Tritium oxide (HTO) is much more toxic than tritium (HT) and so presents a radiological hazard to workers. Tritium water vapor penetrates through a wide variety of rubbers and plastics. The use of protective gloves play a major role in reducing exposure to tritium. In some facilities where tritium is handled, the greatest occupational dose is received via the permeation of tritium oxide through protective material.⁽²⁾ When selecting materials for protective clothing against tritium or tritium oxide, permeability is a primary consideration.

Permeation rates through films can be measured by one of several methods depending on transmission principles. The most common methods involve measurement of pressure, volume and concentration related variables. The test procedure chosen for this work was ASTM Designation: E96-90, the water method. Normal water vapor data has been used to estimate tritium permeation rates since permeation rates of tritiated species are the same as that of protium species in polymers within experimental error.⁽³⁾

Four sets of samples were cut from smooth and textured areas of gloves from both manufacturers. The thickness of each specimen was measured in four places (center of each quadrant) and averaged. The diameter of each specimen was measured using a ruler, and each specimen was weighed on an analytical balance. Twelve of sixteen total test dishes were filled with water to within 1/4 inch of the specimens. The other four were used for control measurements. The sixteen specimens were attached to each of the test dishes, via a sealant impermeable to water, and the assembly weighed. The dishes were then place in an environmental chamber and weighed periodically. The test temperature and relative humidity in the test chamber were 28°C and 88% respectively.

The change in the quantity of water was plotted versus the change in the time to obtain a straight line (Figures 4 - 7). The slope from this line was multiplied by the measured specimen thickness and divided by the product of the specimen area times the vapor pressure difference across the film. The permeability coefficient is used to express the permeability of water vapor through natural latex rubber. It has the dimensions:

$$P = \frac{(\text{quantity of permeant}) \times (\text{film thickness})}{(\text{area}) \times (\text{time}) \times (\text{pressure drop across the film})}$$

The units found in the literature to express permeability and used in this study are:

$$P = \frac{\text{cm}^3 \text{ cm}}{\text{cm}^2 \text{ s Pa}}$$

Literature values for permeability of water vapor through natural rubber is

$$1720 \times 10^{-13} \frac{\text{cm}^3 \text{ cm}}{\text{cm}^2 \text{ s Pa}} \quad (4)$$

Permeability values for latex rubber gloves are not specified in Manual 5Q1.11, therefore permeability rates measured in this study were compared to literature values.

RESULTS

CHEMICAL ANALYSIS

Rubber gloves manufactured by Ansell Edmont were exposed to chemicals specified in WSRC Manual 5Q1.11, the Protective Clothing Specifications, with the following results:

- (1) Exposure to hydrofluoric acid, nitric acid and sulfuric acid produced no notable change in the physical appearance of the 1990 or 1992 glove material after 8 hours.
- (2) After exposure to hydrochloric acid for 2 hours the 1992 glove samples were starting to turn dark. However, they still retained most of their elasticity. After 8 hours exposure to hydrochloric acid, the 1990 and 1992 glove material was dark and brittle.
- (3) After only 2 hours of exposure to nitric acid, a noticeable loss in elastic properties could be seen in the 1992 samples. After 8 hours the 1990 and 1992 samples were extremely brittle.

MECHANICAL TESTING

Tensile measurements and elongation percent for gloves manufactured by Ansell Edmont and North Brothers are given in Tables 3 - 11 and Figures 1 - 3. Specimens from gloves manufactured by North Brothers, in the "unwashed" condition, were tested for ultimate tensile strength, ultimate elongation percent and tension set. All specimens complied with acceptable glove characteristics specified in WSRC Manual 5Q1.11 except tensile samples immersed in distilled water and heat aged (See Figure 1).

Specimens from gloves manufactured by Ansell Edmont, in the "unwashed" condition and after up to 7 wash-dry cycles, were tested for ultimate tensile strength, ultimate elongation percent and tension set. All 1990 and 1992 samples complied with the acceptable glove characteristics specified in the protective clothing specification. Although some tensile measurements after washing and exposure to nitric acid appeared erratic and were less than 1600 psi, tensile strength after exposure to nitric acid was not specified in the protective clothing specification. Therefore all glove samples complied with the required specifications.

PERMEATION

Permeability of water vapor through the gloves manufactured by North Brothers and Ansell Edmont are given in Tables 12 and 13. The values appear to be in the range of literature values for natural rubber. Permeability through samples from smooth areas of gloves were compared with samples from textured areas. "Dummy" samples versus real samples were also examined.

Statistical analysis of data from this report was performed using the statistical software "JMP"(5). 95% confidence curves show the correlation between two variables in the model. When no correlation between the variables exists the confidence curves do not intersect the horizontal line in the middle of the leverage plot. Borderline correlation occurs when the curves are asymptotic to the horizontal line, and correlation exists when the confidence curves intersect the horizontal line. The analysis was first used to determine whether permeation of water vapor through the glove material was dependent on the manufacturer. The analysis showed no correlation between manufacturer and permeation rates (See Figure 8). The analysis was then used to determine if the rate of transmission varied depending on the finish of the glove material. No correlation between smooth and textured samples was indicated (Figure 9). Finally, the analysis was used to determine if there was a difference in permeation rate between samples which initially had water in the test dishes and those which did not (dummy samples). The analysis showed that there is a correlation between "dummy" and real samples (see Figure 10).

DISCUSSION

The chemical composition of the gloves manufactured in 1990 and 1992 by Ansell Edmont appears to have been changed somewhat. In chemical tests, the 1992 glove samples began to show signs of deterioration after two hours of exposure to nitric and hydrochloric acids. The 1990 samples were generally unchanged at that point. Further support for the change in composition can be seen in the measured values for the ultimate tensile strength after exposure to nitric acid. Both the 1990 and 1992 samples exhibited a decrease, however the ultimate tensile strength in the 1992 was significantly lower than the 1990 samples (See Figures 1 and 2)

CONCLUSIONS

As a result of mechanical testing and permeation studies of latex rubber gloves manufactured by North Brothers and Ansell Edmont, the following conclusions are drawn:

- (1) Natural latex rubber gloves, "off the shelf", manufactured by North Brothers, complied with specified tensile requirements in the following conditions: as-received, and after exposure to sulfuric acid and after exposure to sodium hydroxide. Ultimate tensile strength after heat aging and after immersion in distilled water was slightly lower than the specification in Manual 5Q1.11 for protective clothing. All elongation percent samples complied with all specifications except the as-received samples.
- (2) Re-cycling latex rubber gloves, manufactured by Ansell Edmont, does not affect the acceptable glove characteristics specified in the protective clothing specifications.
- (3) Permeability of water vapor through gloves manufactured by North Brothers and Ansell Edmont are very similar and both are within the scope of literature values.

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TABLE 1
Chemical Resistance - Design Conditions

Chemical	Concentration	Min. Breakdown Time
Hydrofluoric acid	48%	8 Hours
Nitric acid	50%	8 Hours
Sulfuric acid	50%	8 Hours
Hydrochloric acid	37%	8 Hours
Sodium hydroxide	50%	8 Hours

TABLE 2
Acceptable Glove Characteristics

1	Tensile Strength, psi	
	Initial	4,500 Min.
	After Aging	4,000 Min.
	After immersion in Distilled Water	3,700 Min.
2	Ultimate Elongation, percent	
	Initial	800 Min.
	After Aging	700 Min.
	After immersion in Distilled Water	700 min.
3	Tension Set, percent	10.0 Max.
4	Thickness, mils	
	palm, back	18 mils
	finger crotch	16 mils

Table 3
Mechanical Properties of North Brothers Gloves

Test Group	Ultimate Tensile Strength, psi	Ultimate Elongation, percent
As Received	4716	760
Heat Aged	3749	700
Distilled Water	2952	742
HNO ₃	4145	750
H ₂ SO ₄	3865	708
NaOH	4220	742

Values for ultimate tensile strength and ultimate elongation are average values from three test samples.

Total tensile set gage length percent was 2%, 3% and 3% from three "as received" samples.

Table 4
Mechanical Properties from Ansell Edmont Gloves

(Un-washed)

Test Group	Ultimate Tensile Strength, psi 1990	Ultimate Tensile Strength, psi 1992	Ultimate Elongation, percent 1990	Ultimate Elongation, percent 1992
As Received	5355	5639	821	813
Heat aged	4769	4582	721	725
Distilled water	3162	3341	742	708
HNO ₃	3033	2635	638	758
H ₂ SO ₄	5651	5591	852	850
NaOH	5829	5051	846	783

Values for ultimate tensile strength and ultimate elongation are average values from three test samples.

Table 5
Mechanical Properties from Ansell Edmont Gloves

After 1 wash-dry cycle

Test Group	Ultimate Tensile Strength, psi 1990	Ultimate Tensile Strength, psi 1992	Ultimate Elongation, percent 1990	Ultimate Elongation, percent 1992
As Received	5532	5276	813	788
Heat aged	4735	3427	746	737
Distilled water	3886	3215	758	708
HNO ₃	1835	591	717	433
H ₂ SO ₄	5495	5486	829	817
NaOH	5820	4159	804	754

Table 6
Mechanical Properties from Ansell Edmont Gloves

After 2 wash-dry cycles

Test Group	Ultimate Tensile Strength, psi 1990	Ultimate Tensile Strength, psi 1992	Ultimate Elongation, percent 1990	Ultimate Elongation, percent 1992
As Received	5652	5509	808	813
Heat aged	4910	4437	783	763
Distilled water	3719	3721	752	754
HNO ₃	4215	209	850	417
H ₂ SO ₄	5735	4949	842	767
NaOH	5473	4968	850	765

Values for ultimate tensile strength and ultimate elongation are average values from three test samples.

Table 7
Mechanical Properties from Ansell Edmont Gloves

After 3 wash-dry cycles

Test Group	Ultimate Tensile Strength, psi 1990	Ultimate Tensile Strength, psi 1992	Ultimate Elongation, percent, 1990	Ultimate Elongation, percent, 1992
As Received	5682	5203	796	786
Heat aged	5165	4263	829	746
Distilled water	4301	4026	802	777
HNO ₃	2985	2565	740	633
H ₂ SO ₄	5453	4862	796	802
NaOH	5532	4794	827	783

Table 8
Mechanical Properties from Ansell Edmont Gloves

After 4 wash-dry cycles

Test Group	Ultimate Tensile Strength, psi 1990	Ultimate Tensile Strength, psi 1992	Ultimate Elongation, percent, 1990	Ultimate Elongation, percent, 1992
As Received	5185	5129	798	767
Heat aged	4432	4542	792	794
Distilled water	4243	4119	804	767
HNO ₃	5129	3089	831	633
H ₂ SO ₄	5233	4777	792	781
NaOH	5293	5100	775	765

Values for ultimate tensile strength and ultimate elongation are average values from three test samples.

Table 9
Mechanical Properties from Ansell Edmont Gloves

After 5 wash-dry cycles

Test Group	Ultimate Tensile Strength, psi 1990	Ultimate Tensile Strength, psi 1992	Ultimate Elongation, percent 1990	Ultimate Elongation, percent 1992
As Received	5363	4733	775	742
Heat aged	4921	4332	792	708
Distilled water	3878	3889	767	696
HNO ₃	3759	965	783	483
H ₂ SO ₄	5441	5468	779	775
NaOH	5229	5512	771	792

Table 10
Mechanical Properties from Ansell Edmont Gloves

After 6 wash-dry cycles

Test Group	Ultimate Tensile Strength, psi 1990	Ultimate Tensile Strength, psi 1992	Ultimate Elongation, percent 1990	Ultimate Elongation, percent 1992
As Received	5228	5282	783	767
Heat aged	4286	3810	742	746
Distilled water	3979	3623	752	704
HNO ₃	4967	1052	858	483
H ₂ SO ₄	5569	5143	825	800
NaOH	5435	4729	817	746

Values for ultimate tensile strength and ultimate elongation are average values from three test samples.

Table 11
Mechanical Properties from Ansell Edmont Gloves

After 7 wash-dry cycles

Test Group	Ultimate Tensile Strength, psi 1990	Ultimate Tensile Strength, psi 1992	Ultimate Elongation, percent 1990	Ultimate Elongation, percent 1992
As Received	5477	4906	808	758
Heat aged	4450	3839	717	733
Distilled water	3649	3834	758	750
HNO ₃	3862	2487	800	725
H ₂ SO ₄	4548	4938	767	775
NaOH	5446	4965	808	788

Table 12

Permeability Data for Ansell Edmont Gloves

Specimen number	Finish	Permeability $\frac{\text{cm}^3 \cdot \text{cm}}{\text{cm}^2 \cdot \text{s} \cdot \text{Pa}}$
1	rough	2052.16×10^{-13}
2	rough	3234.60×10^{-13}
3	rough	2760.26×10^{-13}
4	rough	dummy
5	smooth	1570.93×10^{-13}
6	smooth	1664.03×10^{-13}
7	smooth	4510.50×10^{-13}
8	smooth	dummy

Table 13

Permeability Data for North Brothers Gloves

Specimen number	Finish	Permeability $\frac{\text{cm}^3 \cdot \text{cm}}{\text{cm}^2 \cdot \text{s} \cdot \text{Pa}}$
9	rough	9411.1×10^{-13}
10	rough	3349.0×10^{-13}
11	rough	8163.2×10^{-13}
12	rough	dummy
13	smooth	676.12×10^{-13}
14	smooth	4737.9×10^{-13}
15	smooth	7694.8×10^{-13}
16	smooth	dummy

Figure 1. Ultimate tensile strength and elongation percent for North Brothers Gloves.

Figure 2. Ultimate tensile strength and elongation percent for Ansell Edmont Gloves manufactured in 1990.

Figure 3. Ultimate tensile strength and elongation percent for Ansell Edmont gloves manufactured in 1992.

Figure 4. Ansell Edmont Glove Samples: Change in quantity of water versus the change in time. Specimens 1-3 are real samples and Specimen 4 is a "dummy" sample.

Figure 5. Ansell Edmont Glove Samples: Change in quantity of water versus the change in time. Specimens in 5-7 are real and 8 is the "dummy" sample.

Figure 6. North Brothers glove samples: change in quantity versus the change in time. Specimens 9 - 11 are real samples and specimen 12 is the "dummy"

Figure 7. North Brothers glove samples: change in quantity versus the change in time. Specimens 13 - 15 are real samples and specimen 16 is the "dummy" sample

Effect Test			
Sum of Squares	F Ratio	DF	Prob > F
0.00001334	1.2310	1	0.2889

Least Squares Means			
Level	Least Sq Mean	Std Error	Mean
Edmund	-.001622944	0.0012571182	-.002889
North	-.0034492174	0.0012571182	-.004715

Figure 8 Linear fit of permeability to manufacturer. Lack of intersection of the 95% confidence curve with the horizontal line indicates no correlation exists between permeability and the manufacturer. Also, F statistic indicates that 29% of the time the results would occur by random chance.

Effect Test			
Sum of Squares	F Ratio	DF	Prob > F
0.00002142	1.9767	1	0.1851

Least Squares Means			
Level	Least Sq Mean	Std Error	Mean
Smooth	-.0013790274	0.0012571182	-.002645
Textured	-.0036931844	0.0012571182	-.004939

Figure 9. Linear fit of permeability to glove finish. Lack of intersection of the 95% confidence curve with the horizontal line indicates no correlation exists between permeability and the finish of the glove material. Also, F statistic indicates that 19% of the time the results would occur by random chance.

Effect Test			
Sum of Squares	F Ratio	DF	Prob > F
0.00007693	7.0991	1	0.0206

Least Squares Means			
Level	Least Sq Mean	Std Error	Mean
Dummy	-.0000041285	0.0016459540	-.000004
Sample	-.0050680833	0.0009502920	-.005068

Type denotes whether the sample is a dummy sample or a real sample

Figure 10. Linear fit of permeability to sample type. The intersection of the 95% confidence curve with the horizontal line indicates that a correlation exists between permeability and whether the sample is real or a "dummy". Also, F statistic indicates that 2% of the time the results would occur by random chance.

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