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Contamination of Critical Surfaces from NVR Glove Residues Via Dry Handling and Solvent Cleaning

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Contamination of Critical Surfaces from NVR Glove Residues Via Dry Handling and Solvent Cleaning

Abstract

Gloves are often used to prevent the contamination of critical surfaces during handling. The type of glove chosen for use should be the glove that produces the least amount of non-volatile residue (NVR). This paper covers the analysis of polyethylene, nitrile, latex, vinyl, and polyurethane gloves using the contact transfer and gravimetric determination methods covered in the NASA GSFC work instruction "Gravimetric Determination and Contact Transfer of Non-volatile Residue (NVR) in Cleanroom Glove Samples," 541-WI-5330.1.21 and in the ASTM Standard E-1731M-95, "Standard Test Method for Gravimetric Determination of Non-Volatile Residue from Cleanroom Gloves." The tests performed focus on contamination of critical surfaces at the molecular level. The study found that for the most part, all of the gloves performed equally well in the contact transfer testing. However, the polyethylene gloves performed the best in the gravimetric determination testing, and therefore should be used whenever solvent contact is a possibility. The nitrile gloves may be used as a substitute for latex gloves when latex sensitivity is an issue. The use of vinyl gloves should be avoided, especially if solvent contact is a possibility. A glove database will be established by Goddard Space Flight Center (GSFC) Code 541 to compile the results from future testing of new gloves and different glove lots.

Introduction

Contamination can be an issue when working on both flight and non-flight hardware. During handling of critical surfaces, gloves are worn to prevent both the introduction and the spread of contamination. Situations requiring the use of gloves are varied, but include surface preparations, cleanroom operations, component assembly, and the cleaning of parts.

Although gloves are worn to prevent contamination, they can also become a source of contamination if the proper precautions are not taken. Gloves can be the source of non-volatile residue, or NVR, which is defined as a molecular organic species that is non-volatile at standard temperature and pressure, but becomes volatile in vacuum.

The NVR can be transferred from the surface of the glove to the critical surface in one of two ways. The first is through dry handling, or simple contact between the glove and the critical surface. The second method of transfer is solvent contact, in which a solvent comes in contact with the glove and then comes in contact with the critical surface, transferring the contamination from the glove to the surface.

The presence of the NVR on the critical surface is detrimental in many ways. The NVR can interfere with bond strength, preventing the adhesive from bonding to both surfaces optimally. This could ultimately lead to failure of the adhesive joint. The NVR can also contaminate optics, degrading the performance of the optical hardware. Finally, the presence of NVR on a critical surface can lead to cross contamination of a clean surface during thermal vacuum exposure or when it reaches orbit.

Glove choice can be influenced by a number of factors, most prominently by the type of fit required and whether any special properties are required. Contamination risk should also be a deciding factor because of the problems that non-volatile residue can cause. It is important to make sure that the gloves chosen for use have a low NVR value. The most commonly used gloves at Goddard Space Flight Center (GSFC) are polyethylene, nitrile, and latex, and the study therefore centered on these types of gloves.

This paper covers the analysis of two brands of polyethylene gloves, seven brands of nitrile gloves, four brands of latex gloves, one brand of vinyl glove, and one brand of polyurethane glove. The test data was compiled to determine which type of glove had the lowest overall NVR. In addition, data previously gathered for some of the tested gloves was analyzed to determine the lot-to-lot variation.

Experimental

The type of gloves tested, the method used to test the gloves, and the equipment used to conduct the study are all important facets of the study.

Gloves

As stated previously, polyethylene, nitrile, latex, vinyl, and polyurethane gloves were tested. Each of the fifteen gloves was given an alpha-numeric designation: the vinyl glove was given V; the latex gloves were designated as L1-L4; the nitrile gloves as N1-N7; the polyethylene as P1 and P2; and the polyurethane glove was designated as PU.

The most popular gloves used at GSFC are polyethylene, nitrile, and latex, though occasionally other types of gloves are used. The cleanrooms at GSFC use latex gloves, though nitrile gloves are also available for use. Vinyl gloves are occasionally used, though in actuality, they should be avoided as they contain dioctyl phthalate (DOP), which can cause significant contamination issues. As the study demonstrates, the amount of NVR released by vinyl gloves is significant, especially when compared to the amount of NVR produced by the polyethylene and nitrile gloves.

Latex sensitivity may be an issue for some individuals who are repeatedly exposed to latex products and may develop an allergic reaction to the latex. The latex sensitivity often will cause dry and raw skin in the area that comes in contact with the latex, and if the case is severe, the allergic reaction may cause dermatitis and blisters. For this reason, many individuals prefer to use nitrile gloves as a latex free alternative. The nitrile gloves are form fitting like the latex gloves, but since they contain no natural rubber latex, latex sensitivity is no longer an issue.

Polyethylene gloves are another popular alternative to latex gloves. However, there is one significant drawback to the polyethylene gloves: they are not fitted like the latex and nitrile gloves, and are therefore much more bulky to wear. The bulkiness of the gloves makes it difficult to perform operations requiring precision while wearing them, and for that reason many individuals prefer the nitrile gloves.

Test Method

Each of the gloves were tested following the methods set forth in "Gravimetric Determination and Contact Transfer of Non-volatile Residue (NVR) in Cleanroom Glove Samples," 541-WI-5330.1.21. This work instruction is based on ASTM E-1731M-95, "Standard Test Method for Gravimetric Determination of Non-Volatile Residue from Cleanroom Gloves." The main difference between the work instruction and the ASTM standard is that the work instruction calls for the use of the RapidVap® in place of evaporation in a fume hood. This change decreases the specimen preparation from 3-5 days down to 1-2 days. The use of the RapidVap® in place of hood evaporation was researched before implementation, and it was found that the difference in results is insignificant.

Although the contact transfer and gravimetric determination methods are used to estimate NVR values for dry handling and solvent contact, it should be noted that the conditions the gloves are exposed to during the tests are harsher than the conditions which would be seen during general lab use. In most cases, general lab use would not involve immersion and exposure to a solvent for the time required to conduct the test. In addition, the amount of pressure required in the contact transfer test is much more than would be seen during general use. However, following the work instruction provides a uniform test for the comparison of the amount of NVR produced by different types of gloves. In addition, it allows the data gathered to be compared with data collected by outside sources that followed the ASTM standard, and allows guidelines to be set to determine the existence of lot-to-lot variation.

Contact Transfer Test Using the guidelines set forth, each of the gloves was tested in two ways. The first test is contact transfer, which correlates to dry handling. Before conducting the contact transfer testing, it is important to first clean and verify the steel witness plates that will be used during the test. Each of the plates is rinsed front and back with isopropyl alcohol (IPA) and allowed to dry. The plates are then rinsed front and back with chloroform and allowed to dry. These two steps are repeated twice for a total of three rinses with the IPA and chloroform. After cleaning, a rinse sample of each plate is evaporated to measure the amount of residue on the plate, and the residue is analyzed with a Fourier Transform Infrared Spectrophotometer (FTIR) to determine the composition of the remaining residue. If the residue weighs less than or equal to 0.2mg and the IR shows a %T of $\geq$99% in the mid-IR region (4000-400cm^{-1}), the plate is verified as clean.

The contact transfer test involves turning the glove to be tested inside-out and inserting a steel witness plate inside the glove. The gloves to be tested are then wrapped in foil and placed in the hydraulic press. A weight of 1,000kg, equivalent to 960kPa or 139psi of pressure, was applied for 90 minutes. At the conclusion of the 90 minutes, the plates were removed from the gloves and rinsed into pre-weighed aluminum pans and evaporated. A blank was also run with each set of gloves to make sure no contamination was present in the rinse solvent. The evaporated dishes were then weighed to determine the amount of residue and ultimately the amount of NVR. Three trials were performed for each glove, and the results were averaged to find the mean and standard deviation.

Gravimetric Determination Test The second test conducted is gravimetric determination, which correlates to solvent contact. All of the gloves were tested using isopropyl alcohol. Some of the gloves had also been tested using ethyl alcohol and acetone; this data has been included when available. The isopropyl alcohol, ethyl alcohol, and acetone were used for the gravimetric determination testing because these three solvents are commonly used for cleaning at Goddard Space Flight Center.

To perform the gravimetric determination test, two 5cmx5cm pieces are cut from the center of an unworn glove, taking care not to use any part of the glove from the fingers or cuff. The area of each piece was measured with a ruler and recorded for use in the final calculations. The glove pieces are then placed in a 500ml beaker with 300ml of solvent. A 300ml solvent blank is run with each set of gloves to ensure that there is no contamination from the solvent itself. The beakers are then placed in an ultrasonic bath and agitated for 15 minutes at 35°C. After 15 minutes the beakers are removed from the bath and the glove pieces are removed from the solvent and discarded. The solvent from each beaker is transferred to 600ml RapidVap®* beakers. The samples are then run in the RapidVap® until approximately 10ml of solvent remains. The remaining solvent is transferred to the corresponding pre-weighed aluminum pan and evaporated. The pans are reweighed to obtain a post weight and determine the amount of residue and ultimately the amount of NVR. Three trials were run for each glove, and the resulting numbers were averaged to give a mean and standard deviation.

Equipment

Three different pieces of equipment were used to conduct this study. The first is an ultrasonic bath, which was used to agitate the gravimetric determination samples for 15 minutes at a temperature of 35°C, in accordance with "Gravimetric Determination and Contact Transfer of Non-volatile Residue (NVR) in Cleanroom Glove Samples," 541-WI-5330.1.21. The second piece of equipment used in this study is a Labconco RapidVap®, which was used to evaporate the gravimetric determination samples from 300ml to ~10ml in accordance

* The RapidVap® is manufactured by Labconco, Kansas City, MO.

with 541-WI-5330.1.21. The third piece of equipment is an Ohaus Analytical Standard Balance, accurate to 0.0001g, which was used to weigh all of the sample pans for both test methods.

Data

In order to analyze the results of the contact transfer and gravimetric determination tests, the amount of non-volatile residue needed to be calculated. To calculate the amount of NVR produced, the following calculation was used:

NVR=Total amount of NVR ($\mu g/cm^2$)
S_a= Adjusted sample weight (mg)
A=Witness Plate area (cm^2)

$$NVR = \frac{S_a}{A} \times \frac{10^3 \mu g}{1mg}$$

The adjusted sample weight (S_a) was determined by correcting the weight of the sample for the difference between the initial and final blank weights. The resultant NVR value was given in $\mu g/cm^2$, and was then used to measure the performance of the gloves.

Analysis

The data from this study was analyzed in two ways. First, by comparing the results of all the gloves, thereby allowing the selection of the best overall gloves. Secondly, the data obtained during this study was compared to data compiled during previous testing, giving a comparison of the same gloves with a different lot number. This made it possible to make some observations about the existence of lot-to-lot variation.

Amount of NVR

The glove data was analyzed to determine which glove had the least amount of NVR for both the contact transfer test and the gravimetric determination test. A table summarizing the NVR data for the gloves can be found in the Appendix (Table 1), in addition to plots showing the relationship between the NVR values of all of the gloves (Figures 1-4).

Contact Transfer All of the gloves had an NVR of <$3\mu g/cm^2$ and would be appropriate for dry handling use. The gloves with the least amount of residue were P1, N3, N4, N2, L3, and L4. These gloves all had an NVR of $\leq 0.5\mu g/cm^2$, though it should be noted that $0.5\mu g/cm^2$ is near the detection limits for this test.

Gravimetric Determination For work involving solvent contact, polyethylene gloves should be the first choice. The P1 and P2 gloves both had an NVR $\leq 6\mu g/cm^2$ in isopropyl alcohol, an NVR of less than $4\mu g/cm^2$ in ethyl alcohol, and an NVR of less than $6\mu g/cm^2$ in acetone. The NVR values for the polyethylene gloves was much less than the value found for other gloves in all three solvents.

If polyethylene gloves are not an option, the second choice should be a nitrile glove, which generally perform better than latex gloves in isopropyl alcohol and ethyl alcohol. However, the nitrile gloves do not perform as well as the latex gloves in acetone: the N3 gloves had an NVR of $234\mu g/cm^2$, as opposed to the $180\mu g/cm^2$ and $210\mu g/cm^2$ seen with the latex gloves. The N5 and N6 nitrile gloves both performed the worst out of all fifteen tested gloves. The N5 and N6 gloves had an NVR of $261\mu g/cm^2$ and $309\mu g/cm^2$ in isopropyl alcohol, respectively; an NVR of more than $300\mu g/cm^2$ in ethyl alcohol; and an NVR of more than $500\mu g/cm^2$ of residue in acetone.

However, it should be noted that the N5 and N6 nitrile gloves have an interior coating, which most likely distorted the data. The N5 gloves have a vegetable starch powdered interior coating and the N6 gloves have a polymer gel coating on the interior surface. Because the test method calls for exposure of both the interior and exterior of the glove, the interior coating on these gloves was most likely extracted along with the NVR from the exterior surface. This situation illustrates the earlier point: that this test method is more aggressive than general lab exposure, and is thus inappropriate, especially for the testing of gloves with a coated interior. A modified test method for coated gloves that would eliminate the exposure of the interior side of the glove would allow the inclusion of coated gloves in the comparison.

The polyurethane glove (PU) had an NVR of 26μg/cm^2 in the isopropyl alcohol., performing as well as the nitrile gloves. This type of glove would possibly work as an alternative to the polyethylene or nitrile gloves.

Latex gloves should be avoided if at all possible, as none of the latex gloves achieved NVR values below 95μg/cm^2 when isopropyl alcohol was used and none was below 125μg/cm^2 when ethyl alcohol was the solvent. The latex gloves did perform better with the acetone than the nitrile glove that was tested, with an NVR of 180μg/cm^2 and 210μg/cm^2, while the nitrile glove (N3) had an NVR of 234μg/cm^2. Acetone should be avoided as a solvent due to its aggressive nature. If it must be used, extreme care should be taken to avoid contact between the gloves and the solvent.

The V vinyl gloves performed the worst in the isopropyl alcohol gravimetric determination test out of all fifteen tested gloves, with an NVR of 3,616μg/cm^2. Vinyl gloves contain dioctyl phthalate (DOP), which can cause significant contamination issues. Vinyl gloves should never be used, and should especially be avoided during solvent cleaning, as the results of the gravimetric determination test illustrated. The risk of contamination from the use of vinyl gloves is discussed in GSFC Code 541 Material TIP #005: "Plasticizer Contamination from Polyvinyl Chloride" (June 1977).

Lot-to-Lot Comparison

The presence of a variation in the NVR from one lot to another is an indication that there has possibly been a change in the production process or that there is a lack of control over the process. The change can be either an increase or a decrease. Overall, a lot-to-lot comparison shows the consistency and reliability of the glove in question. The lot-to-lot comparison was done for the contact transfer method and the isopropyl alcohol gravimetric determination method. A table summarizing the lot-to-lot comparison can be found in the Appendix (Table 2). Plots showing how the NVR values for the gloves vary from one lot to another are also located in the Appendix (Figures 5 and 6).

For dry handling, several of the gloves that were discussed in previous sections of this memo as being the best for dry handling were also the gloves that had the most variation from lot-to-lot. In addition, in some cases the gloves with the least amount of variation from one lot to another in the contact transfer test were not the gloves that were cited in the Analysis section as being the best for use. However, it is important to note that for the lot-to-lot comparison there are only two data points: an initial test value and a second test value. Therefore, further testing could provide more information on the typical amount of variation for the gloves.

For solvent contact with isopropyl alcohol, the polyethylene gloves and the nitrile gloves had the least amount of variation from lot-to-lot. These same gloves were recommended for solvent cleaning. The N5 and N6 nitrile gloves had the most variation from lot-to-lot, most likely due to the presence of the interior coating. As with the dry handling results, the results for solvent contact indicate the need for monitoring the NVR levels of gloves from lot-to-lot.

Summary

Analysis of the results found that for dry handling, the polyethylene gloves, the nitrile gloves, and the latex gloves performed equally well. Any of these gloves would be a good first choice, depending on the situation and application. Nitrile gloves are also a suitable substitute for latex gloves if latex sensitivity is an issue.

For solvent contact, polyethylene gloves were found to have the least amount of extractable residue in all solvents, and they also have a minimal lot-to-lot variation. The nitrile gloves were second only to the polyethylene gloves in the isopropyl alcohol and ethyl alcohol. They are a suitable replacement for the latex gloves in any of the solvents. The latex gloves had higher NVR amounts compared to the nitrile gloves, but they may be used if required. If the latex gloves are used, any contact with acetone should be avoided. The polyurethane gloves may be used on a case-by-case basis, as the set that was tested in isopropyl alcohol was found to have an NVR level comparable to that found with nitrile gloves. Vinyl gloves should never be used, and should especially be avoided during solvent cleaning. The N5 and N6 nitrile gloves had the highest NVR in all solvents, but the data for these gloves is most likely skewed by the interior coating. An alternative test method for solvent contact analysis of coated gloves should eliminate the exposure of the interior of the glove to solvent, and would alleviate the problem of skewed NVR data.

Conclusions and Recommendations

1. All of the gloves performed comparably in the contact transfer testing, and though the use of a polyethylene glove is recommended, a suitable nitrile or latex glove could be used on a case-by-case basis.

2. The polyethylene gloves performed the best in both the contact transfer testing and the gravimetric determination testing and should be used whenever solvent contact is a possibility.

3. Nitrile gloves may be used as a substitute for latex gloves when latex sensitivity is an issue.

4. The "Standard Test Method for Gravimetric Determination of Non-Volatile Residue from Cleanroom Gloves," ASTM Standard E-1731M-95 provides a baseline for the comparison of the performance of most gloves.

5. Further testing should be performed on gloves to determine the extent of lot-to-lot variation.

6. A test method should be developed to test gloves with an interior coating in order to eliminate the possibility of the coating skewing the gravimetric determination test results.

7. Vinyl gloves should never be used and should especially be avoided during solvent cleaning. Vinyl gloves contain dioctyl phthalate (DOP), which can cause significant contamination issues.

8. Glove database will be created and maintained by Code 541.

References

1. American Society for Testing and Materials. (1997). Standard Test Method for Gravimetric Determination of Non-Volatile Residue from Cleanroom Gloves (ASTM E-1731M-95).

2. Goddard Space Flight Center/ Materials Control & Applications Branch. (1977). Plasticizer Contamination from Polyvinyl Chloride (Material TIP #005).

3. National Aeronautics and Space Administration/ Goddard Space Flight Center. (2002). Gravimetric Determination and Contact Transfer of Non-volatile Residue (NVR) in Cleanroom Glove Samples (NASA GSFC Work Instruction 541-WI-5330.1.21).

Appendix

Glove Data

Amount of NVR

Table 1. Summary of Data for the Least Amount of NVR

Chart I.D.	Additional Information	Type of Glove	NVR (ug/cm^2) Contact Transfer	IPA	Acetone	Ethanol
V		Vinyl	2.6	3616	-----	-----
L1		Latex	-----	96	-----	-----
L2		Latex	0.7	120	-----	-----
L3	Powder free	Latex	0.5	112	211	130
L4		Latex	0.5	208	181	179
N1	Class 10	Nitrile	0.9	31	-----	-----
N2	Class 100	Nitrile	0.4	14	-----	-----
N3		Nitrile	0.3	31	234	106
N4		Nitrile	0.4	60	-----	-----
N5	Contains a vegetable starch powdere on interior of glove	Nitrile	1.5	261	505	319
N6	Contains a polymer gel coating on interior of glove	Nitrile	1.8	309	539	339
N7	Class 10	Nitrile	0.7	15	-----	-----
P1		Polyethylene	0.3	6	6	3
P2		Polyethylene	1.1	6	4	4
PU		Polyurethane	0.7	26	-----	-----

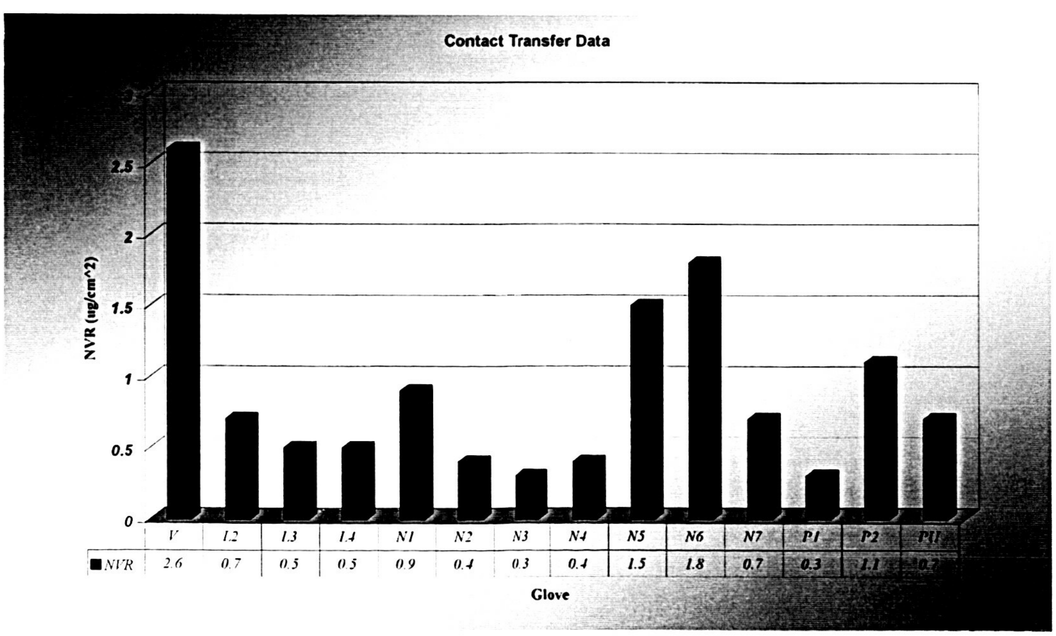

Figure 1. The relative amounts of NVR ($\mu g/cm^2$) found through contact transfer testing.

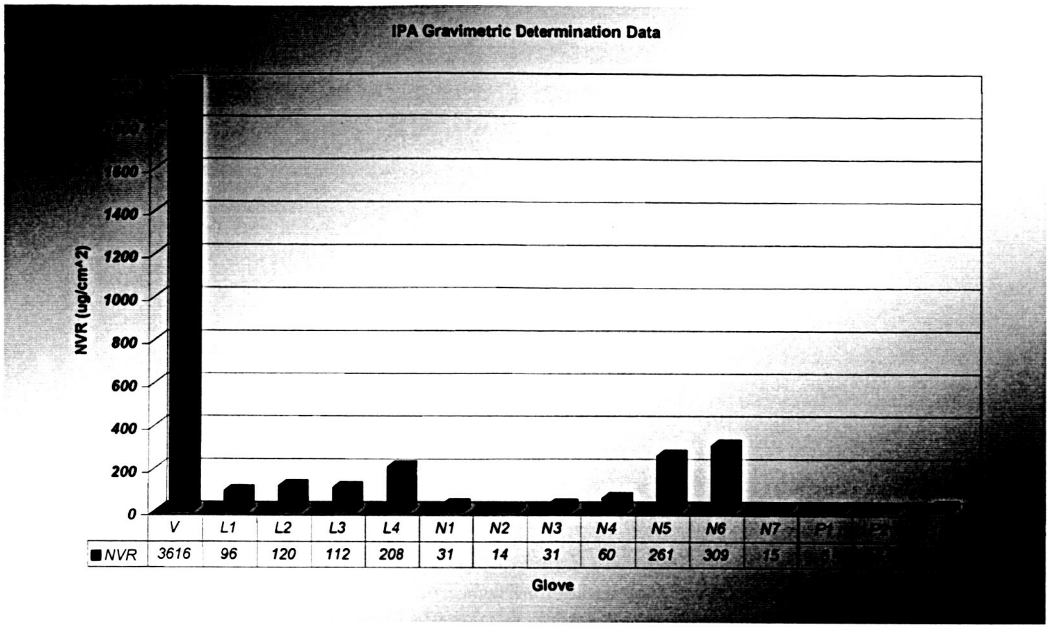

Figure 2. The relative amounts of NVR ($\mu g/cm^2$) found through gravimetric determination with isopropyl alcohol.

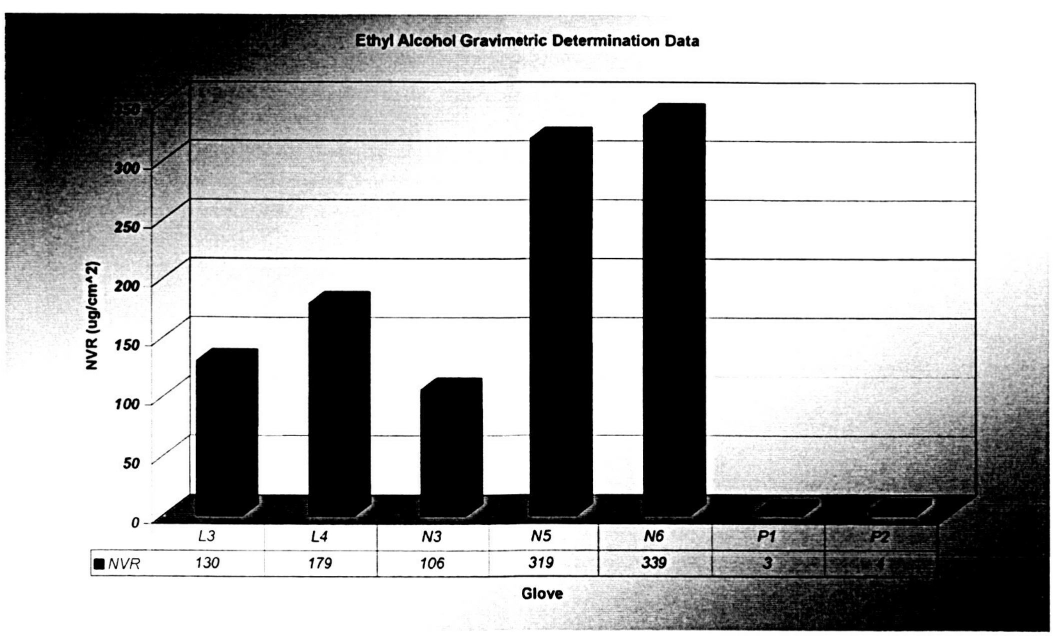

Figure 3. The relative amounts of NVR ($\mu g/cm^2$) found through gravimetric determination with ethyl alcohol.

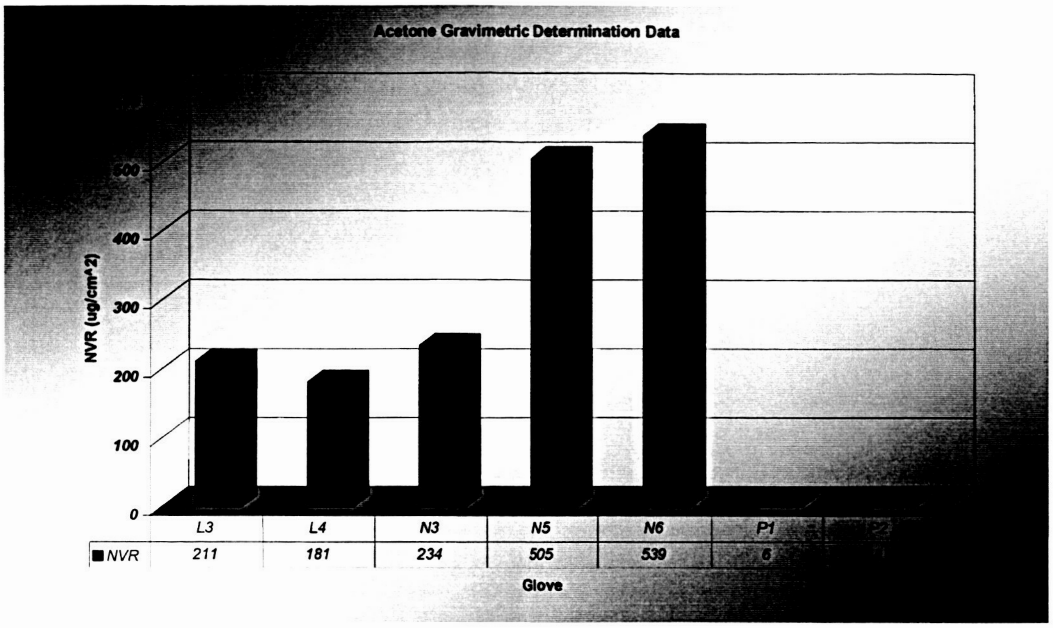

Figure 4. The relative amounts of NVR ($\mu g/cm^2$) found through gravimetric determination with acetone.

Lot-to-Lot Variation

Table 2. Summary of Data for Lot-to-Lot Variation

Chart I.D.	Additional Information	Type of Glove	Gravimetric Determination (ug/cm^2)		Contact Transfer (ug/cm^2)	
			Initial Test	Second Test	Initial Test	Second Test
L3		Latex	199	112	1.8	0.5
L4		Latex	281	208	1.7	0.5
N1	Class 10	Nitrile	10	31	0.7	0.9
N2	Class 100	Nitrile	20	14	1.0	0.4
N3		Nitrile	6	31	1.5	0.3
N5	Contains a vegetable starch powdere on interior of glove	Nitrile	9962	261	1.0	1.5
N6	Contains a polymer gel coating on interior of glove	Nitrile	3667	309	0.8	1.8
N7		Nitrile	37	15	0.2	0.7
P1		Polyethylene	7	6	2.7	0.3
P2		Polyethylene	5	6	0.5	1.1

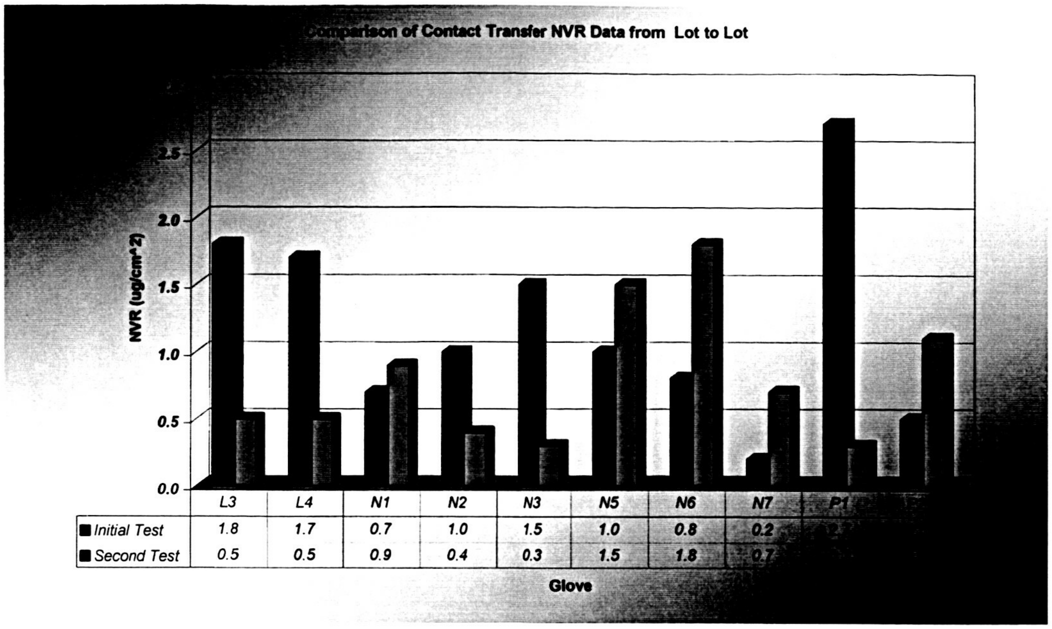

Figure 5. Lot-to-lot variation for gloves tested with contact transfer.

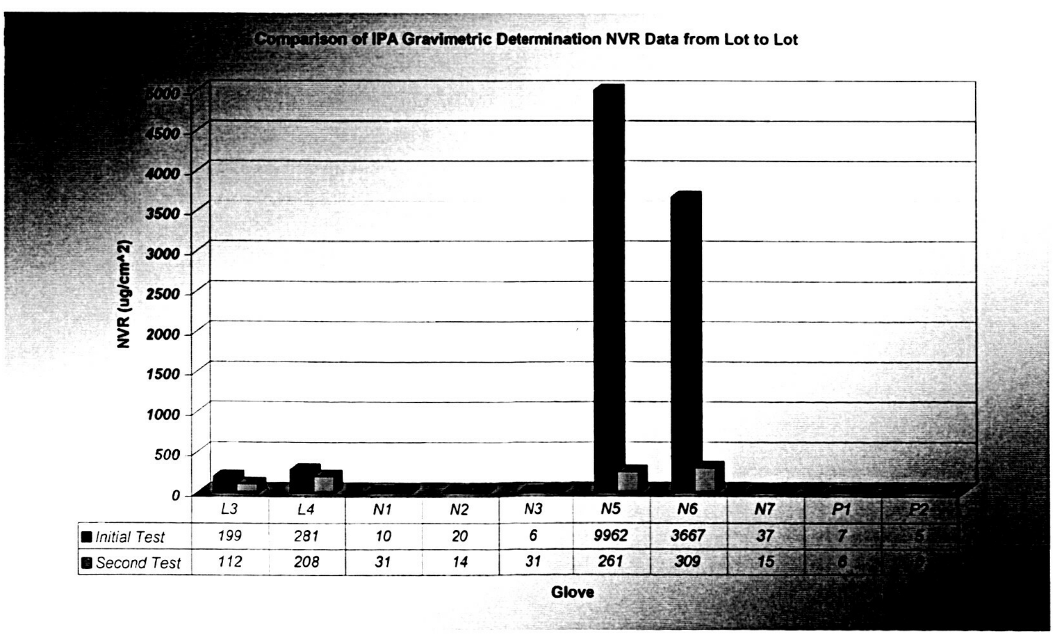

Figure 6. Lot-to-lot variation for gloves tested with gravimetric determination in isopropyl alcohol.

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13. ABSTRACT *(Maximum 200 words)*

Gloves are often used to prevent the contamination of critical surfaces during handling. The type of glove chosen for use should be the glove that produces the least amount of non-volatile residue (NVR). This paper covers the analysis of polyethylene, nitrile, latex, vinyl, and polyurethane gloves using the contact transfer and gravimetric determination methods covered in the NASA GSFC work instruction "Gravimetric Determination and Contact Transfer of NVR in Cleanroom Glove Samples," 541-WI-5330.1.21 and in the ASTM Standard E-1731M-95, "Standard Test Method for Gravimetric Determination of Non-Volatile Residue from Cleanroom Gloves." The tests performed focus on contamination of critical surfaces at the molecular level. The study found that for the most part, all of the gloves performed equally well in the contact transfer testing. However, the polyethylene gloves performed the best in the gravimetric determination testing, and therefore should be used whenever solvent contact is a possibility. The nitrile gloves may be used as a substitute for latex gloves when latex sensitivity is an issue. The use of vinyl gloves should be avoided, especially if solvent contact is a possibility. A glove database will be established by Goddard Space Flight Center (GSFC) Code 541 to compile the results from future testing of new gloves and different glove lots.

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