Quantifying Non-Volatile Residue Foil Removal Error

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Professional Readiness Engineering Program - Level One

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Problem Definition

Background:

- Non-Volatile residue (NVR) can cause hardware to fail
  - Degrade optics and sensors
  - Change thermal properties
  - Cause mechanical failures
- NVR sensitivity increases with more challenging missions

Problem: error bars for NVR sample results can be large, especially for small surface areas

Significance: Project cleaning costs increase due to precautionary cleanings

Goal: Quantify and reduce the error associated with NVR foil processing to improve the accuracy of reported results and decrease mission cleaning costs

Contamination Background

Particulate: deposits of visible, µm-sized conglomerates of matter

- Tapelifts
- Particle Fallout Wafers
- Particle Counters

Molecular: build up of individual molecules of foreign matter

- NVR Deposition Monitors
- NVR Plates or Foils

[1] L. Hahn "Mechanical Advice: Windshield has a Hazy Film"

Problem Definition Cont.

ASTM Standard for Gravimetric Determination of NVR includes multiple methods and recommends implementing a quality control program

Previous Studies:

1. 1996 SSDIF NVR Plate Evaluation
   - Scattered NVR mass vs. exposure time data
   - No correlation between NVR and Surface Acoustic Wave or Temperature-controlled Quartz Crystal Microbalance (TQCM) instruments
2. SSDIF Follow-on Experiment
   - Filtration of collected solvent unnecessary
   - Chance for error in each step of process, historical ±0.1mg accuracy assumption may not be true
   - NVR plate and TQCM discrepancies still unexplained

Trial	Mass Applied	NVR Removed	Delta
1	0.5 mg	0.7 mg	+ 0.2 mg
2	1.3 mg	1.3 mg	+ 0.0 mg
3	1.5 mg	1.6 mg	+ 0.1 mg
4	2.1 mg	2.2 mg	+ 0.1 mg
5	0.8 mg	0.7 mg	- 0.1 mg

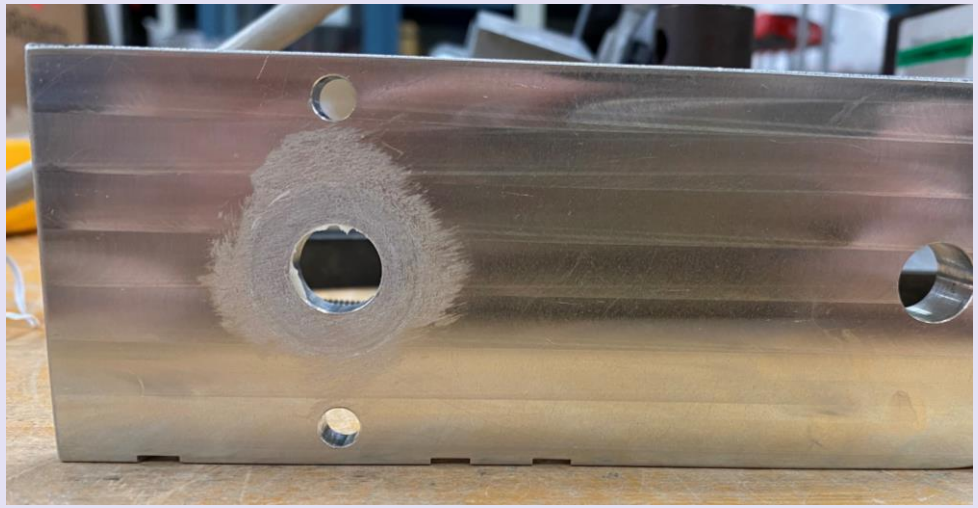
Trial	Processing Batch	Exposure	Mass
1	Group One	32 days	0.4 mg/ft^2
2	Group One	32 days	0.2 mg/ft^2
3	Group Two	53 days	0.4 mg/ft^2
4	Group Two	28 days	0.4 mg/ft^2
5	Group Three	88 days	0.9 mg/ft^2
6	Group Three	63 days	0.4 mg/ft^2

Table 1. Data collected in the SSDIF follow-on experiment [2]

[2] Lange, R., Mitchell, W., "Investigation of NVR Plate Results"

Project Significance

- RST joint on Spacecraft Upper Skirt to deploy via friction
  - Braycote could spread onto joint surfaces requiring cleaning
  - NVR rinse to certify surface is at specified cleanliness level and enough Braycote was removed to result in a satisfactory coefficient of friction



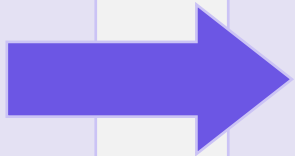
Braycote applied to test coupon

Coupon visibly clean, 3.78mg NVR collected

PREP I Project Goals

Objectives:

- Identify significant, uncontrolled variables in NVR processing
- Quantify and reduce error associated with the NVR removal process



Impact:

- Enhanced foil processing
- Improved cleanroom monitoring
- Reduce costs to the project with fewer unnecessary, precautionary cleanings

Scope

- ASTM E-1235 details procedure for gravimetric determination of NVR
- Variables within standard
  - Exposure/Processing Time
  - Contamination Species
  - Contamination Load
  - Rinse Solvent
  - Temperature
  - Humidity
  - Handling
  - Condition of Materials
  - Evaporation Method
  - Lab Equipment
  - Rinse Filtration
  - Foils vs. Plates
  - Long-term Storage
  - Transportation

[3] "ASTM E1235-12: Standard Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft"

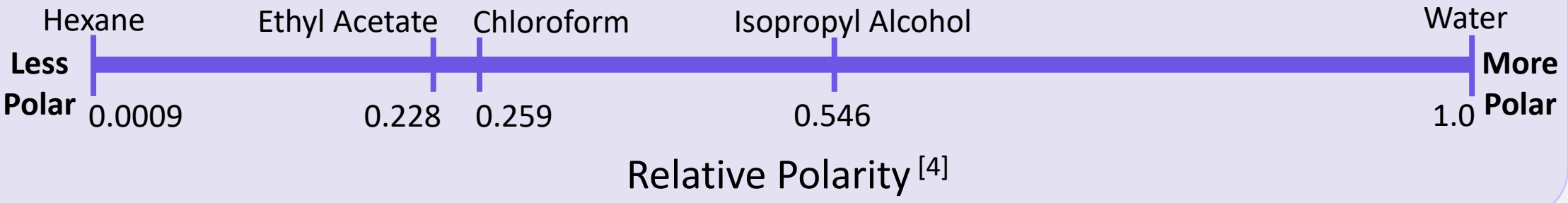
Scope

- ASTM E-1235 details procedure for gravimetric determination of NVR
- Variables within standard
  - **Exposure/Processing Time**
  - **Contamination Species**
  - **Contamination Load**
  - **Rinse Solvent**
  - Temperature
  - Humidity
  - Handling
  - Condition of Materials
  - Evaporation Method
  - Lab Equipment
  - ~~Rinse Filtration~~
  - Foils vs. Plates
  - Long-term Storage
  - Transportation

[3] "ASTM E1235-12: Standard Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft"

Variable Selection - Solvent

- At GSFC, Chloroform NVR plate rinse may be followed by a rinse using Isopropyl Alcohol (IPA)
- Polar solvents dissolve polar solutes, non-polar solvents dissolve non-polar solutes [4]
- Ethyl Acetate proposed as a safer and more environmentally friendly replacement for Chloroform [3]



[3] "ASTM E1235-12: Standard Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft"
[4] Murov, S., "Properties of Organic Solvents"

Experiment Design

- Variable identification
  - Rinsing solvent
  - Contaminant
  - Initial contaminant mass
  - Time elapsed prior to rinse
- Environmental Monitoring
  - Balance calibration
  - Temperature
  - Relative humidity
  - Certified materials

Trial	Foil Rinsed	Solvent	Contaminant	Contaminant Mass
1	+ 00:00 hr	Isopropyl Alcohol	Paraffin Oil	1.00 mg
2	+ 00:00 hr	Chloroform	Paraffin Oil	1.00 mg
3	+ 00:00 hr	Ethyl Acetate	Paraffin Oil	1.00 mg
4	+ 00:00 hr	Isopropyl Alcohol	Dioctyl Phthalate	1.00 mg
5	+ 00:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
6	+ 00:00 hr	Ethyl Acetate	Dioctyl Phthalate	1.00 mg
7	+ 00:00 hr	Isopropyl Alcohol	Triphenyl Phosphate	1.00 mg
8	+ 00:00 hr	Chloroform	Triphenyl Phosphate	1.00 mg
9	+ 00:00 hr	Ethyl Acetate	Triphenyl Phosphate	1.00 mg
10	+ 00:00 hr	Isopropyl Alcohol	DC 704	1.00 mg
11	+ 00:00 hr	Chloroform	DC 704	1.00 mg
12	+ 00:00 hr	Ethyl Acetate	DC 704	1.00 mg
13	+ 00:00 hr	Chloroform	Dioctyl Phthalate	0.0 mg
14	+ 00:00 hr	Chloroform	Dioctyl Phthalate	0.25 mg
15	+ 00:00 hr	Chloroform	Dioctyl Phthalate	0.50 mg
16	+ 00:00 hr	Chloroform	Dioctyl Phthalate	0.75 mg
17	+ 00:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
18	+ 00:00 hr	Chloroform	Dioctyl Phthalate	1.25 mg
19	+ 00:00 hr	Chloroform	Dioctyl Phthalate	1.50 mg
20	+ 00:00 hr	Chloroform	Dioctyl Phthalate	1.75 mg
21	+ 00:00 hr	Chloroform	Dioctyl Phthalate	2.00 mg
22	+ 00:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
23	+ 00:30 hr	Chloroform	Dioctyl Phthalate	1.00 mg
24	+ 01:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
25	+ 02:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
26	+ 03:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
27	+ 04:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
28	+ 05:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
29	+ 06:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
30	+ 07:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
31	+ 08:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
32	+ 16:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
33	+ 24:00 hr	Chloroform	Dioctyl Phthalate	1.00 mg
34	+ 00:00 hr	Isopropyl Alcohol	None	0.00 mg
35	+ 00:00 hr	Chloroform	None	0.00 mg
36	+ 00:00 hr	Ethyl Acetate	None	0.00 mg

Full factorial approach – 72 runs (36 trials, each repeated)

Methodology Development

Design of Experiments (DOE): systematic method to study individual and interactive effects between multiple input variables and the corresponding responses

Advantages:

- Minimize number of experiment trials
- Collected all desired output data

Issues:

- Contaminant is categorical variable
- More appropriate for solvent too

Trial	Wait Time (A)	Initial Mass (B)	Solvent (C)	Contam. (D)
1	0 hr	0 mg	IPA	-1
2	24 hr	0 mg	IPA	-1
3	0 hr	2 mg	IPA	-1
4	0 hr	0 mg	Chloroform	-1
5	0 hr	0 mg	IPA	1
6	24 hr	2 mg	IPA	-1
7	24 hr	0 mg	Chloroform	-1
8	24 hr	0 mg	IPA	1
9	0 hr	2 mg	Chloroform	-1
10	0 hr	2 mg	IPA	1
11	0 hr	0 mg	Chloroform	1
12	24 hr	2 mg	Chloroform	-1
13	24 hr	0 mg	Chloroform	1
14	24 hr	2 mg	IPA	1
15	24 hr	2 mg	Chloroform	-1
16	24 hr	2 mg	Chloroform	1

DOE approach – 32 runs (16 trials, each repeated)

Methodology Development Cont.

- Calculate effect of each main variable from collected data
- Determine effect of second, third and fourth level variable interactions
- Improved data analysis for a better understanding of what impacts NVR accuracy

Trial	AxB	AxC	AxD	BxC	BxD	CxD	AxBxC	AxBxD	BxCxD	AxBxCxD
1	1	1	1	1	1	1	-1	-1	-1	1
2	-1	-1	-1	1	1	1	1	1	-1	-1
3	-1	1	1	-1	-1	1	1	1	1	-1
4	1	-1	1	-1	1	-1	1	-1	1	-1
5	1	1	-1	1	-1	-1	-1	1	1	-1
6	1	-1	-1	-1	-1	1	-1	-1	1	1
7	-1	1	-1	-1	1	-1	-1	1	1	1
8	-1	-1	1	1	-1	-1	1	-1	1	1
9	-1	-1	1	1	-1	-1	-1	1	-1	1
10	-1	1	-1	-1	1	-1	1	-1	-1	1
11	1	-1	-1	-1	-1	1	1	1	-1	1
12	1	1	-1	1	-1	-1	1	-1	-1	-1
13	-1	1	1	-1	-1	1	-1	-1	-1	-1
14	1	-1	1	-1	1	-1	-1	1	-1	-1
15	1	1	-1	1	-1	-1	1	-1	-1	-1
16	1	1	1	1	1	1	1	1	-1	1

Experiment Design

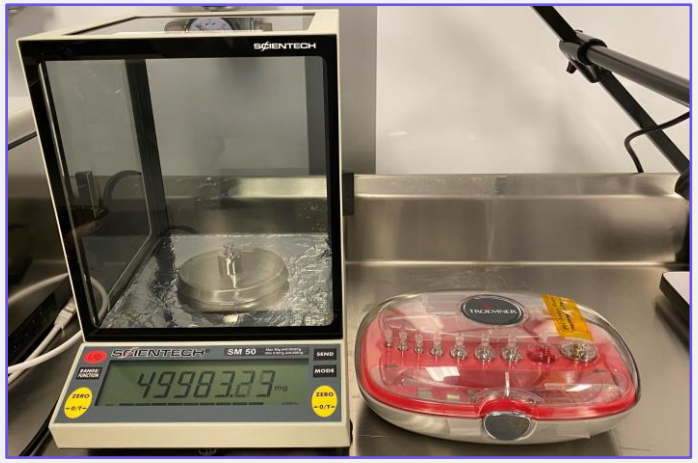
- JMP® software simplifies process
- Use numerical and categorical variables
  - High/low values for numerical variables
  - List all options for categorical variables
- Select desired effects and interactions
- Randomized trial order
- Minimize number of trials

Trial	Initial Mass	Foil Rinsed	Solvent	Contaminant
1	2.00 mg	+ 00:00 hr	Chloroform	Triphenyl Phosphate
2	2.00 mg	+ 24:00 hr	IPA	Paraffin Oil
3	2.00 mg	+ 00:00 hr	Ethyl Acetate	DEHIP
4	2.00 mg	+ 00:00 hr	IPA	DEHIP
5	2.00 mg	+ 00:00 hr	Chloroform	Paraffin Oil
6	2.00 mg	+ 24:00 hr	Ethyl Acetate	DEHIP
7	0.00 mg	+ 24:00 hr	Chloroform	Triphenyl Phosphate
8	0.00 mg	+ 00:00 hr	IPA	DC 704
9	0.00 mg	+ 00:00 hr	IPA	Triphenyl Phosphate
10	2.00 mg	+ 24:00 hr	Ethyl Acetate	Triphenyl Phosphate
11	0.00 mg	+ 24:00 hr	Ethyl Acetate	DEHIP
12	0.00 mg	+ 24:00 hr	Chloroform	Paraffin Oil
13	2.00 mg	+ 24:00 hr	IPA	DC 704
14	2.00 mg	+ 00:00 hr	Chloroform	DC 704
15	2.00 mg	+ 00:00 hr	Ethyl Acetate	Paraffin Oil
16	2.00 mg	+ 24:00 hr	Ethyl Acetate	DC 704
17	2.00 mg	+ 24:00 hr	Chloroform	DEHIP
18	2.00 mg	+ 24:00 hr	IPA	Triphenyl Phosphate
19	0.00 mg	+ 00:00 hr	Ethyl Acetate	DEHIP
20	0.00 mg	+ 24:00 hr	IPA	DEHIP
21	0.00 mg	+ 00:00 hr	IPA	Paraffin Oil
22	0.00 mg	+ 24:00 hr	Chloroform	DC 704
23	0.00 mg	+ 00:00 hr	Chloroform	DEHIP
24	0.00 mg	+ 00:00 hr	Ethyl Acetate	Triphenyl Phosphate
25	0.00 mg	+ 24:00 hr	Ethyl Acetate	Paraffin Oil

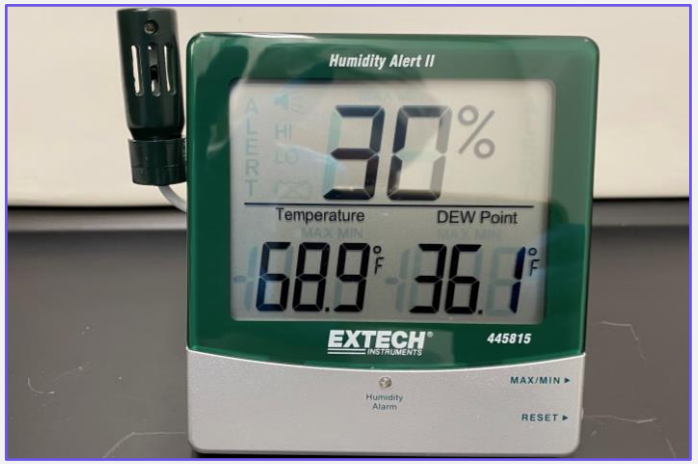
JMP approach – 25 total runs

Workspace Preparations

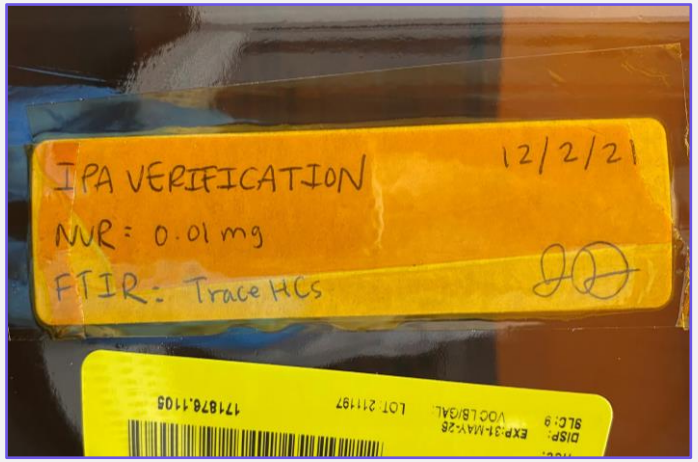
Fume Hood & Waste Container



Balance Calibration



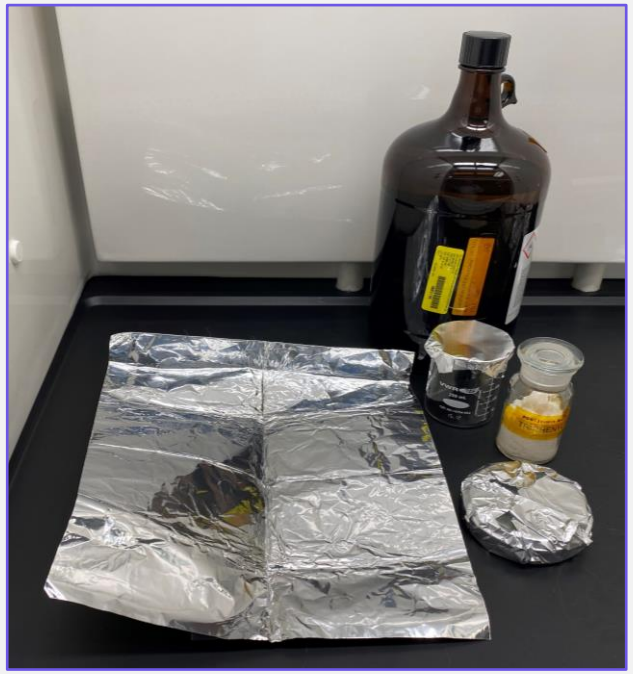
Room Monitoring



Solvent Certification

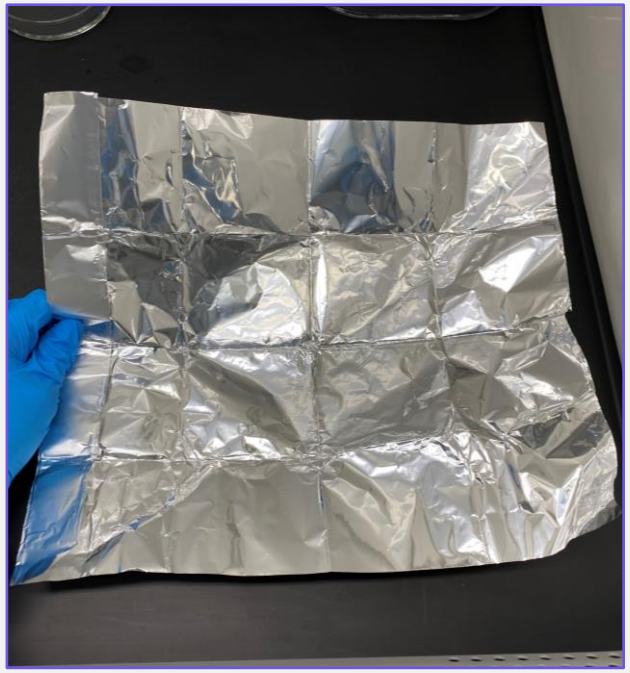
Glassware & Foil Certification

Foil Preparation Procedure

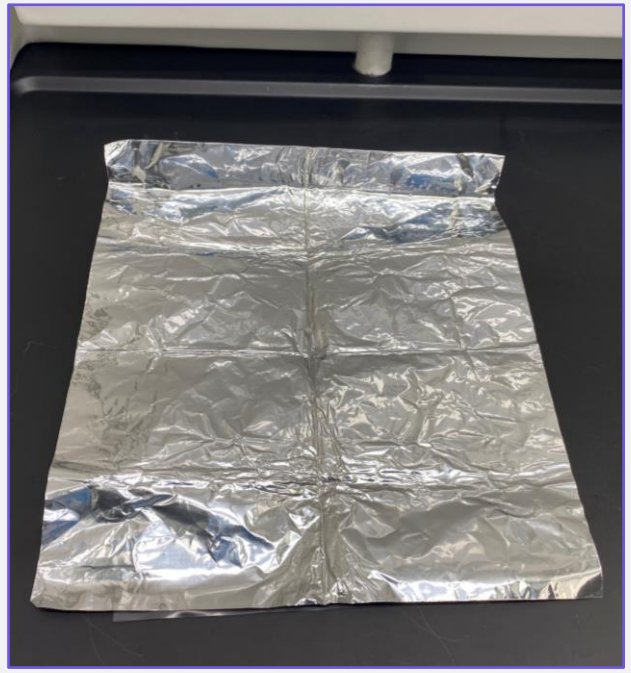


Prepare contaminants, foils, glassware and solvents

Add appropriate mass of contaminant to foil



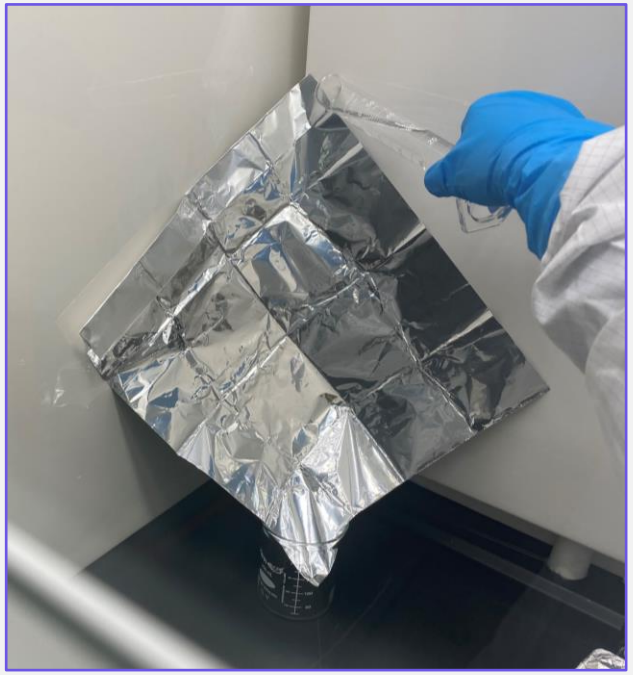
Dissolve contaminant with 5mL Chloroform



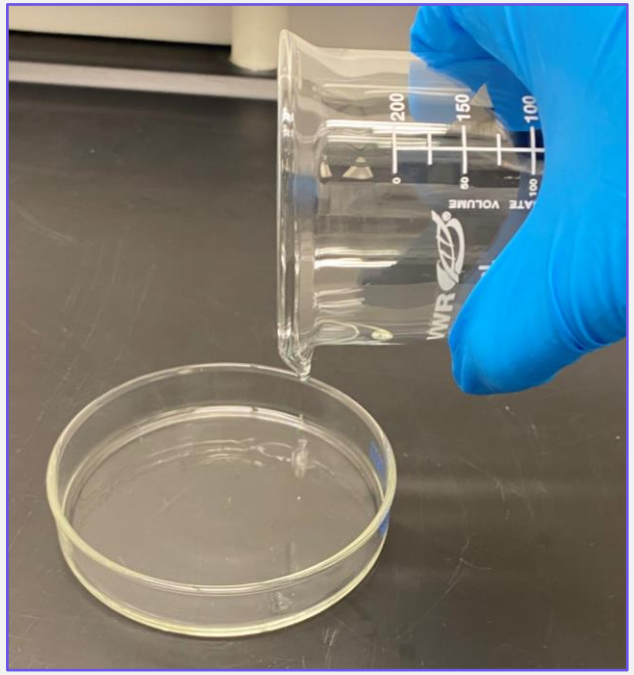
Allow to evaporate and for wait time to elapse

Prepared 25 foils in total

NVR Rinse Procedure

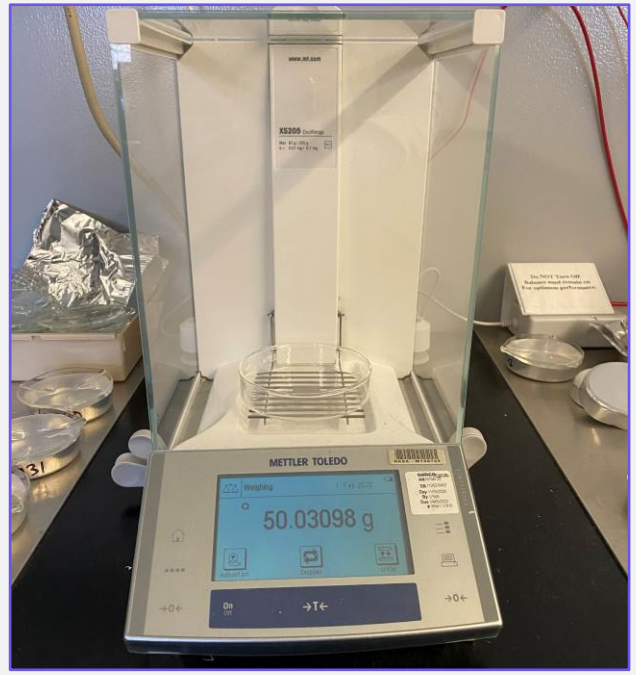


Rinse foil with appropriate solvent



After evaporation, transfer to evaporating dish

Allow evaporation to finish, then cover and bag

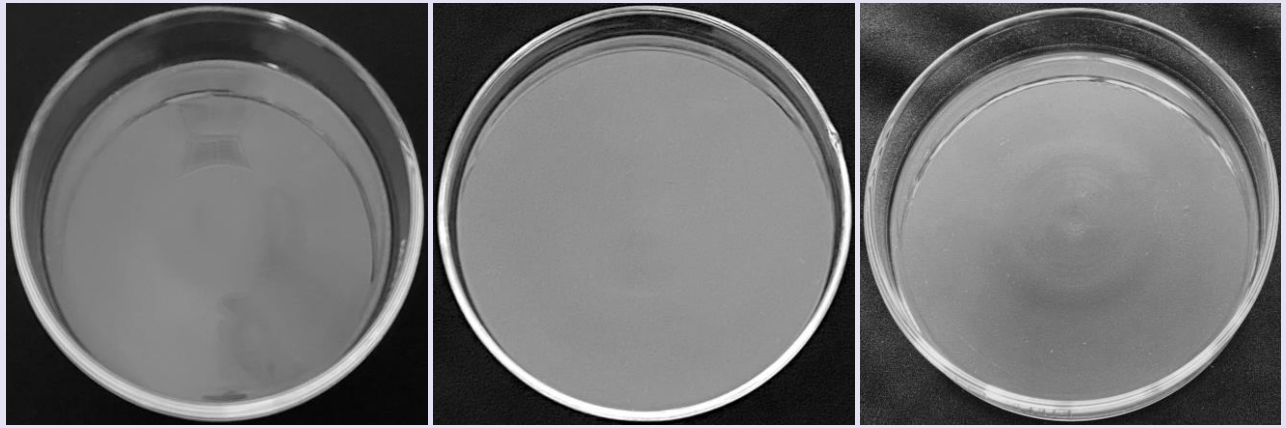


Determine mass of NVR from change in petri dish mass

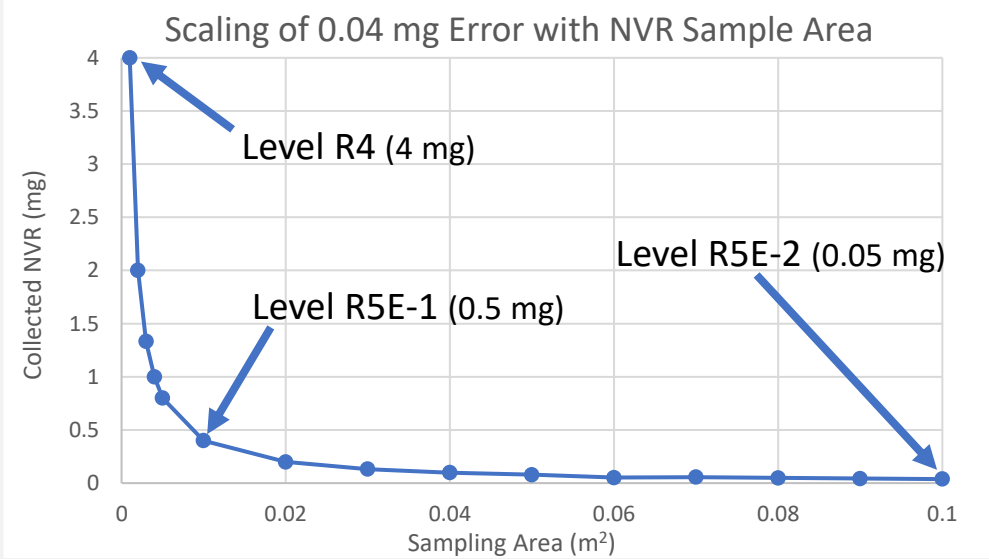
All 25 NVR samples successfully collected

Blank Foils Collected NVR

- Chloroform Blank Foils: 0.01 mg – 0.06 mg
- Ethyl Acetate Blank Foils: 0.00 mg – 0.03 mg
- Isopropyl Alcohol Blank Foils: 0.00 mg – 0.06 mg



Ethyl Acetate | Chloroform | Isopropyl Alcohol



Balance Uncertainty: ±0.04 mg

Solvent NVR from Initial Certifications:

Chloroform: 0.04 mg/0.1 L	Used 60mL → 0.02mg
Ethyl Acetate: 0.05 mg/0.1 L	Used 60mL → 0.03mg
IPA: 0.01 mg/0.1 L	Used 60mL → 0.01mg

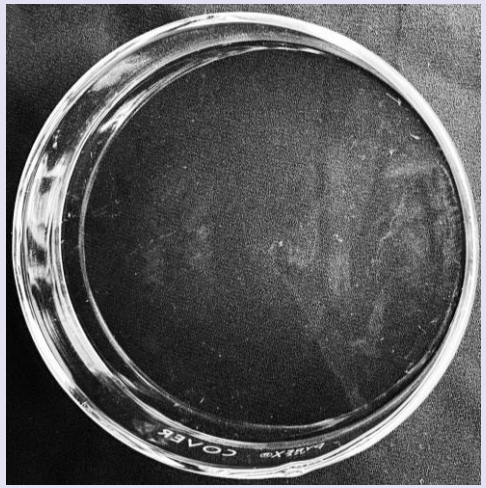
Producing accurate results with method and equipment

Contaminated Foils Results

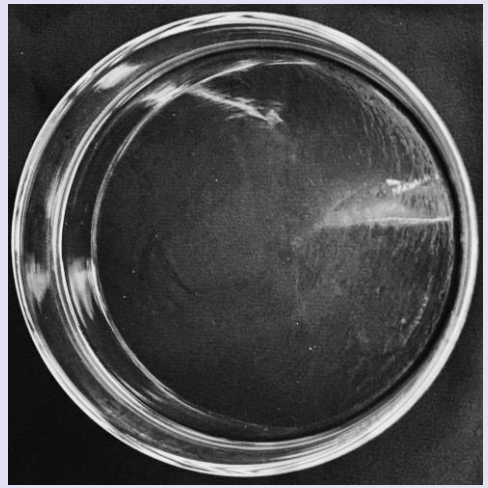
- Chloroform Trials: 1.3% - 9.7% variance
- Ethyl Acetate Trials: 0.0% - 9.8 % variance
- Isopropyl Alcohol Trials: 12.8% - 64.5% variance

Chloroform – Triphenyl Phosphate

Ethyl Acetate – Di (2-Ethylhexyl) Isophthalate

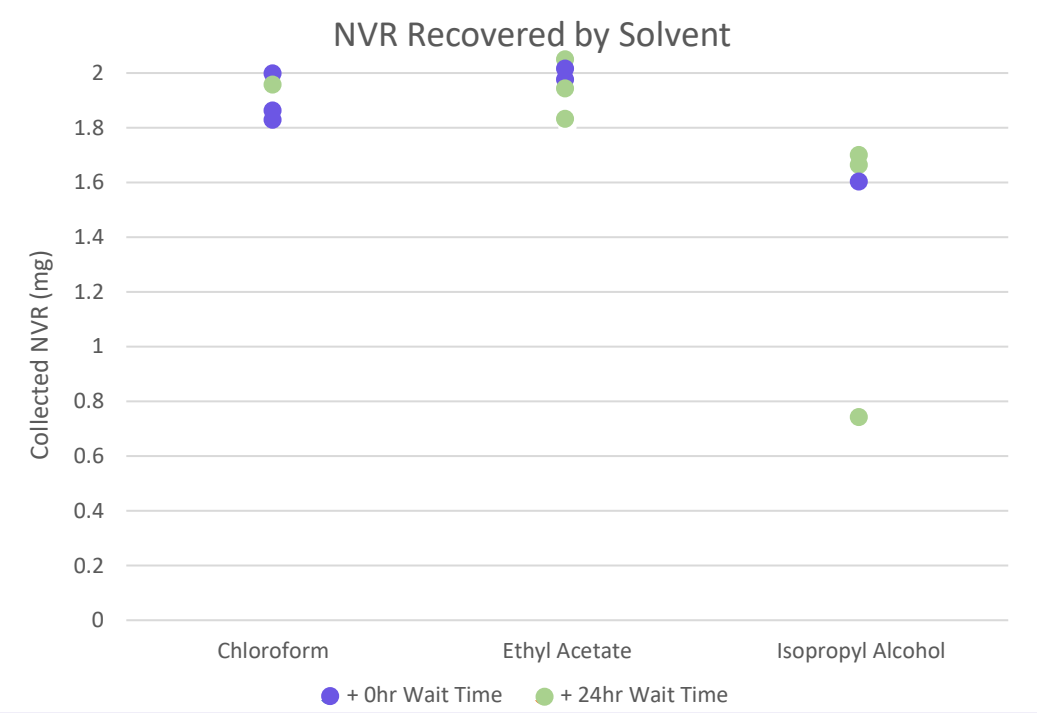


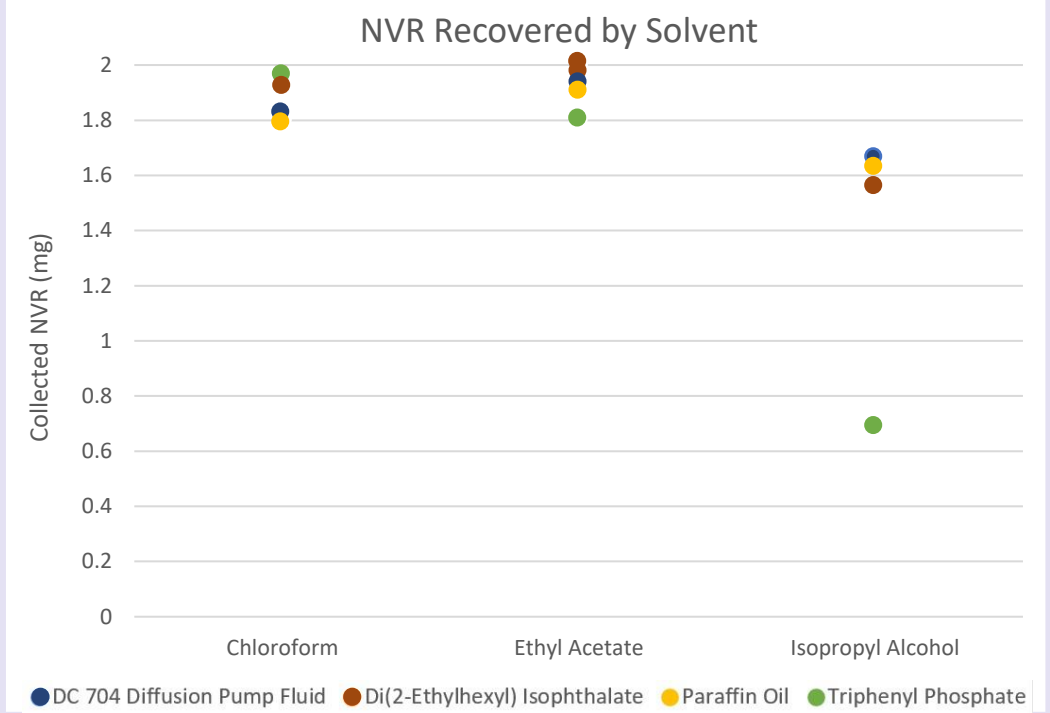
Isopropyl Alcohol – Paraffin Oil



Isopropyl Alcohol – DC 704 Diffusion Pump Fluid

Results - Solvent





Ethyl Acetate: 1.93 mg, SD 0.07 mg

Chloroform: 1.90 mg, SD 0.07 mg

Isopropyl Alcohol: 1.40 mg, SD 0.40 mg

Foil Cleanliness Levels

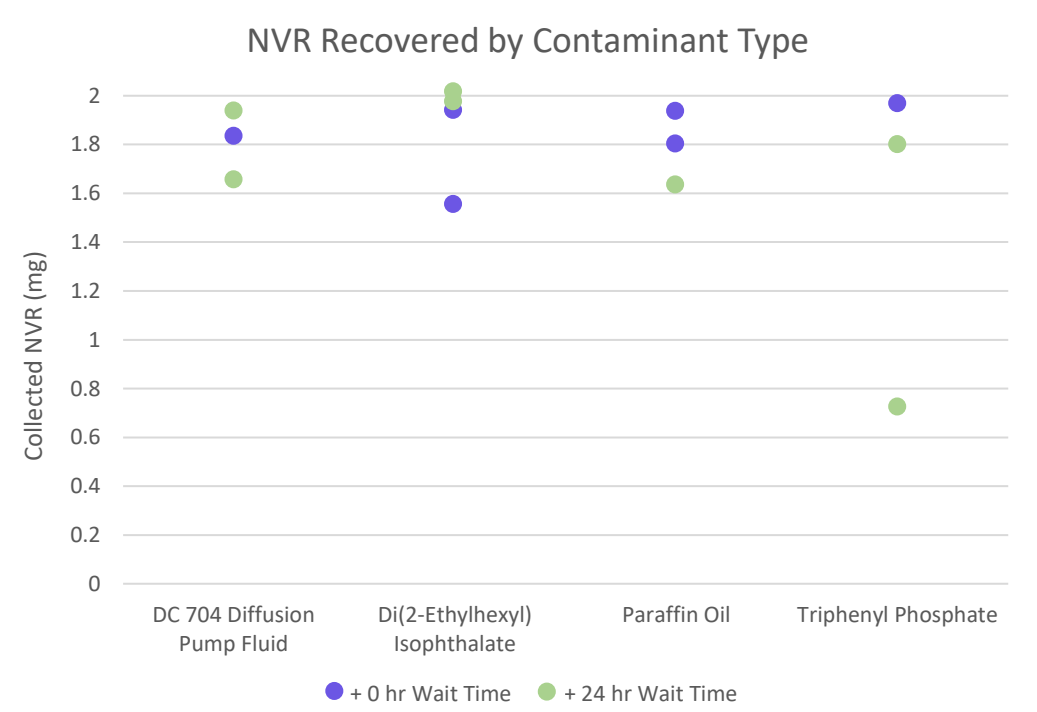
- Certification level of NVR Cleanliness (IEST-STD-CC1246E) [6]
  - Chloroform with Contaminant: R2-R3
  - Ethyl Acetate with Contaminant: R2-R3
  - Isopropyl Alcohol with Contaminant: R1-R2
- All contaminated foils initially prepared at Level R3, 2.15mg/0.1m^2
- Misleading certification level for foils rinsed with Isopropyl Alcohol

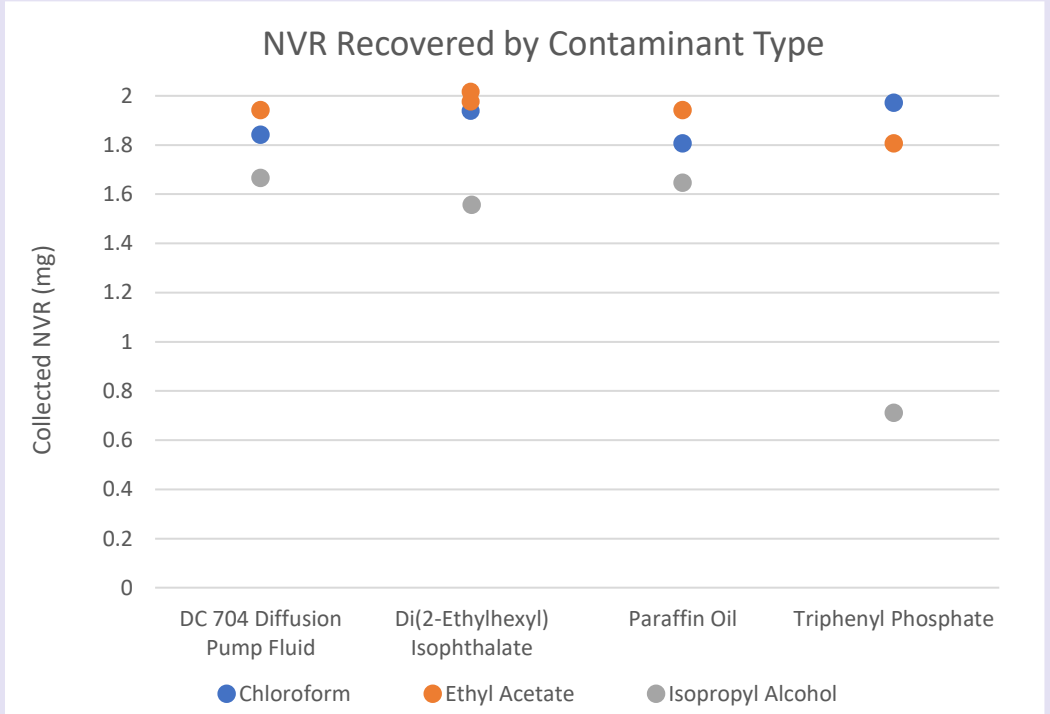
Level (µg/cm^2) [Former Designation]	Maximum Allowable (NVR / 0.1m^2)
R1E-2 [A/100]	10 µg
R2E-2 [A/50]	20 µg
R5E-2 [A/20]	50 µg
R1E-1 [A/10]	100 µg
R2E-1 [A/5]	200 µg
R5E-1 [A/2]	500 µg
R1 [A]	1 mg
R2 [B]	2 mg
R3 [C]	3 mg

Table 2. IEST cleanliness levels [6]

[6] "Product Cleanliness Levels – Applications, Requirements, and Determination"

Results - Contaminant





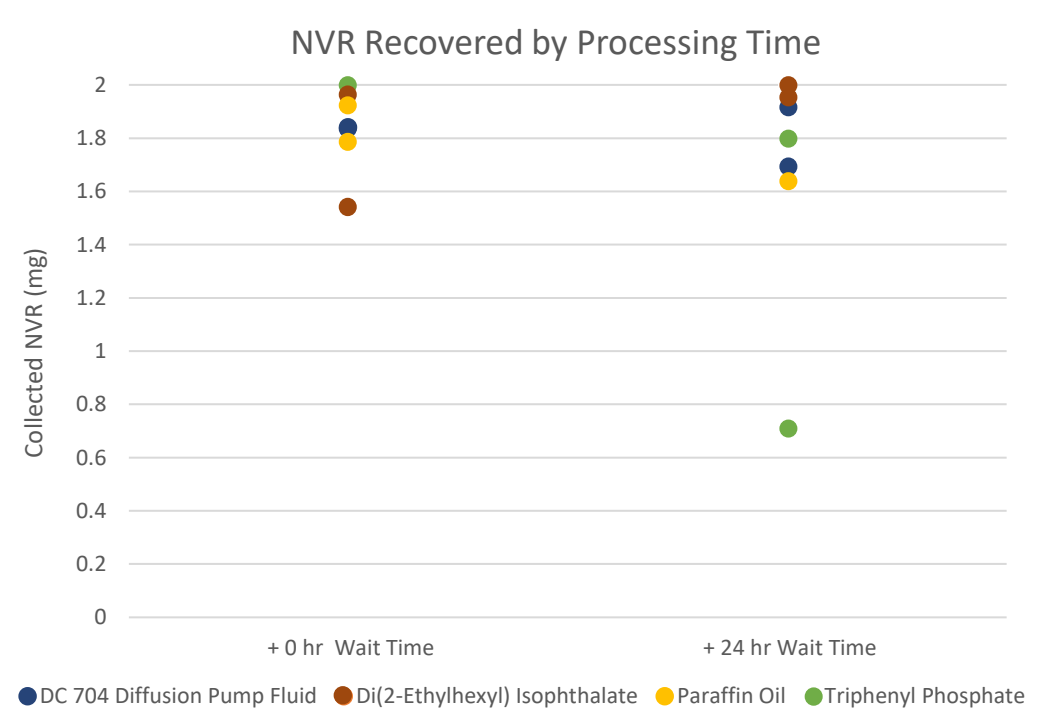
Di(2-Ethylhexyl) Isophthalate: 1.87 mg, SD 0.18 mg

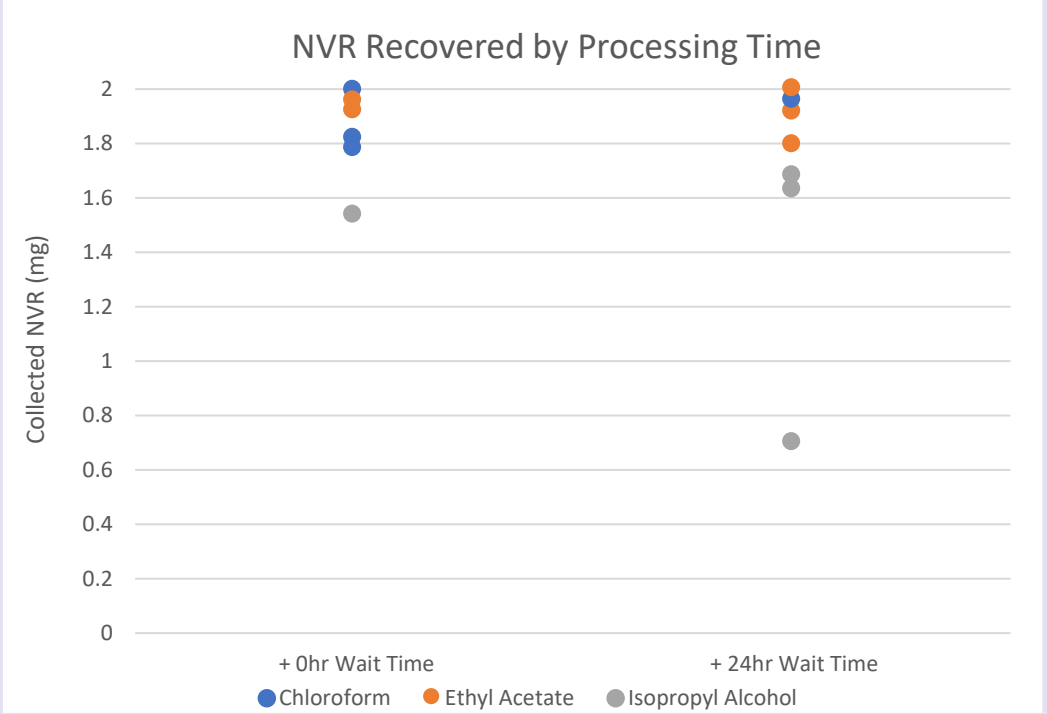
DC 704 Diffusion Pump Oil: 1.81 mg, SD 0.11 mg

Paraffin Oil: 1.80 mg, SD 0.12 mg

Triphenyl Phosphate: 1.50 mg, SD 0.56 mg

Results – Processing Time



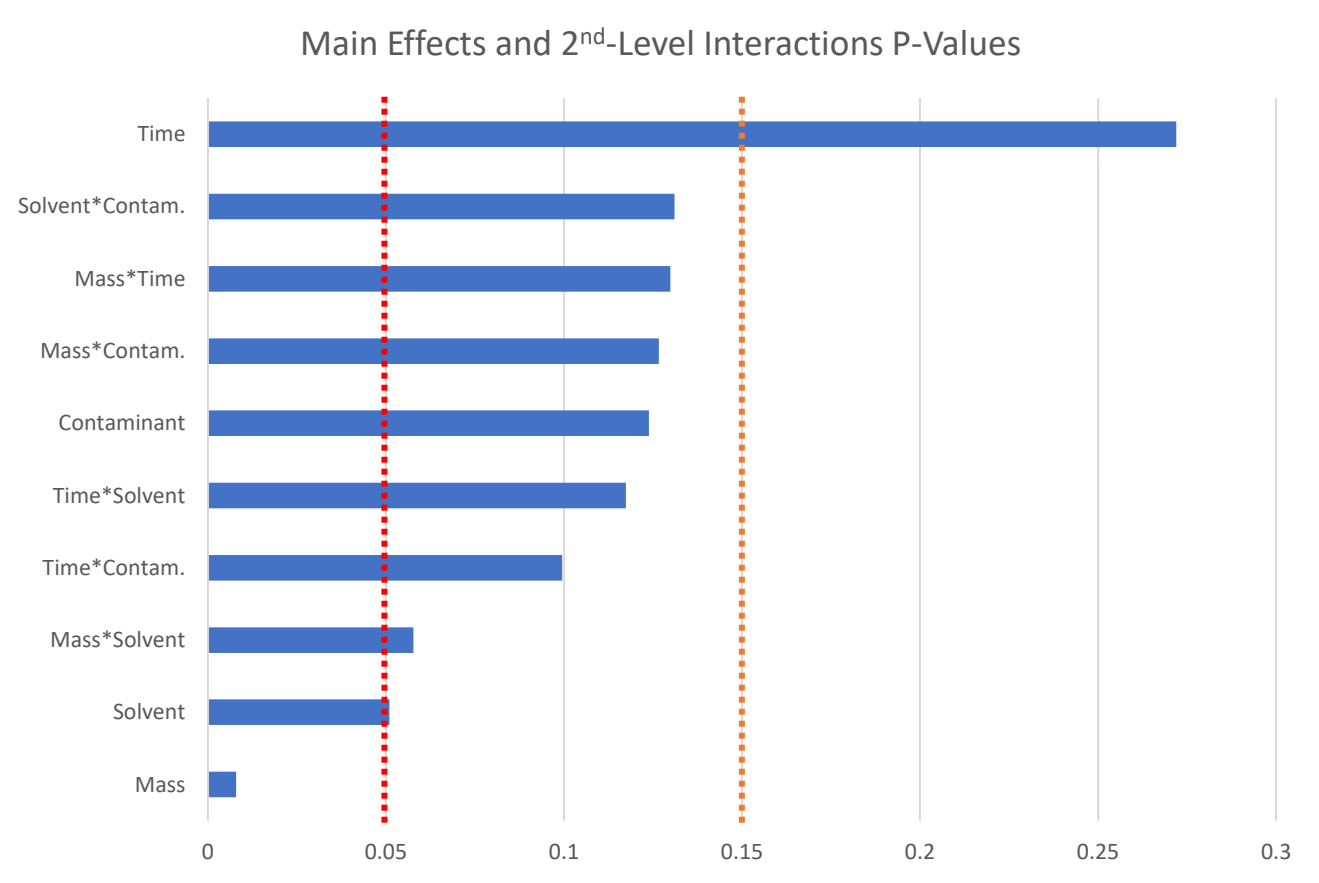


+ 0hr Wait Time: 1.85 mg, SD 0.14 mg

+ 24hr Wait Time: 1.68 mg, SD 0.42 mg

+ 24hr Wait Time: 1.84 mg, SD 0.14 mg

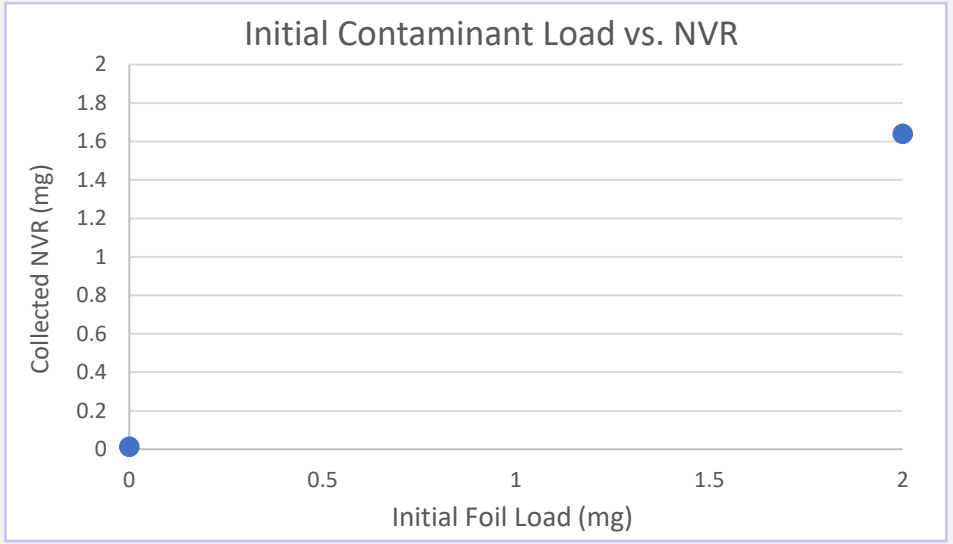
DOE Significant Effects

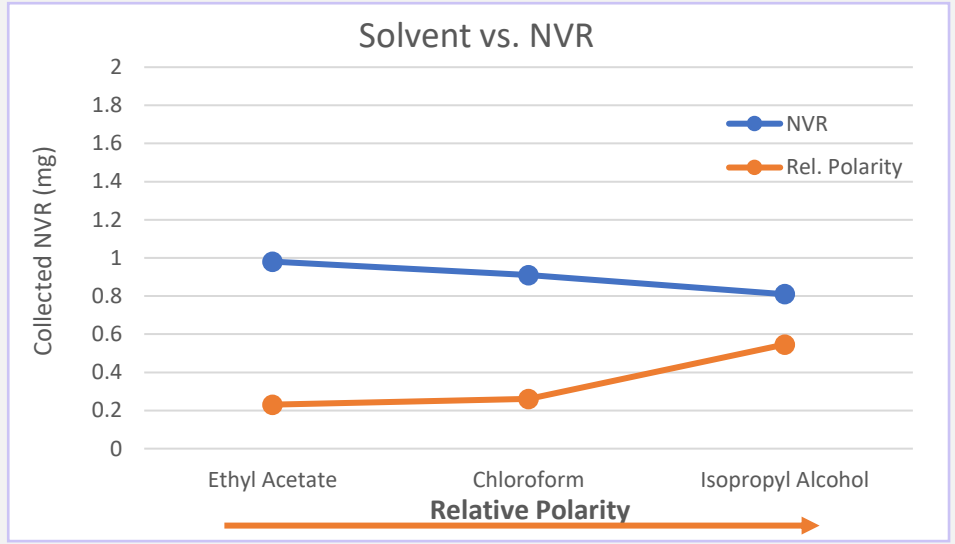


- JMP ranking of main effects and secondary interactions
- Initial Contaminant Mass and Solvent main effects are statistically significant (P-value ≤ 0.05)
- All other effects except Time are likely significant (P-value ≤ 0.15)

JMP Effect Trends

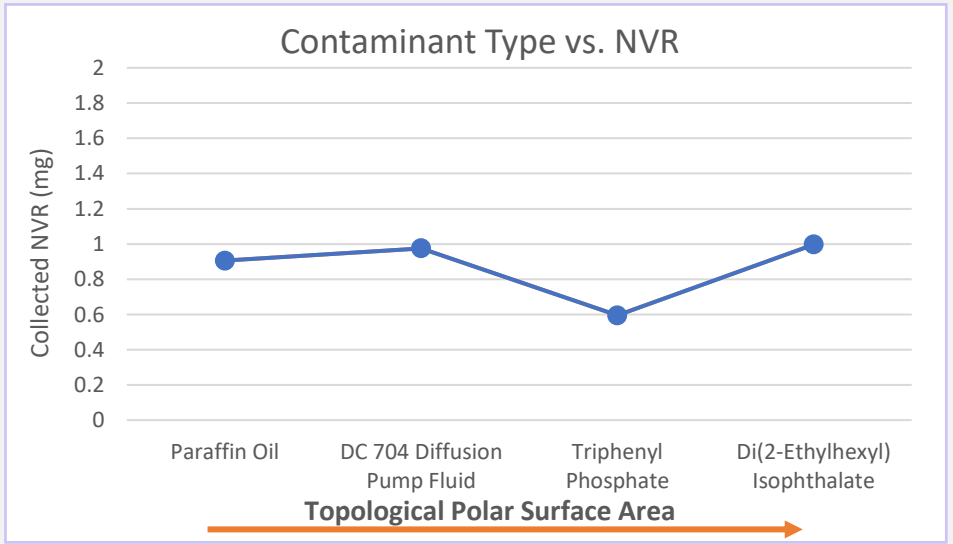
Contaminated and Blank Foil Delta: 1.63 mg

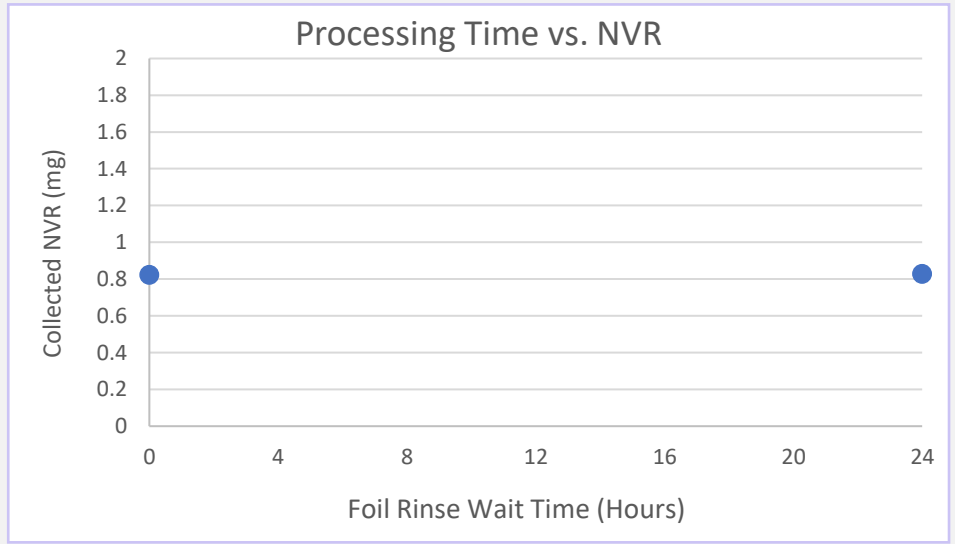




Isopropyl Alcohol and Ethyl Acetate Delta: 0.15 mg

DEHIP and Triphenyl Phosphate Delta: 0.40 mg





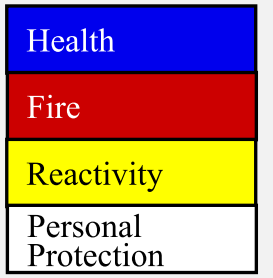
0hr and 24hr Processing Time Delta: 0.01 mg

Results

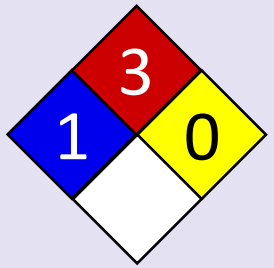
- Processing of clean foils returns accurate results
- Rinse solvent has a significant effect on collected NVR
  - Chloroform (1.90mg) and Ethyl Acetate (1.93mg) perform similarly, with R1E-1 (A/10) error for the average NVR removal of both solvents
  - Isopropyl Alcohol less effective (1.40mg) and not consistent, R1 (A) error
- NVR removal can vary by contaminant species
  - FTIR analysis of collected NVR could alert to presence of problematic types
- Time between receiving and rinsing foils is not a significant effect
  - Immediate processing not critical for accurate results with proper storage

Confirmed ± 0.1 mg NVR foil processing accuracy with specified procedure.
Isopropyl Alcohol should not be used to certify foils to levels cleaner than R1

Results

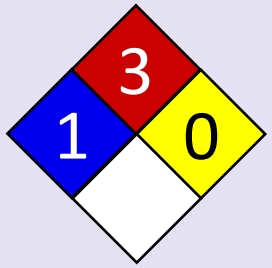


Hazard	Isopropyl Alcohol
ACGIH Threshold Limit Values Time Weighted Average	200 ppm
ACGIH Listed Carcinogenic	Not Listed
LD50 Oral Toxicology	4,396 mg/kg (Rat)
LD50 Dermal Toxicology	12,870 mg/kg (Rabbit)
Ecotoxicity (Fathead Minnow)	LC50 >1,000 mg/L; 96hr



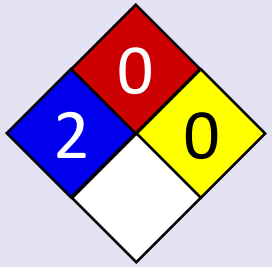
Chronic Effects: Repeated skin contact may cause dermatitis [7]

Hazard	Ethyl Acetate
ACGIH Threshold Limit Values Time Weighted Average	400 ppm
ACGIH Listed Carcinogenic	Contains no known
LD50 Oral Toxicology	5,620 mg/kg (rat)
LD50 Dermal Toxicology	18,000 mg/kg (rabbit)
Ecotoxicity (Fathead Minnow)	LC50 = 230 mg/L; 96hr Biodegrades at high rate



Chronic Effects: May cause respiratory tract irritation. Chronic inhalation may result in potential narcotic effects [8]

Hazard	Chloroform
ACGIH Threshold Limit Values Time Weighted Average	10 ppm
ACGIH Listed Carcinogenic	Confirmed Animal Carcinogen
LD50 Oral Toxicology	450 mg/kg (Rat)
LD50 Dermal Toxicology	LD50 > 20 g/kg (Rabbit)
Ecotoxicity (Fathead Minnow)	LC50 = 129 mg/L; 96hr



Chronic Health Effects: Identified as a possible cancer hazard from animal laboratory testing. Mutagenic effects discovered in some laboratory testing. Repeated or prolonged contact with skin contact may cause defatting and dermatitis. May cause reproductive and fetal effects. The toxicity of Chloroform may increase with exposure to alcohol, steroids, and ketones. Liver, kidney, and heart damage may result from prolonged exposure. Aspixiation hazard, aspiration of the material into the lungs may cause chemical pneumonitis, which may be fatal [9]

Ethyl Acetate is recommended for use as an NVR solvent given similar performance to Chloroform with fewer health and environmental hazards

[7] "Material Safety Data Sheet: 2-Propanol 99-100%"

[8] "Material Safety Data Sheet: Ethyl Acetate"

[9] "Material Safety Data Sheet: Chloroform"

Training and Accomplishments

Roman Space Telescope:

- Image Analysis
- Grism and Prism Support
- Spacecraft Skirt Braycote Cleaning Methods Testing
- DAC Coupon TVAC Tests
- Cleanroom Support
- Hardware Inspections

2021 CCMPP Workshop:

- Registration Tracking
- Material Collection

Training	Type	Date	Hours
Code 549 Hazard Awareness Training for Key Card Access to the I&T Facility	Technical	8/2/2021	1
Cleanroom Gowning & SSDIF Walkdown	Technical	8/6/2021	1
Oxygen Deficiency Hazard	Technical	8/6/2021	1
Confined Space	Technical	8/11/2021	1.5
Review and Marking Documents for Export Control (EC)	Technical	8/24/2021	1
Export Control On-the-Job Training	Technical	8/24/2021	1
Image Analysis Training	Technical	8/31/2021	3
Electrostatic Discharge Control Operator Initial	Technical	9/3/2021	4.5
RST SSDIF Access Training	Technical	9/17/2021	2
Flammable and Combustible Liquids	Technical	10/28/2021	1
GSFC Nanotechnology Safety Training	Technical	10/28/2021	1
Compressed Gas Safety	Technical	10/29/2021	1
General Cryogenic Safety	Technical	11/2/2021	1
Personal Protective Equipment Overview	Technical	11/2/2021	1
Fire Extinguisher Awareness	Technical	11/2/2021	1
Hazardous Waste Management	Technical	11/2/2021	1
Pressure System Safety Awareness	Technical	11/5/2021	2.5
Laboratory Safety	Technical	11/2/2021	1
2021 CCMPP Workshop	Technical	11/8 -11/10/21	9.5
Total Technical Hours:			36
Presentation Skills for Technical Professionals	Non-Technical	11/16/2021	7
Building Your Presentation	Non-Technical	01/05/2022	0.5
Total Non-Technical Hours:			7.5
Total PREP I Hours:			43.5

Learning Experiences and Challenges

- Introduced to DOE and gained familiarity with the JMP® program
- Learned how NVR rinse samples are collected, practiced completing the procedure
- Became acquainted fume hood certification process, hazardous waste container requirements and the P-card order process
- Found workaround for the balance calibration issue
- Became more familiar with capabilities of 541's Materials Lab and 549's Chemical Lab

Future Work

- Additional procedure verification testing
  - Foils vs. plates performance
  - Transporting vs. rinsing on site
  - Additional solvent testing, including Hexane/Isopropyl alcohol mixture
  - Expand on contaminant testing – more representative silicone, polar species, common types found on flight hardware
- Are NVR foils representative of collected NVR on all surfaces (more/ less collects on glass, plastics, etc.)
- Hansen Solubility Parameters calculations to optimize NVR recovery and tune solvent mixtures to have a lower toxicity than individual solvents

[10] "Hansen Solubility Parameters Basics"

Summary

- Investigated uncontrolled variables in the NVR removal process
  - Contaminant Mass and Solvent identified as significant variables
  - Contaminant Species and all second-level interactions likely to be significant
  - Confirmed ±0.1 mg accuracy for Ethyl Acetate and Chloroform
  - Isopropyl Alcohol should not be used to certify foils to cleanliness levels better than R1, 1mg/0.1m^2, due to ±0.6 mg average removal error
- Exceeded PREP training requirements completing 43.5 hours, 36 hours were technical
- Provided project support for RST

Acronym List

- ACGIH: American Conference of Governmental Industrial Hygienists
- ASTM: American Society for Testing and Materials
- CC: Contamination Control
- CCIP: Contamination Control Implementation Plan
- CCMPP: Contamination, Coatings, Materials, and Planetary Protection
- DAC: Deployable Aperture Cover
- DEHIP: Di(2-Ethylhexyl) Isophthalate
- DOE: Design of Experiments
- FTIR: Fourier Transform Infrared
- GSFC: Goddard Space Flight Center
- I&T: Integration and Testing
- IPA: Isopropyl Alcohol
- LD50: Median Lethal Dose
- NVR: Non-Volatile Residue
- OSSI: One Stop Shopping Initiative
- PREP: Professional Readiness Engineering Program
- RST: Roman Space Telescope
- SAW: Surface Acoustic Wave
- SD: Standard Deviation
- SSDIF: Spacecraft Systems Development and Integration Facility
- STOP: Structural Thermal Optical Performance
- SWFO: Space Weather Follow On
- TQCM: Temperature-controlled Quartz Crystal Microbalance
- TVAC: Thermal Vacuum
- WFIRST: Wide Field Infrared Survey Telescope

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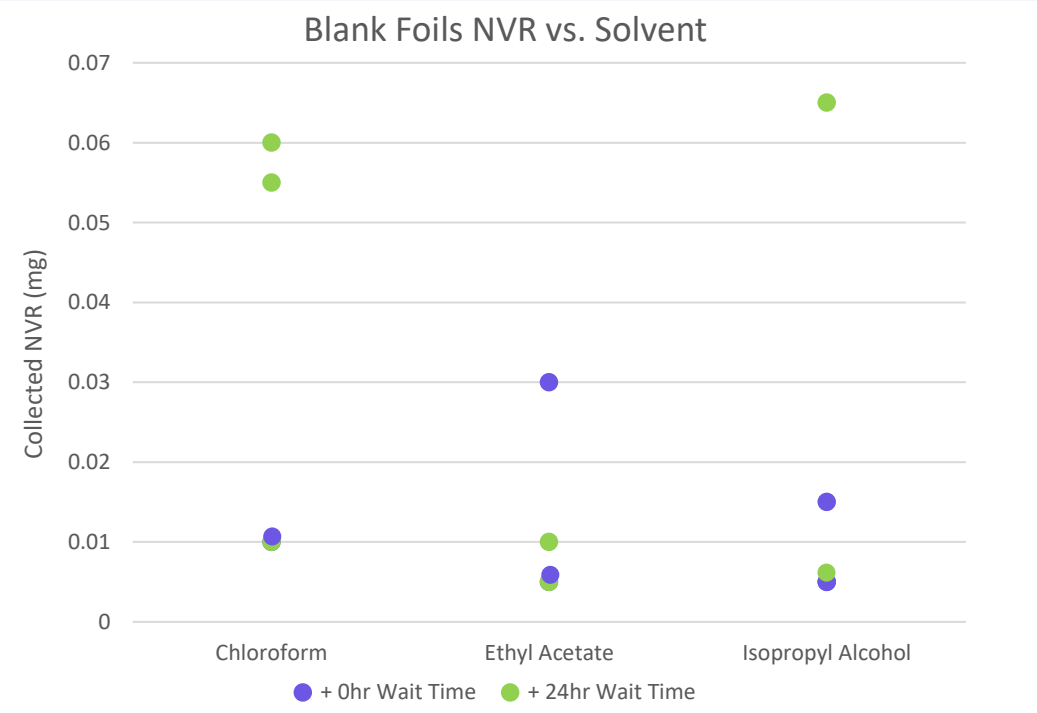
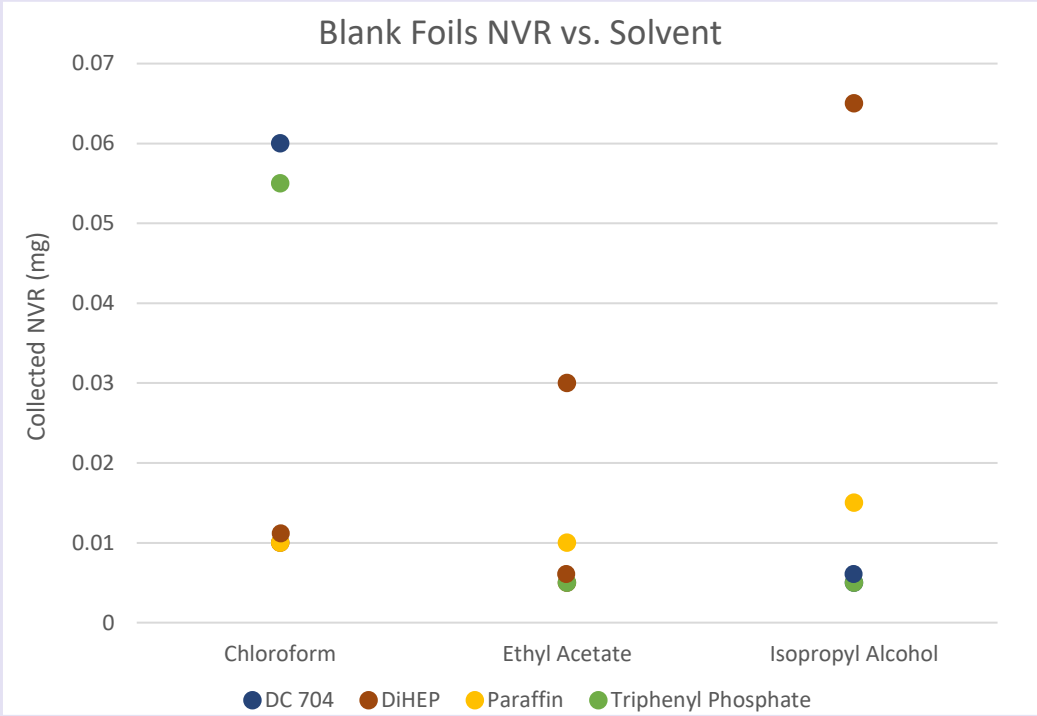
- Josh Thomas
- Elaine Stewart
- Alan Abeel
- Therese Errigo
- Code 546
- Code 541
- Code 549
- RST

Back-up Slides

Results – Blank Foils, Solvent



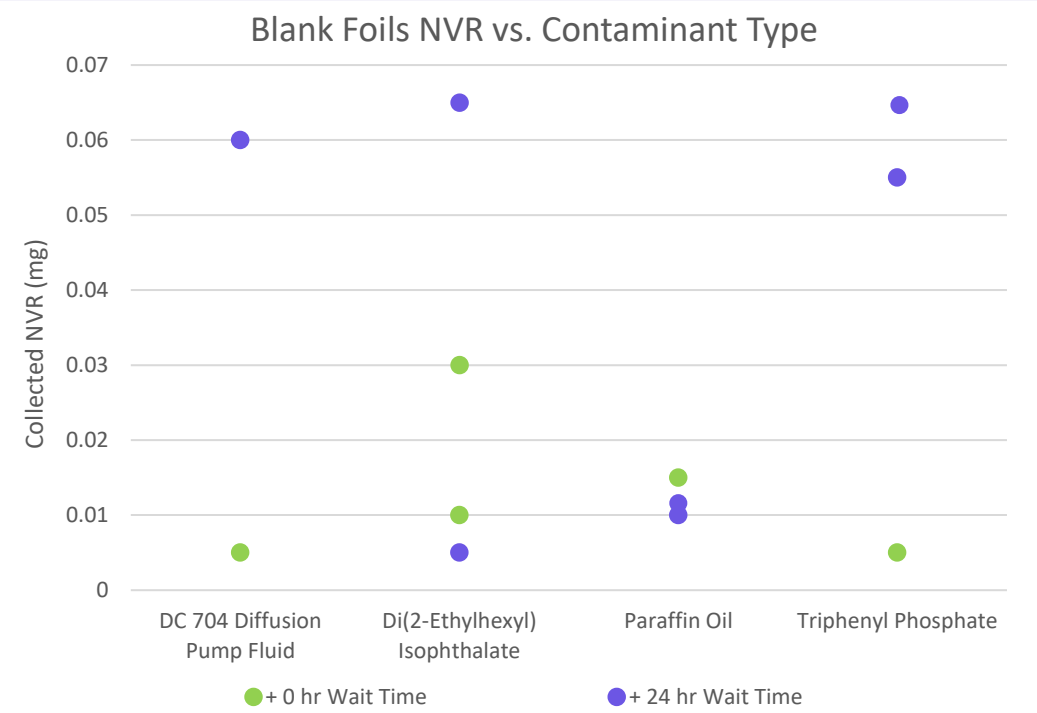


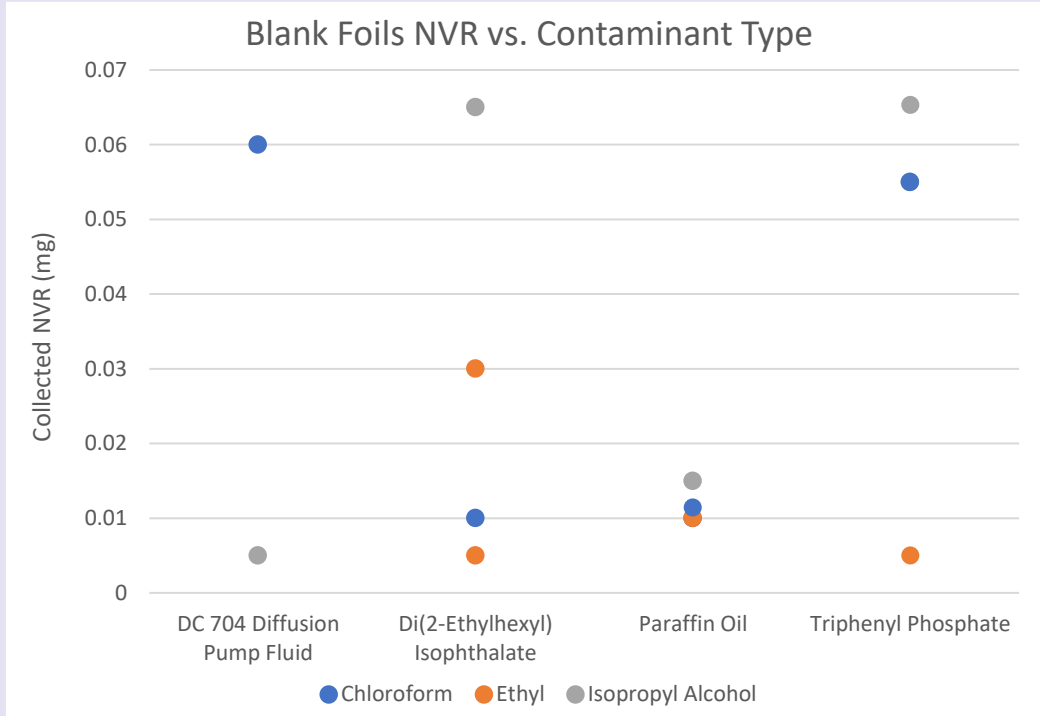
Ethyl Acetate: 0.01 mg, SD 0.01 mg

Chloroform: 0.03 mg, SD 0.02 mg

Isopropyl Alcohol: 0.02 mg, SD 0.02 mg

Results – Blank Foils, Contaminant





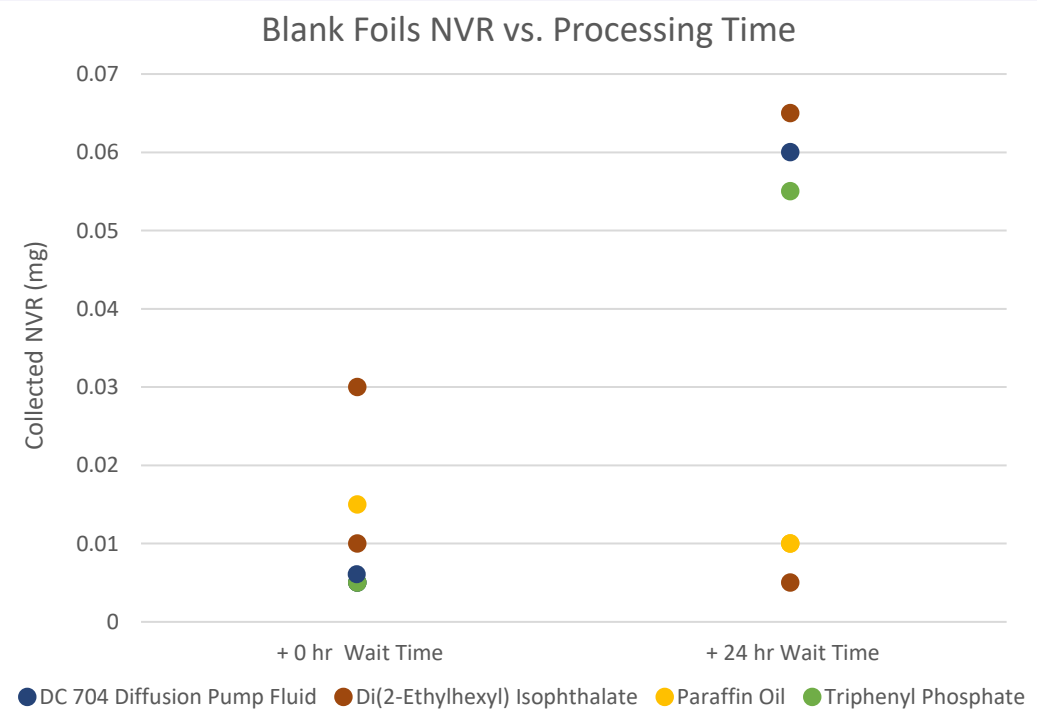
Di(2-Ethylhexyl) Isophthalate: 0.03 mg, SD 0.03 mg

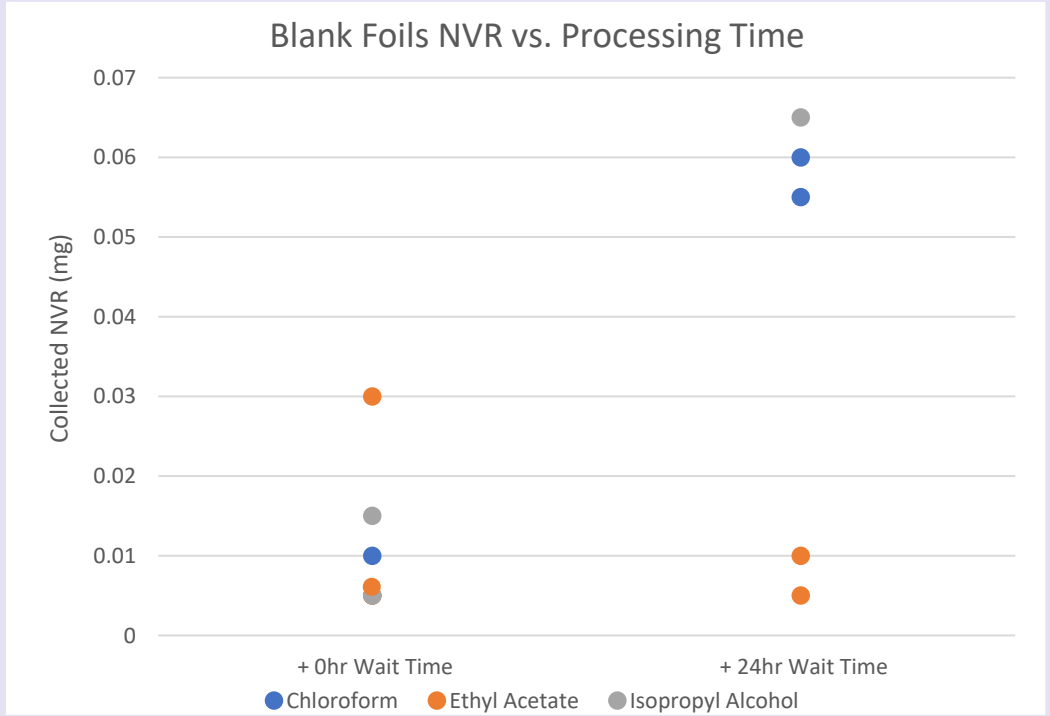
DC 704 Diffusion Pump Oil: 0.03 mg, SD 0.02 mg

Paraffin Oil: 0.01 mg, SD 0.00 mg

Triphenyl Phosphate: 0.02 mg, SD 0.02 mg

Results – Blank Foils, Processing Time





+ 0hr Wait Time: 0.01 mg, SD 0.01 mg

+ 24hr Wait Time: 0.03 mg, SD 0.03 mg

About Me

- B.S. in Aerospace Engineering from the University of Maryland
- OSSI Intern with Code 591, June 2018
  - WFIRST Wide Field Instrument Error Budgets
  - Structural Thermal Optical Performance (STOP) Analysis
- Pathways Intern with Code 546, August 2019
  - RST Observatory Contamination Control Implementation Plan (CCIP), Bakeout Tracking
  - SWFO instrument and mission contamination support
- Converted to full-time August 2021

WFIRST Mock-up, 2018