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# **Firbimatic Vacuum Degreaser Cleaning Study**

*B.D. Morris*

*Marshall Space Flight Center, Huntsville, Alabama*

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***December 2019***

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National Aeronautics and  
Space Administration

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## LIST OF ACRONYMS

CFC	chlorofluorocarbon
EPA	Environmental Protection Agency
UV	ultraviolet



## TECHNICAL MEMORANDUM

### **FIRBIMATIC VACUUM DEGREASER CLEANING STUDY**

#### **1. INTRODUCTION**

The purpose of this cleaning study was to establish the baseline of contaminants that can be removed using the Firbimatic Multisolvent 50-volt vacuum degreaser using Kyzen's Metalnox® M6386 Solvent on 2219 aluminum alloy panels. Four different cleaning methods were used with six known contaminants. For each contaminant, five panels were contaminated—one was kept as a control, and the remaining four were cleaned using the vacuum degreaser. All applicable NASA, company, laboratory, and test-specific standard test practices were followed. Pre- and post-test results and photographs can be found in the appendices.

## 2. BACKGROUND

Cleaning technologies have evolved over decades, particularly in the aerospace industry and as ozone-depleting chemicals such as chlorofluorocarbons (CFCs) have been removed from service. Solvent degreasers are low maintenance, low cost, and compatible with most substrates.

Chemistries such as Kyzen's Metalnox M6386 cleaning blend are designed to clean a range of oils and coolants as well as metal fines and are safe on steel, brass, aluminum, and other metals.

Metalnox M6386 is compatible with a variety of metals, removes both polar and non-polar soils, solvates a range of soils, has low surface tension to help penetrate and remove soils from blind holes and crevices, and exhibits low odor on parts upon exiting the system. Other benefits include freedom from chemical residue and a chemistry that is not listed as a hazardous air pollutant by the EPA.

The benefits of the vacuum degreaser is that the overall process time is shorter, each stage of the cleaning method can be modified for best efficiency and is consistent from cycle to cycle, and the overall solvent usage is much less than previous methods.

### **3. FIRBIMATIC MULTISOLVENT 50-VOLT VACUUM DEGREASER DESCRIPTION**

The Firbimatic Multisolvent 50-volt vacuum degreaser's washing chamber, tanks, distiller, separators, condensers, and pipework are all made of stainless steel. A rotary vane vacuum pump is used for a complete cycle under deep vacuum. Parts are placed in a basket with a lid in order to prevent the fall of the parts during rotation. The Firbimatic incorporates a solvent storage tank and high-efficiency distillation unit. During the vacuum-degreasing cleaning process, all cleaning work is conducted inside a sealed unit, isolating any operator from potential chemistry contamination as well as reducing any fugitive emissions such as volatile organic compounds that could contribute to global warming. Ambient area personnel are not exposed to an open process tank subject to emissions migration created by wind drafts or improper system operation and lack of proper ventilation.

Dirty metal parts enter the system, and clean parts exit only after all the proper cycles have been completed. The process chamber door is sealed before the cleaning cycle starts and only opened after the process chamber has been evacuated of residual cleaning solvent. Clean and dry parts can be removed and generally are immediately ready for the next stage because lower part temperature allows rapid handling. Waste is separated for periodic disposal but at a lower volume compared with discharging the entire tank bath, as was done in the past.

#### 4. CONTAMINANTS

The contaminants used for this study are listed in table 1:

Table 1. Contaminants used in this study.

Contaminants
Premalube™ Xtreme #1
Castrol Brayco Micronic 882
Mil-PRF-81322G (Aeroshell)
Synthetic Sebum
Mobil DTE-25
Krytox™

These were chosen as typical grease or hydraulic fluid contaminants to be removed from flight hardware with different chemistries. Premalube™ Xtreme #1 is known to be resistant to water, and the Krytox™ is difficult to clean because of its chemical inertness.



## 5. SAMPLE PREPARATION

Samples were visibly inspected and cleaned using Solstice® solvent before contaminants were applied to the aluminum panels. Contaminants were applied to one side of the aluminum panel using a 1-in nylon brush. Photographs of the aluminum panel were taken before and after cleaning (i.e., after application of the contaminant and after the panel was cleaned) in both normal (white) light and ultraviolet (UV) light.

## 6. CLEANING METHODS

One solvent, METALNOX M6386, was used for all cleaning methods and contaminants. Four cleaning methods were tested for each of the six contaminants in the study. For each cleaning method, five panels were tested. Four panels were cleaned, and one panel was used as the control panel. The sample panels were weighed before and after contaminant application and after the contaminants were removed. The Firbimatic can be programmed for different dwell times in each step, e.g., ultrasonic cleaning, spray rinse with basket rotation, etc. The four cleaning methods used are listed in tables 2–5 as method 1, method 2, method 3, and method 4, with each one taking progressively more time for cleaning the panels.

Table 2. Cleaning method 1.

Step	Description
1	30 s preclean spray wash with basket rotation
2	3-min ultrasonic cleaning with basket rotation
3	30 s spray rinse with basket rotation
4	3-min dry cycle with basket rotation

Table 3. Cleaning method 2.

Step	Description
1	1-min preclean spray wash with basket rotation
2	10-min ultrasonic cleaning with basket rotation
3	5-min spray rinse with basket rotation
4	2-min vapor degreasing with basket rotation
5	2-min dry cycle with basket rotation

Table 4. Cleaning method 3.

Step	Description
1	3-min preclean spray wash with basket rotation
2	30-min ultrasonic cleaning with basket rotation
3	10-min spray rinse with basket rotation
4	5-min vapor degreasing with basket rotation
5	3-min dry cycle with basket rotation

Table 5. Cleaning method 4.

Step	Description
1	3-min preclean spray with basket rotation
2	45-min ultrasonic cleaning with basket rotation
3	3-min spray rinse with basket rotation
4	2-min vapor degreasing with basket rotation
5	2-min dry cycle with basket rotation

## 7. EQUIPMENT USED

The equipment used in this cleaning study were the Firbimatic Multisolvent 50-volt vacuum degreaser, the Mettler Toledo XP205 balance, and a Nikon camera with white light and UV light, all of which are located in Building 4711.



Figure 1. Firbimatic Multisolvent 50-volt vacuum degreaser.



Figure 2. Mettler Toledo XP205 balance.

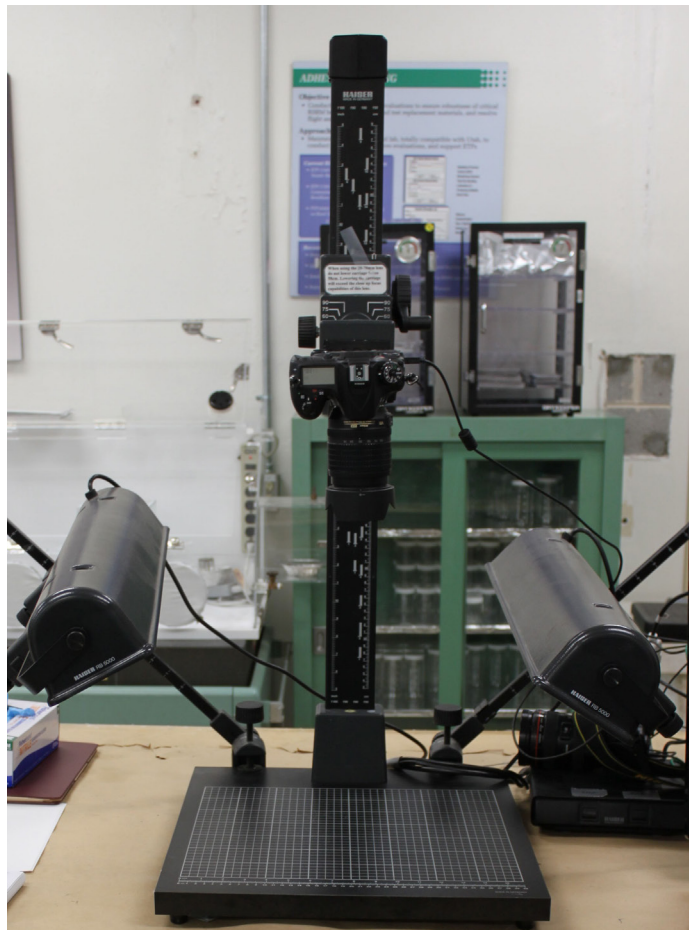


Figure 3. Nikon camera with white light and UV.

## 8. CONCLUSIONS

The Firbimatic vacuum degreaser used with Kyzen's Metalnox M6386 removed 100% of the Premalube Xtreme #1, Castrol Brayco Micronic 882, Mil-PRF-81322G (Aeroshell), synthetic sebum, and Mobil DTE™ 25 contaminants, for methods 3 and 4. Method 2 may be adequate for some contaminants. The quick wash method (method 1) did not remove much Krytox, but the longer cleaning methods removed up to 97.9% of the contaminant. The vacuum degreaser system was programmed to clean at a temperature of 80 °C (176 °F). Krytox is designed for high-temperature environments in the range of 371 °C to 399 °C (700 °F to 750 °F). Future test temperatures up to 205 °C for the next vapor degreasing study will increase the possibility that a greater amount of contaminants can be removed than at just 80 °C. As the results show, vacuum degreasing is a leading solution for removing contaminants.

The appendix lists the cleaning results for this study in the form of weight change tables and pre- and post-test photographs. Contaminant removal of >100% may indicate removal of substrate material, humidity effects, or instrument variability. Repeatability for the Mettler Toledo XP205 balance is 0.015 mg for a test weight of 10 g.

## APPENDIX A—AVERAGES

### A.1 DATA TABLE, KYZEN'S METALNOX M6386 SOLVENT ON CONTAMINANTS— OVERALL AVERAGES

Table 6 shows the averages of each cleaning method.

Table 6. Overall averages for Kyzen's Metalnox M6386 solvent on contaminants.

Contaminant	Quick Wash (%)	10-min Wash (%)	30-min Wash (%)	45-min Wash (%)
Premalube	99.86	100.12	100.30	100.31
Brayco	99.98	100.05	100.12	100.13
AeroShell	103.58	100.06	100.14	100.12
Synthetic Sebum	99.83	100.11	100.98	100.97
Mobil DTE	102.45	100.03	100.43	100.16
Krytox	39.28	66.22	82.52	91.61

## APPENDIX B—METHOD 1

### B.1 DATA TABLE, QUICK WASH (METHOD 1) ANALYSIS USING KYZEN'S METALNOX M6386 SOLVENT ON CONTAMINANTS

The analysis data for cleaning method 1 are listed in table 7.

Table 7. Method 1 (quick wash) analysis data.

Panel #	Contaminant	Initial Weight (g)	Weight after Adding Contaminant (g)	Weight after Cleaning (g)	Weight of Contaminant (g)	Contaminant Removed (%)	Averages (%)
1	Premalube	43.91258	44.70025	44.69308	0.78767	0.91	Control
2		43.75788	44.37609	43.75907	0.61821	99.81	99.86
3		43.79779	44.27357	43.79823	0.47578	99.91	
4		43.90717	44.49134	43.90874	0.58417	99.73	
5		43.79175	44.27962	43.79178	0.48787	99.99	
6	Brayco	43.98086	44.37929	44.37466	0.39843	1.16	Control
7		43.87616	44.28642	43.87615	0.41026	100.00	99.98
8		43.91404	44.34049	43.91416	0.42645	99.97	
9		44.02074	44.55132	44.02081	0.53058	99.99	
10		44.32263	44.66087	44.32283	0.33824	99.94	
11	AeroShell	44.23163	45.03320	45.03221	0.80157	0.12	Control
12		44.18912	45.26774	44.03484	1.07862	114.30	103.58
13		43.92492	44.67356	43.92489	0.74864	100.00	
14		44.18931	45.05438	44.18903	0.86507	100.03	
15		43.91668	44.68212	43.91694	0.76544	99.97	
16	Synthetic Sebum	44.02151	44.19845	44.19326	0.17694	2.93	Control
17		43.86736	44.00393	43.86745	0.13657	99.93	99.83
18		43.79821	44.00393	43.79892	0.20572	99.65	
19		44.01878	44.14728	44.01926	0.12850	99.63	
20		43.97281	44.14235	43.97260	0.16954	100.12	
21	Mobil DTE	44.02174	44.32643	44.32585	0.30469	0.19	Control
22		43.94470	44.17630	43.92150	0.23160	110.02	102.45
23		43.92136	44.33592	43.92150	0.41456	99.97	
24		44.08395	44.30450	44.08421	0.22055	99.88	
25		43.97950	44.38789	43.97975	0.40839	99.94	
26	Krytox	43.93901	44.27200	44.27195	0.33299	0.02	Control
27		44.00892	44.15383	44.07666	0.14491	53.25	39.28
28		43.90540	44.00473	43.97539	0.09933	29.54	
29		44.18619	44.35235	44.28979	0.16616	37.65	
30		43.86186	43.93387	43.90745	0.07201	36.69	



## B.2 CLEANING METHOD 1—IMAGES OF SAMPLE PANELS WITH CONTAMINANTS— BEFORE AND AFTER CLEANING, WITH WHITE LIGHT AND UV LIGHT

Figures 4–27 are images of sample panels with contaminants, before and after cleaning, using method 1.



Figure 4. Method 1, Premalube, panels 1–5, before cleaning.



Figure 5. Method 1, Premalube, panels 1–5, after cleaning.



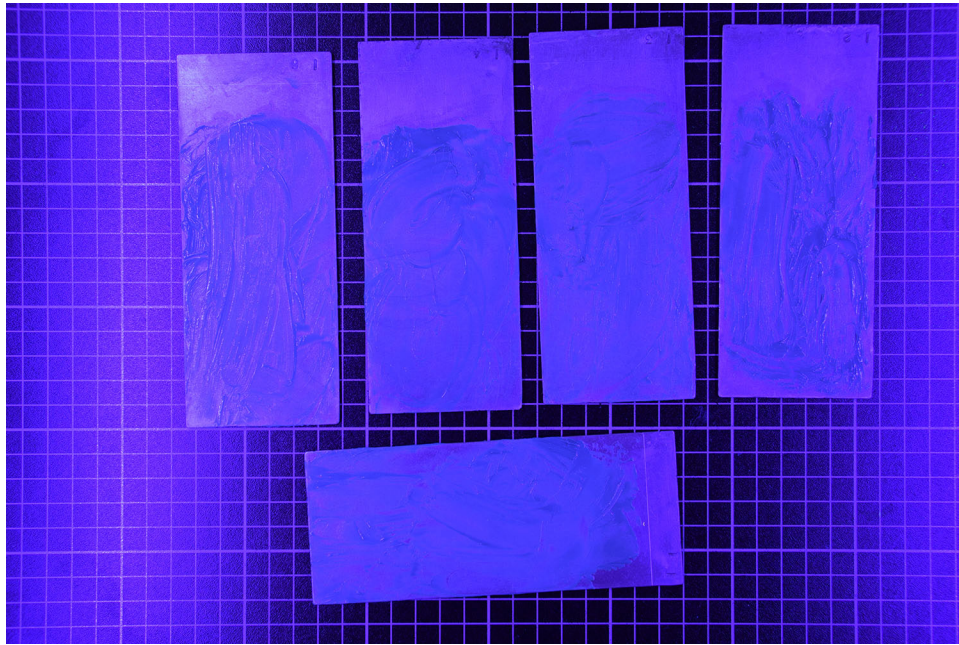


Figure 6. Method 1, Premalube, panels 1–5, before cleaning, UV light.

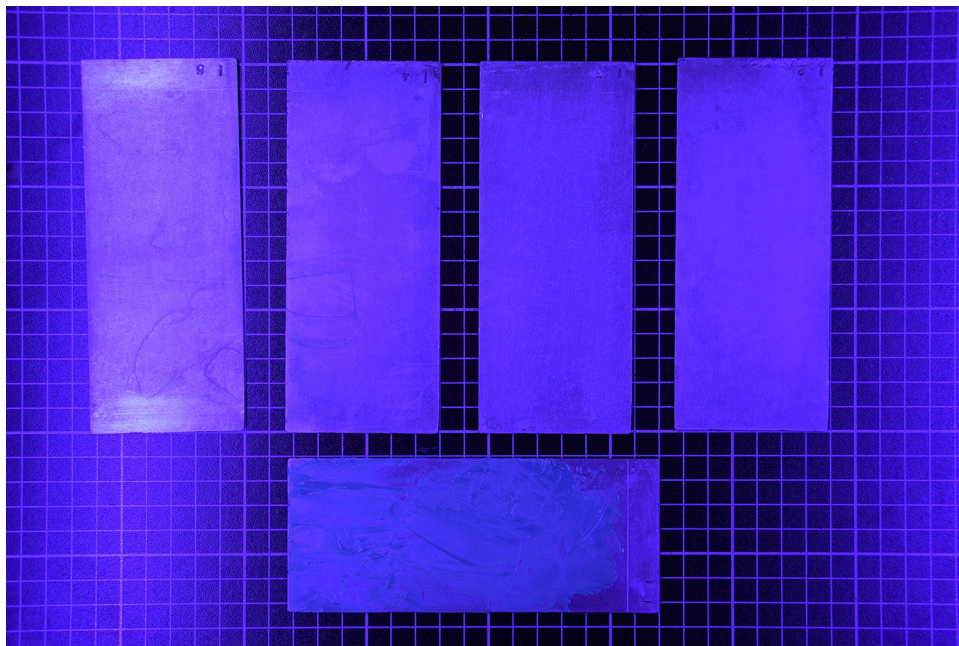


Figure 7. Method 1, Premalube, panels 1–5, after cleaning, UV light.

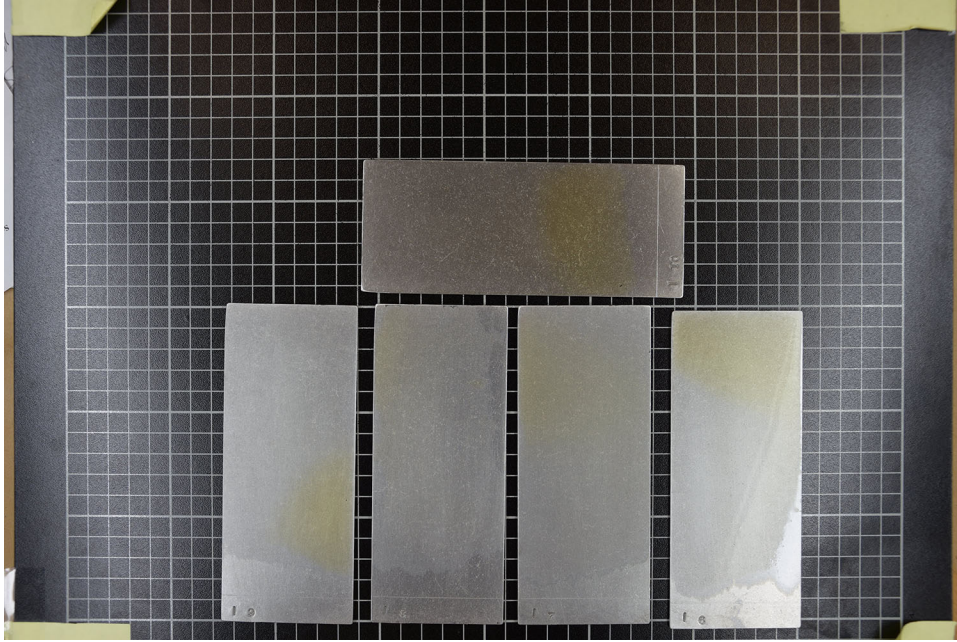


Figure 8. Method 1, Brayco, panels 6–10, before cleaning.

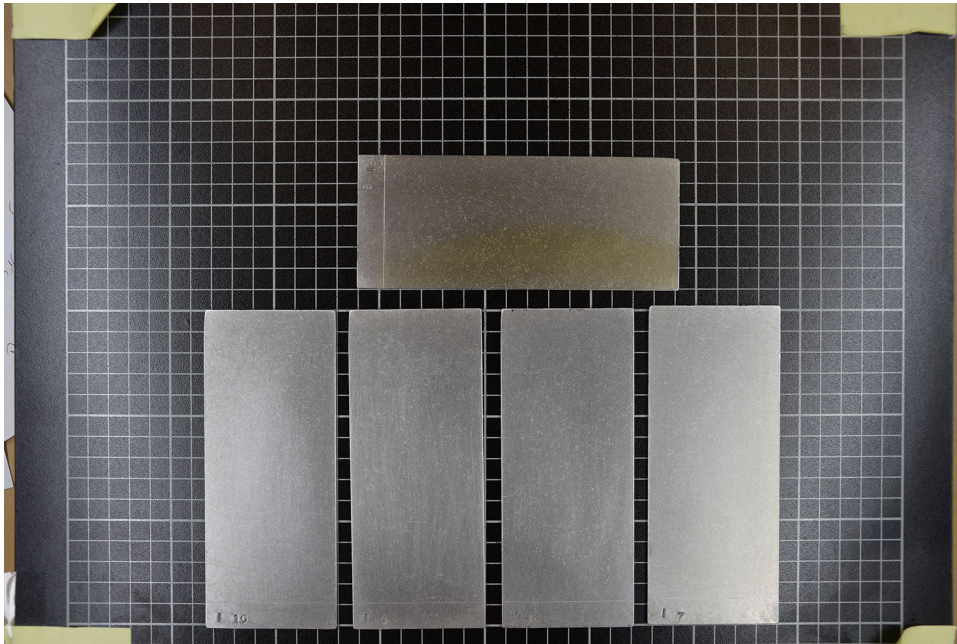


Figure 9. Method 1, Brayco, panels 6–10, after cleaning.



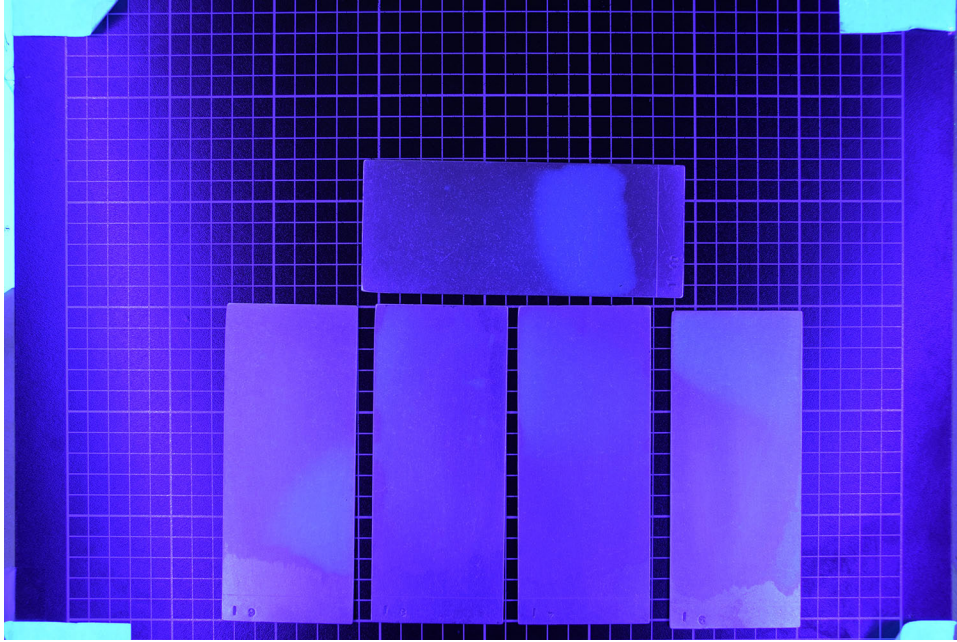


Figure 10. Method 1, Brayco, panels 6–10, before cleaning, UV light.

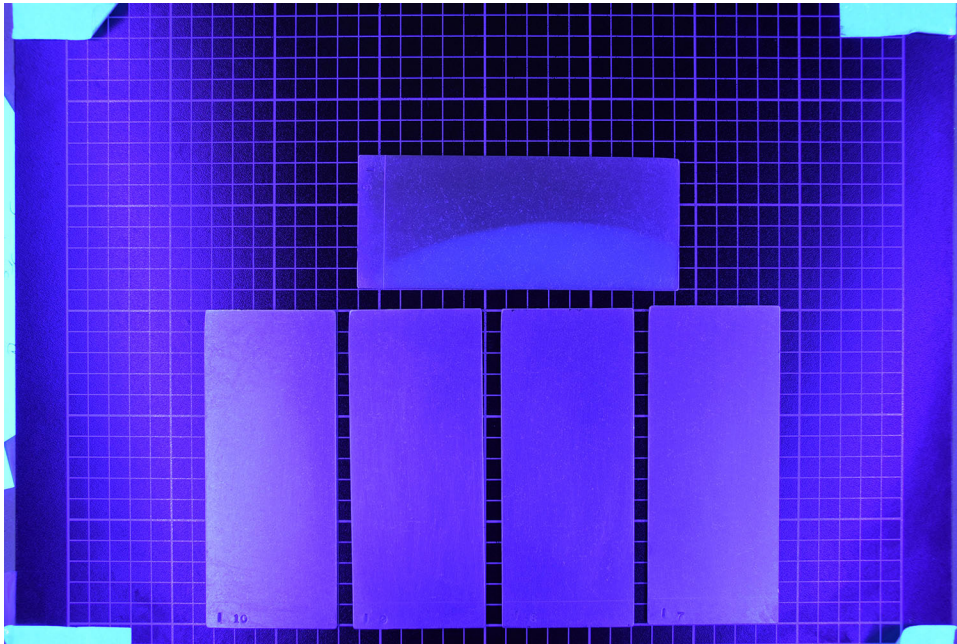


Figure 11. Method 1, Brayco, panels 6–10, after cleaning, UV light.

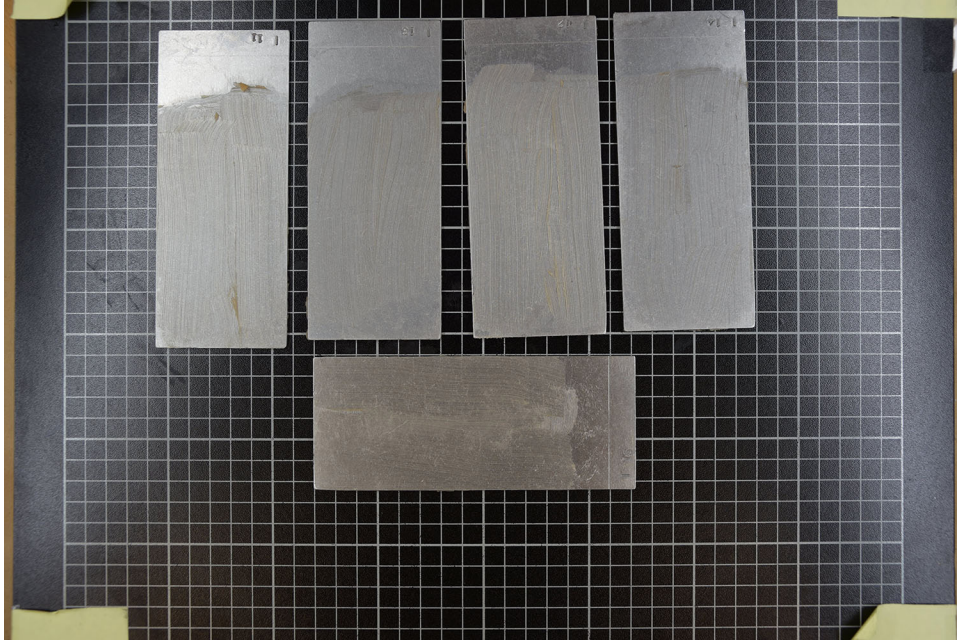


Figure 12. Method 1, AeroShell, panels 11–15, before cleaning.

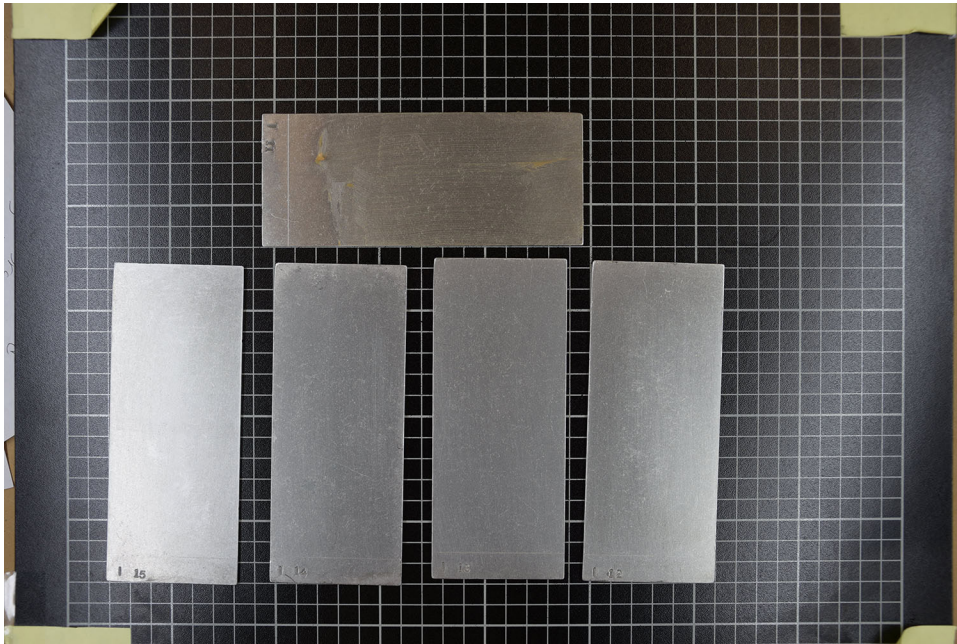


Figure 13. Method 1, AeroShell, panels 11–15, after cleaning.



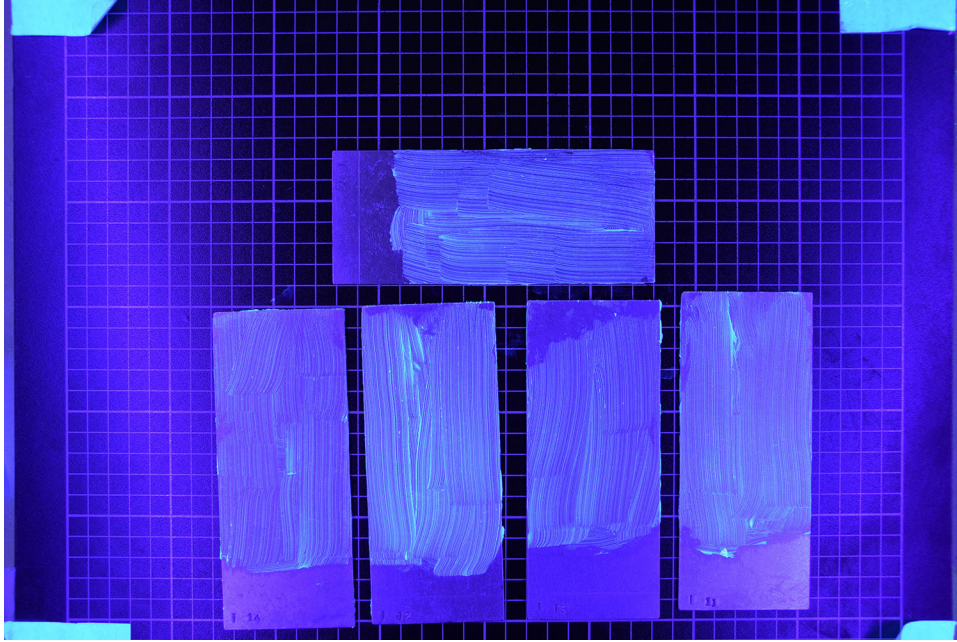


Figure 14. Method 1, AeroShell, panels 11–15, before cleaning, UV light.

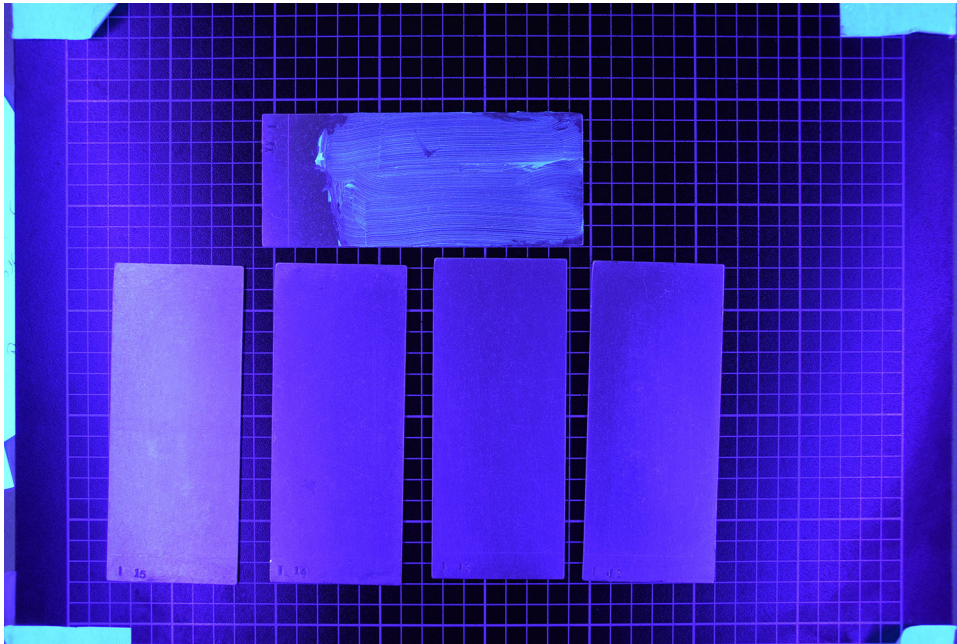


Figure 15. Method 1, AeroShell, panels 11–15, after cleaning, UV light.

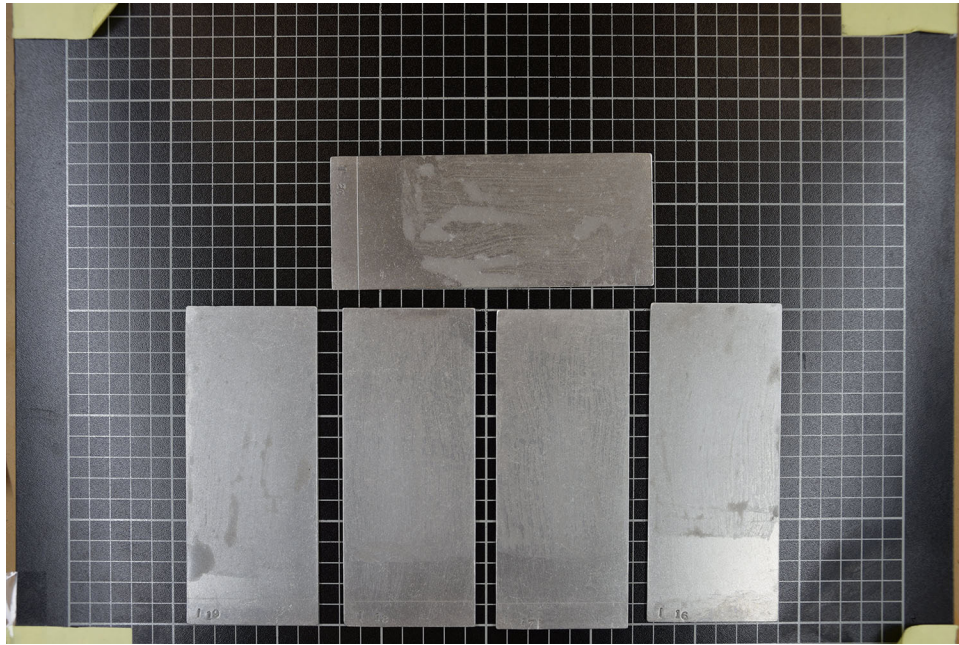


Figure 16. Method 1, synthetic sebum, panels 16–20, before cleaning.

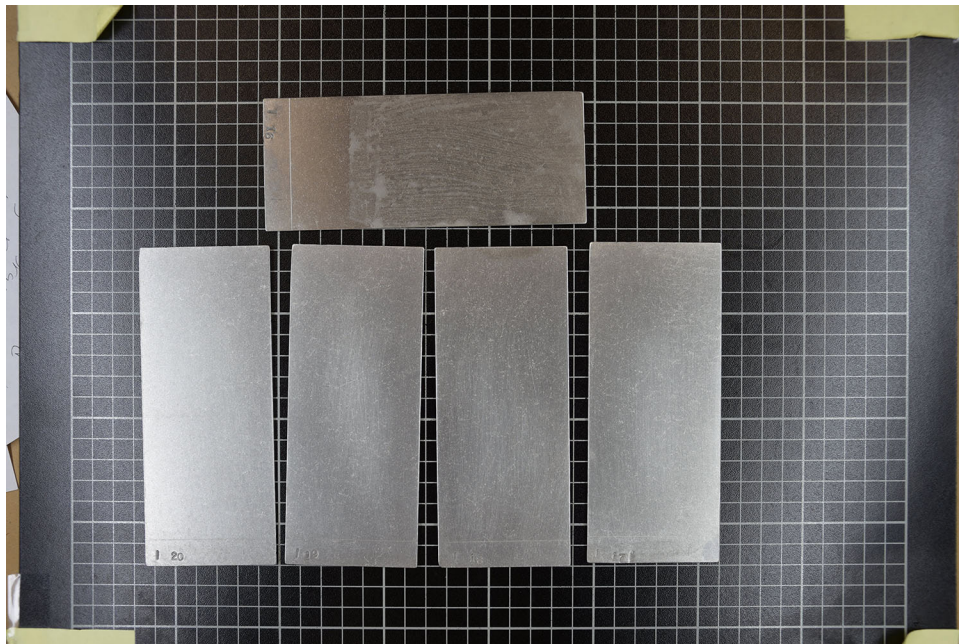


Figure 17. Method 1, synthetic sebum, panels 16–20, after cleaning



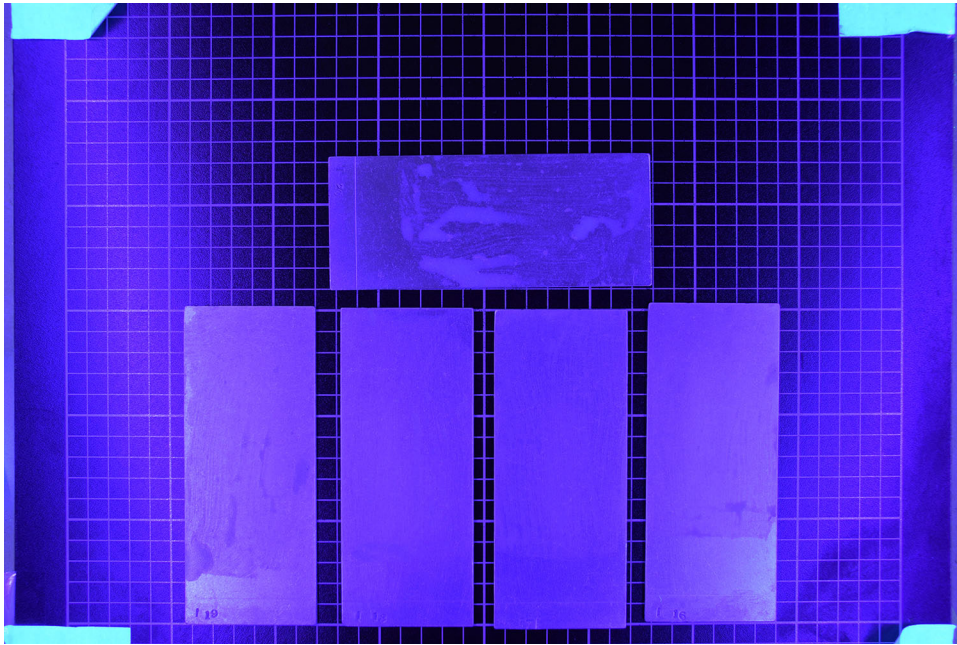


Figure 18. Method 1, synthetic sebum, panels 16–20, before cleaning, UV light.

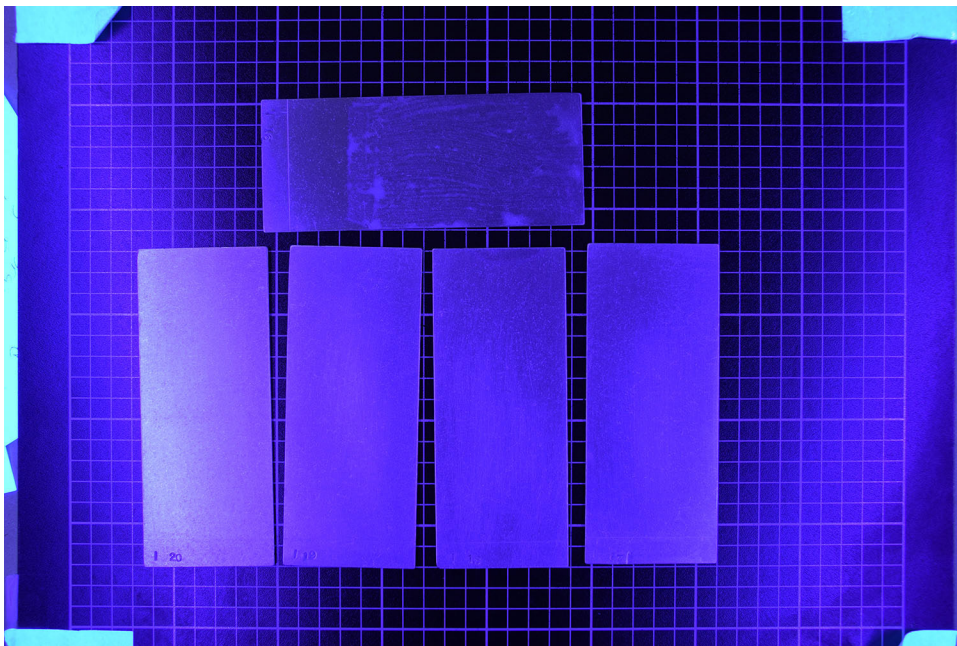


Figure 19. Method 1, synthetic sebum, panels 16–20, after cleaning, UV light.



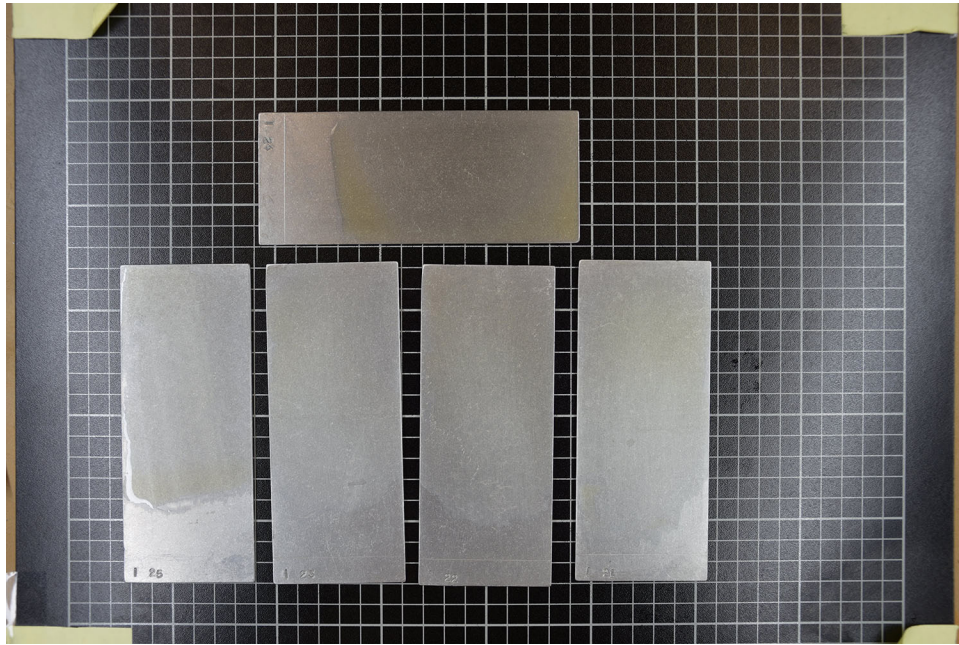


Figure 20. Method 1, Mobil DTE 25, panels 21–25, before cleaning.

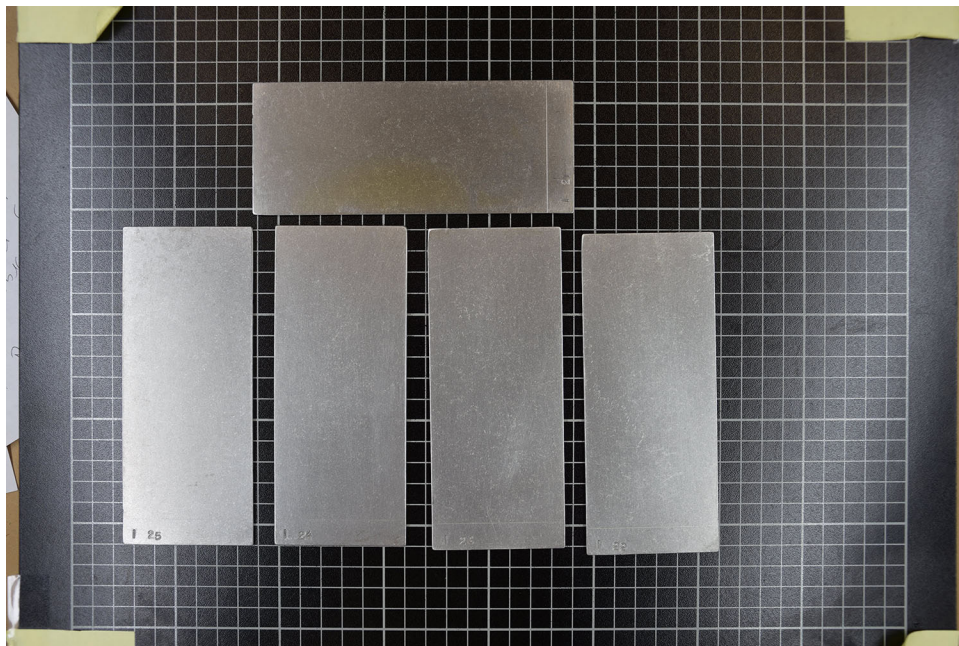


Figure 21. Method 1, Mobil DTE 25, panels 21–25, after cleaning.

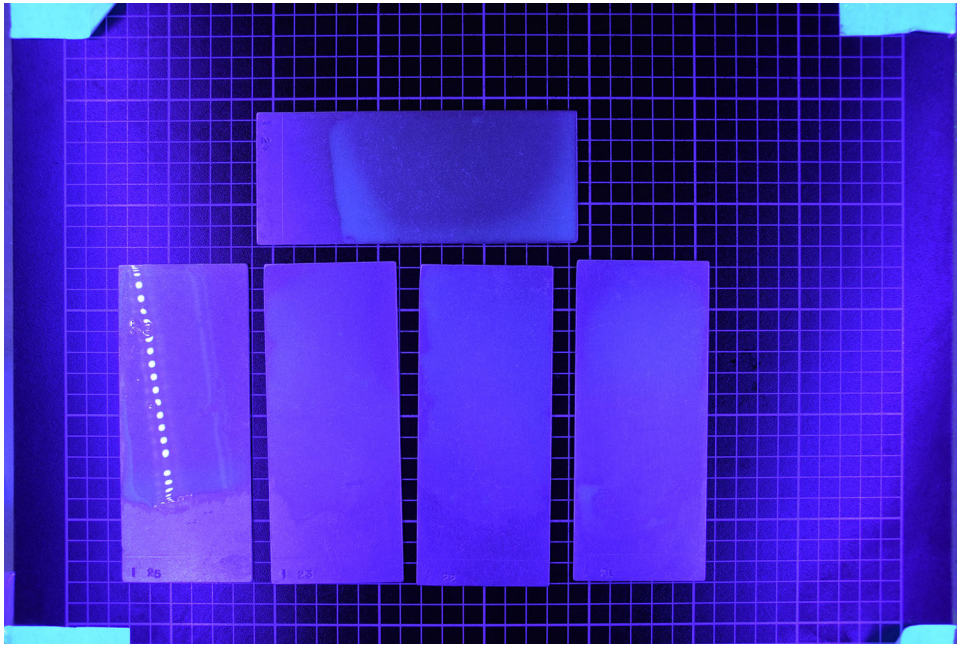


Figure 22. Method 1, Mobil DTE 25, panels 21–25, before cleaning, UV light.

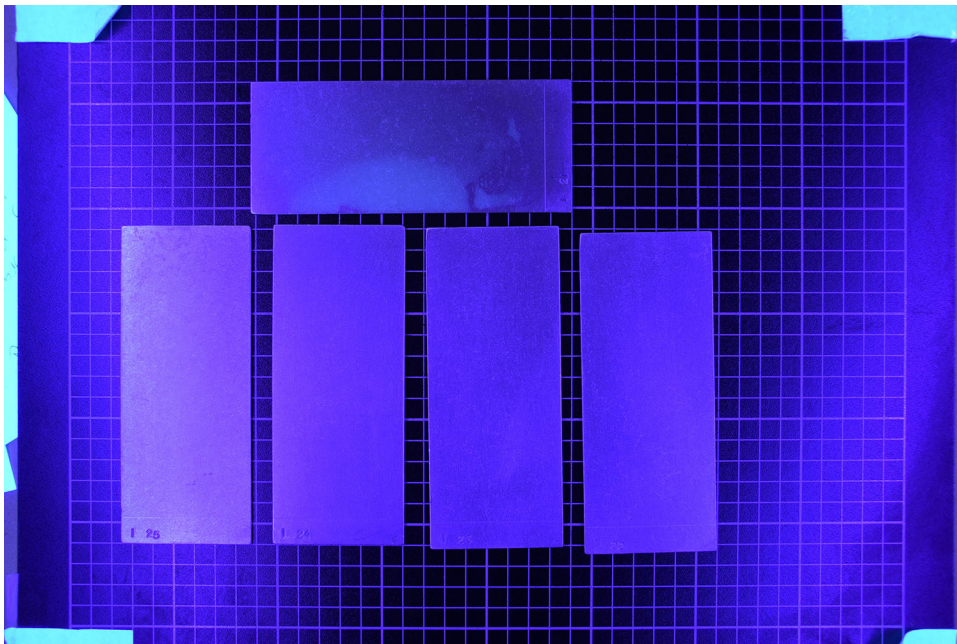


Figure 23. Method 1, Mobil DTE 25, panels 21–25, after cleaning, UV light.



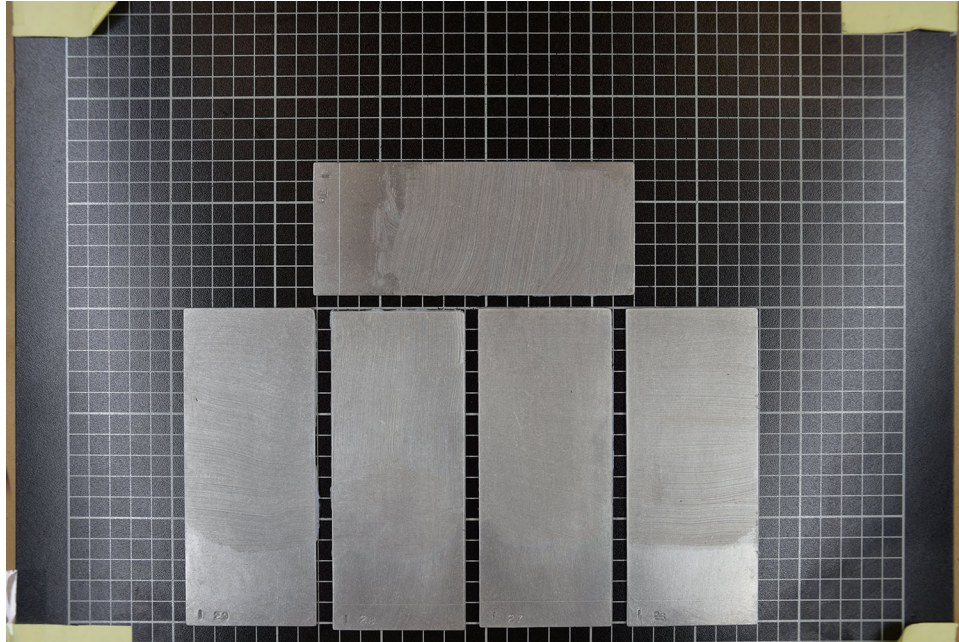


Figure 24. Method 1, Krytox, panels 26–30, before cleaning.

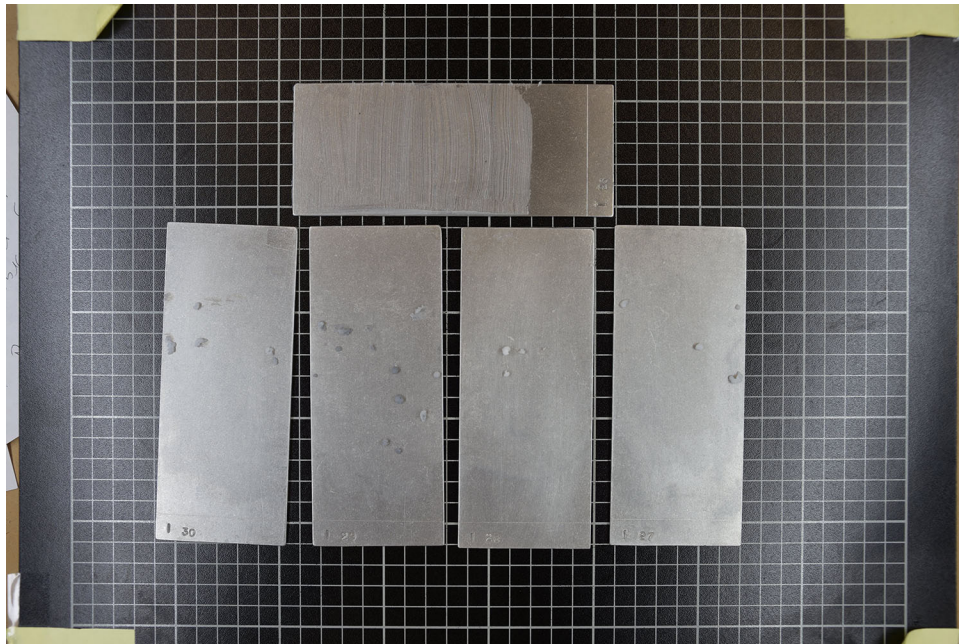


Figure 25. Method 1, Krytox, panels 26–30, after cleaning.

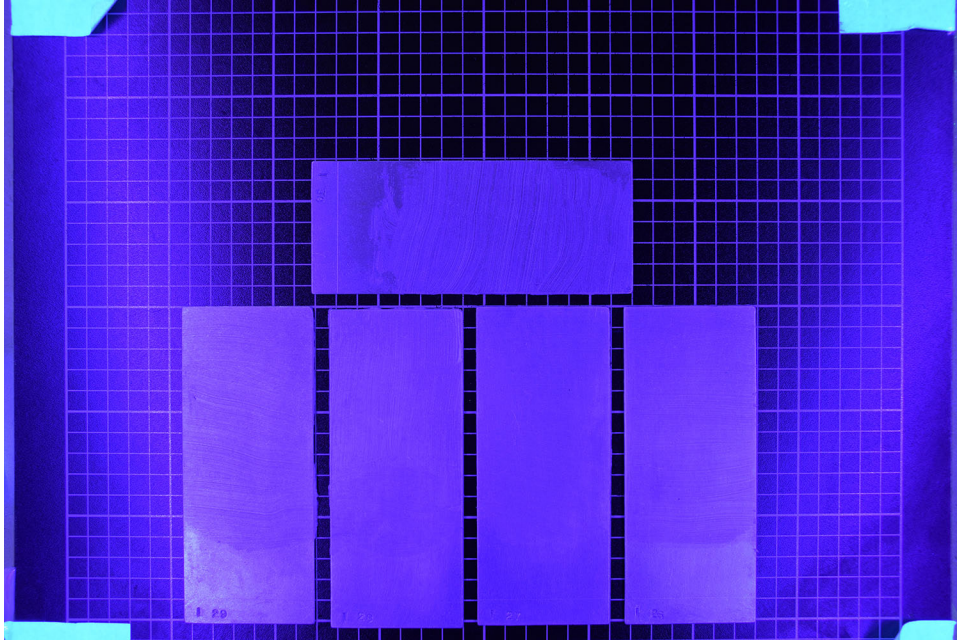


Figure 26. Method 1, Krytox, panels 26–30, before cleaning, UV.

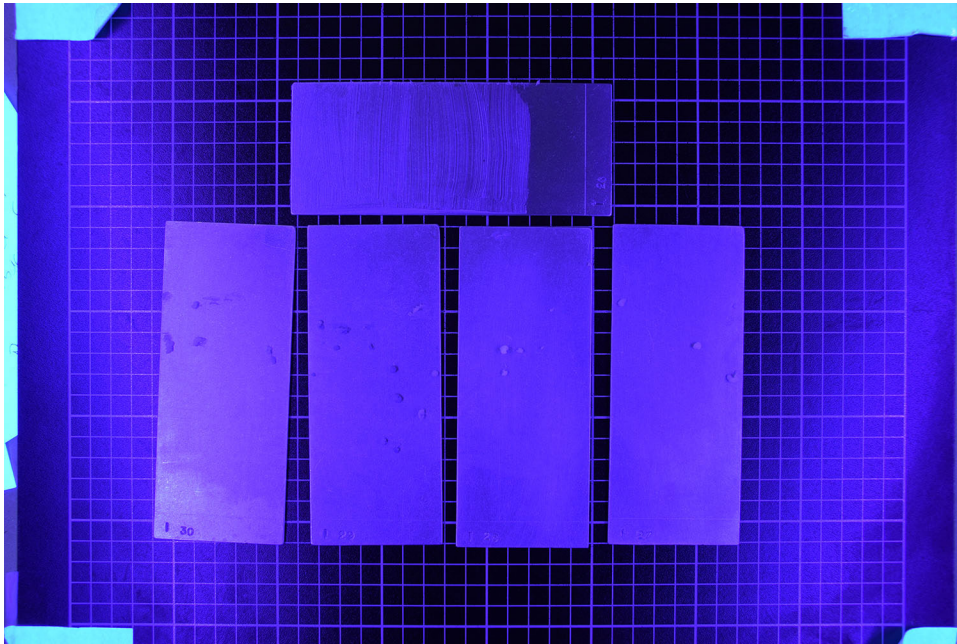


Figure 27. Method 1, Krytox, panels 26–30, after cleaning, UV light.



## APPENDIX C—METHOD 2

### C.1 DATA TABLE, 10-MINUTE WASH (METHOD 2) ANALYSIS USING USING KYZEN'S METALNOX M6386 SOLVENT ON CONTAMINANTS

The analysis data for cleaning method 2 are listed in table 8.

Table 8. Method 2 (10-min wash) analysis data.

Panel #	Contaminant	Initial Weight (g)	Weight After Adding Contaminant (g)	Weight After Cleaning (g)	Weight of Contaminant (g)	Contaminant Removed (%)	Averages (%)
1	Premalube	43.93241	44.14255	44.13903	0.21014	1.68	Control
2		43.78820	44.06618	43.78767	0.27798	100.19	100.12
3		43.81886	44.14190	43.81870	0.32304	100.05	
4		43.98219	44.59861	43.98178	0.61642	100.07	
5		43.80268	44.16377	43.80208	0.36109	100.17	
6	Brayco	43.98456	44.28375	44.28201	0.29919	0.58	Control
7		43.87782	44.26560	43.87755	0.38778	100.07	100.05
8		43.91553	44.10321	43.91546	0.18768	100.04	
9		44.02203	44.37304	44.02203	0.35101	100.00	
10		44.32447	44.64281	44.32418	0.31834	100.09	
11	Aeroshell	44.23719	44.75176	44.70765	0.51457	8.57	Control
12		44.03620	44.42428	44.03590	0.38808	100.08	100.06
13		43.92637	44.57952	43.92615	0.65315	100.03	
14		44.19039	44.67867	44.19014	0.48828	100.05	
15		43.91896	44.46149	43.91861	0.54253	100.06	
16	Synthetic Sebum	44.02548	44.30041	44.30124	0.27493	-0.30	Control
17		43.87102	44.11032	43.87065	0.23930	100.15	100.11
18		43.80181	44.07321	43.80141	0.27140	100.15	
19		44.02139	44.41404	44.02107	0.39265	100.08	
20		43.97493	44.46407	43.97468	0.48914	100.05	
21	Mobil DTE	44.02462	44.46651	44.46427	0.44189	0.51	Control
22		43.94673	44.40106	43.94664	0.45433	100.02	100.03
23		43.92483	44.40106	43.92470	0.47623	100.03	
24		44.08789	44.51223	44.08767	0.42434	100.05	
25		43.98250	44.43890	43.98237	0.45640	100.03	
26	Krytox	43.93901	44.27200	44.27195	0.33299	0.02	Control
27		44.00961	44.31470	44.11192	0.30509	66.47	66.22
28		43.90572	44.06656	43.95818	0.16084	67.38	
29		44.18648	44.44869	44.26473	0.26221	70.16	
30		43.86184	44.03423	43.92930	0.17239	60.87	

## C.2 CLEANING METHOD 2—IMAGES OF SAMPLE PANELS WITH CONTAMINANTS— BEFORE AND AFTER CLEANING, WITH WHITE LIGHT AND UV LIGHT

Figures 28–51 are images of sample panels with contaminants, before and after cleaning, using method 2.



Figure 28. Method 2, Premalube, panels 1–5, before cleaning.

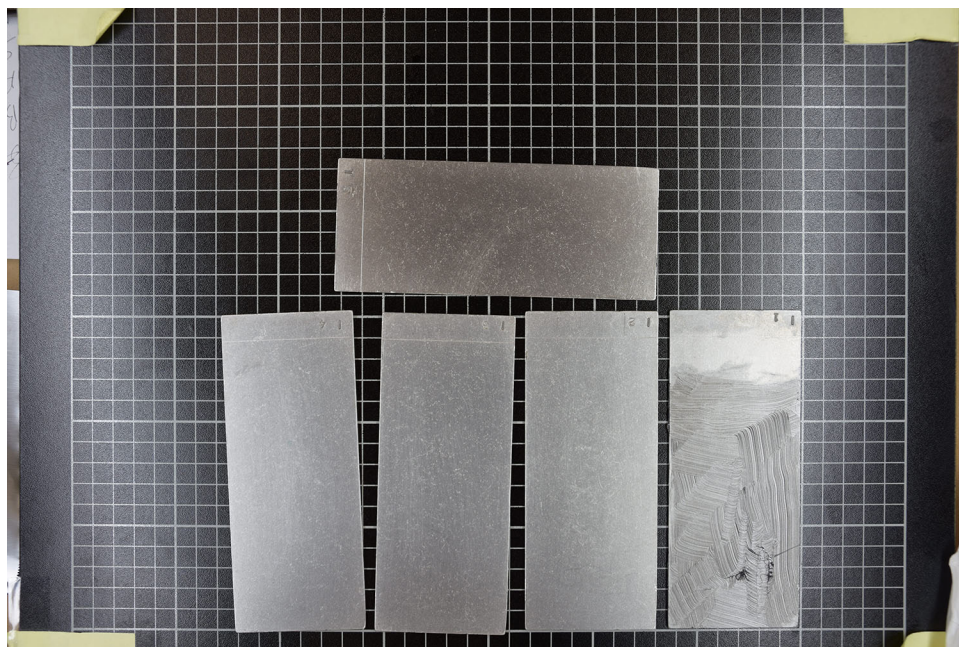


Figure 29. Method 2, Premalube, panels 1–5, after cleaning.





Figure 30. Method 2, Premalube, panels 1–5, before cleaning, UV light.

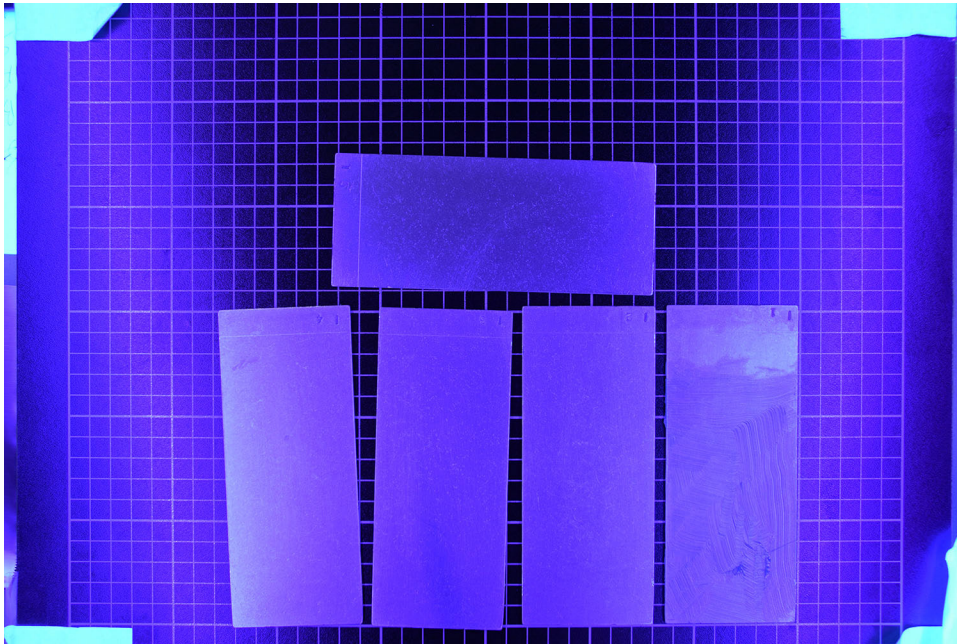


Figure 31. Method 2, Premalube, panels 1–5, after cleaning, UV light.

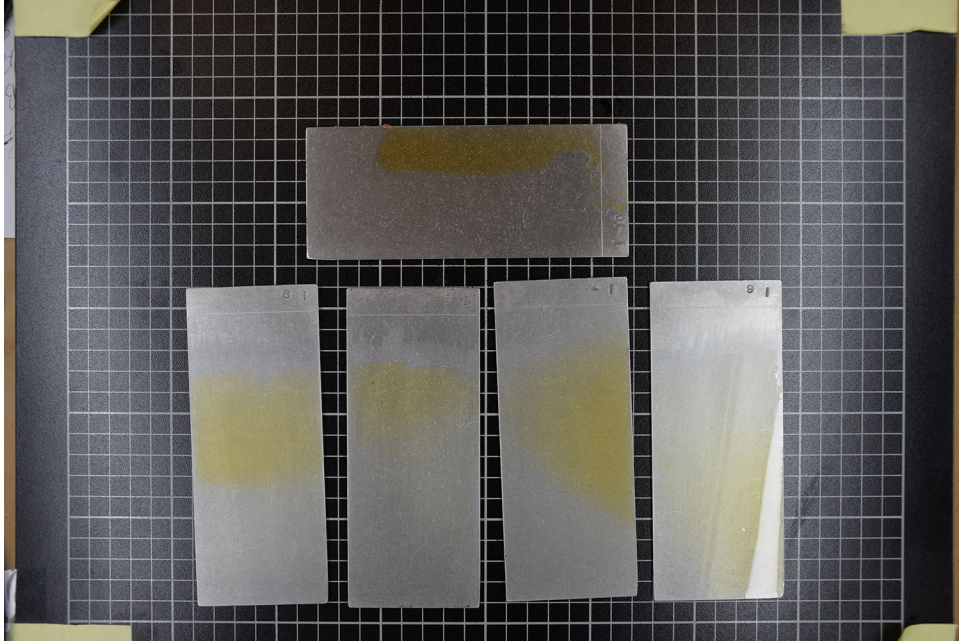


Figure 32. Method 2, Brayco, panels 6–10, before cleaning.

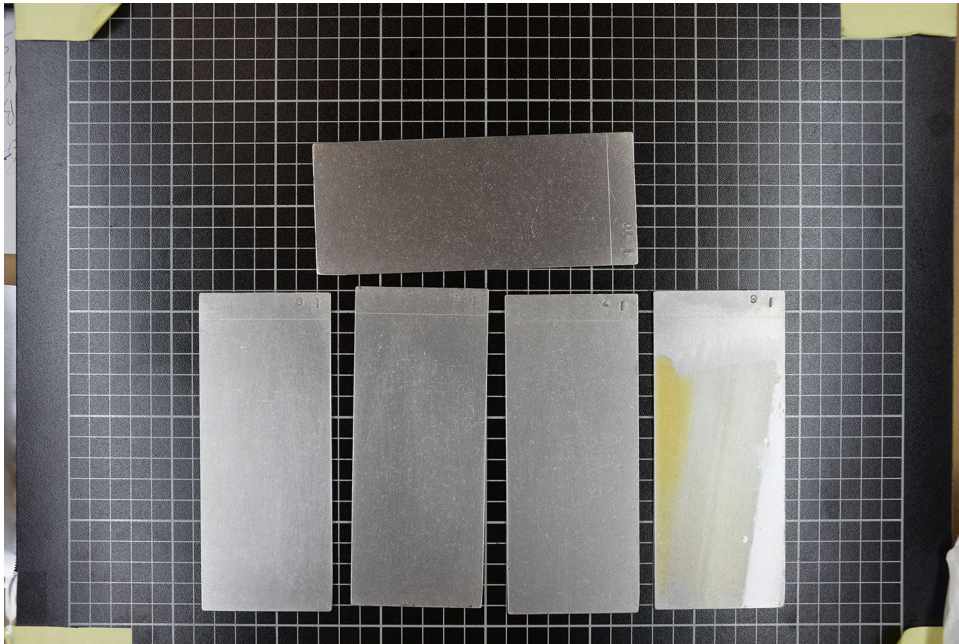


Figure 33. Method 2, Brayco, panels 6–10, after cleaning.



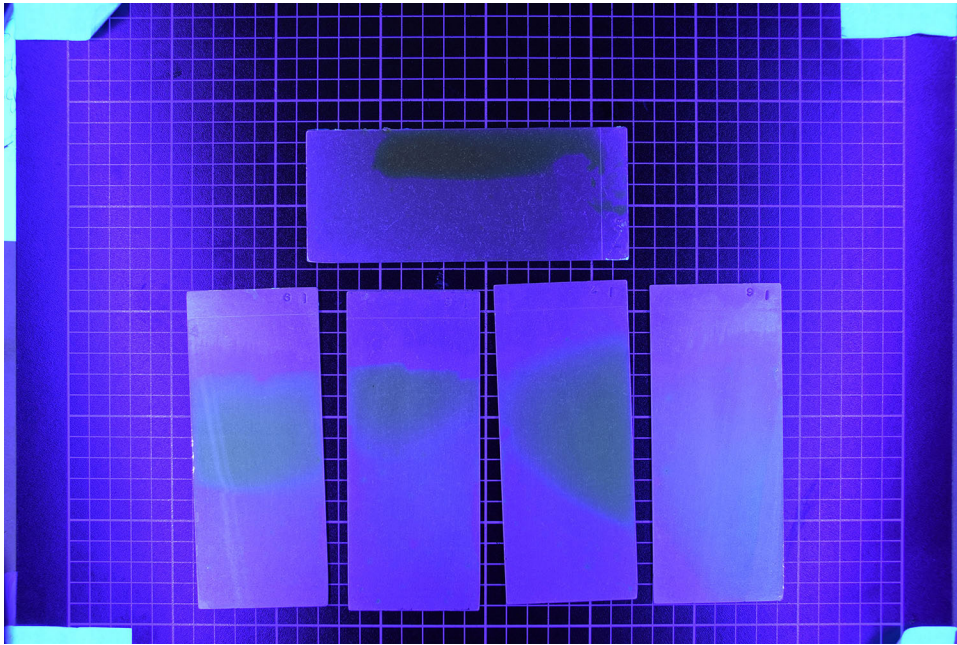


Figure 34. Method 2, Brayco, panels 6–10, before cleaning, UV light.

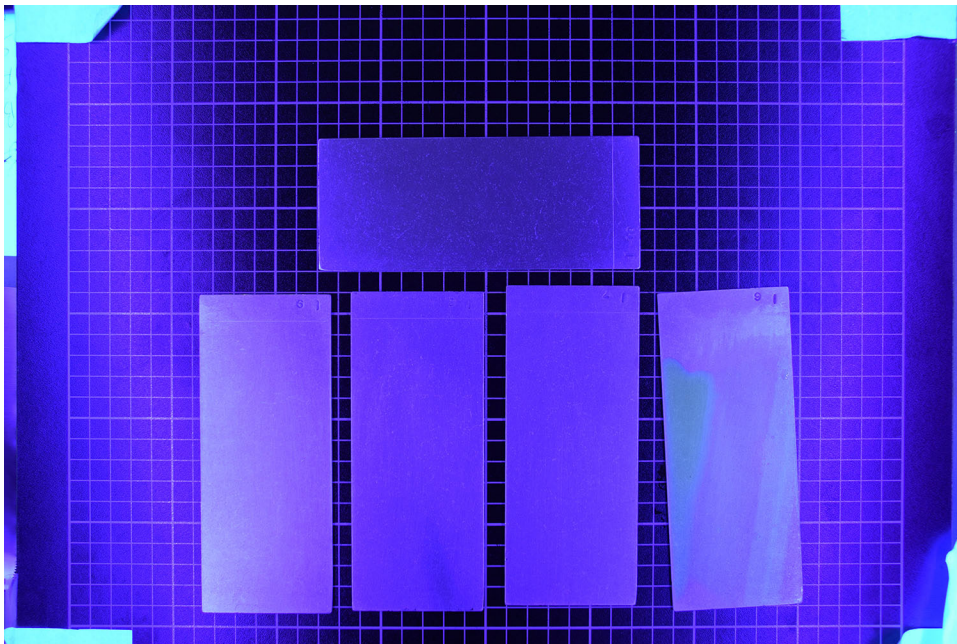


Figure 35. Method 2, Brayco, panels 6–10, after cleaning, UV light.

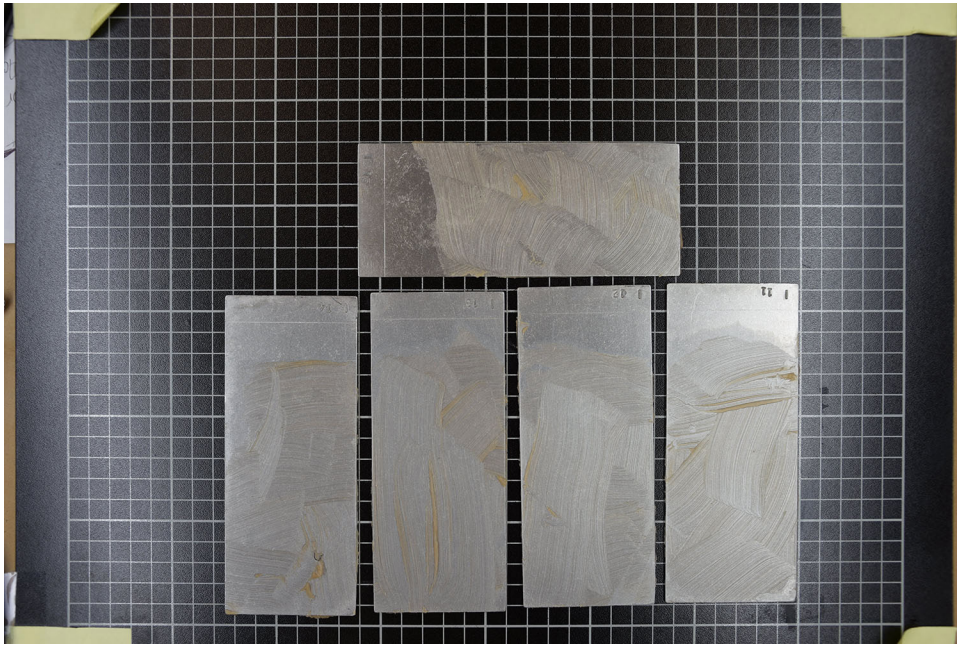


Figure 36. Method 2, AeroShell, panels 11–15, before cleaning.



Figure 37. Method 2, AeroShell, panels 11–15, after cleaning.



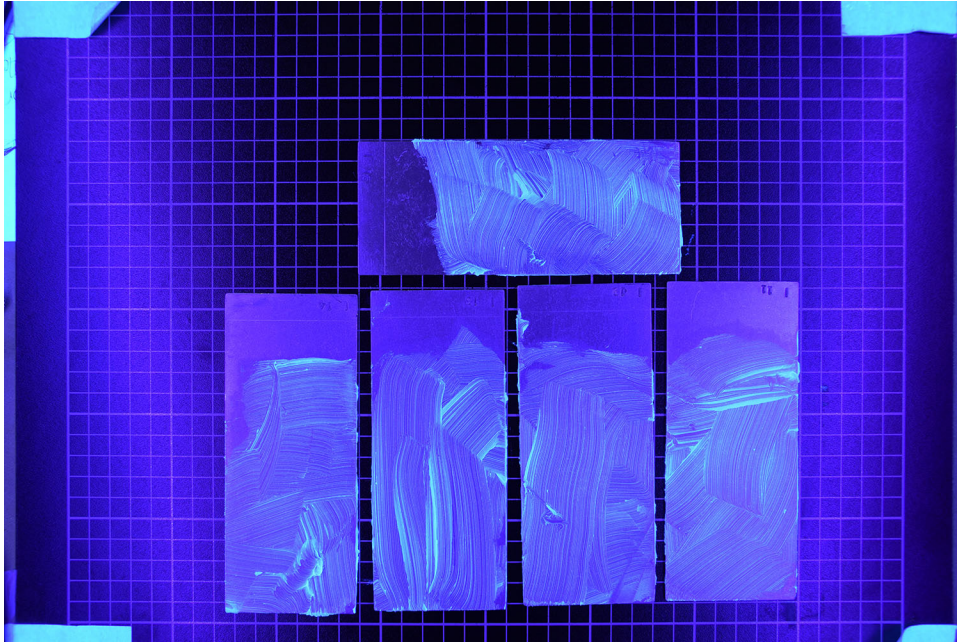


Figure 38. Method 2, AeroShell, panels 11–15, before cleaning, UV light.

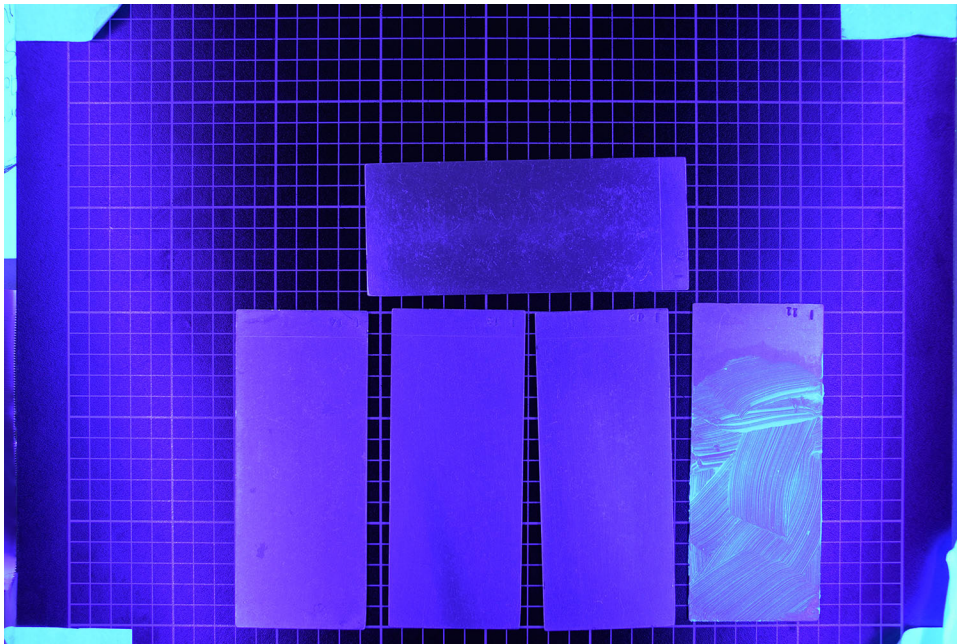


Figure 39. Method 2, AeroShell, panels 11–15, after cleaning, UV light.

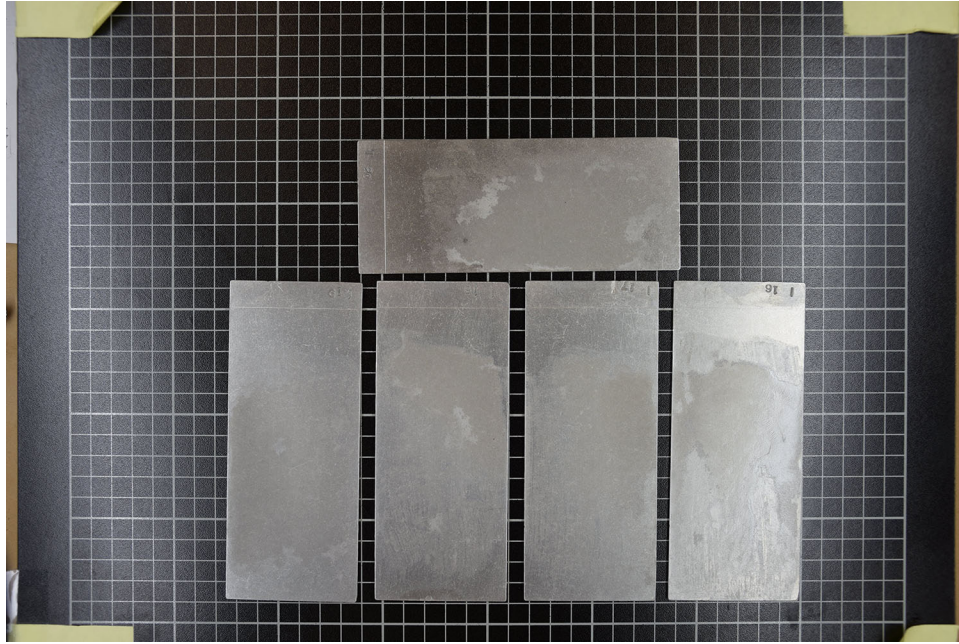


Figure 40. Method 2, synthetic sebum, panels 16–20, before cleaning.

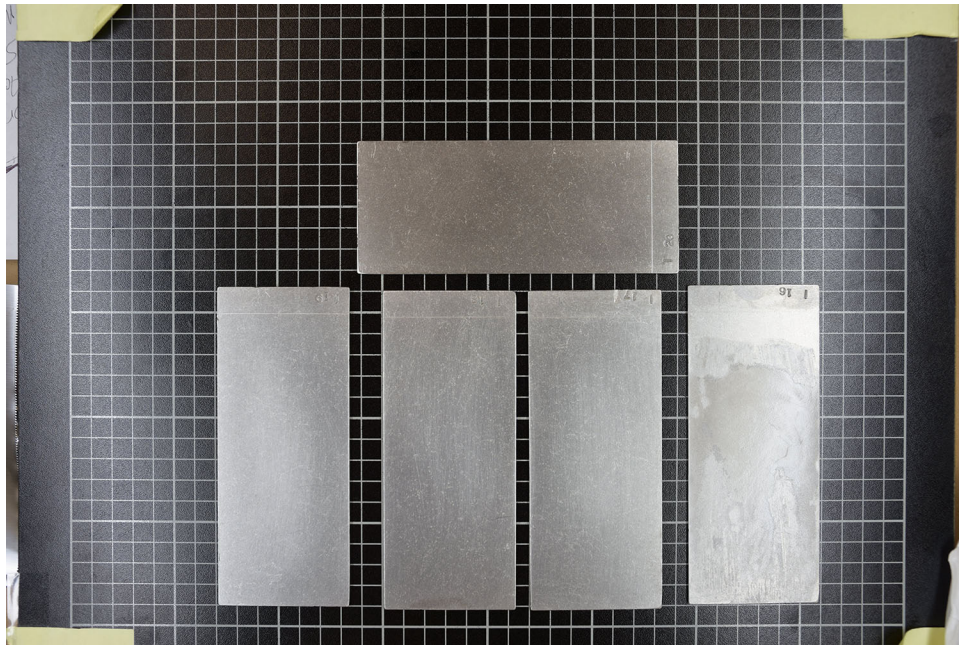


Figure 41. Method 2, synthetic sebum, panels 16–20, after cleaning.



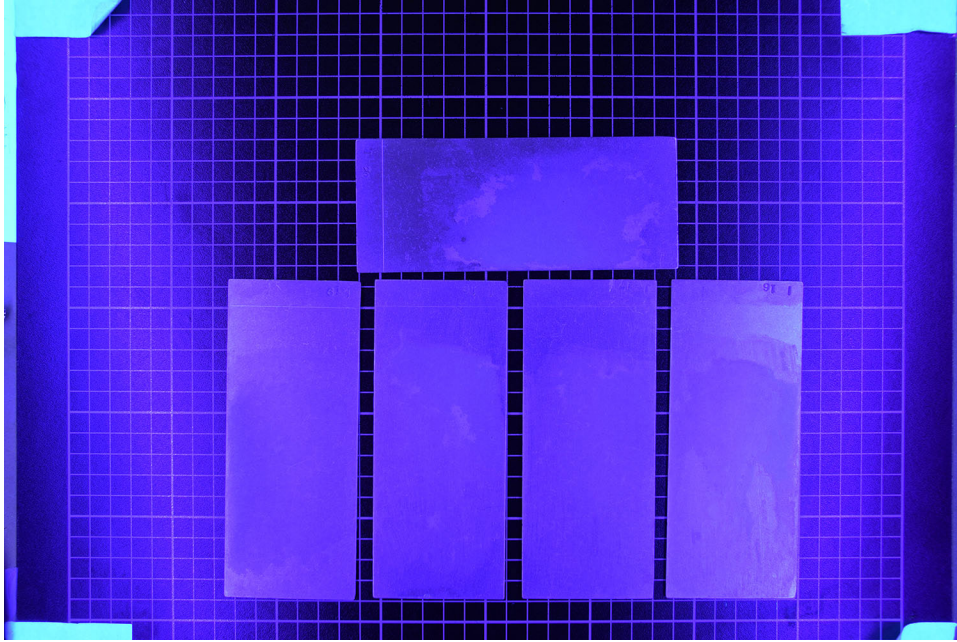


Figure 42. Method 2, synthetic sebum, panels 16–20, before cleaning, UV light.

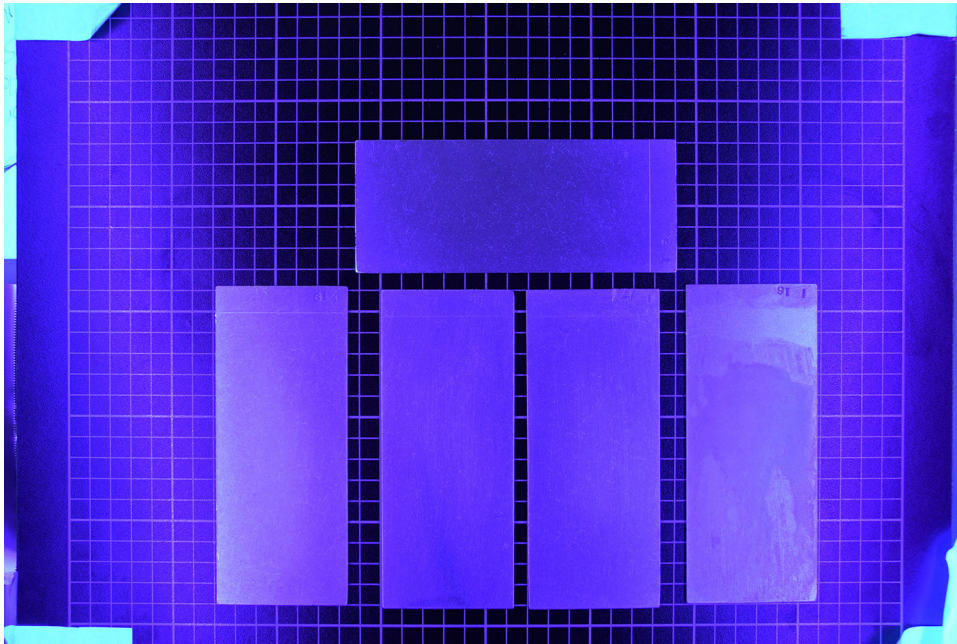


Figure 43. Method 2, synthetic sebum, panels 16–20, after cleaning, UV light.

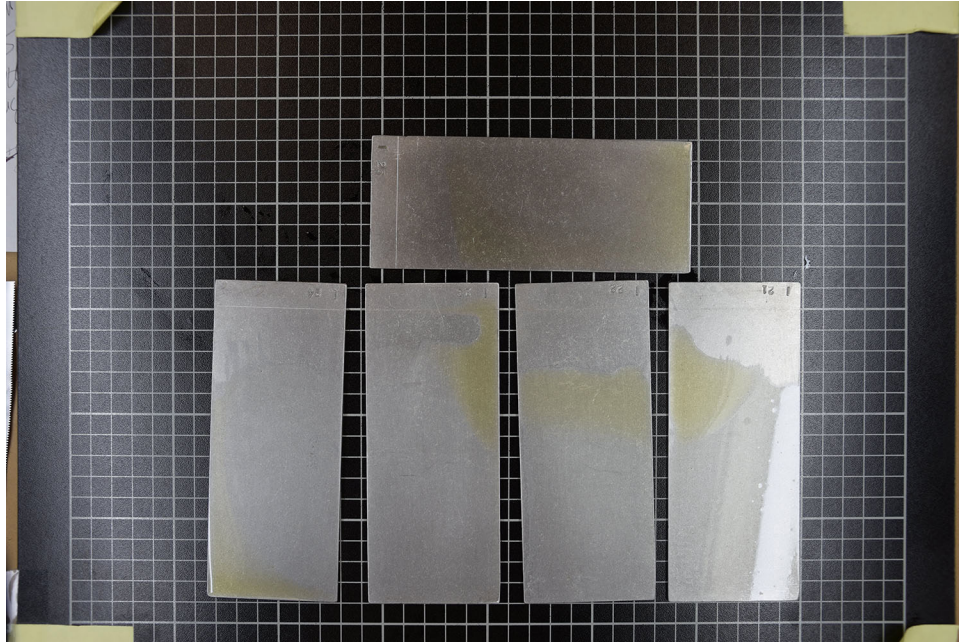


Figure 44. Method 2, Mobil DTE-25, panels 21–25, before cleaning.

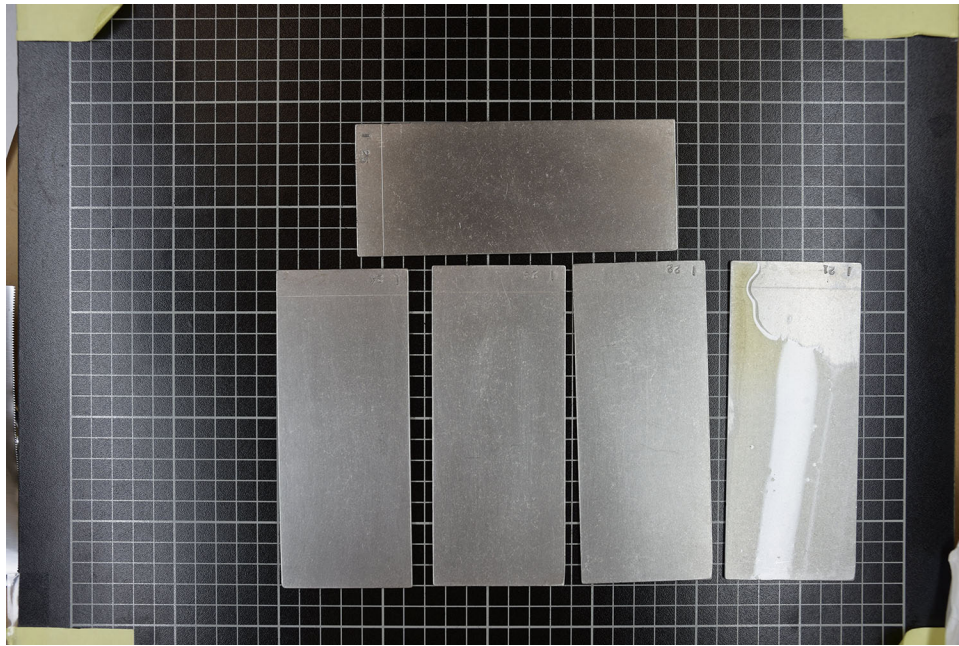


Figure 45. Method 2, Mobil DTE-25, panels 21–25, after cleaning.



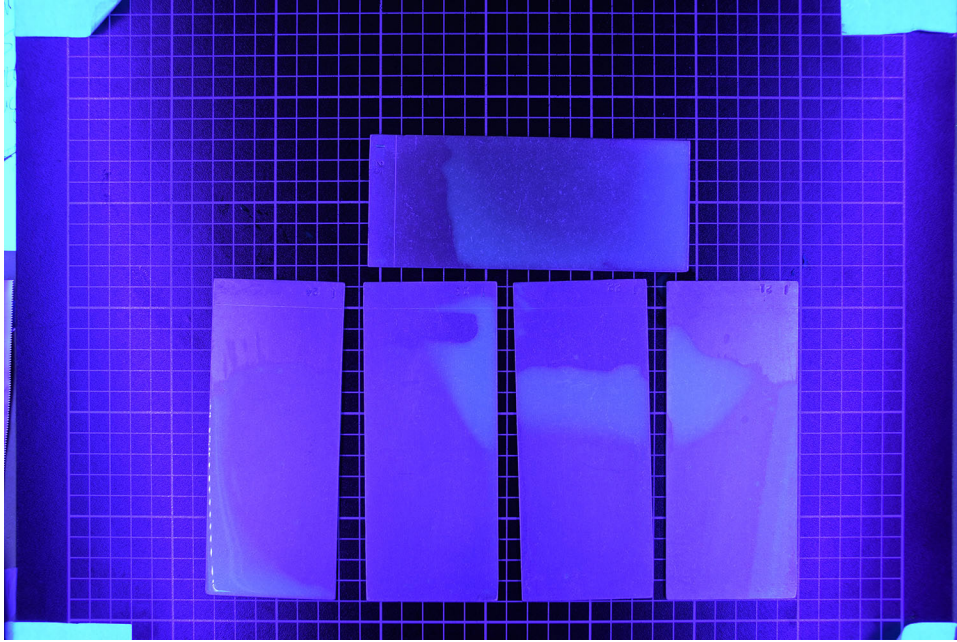


Figure 46. Method 2, Mobil DTE-25, panels 21–25, before cleaning, UV light.

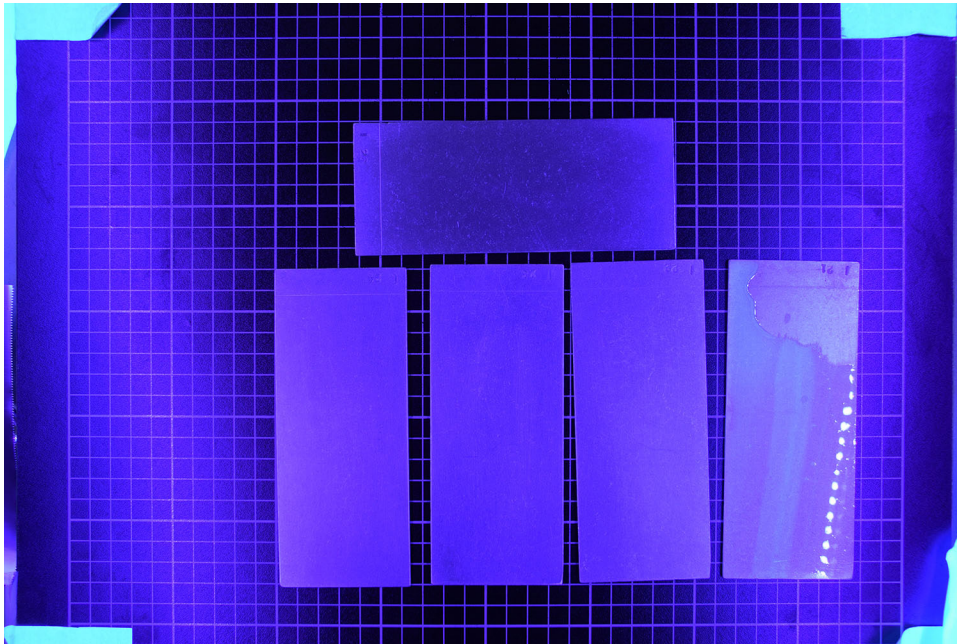


Figure 47. Method 2, Mobil DTE-25, panels 21–25, after cleaning, UV light.

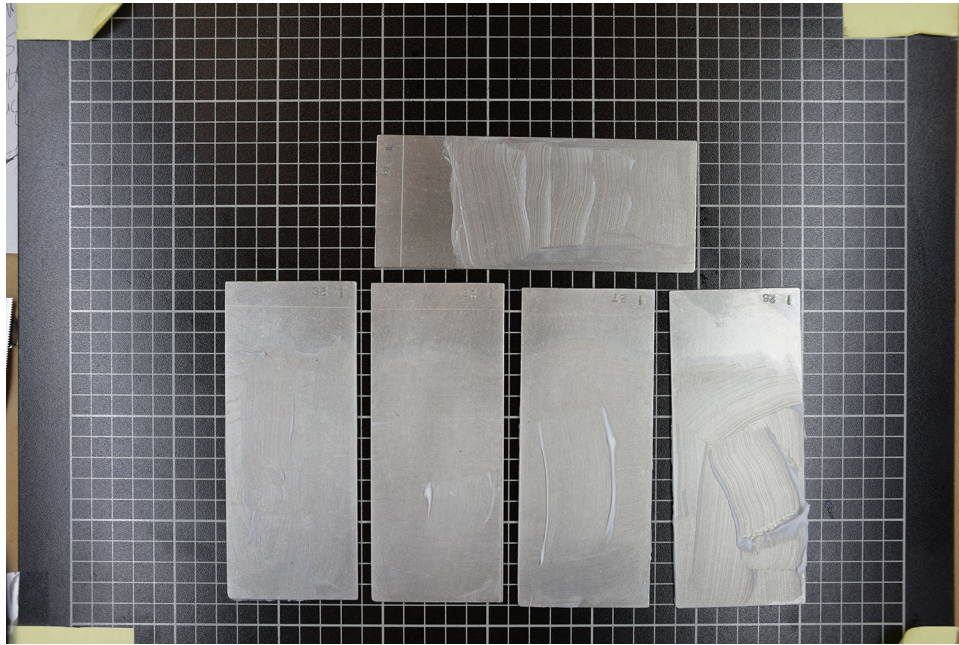


Figure 48. Method 2, Krytox, panels 26–30, before cleaning.

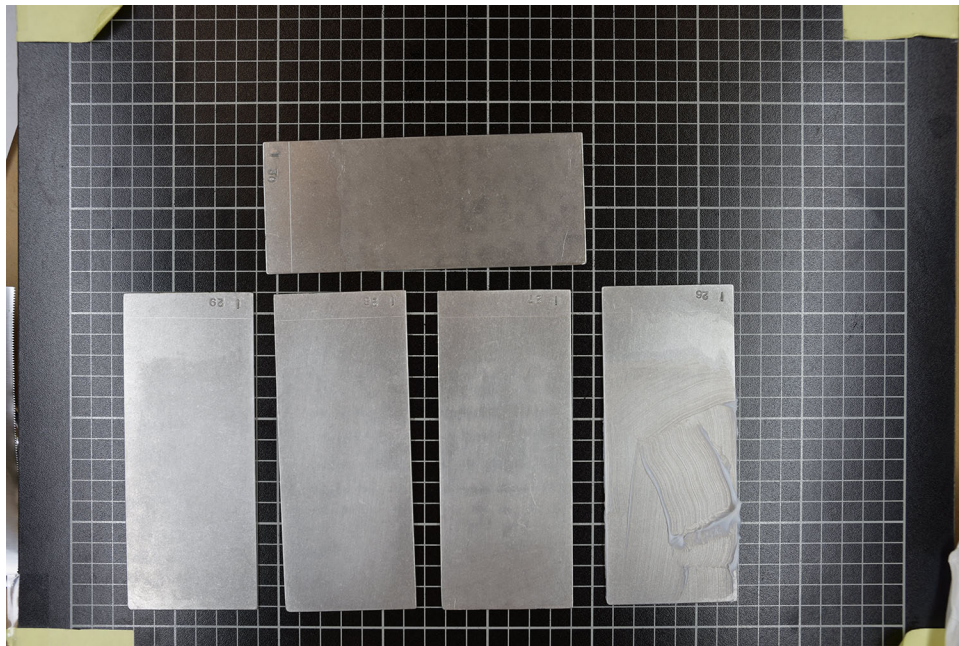


Figure 49. Method 2, Krytox, panels 26–30, after cleaning.



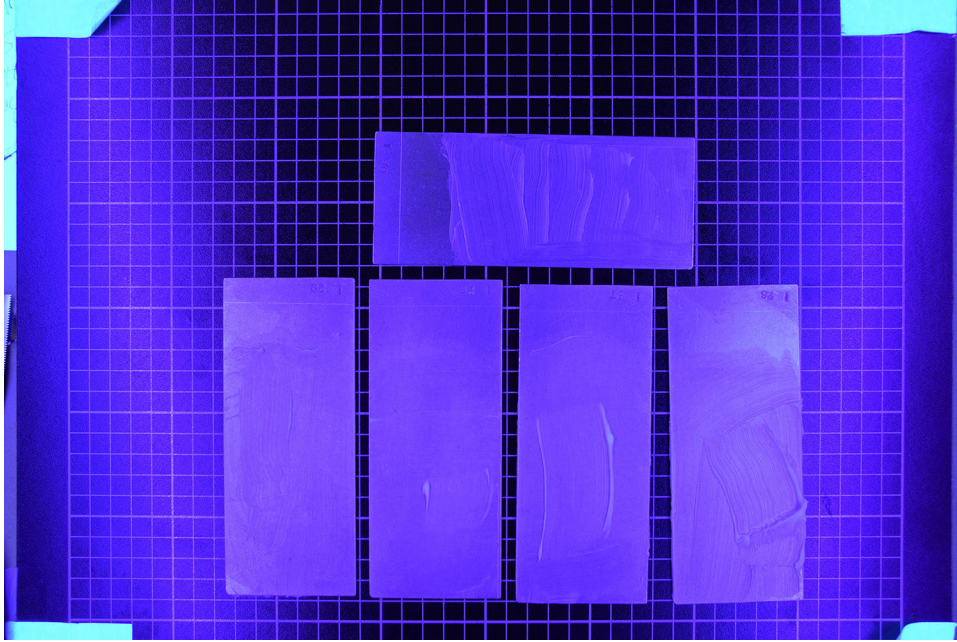


Figure 50. Method 2, Krytox, panels 26–30, before cleaning, UV light.

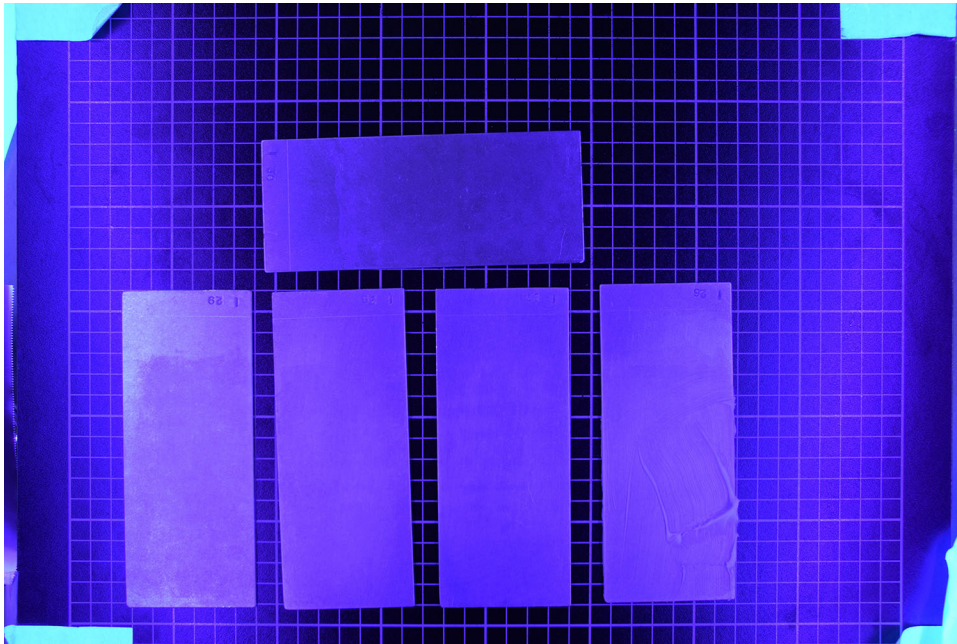


Figure 51. Method 2, Krytox, panels 26–30, after cleaning, UV light.

## APPENDIX D—METHOD 3

### D.1 DATA TABLE, 30-MINUTE WASH (METHOD 3) ANALYSIS USING KYZEN'S METALNOX M6386 SOLVENT ON CONTAMINANTS

The analysis data for cleaning method 3 is listed in table 9.

Table 9. Method 3 (30-min wash) analysis data.

Panel #	Contaminant	Initial Weight (g)	Weight After Adding Contaminant (g)	Weight after Cleaning (g)	Weight of Contaminant (g)	Contaminant Removed (%)	Averages (%)
1	Premalube	43.93085	44.16934	44.16874	0.23849	0.25	Control
2		43.78768	44.06303	43.78732	0.27535	100.13	100.30
3		43.81824	43.99734	43.81772	0.17910	100.29	
4		43.98136	44.28927	43.98016	0.30791	100.39	
5		43.80113	44.06229	43.80007	0.26116	100.41	
6	Brayco	43.98285	44.35890	44.36185	0.37605	-0.78	Control
7		43.87714	44.26015	43.87659	0.38301	100.14	100.12
8		43.91509	44.32183	43.91459	0.40674	100.12	
9		44.02171	44.44975	44.02120	0.42804	100.12	
10		44.32383	44.84769	44.32324	0.52386	100.11	
11	Aeroshell	44.23456	44.82541	44.82400	0.59085	0.24	Control
12		44.03623	44.56593	44.03531	0.52970	100.17	100.14
13		43.92612	44.52077	43.92530	0.59465	100.14	
14		44.18995	44.71734	44.18946	0.52739	100.09	
15		43.91823	44.56328	43.91721	0.64505	100.16	
16	Synthetic Sebum	44.02408	44.09553	44.09551	0.07145	0.03	Control
17		43.87001	43.94591	43.86907	0.07590	101.24	100.98
18		43.80095	43.90274	43.80007	0.10179	100.86	
19		44.02069	44.15423	44.01994	0.13354	100.56	
20		43.97443	44.05187	43.97347	0.07744	101.24	
21	Mobil DTE	44.02259	44.28275	44.28306	0.26016	-0.12	Control
22		43.94652	44.15137	43.94531	0.20485	100.59	100.43
23		43.92411	44.31255	43.92311	0.38844	100.26	
24		44.08758	44.46958	44.08567	0.38200	100.50	
25		43.98163	44.23501	43.98073	0.25338	100.36	
26	Krytox	44.00099	44.49774	44.49754	0.49675	0.04	Control
27		44.01098	44.67137	44.13350	0.66039	81.45	82.52
28		43.93792	44.56720	44.06275	0.62928	80.16	
29		44.19009	44.80841	44.29771	0.61832	82.59	
30		43.86309	44.57673	43.96402	0.71364	85.86	



## D.2 CLEANING METHOD 3—IMAGES OF SAMPLE PANELS WITH CONTAMINANTS— BEFORE AND AFTER CLEANING, WITH WHITE LIGHT AND UV LIGHT

Figures 52–75 are images of sample panels with contaminants, before and after cleaning, using method 3.

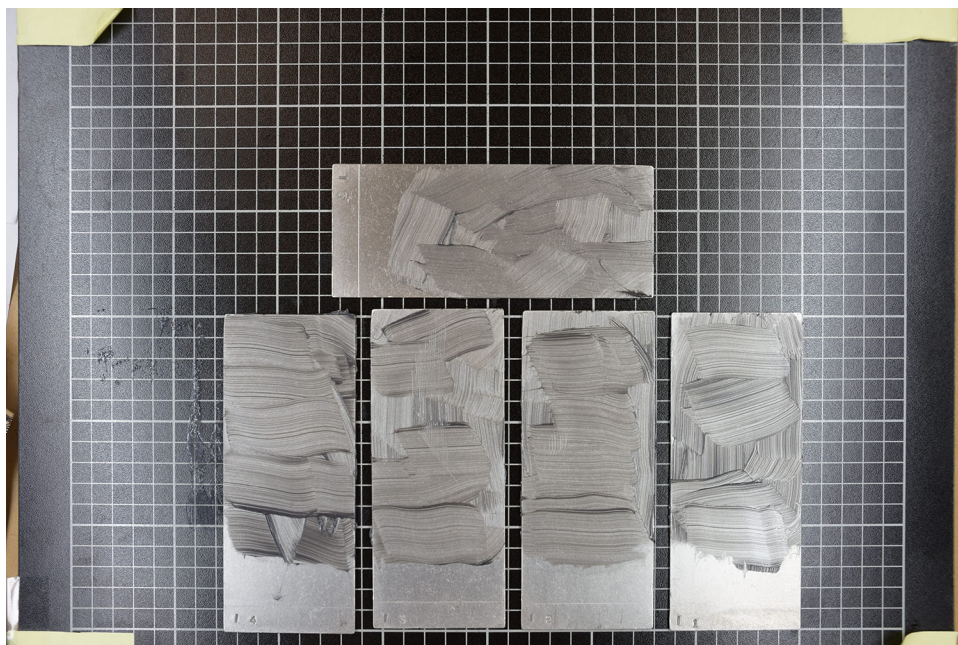


Figure 52. Method 3, Premalube, panels 1–5, before cleaning.

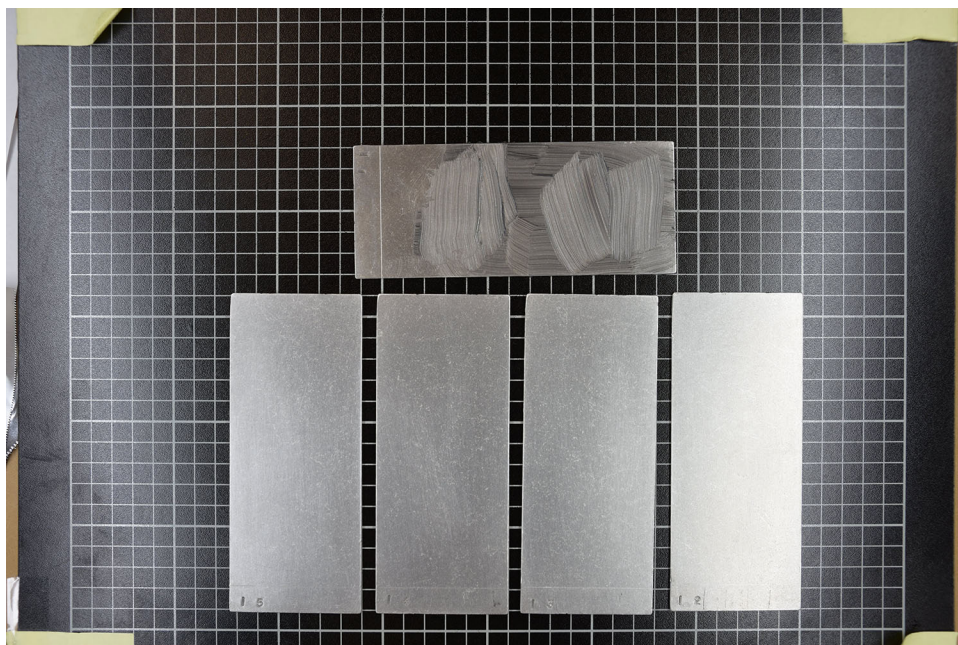


Figure 53. Method 3, Premalube, panels 1–5, after cleaning.





Figure 54. Method 3, Premalube, panels 1–5, before cleaning, UV light.

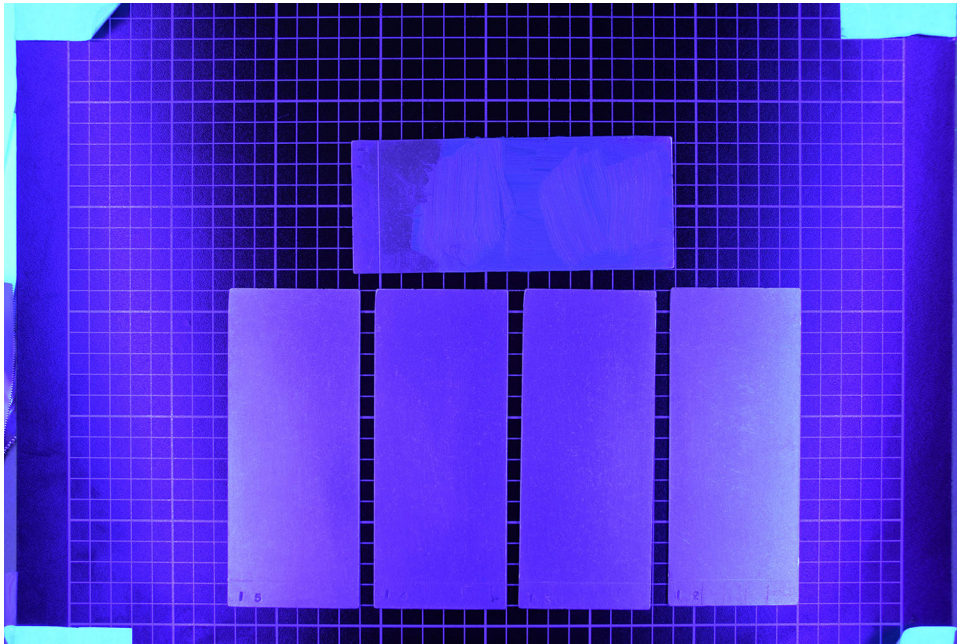


Figure 55. Method 3, Premalube, panels 1–5, after cleaning, UV light.

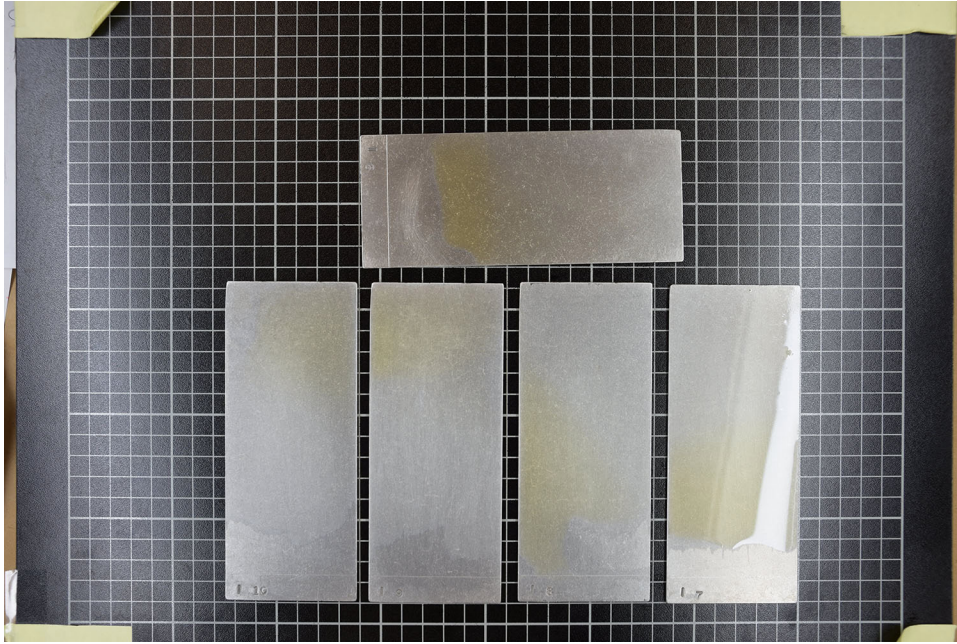


Figure 56. Method 3, Brayco, panels 6–10, before cleaning.

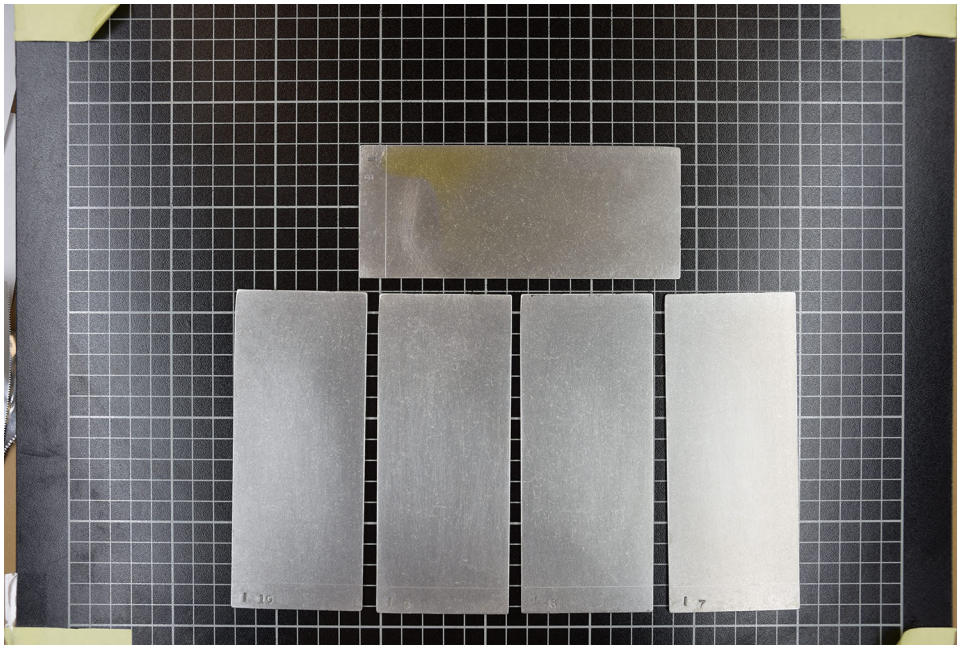


Figure 57. Method 3, Brayco, panels 6–10, after cleaning.



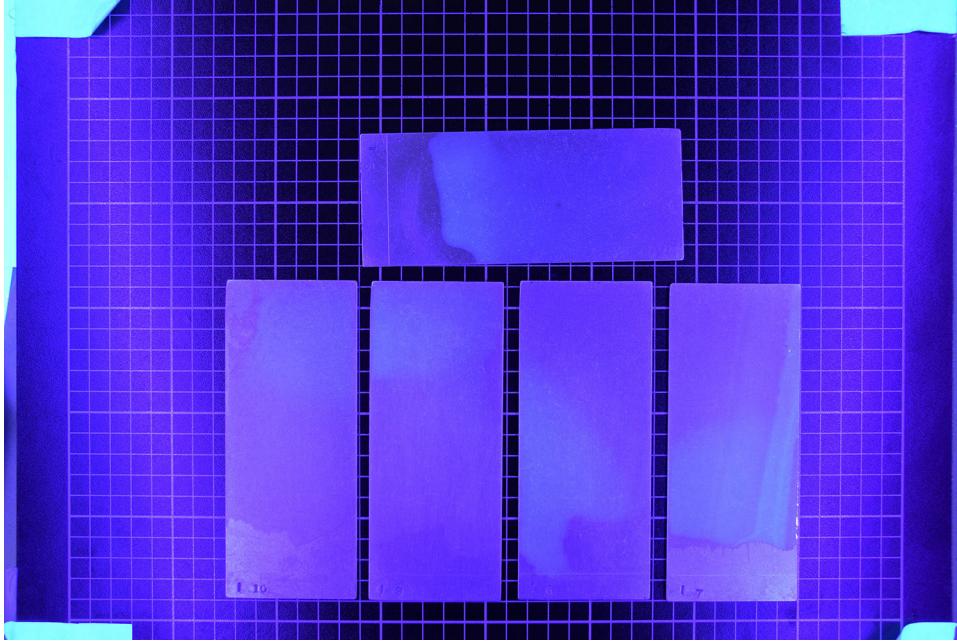


Figure 58. Method 3, Brayco, panels 6–10, before cleaning, UV light.

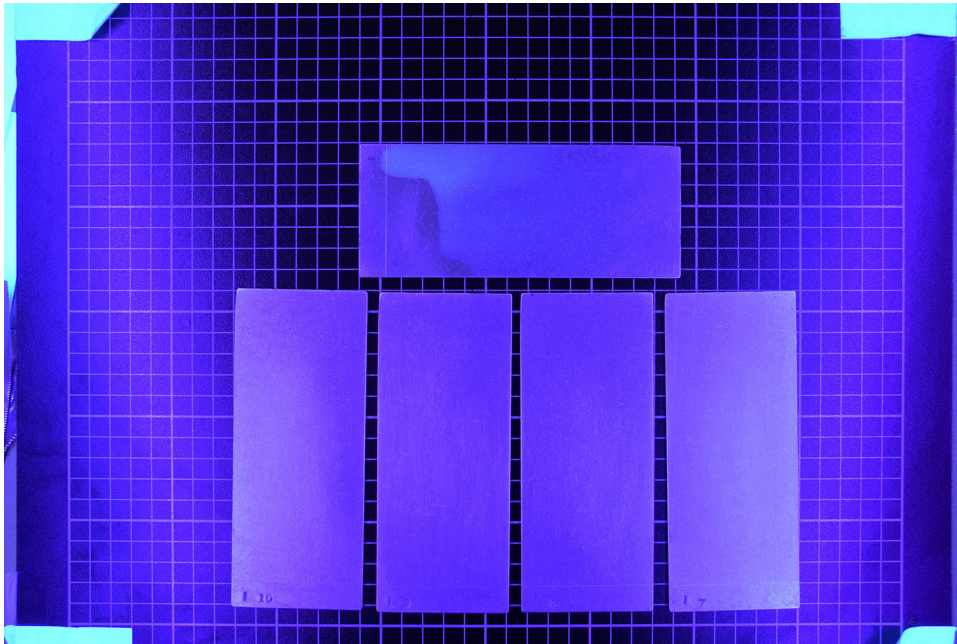


Figure 59. Method 3, Brayco, panels 6–10, after cleaning, UV light.

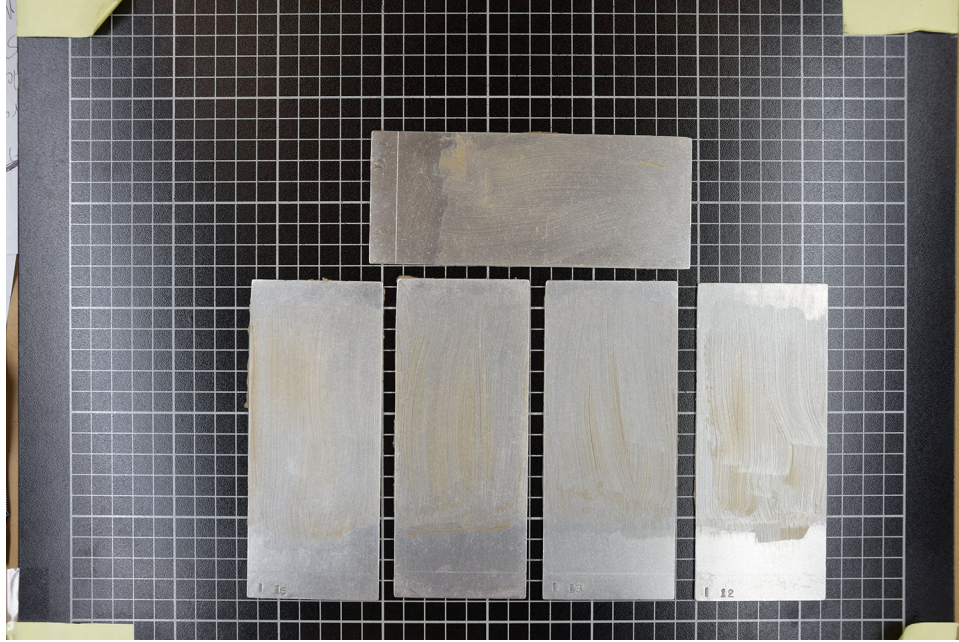


Figure 60. Method 3, AeroShell, panels 11–15, before cleaning.

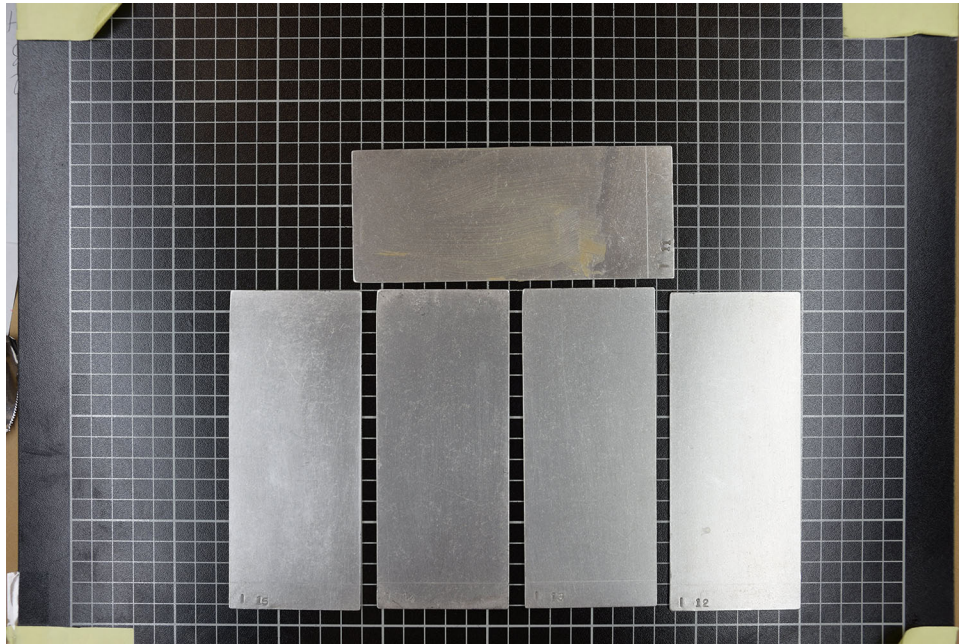


Figure 61. Method 3, AeroShell, panels 11–15, after cleaning.



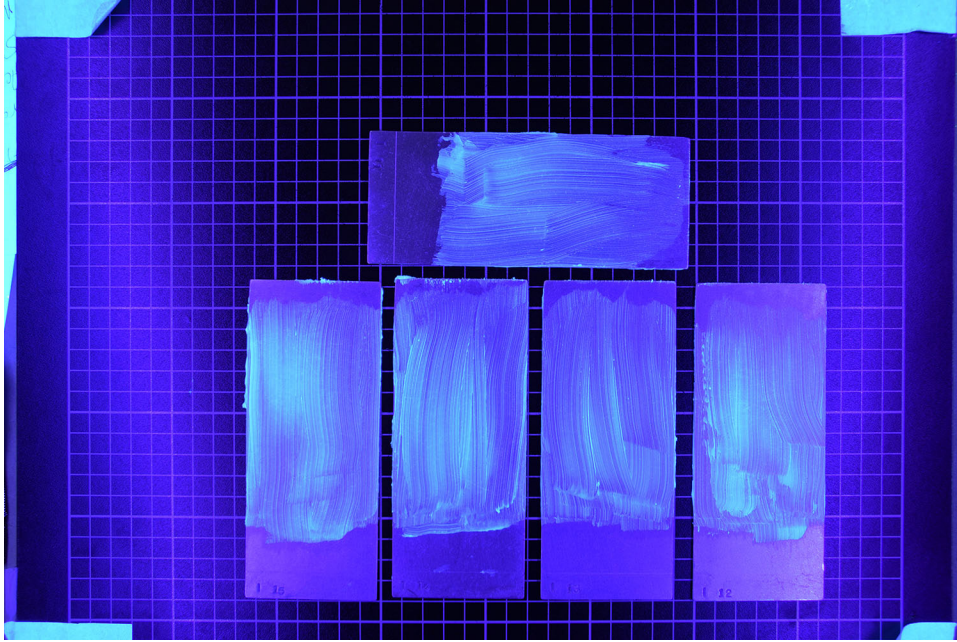


Figure 62. Method 3, AeroShell, panels 11–15, before cleaning, UV light.

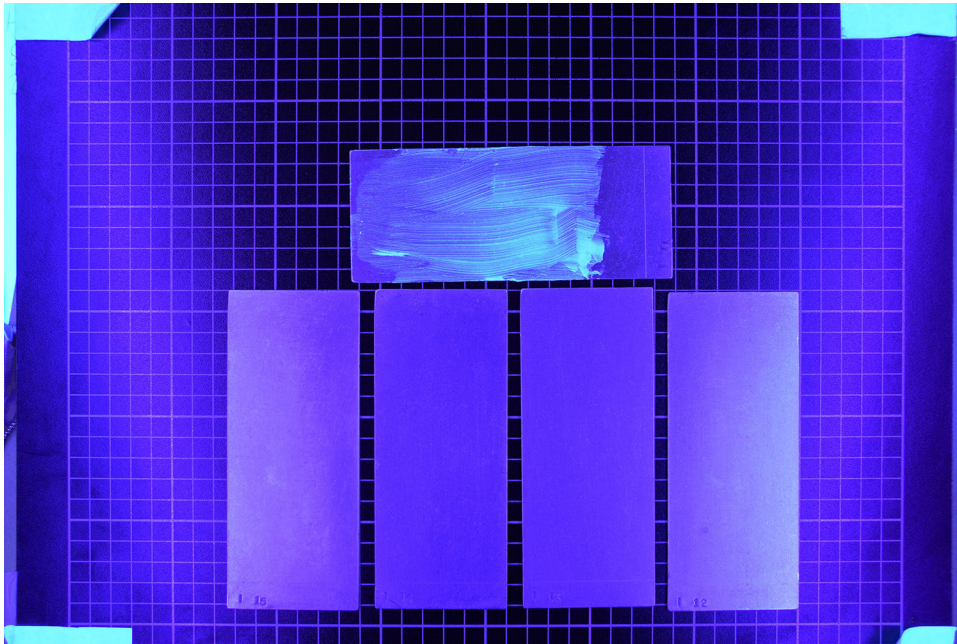


Figure 63. Method 3, AeroShell, panels 11–15, after cleaning, UV light.



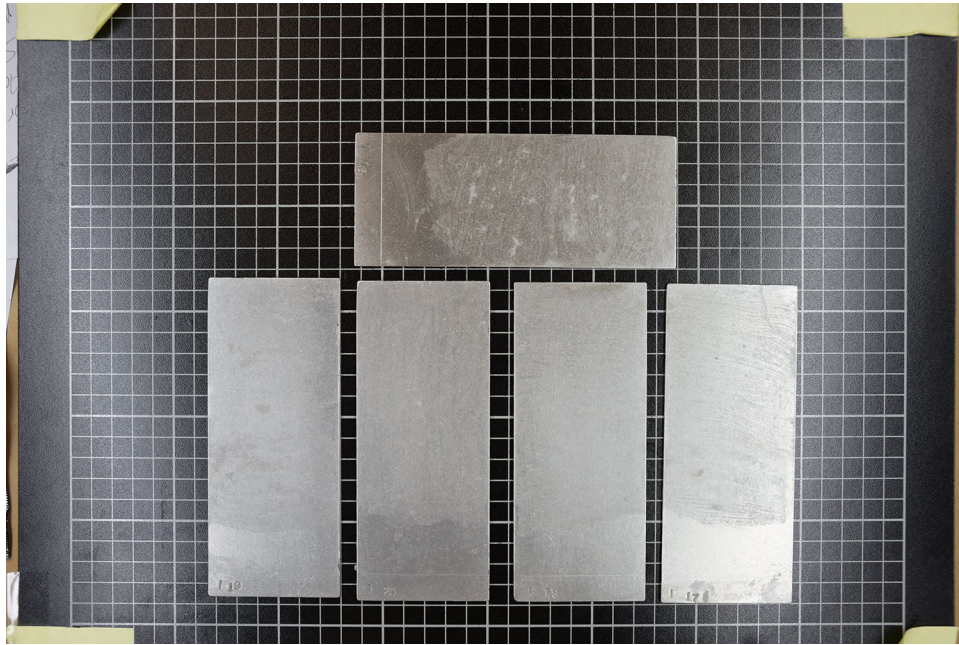


Figure 64. Method 3, synthetic sebum, panels 16–20, before cleaning.

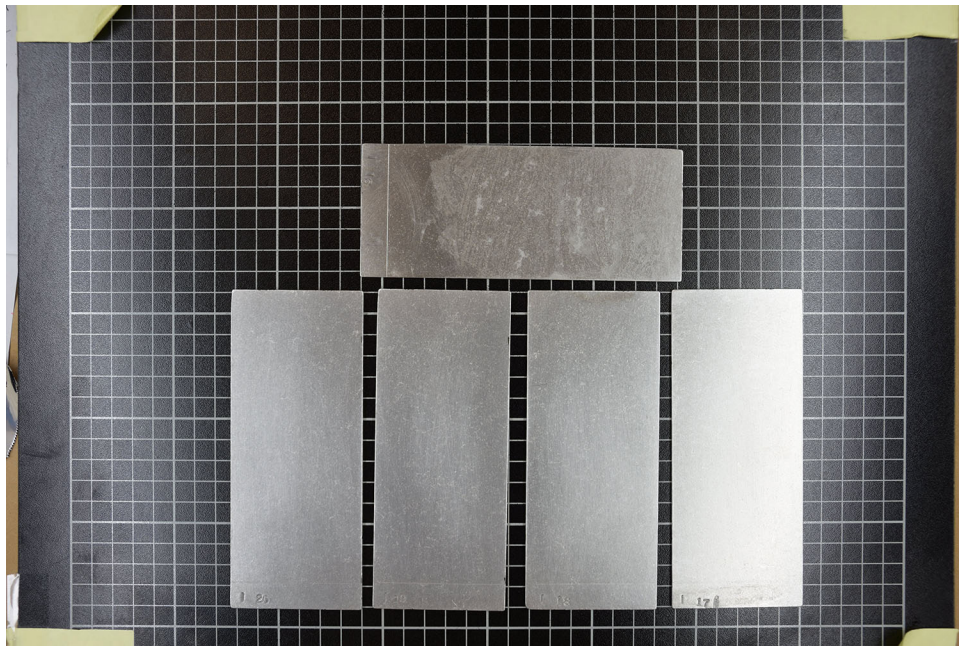


Figure 65. Method 3, synthetic sebum, panels 16–20, after cleaning.

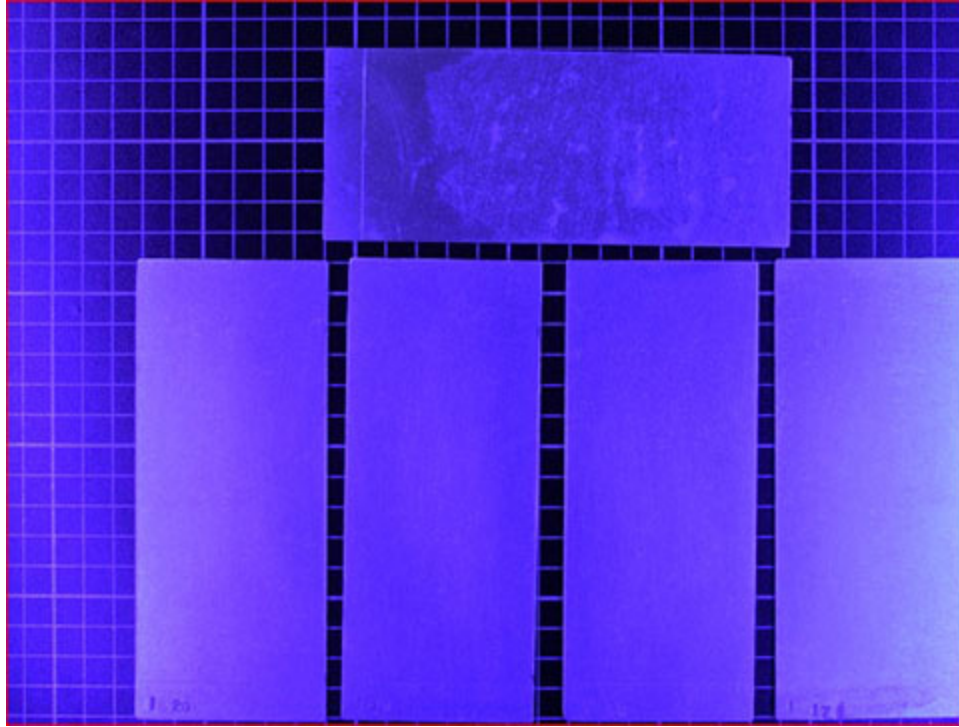


Figure 66. Method 3, synthetic sebum, panels 16–20, before cleaning, UV light.

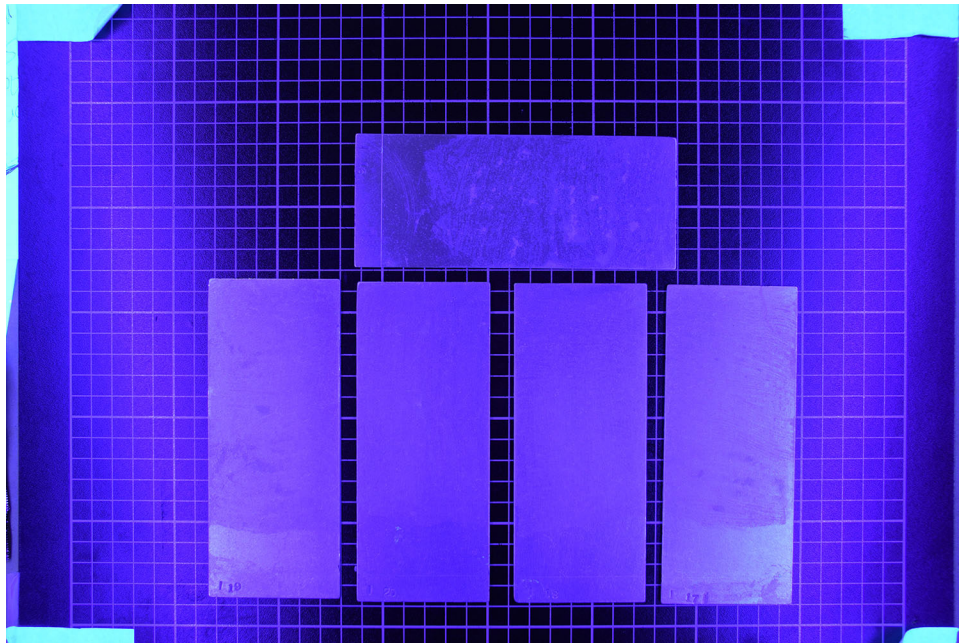


Figure 67. Method 3, synthetic sebum, panels 16–20, after cleaning, UV light.



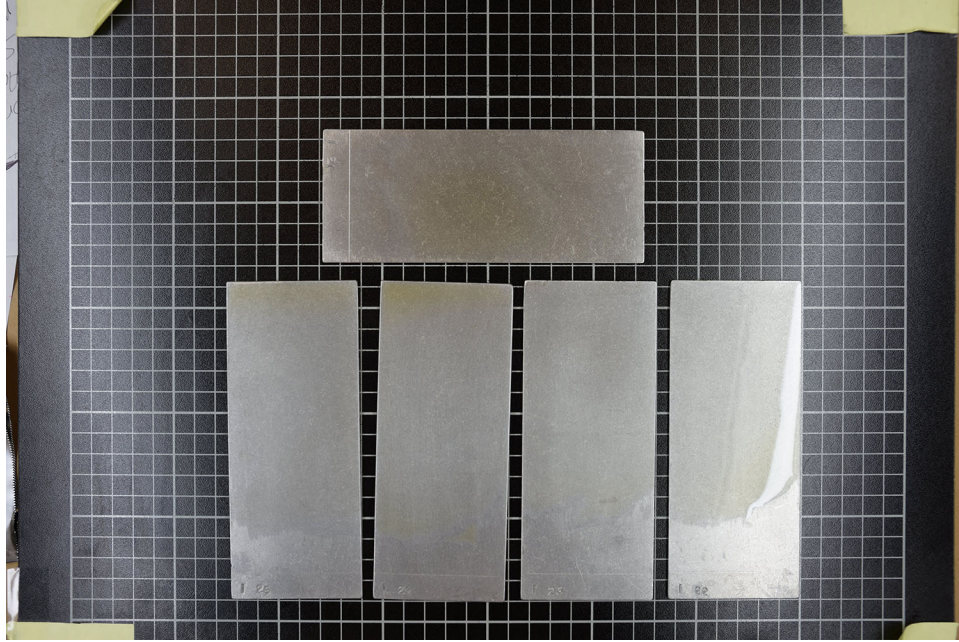


Figure 68. Method 3, Mobil DTE 25, panels 21–25, before cleaning.

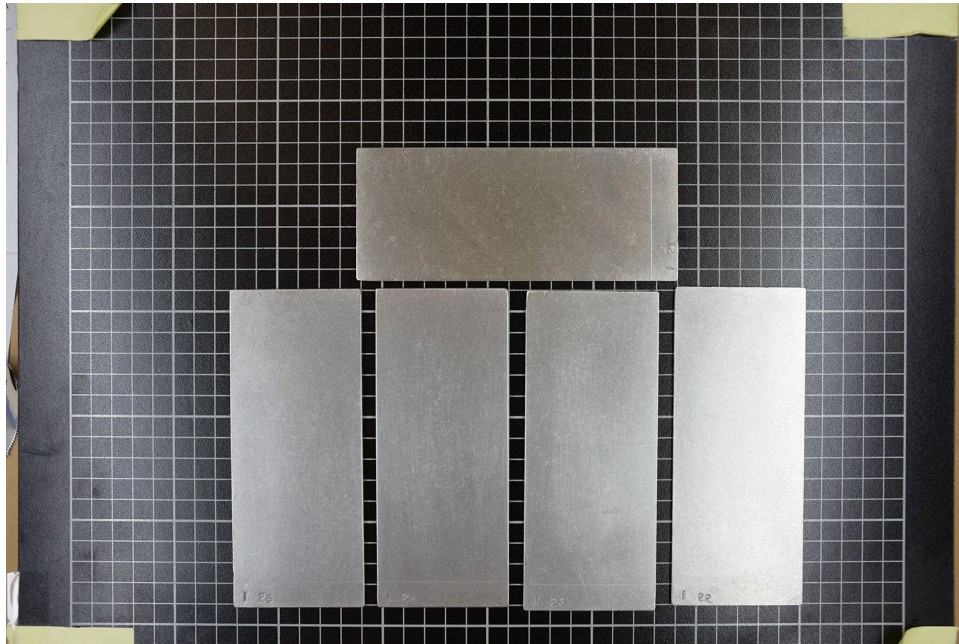


Figure 69. Method 3, Mobil DTE 25, panels 21–25, after cleaning.

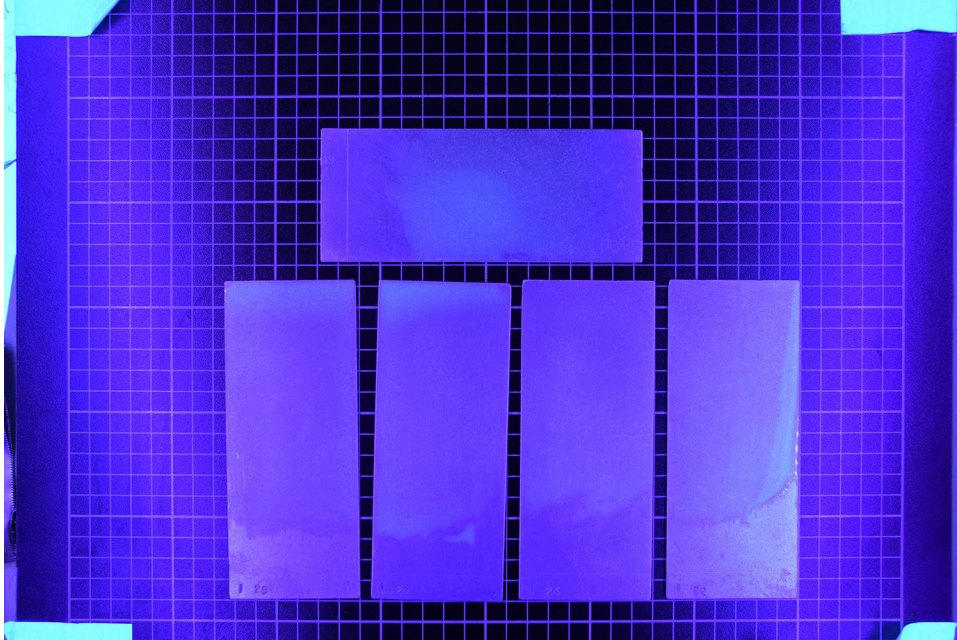


Figure 70. Method 3, Mobil DTE 25, panels 21–25, before cleaning, UV light.

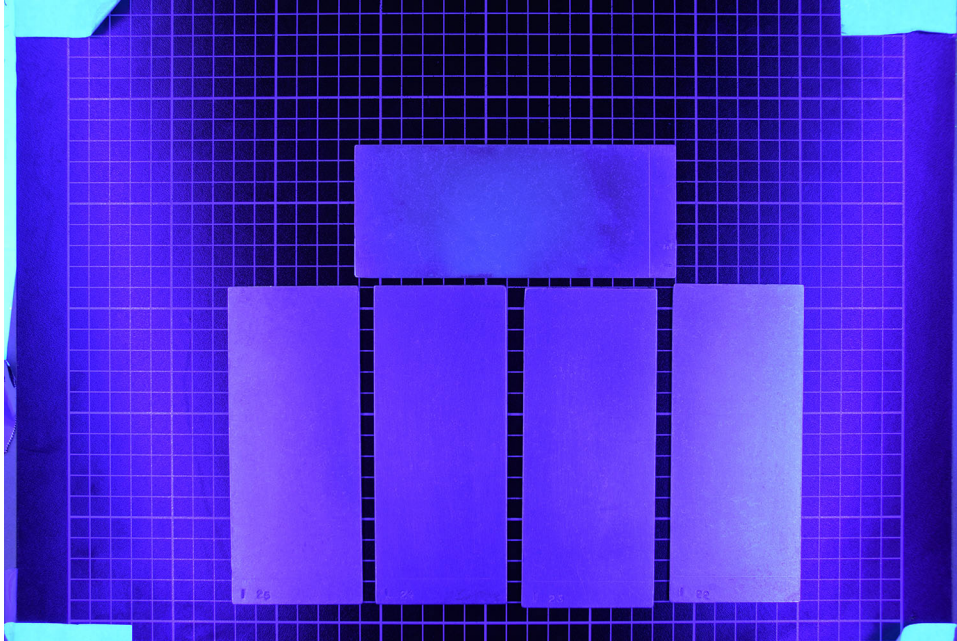


Figure 71. Method 3, Mobil DTE 25, panels 21–25, after cleaning, UV light.





Figure 72. Method 3, Krytox, panels 26–30, before cleaning.



Figure 73. Method 3, Krytox, panels 26–30, after cleaning.



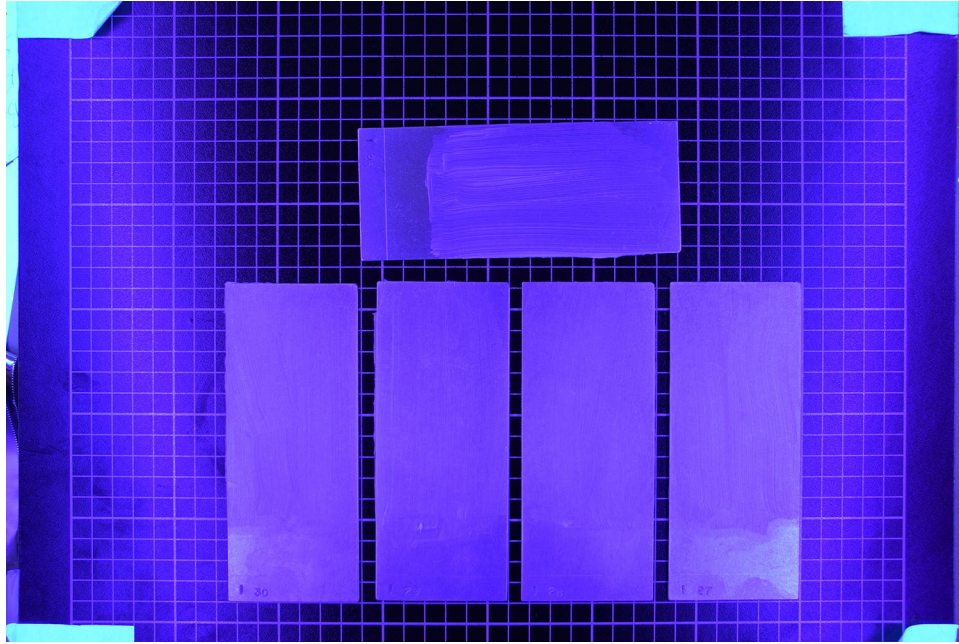


Figure 74. Method 3, Krytox, panels 26–30, before cleaning, UV light.

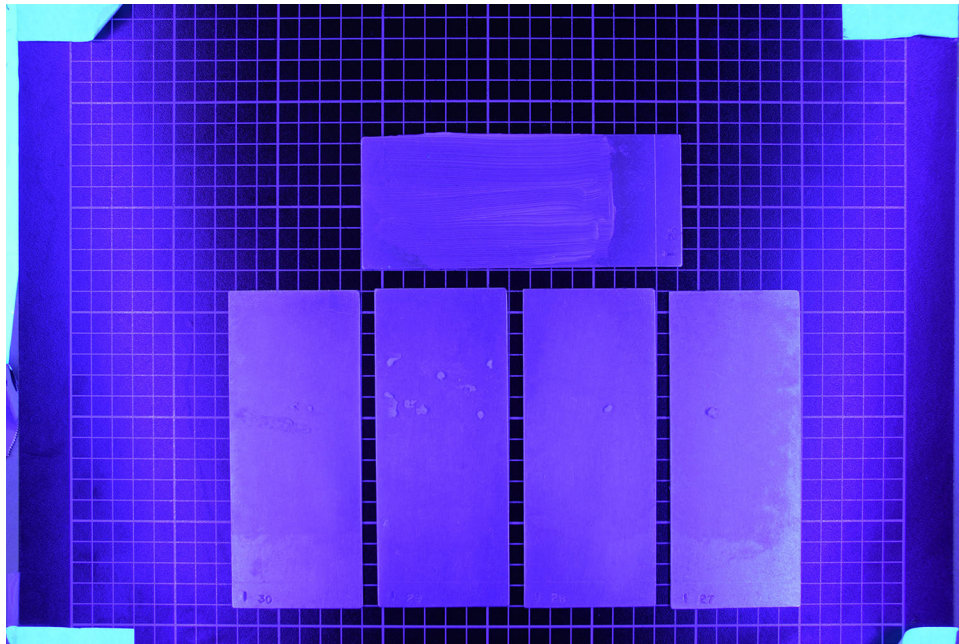


Figure 75. Method 3, Krytox, panels 26–30, after cleaning, UV light.

## APPENDIX E—METHOD 4

### E.1 DATA TABLE, 45-MINUTE WASH (METHOD 4) ANALYSIS USING KYZEN'S METALNOX M6386 SOLVENT ON CONTAMINANTS

The analysis data for cleaning method 4 is listed in table 10.

Table 10. Method 4 (45-min wash) analysis data.

Panel #	Contaminant	Initial Weight (g)	Weight After Adding Contaminant (g)	Weight After Cleaning (g)	Weight of Contaminant (g)	Contaminant Removed (%)	Averages (%)
1	Premalube	43.92755	44.27579	44.23772	0.34824	10.93	Control
2		43.78546	44.02943	43.78482	0.24397	100.26	100.31
3		43.81738	44.07244	43.81603	0.25506	100.53	
4		43.97946	44.19338	43.97863	0.21392	100.39	
5		43.79924	44.16373	43.79898	0.36449	100.07	
6	Brayco	43.98149	44.15586	44.15236	0.17437	2.01	Control
7		43.87655	44.12152	43.87614	0.24497	100.17	100.13
8		43.91443	44.28300	43.91404	0.36857	100.11	
9		44.02101	44.26429	44.02064	0.24328	100.15	
10		44.32311	44.52958	44.32290	0.20647	100.10	
11	AeroShell	44.23172	44.41469	44.41664	0.18297	-1.07	Control
12		44.03511	44.25416	44.03474	0.21905	100.17	100.12
13		43.92524	44.18556	43.92486	0.26032	100.15	
14		44.18931	44.40877	44.18916	0.21946	100.07	
15		43.91706	44.20443	43.91677	0.28737	100.10	
16	Synthetic Sebum	44.02194	44.13207	44.13056	0.11013	1.37	Control
17		43.86896	43.92881	43.86759	0.05985	102.29	100.97
18		43.79985	43.89441	43.79862	0.09456	101.30	
19		44.01975	44.15209	44.01970	0.13234	100.04	
20		43.97324	44.06383	43.97302	0.09059	100.24	
21	Mobil DTE	44.02225	44.19420	44.19183	0.17195	1.38	Control
22		43.94523	44.18108	43.94462	0.23585	100.26	100.16
23		43.92199	44.21743	43.92147	0.29544	100.18	
24		44.08522	44.37660	44.08462	0.29138	100.21	
25		43.98005	44.13993	43.98008	0.15988	99.98	
26	Krytox	43.93901	44.27566	44.27564	0.33665	0.01	Control
27		44.01082	44.41755	44.08361	0.40673	82.10	91.61
28		43.90732	44.33385	43.93918	0.42653	92.53	
29		44.18946	44.88989	44.20390	0.70043	97.94	
30		43.86331	44.34975	43.89323	0.48644	93.85	



**E.2. CLEANING METHOD 4—IMAGES OF SAMPLE PANELS WITH CONTAMINANTS—  
BEFORE AND AFTER CLEANING, WITH WHITE LIGHT AND UV LIGHT**

Figures 76–99 are images of sample panels with contaminants, before and after cleaning, using method 4.



Figure 76. Method 4, Premalube, panels 1–5, before cleaning.

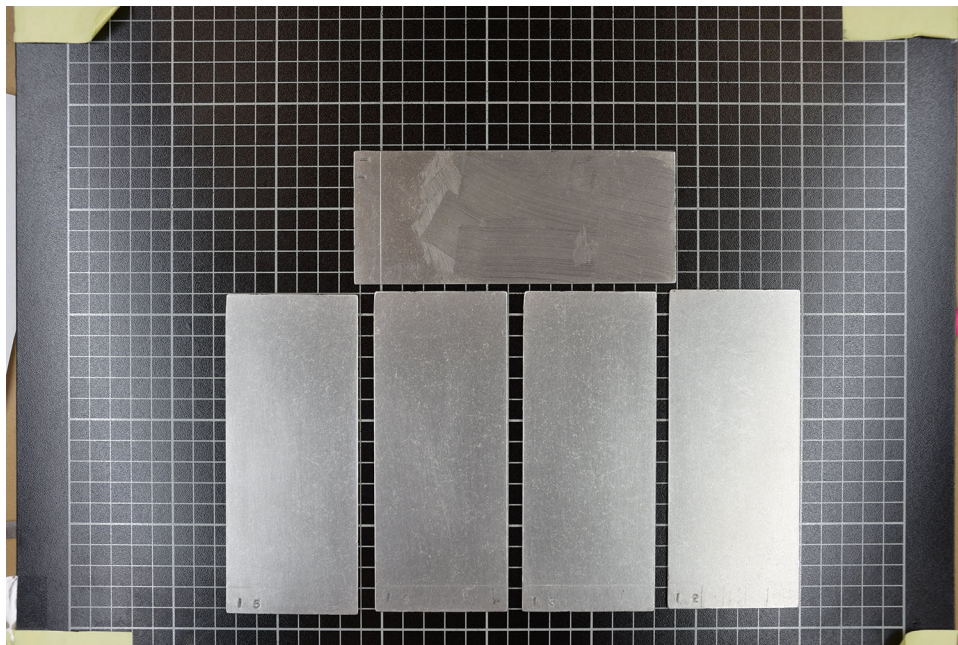


Figure 77. Method 4, Premalube, panels 1–5, after cleaning.

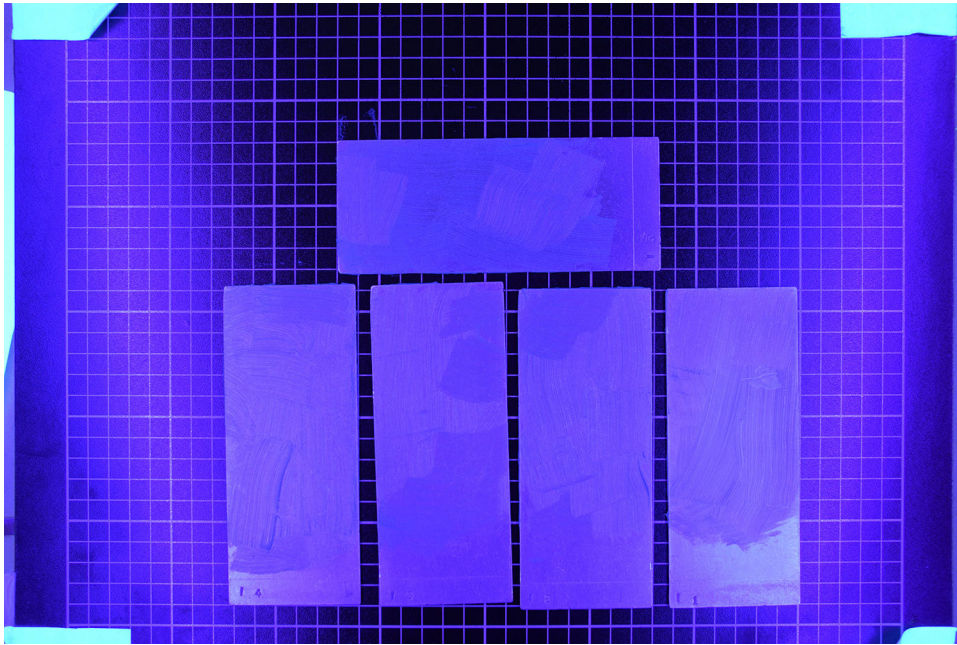


Figure 78. Method 4, Premalube, panels 1–5, before cleaning, UV light.

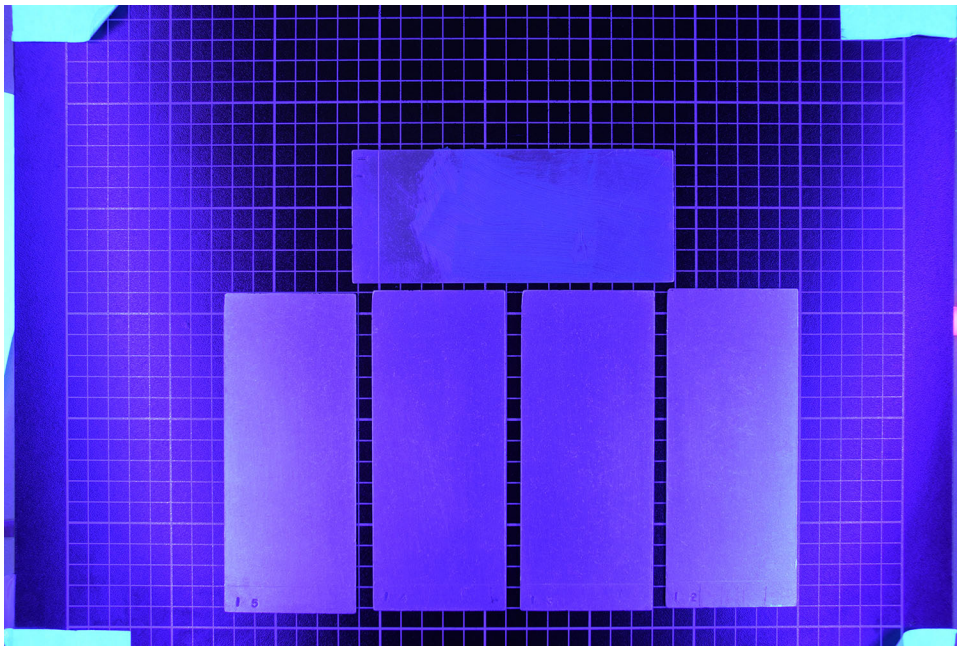


Figure 79. Method 4, Premalube, panels 1–5, after cleaning, UV light.



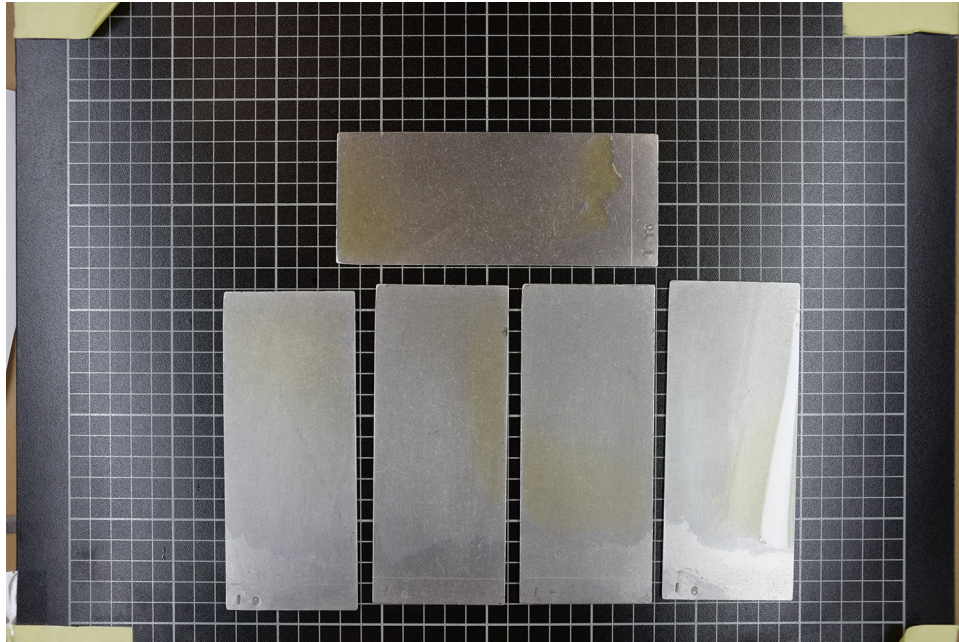


Figure 80. Method 4, Brayco, panels 6–10, before cleaning.

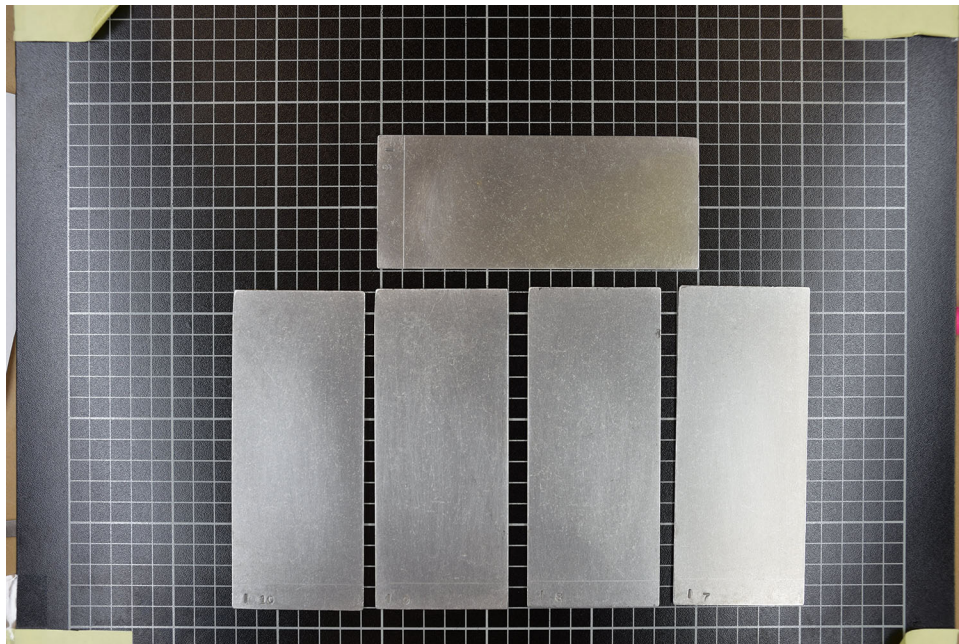


Figure 81. Method 4, Brayco, panels 6–10, after cleaning.

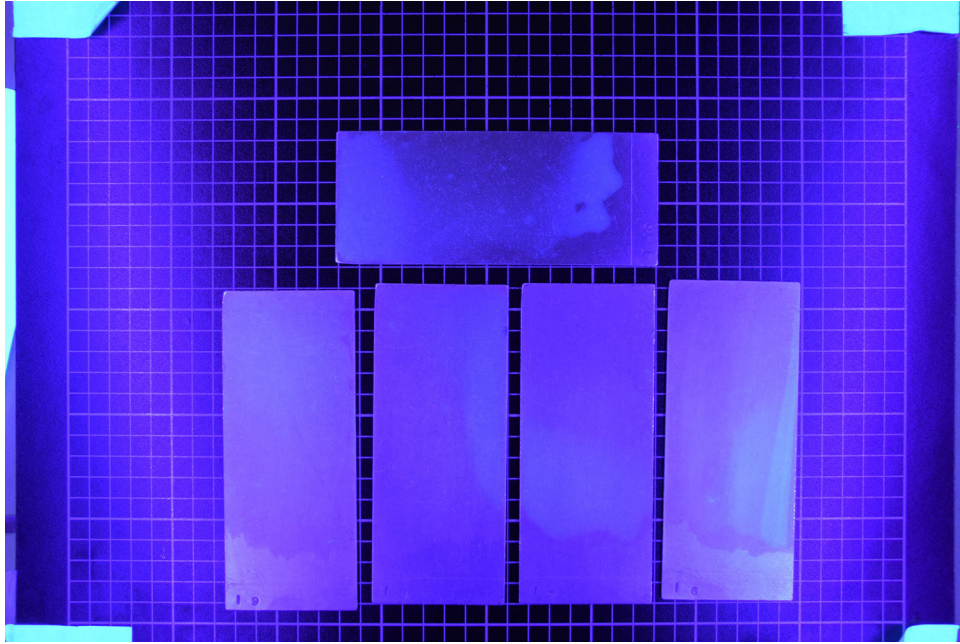


Figure 82. Method 4, Brayco, panels 6–10, before cleaning, UV light.

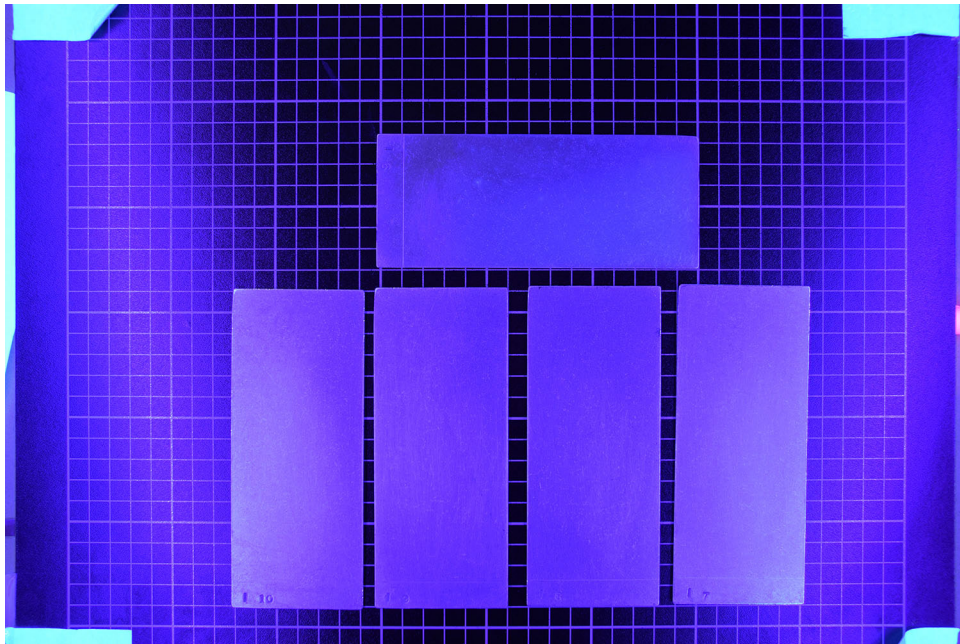


Figure 83. Method 4, Brayco, panels 6–10, after cleaning, UV light.



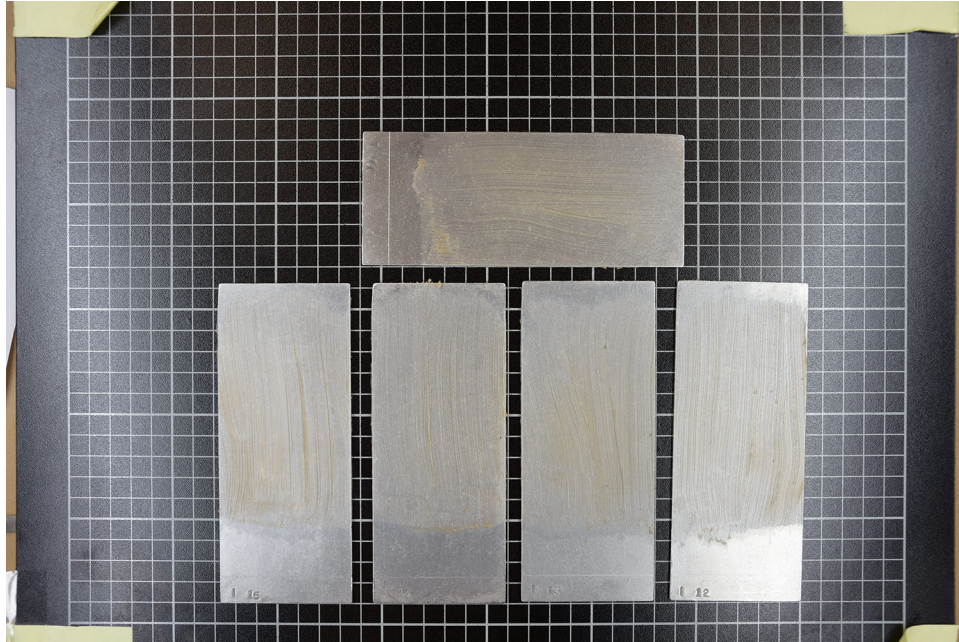


Figure 84. Method 4, AeroShell, panels 11–15, before cleaning.

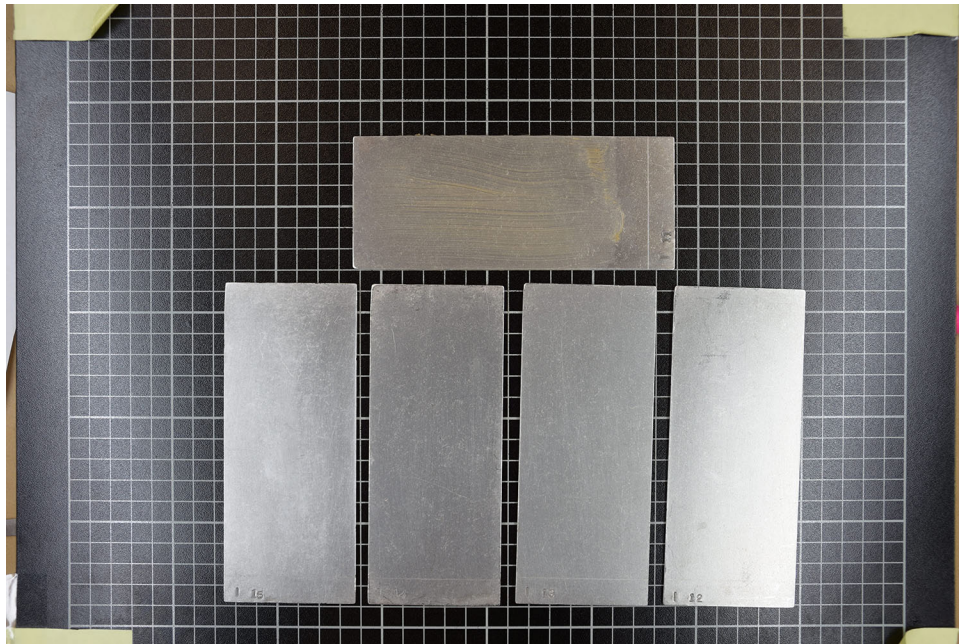


Figure 85. Method 4, AeroShell, panels 11–15, after cleaning.



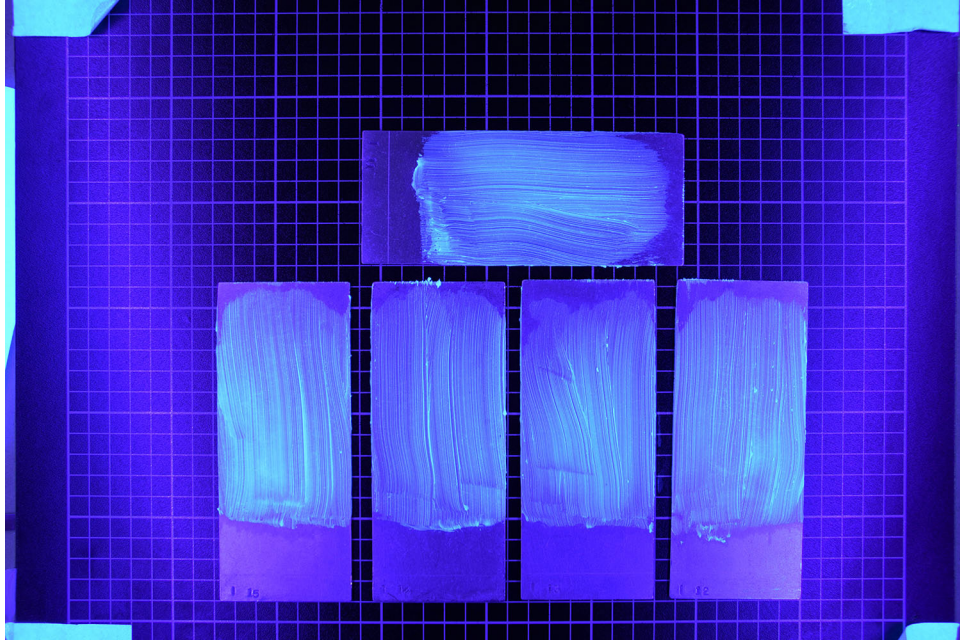


Figure 86. Method 4, AeroShell, panels 11–15, before cleaning, UV light.

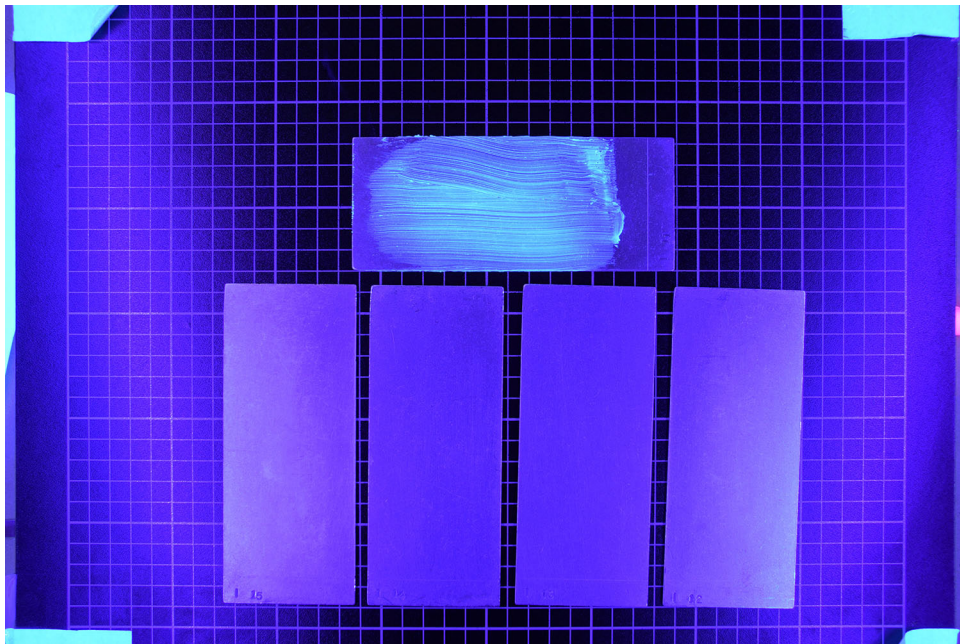


Figure 87. Method 4, AeroShell, panels 11–15, after cleaning, UV light.



Figure 88. Method 4, synthetic sebum, panels 16–20, before cleaning.

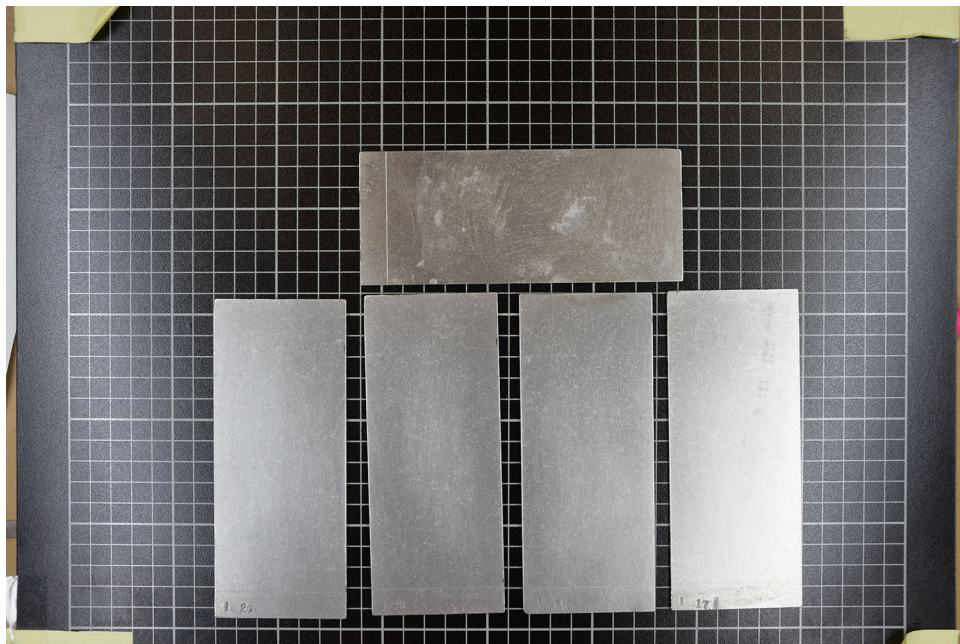


Figure 89. Method 4, synthetic sebum, panels 16–20, after cleaning.



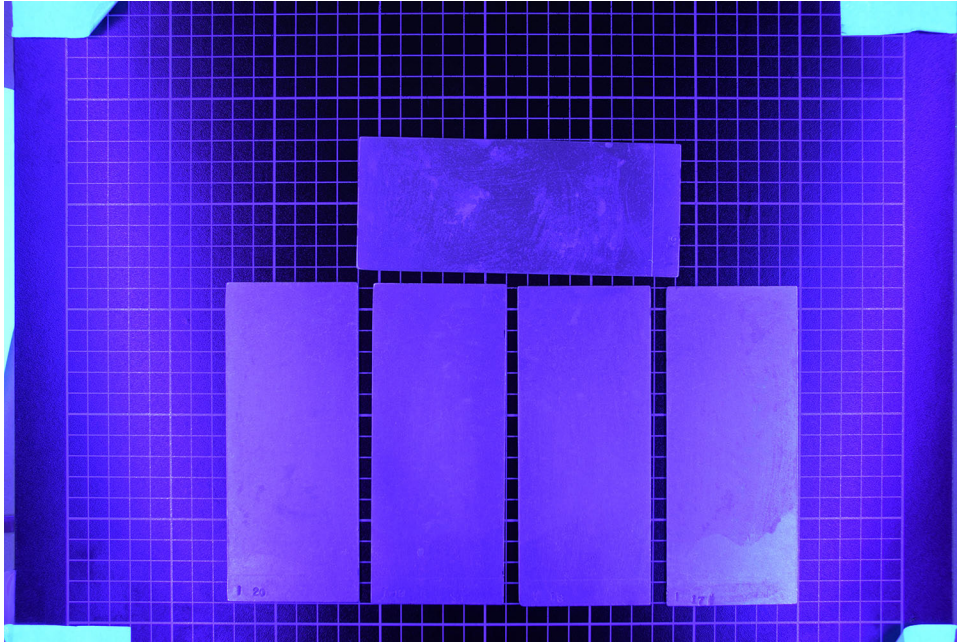


Figure 90. Method 4, synthetic sebum, panels 16–20, before cleaning, UV light.

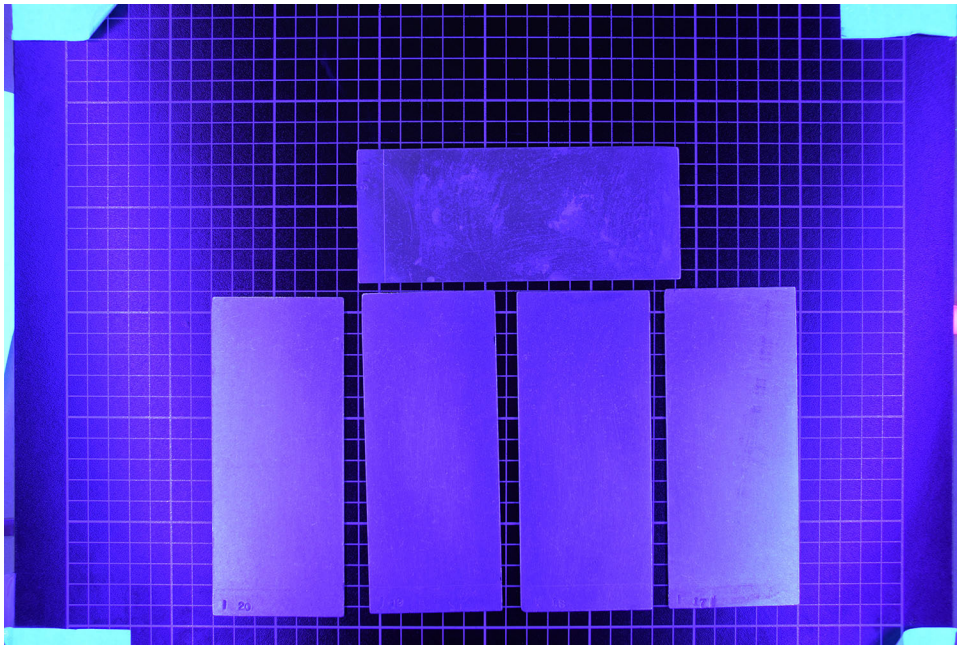


Figure 91. Method 4, synthetic sebum, panels 16–20, after cleaning, UV light.



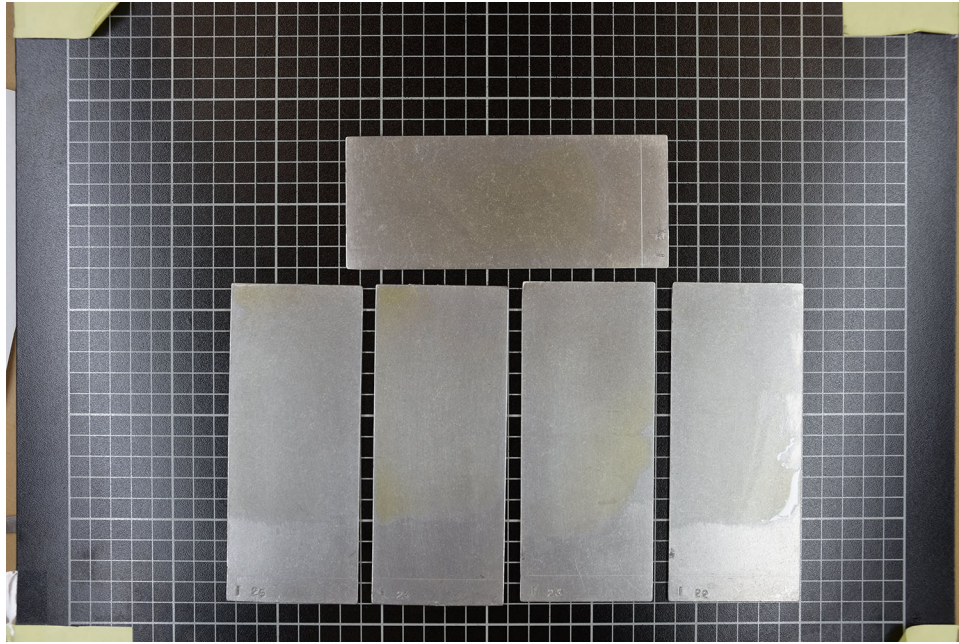


Figure 92. Method 4, Mobil DTE 25, panels 21–25, before cleaning.

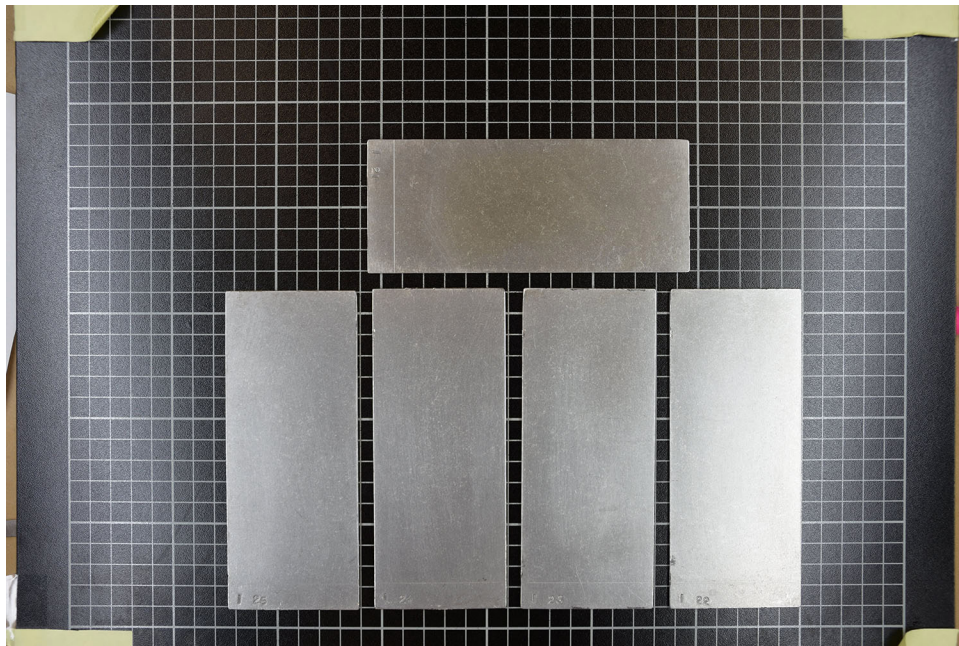


Figure 93. Method 4, Mobil DTE 25, panels 21–25, after cleaning.

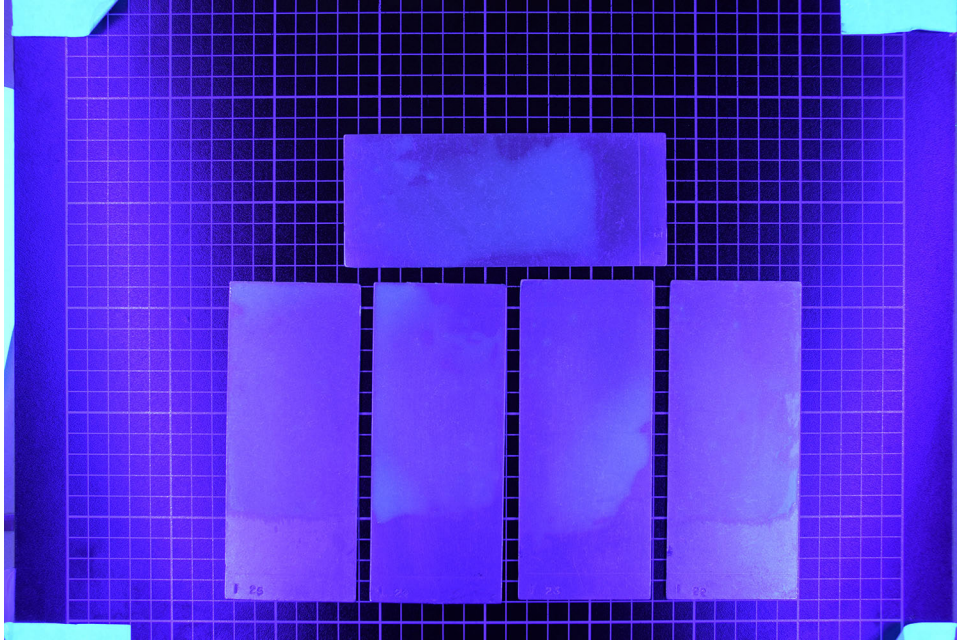


Figure 94. Method 4, Mobil DTE 25, panels 21–25, before cleaning, UV light.

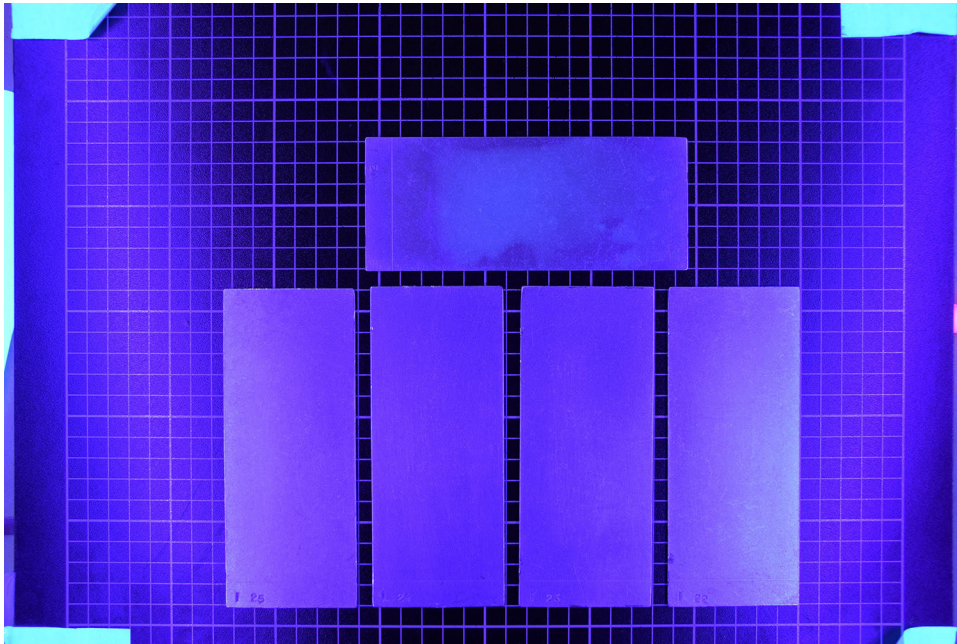


Figure 95. Method 4, Mobil DTE 25, panels 21–25, after cleaning, UV light.





Figure 96. Method 4, Krytox, panels 26–30, before cleaning.



Figure 97. Method 4, Krytox, panels 26–30, after cleaning.



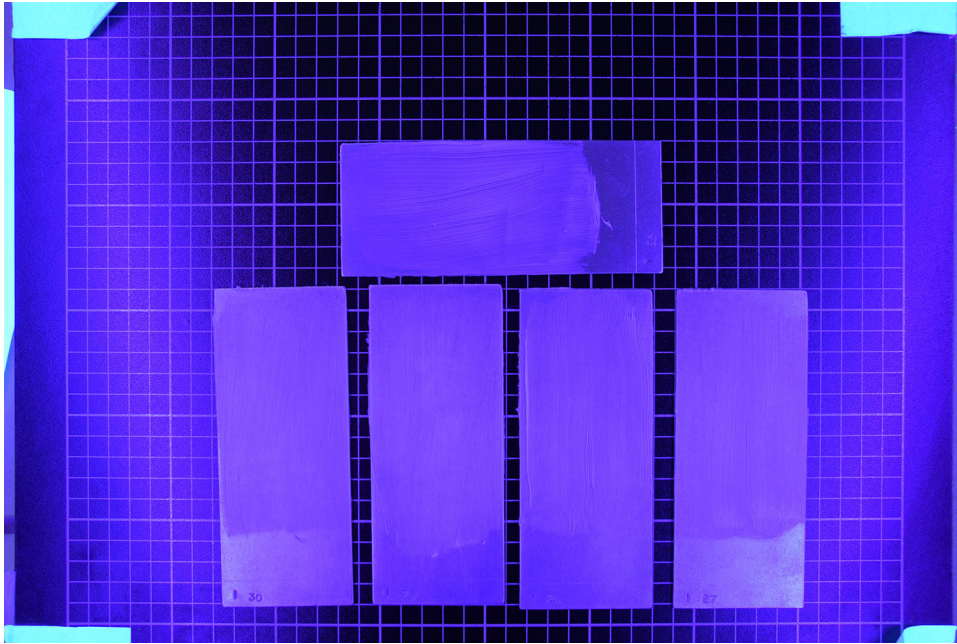


Figure 98. Method 4, Krytox, panels 26–30, before cleaning, UV light.

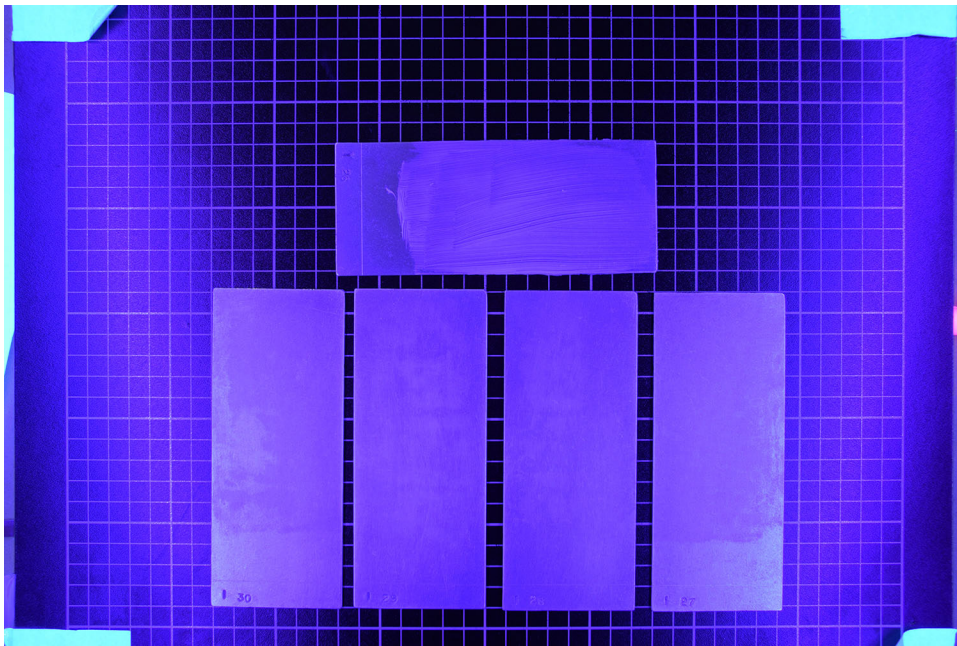


Figure 99. Method 4, Krytox, panels 26–30, after cleaning, UV light.

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