GROUND-BASED MEASUREMENTS OF DM-2 ROCKET EXHAUST EFFLUENTS USING FIXED-FLOW SAMPLERS AND ELECTRETS

By Michael Susko*

INTRODUCTION

Electret devices have been developed by the NASA George C. Marshall Space Flight Center (MSFC) to collect samples of rocket exhaust products for later analysis. The performance of the electrets was compared with that of Thiokol fixed-flow samplers during the static test firing of a solid rocket motor (SRM) demonstration model (DM-2) on January 19, 1978, at the Thiokol static rocket motor test site near Brigham City, Utah.

PROCEDURE

Thiokol fixed-flow air samplers were placed in six near-field and six far-field sites. The MSFC electrets were placed alongside each Thiokol air sampler. Four additional electret samplers were placed in other near- and far-field sites. The near-field location of the Thiokol air samplers and the MSFC electrets during the DM-2 static test is shown in figure 1; the far-field location, in figure 2.

The electret is fabricated by applying a field of 15 kilovolts to Teflon heated to approximately 200° C, near the melting point. When it cools, the Teflon has a permanent charge and is then defined as an electret. Rocket exhaust products are attracted to the surface of this type of electret. The material absorbed on the electret surface is analyzed later using X-ray spectroscopy.

MEASUREMENT OF ROCKET EFFLUENTS

The measurement of the rocket exhaust effluents by Thiokol air samplers and MSFC electrets indicated that the SRM had no significant effect on air quality in the area sampled. Thiokol had only one significant measurement. At Plant 78 (Site 12), Thiokol fixed-flow air samplers obtained a trace of contamination (0.094 mg/m^3 (test); 0.0017 mg/m^3 (background)) approximately 6.43 kilometers at a 330° heading from the static test stand. Of the total

*NASA George C. Marshall Space Flight Center.

weight, 0.0017 mg/m^3 was chlorine (0.0006 part per million), 0.0007 mg/m^3 was sulfur, 0.015 mg/m^3 was silicon, and 0.041 mg/m^3 was aluminum. Quantitative results obtained from X-ray spectroscopy analyses at Site 12 show that the electret had a background count of 1667 and a test count of 2409 after cloud passage, an increase of 742 counts. See table I for the Thiokol fixed-flow sampler results. The background pH (obtained by Thiokol at Plant 78) was basic (5.2) and increased to 7.5 in the test, an increase of 2.3 pH units more basic. One of the additional electrets (E-13) was closer to the static test site - approximately 585 meters at a heading of 325°. When the exhaust cloud passed directly over Site 13, the chlorine count from the X-ray spectroscopy analysis on this electret was 3576, an increase of 1909 counts (table II). Equating the counts of 742 to 0.0006 ppm and 1909 counts results in 0.0015 ppm. Again, no significant measurement of rocket exhaust effluents was found at the test site.

The SRM was oriented west to east and fired toward the east. The surface winds blew from the southeast, but the upper airflow was 25 m/sec from the southwest. At an altitude of approximately 6 kilometers, the windspeed increased to approximately 30 m/sec. A vertical profile of windspeed, wind direction, and air temperature used as inputs to the multilayer diffusion model for the DM-2 static test is given in figure 3.

CONCLUSIONS

The results show that the electrets can be used effectively for sampling rocket exhaust products. A special advantage of electrets is that they do not require power for operation. Consequently, they can be valuable for measuring rocket exhaust effluents in areas where other measuring devices may not be practical. An assessment of the effectiveness of the electret resulted in the following conclusions.

At Plant 78, 6.43 kilometers at a 330° heading from the static test site, Thiokol fixed-flow samplers obtained the only trace of contamination - 0.0017 mg/m^3 or 0.0006 ppm Cl. At this site, the Cl count from the dispersive X-ray spectroscopy analysis was 1667 (background) and 2409 (test), an increase of 742 counts.

An additional electret was placed at Site 13 (585 meters at a 325° heading from the static test firing). With no power available at this site, the electret was the only measurement device. The background count was 1667 and the test count was 3576, an increase of 1909 counts. Equating the 742 counts to 0.0006 ppm, the 1909 counts obtained at the closer test site converts to 0.0015 ppm. Again, no significant amount of rocket exhaust effluents was measured. In addition, simplicity in deployment of the electrets (no power necessary) makes the electret a valuable complementary device in detecting rocket gas effluents.

TABLE I.- QUANTITATIVE RESULTS OBTAINED FROM X-RAY SPECTROSCOPY - SITE 12

[Air sampler 12, 6.43 kilometers at 330° heading from static test stand]

Energy, keV	Element	Total test counts[a]	Background counts
0.689	Fe	6 953	6 547
1.483	Al	74 888	73 595
1.748	Si	68 290	56 240
2.131	Au	1 449	783
2.328	S	4 061	4 692
2.626	Cl	2 409	1 667
3.334	Snα	735	1 130
3.680	Snβ	84	--
5.436	Crα	2 979	2 092
5.929	Crβ	428	--
6.418	Feα	8 097	5 534
7.030	Feβ	908	106
7.502	Ni	483	--
8.0507	Cuα	2 279	2 105
8.930	Cuβ	218	131

[a]1000 seconds.

TABLE II.- QUANTITATIVE RESULTS OBTAINED FROM X-RAY SPECTROSCOPY - SITE 13

[Electret 13, 585 meters at 325° heading from static test stand]

Energy, keV	Element	Total test counts[a]	Background counts
0.685	Fe	6 743	6 547
1.489	Al	72 063	73 595
1.741	Si	80 821	56 240
2.629	Cl	3 576	1 667
3.329	Sn_{α}	1 141	1 130
3.675	Sn_{β}	744	--
4.500	Ti	157	--
5.413	Cr_{α}	3 282	2 092
5.965	Cr_{β}	242	--
6.412	Fe_{α}	9 200	5 534
7.083	Fe_{β}	1 049	106
7.462	Ni	1 011	--
8.055	Cu_{α}	6 275	131
8.925	Cu_{β}	700	--

[a]1000 seconds.

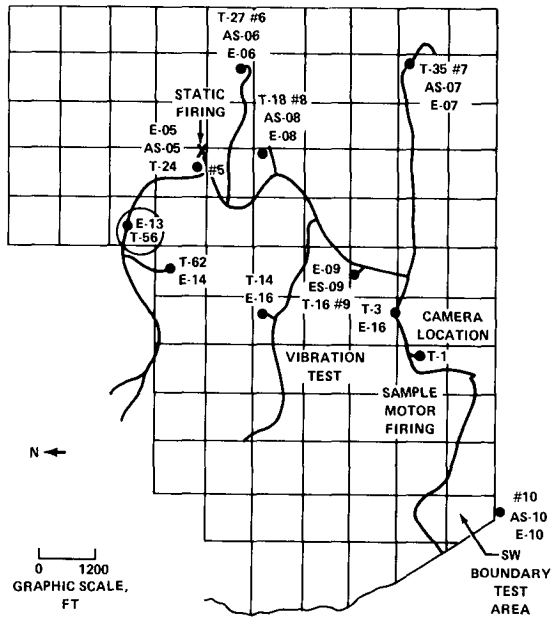


Figure 1.- Near-field location of Thiokol air samplers and MSFC electrets during DM-2 static test.

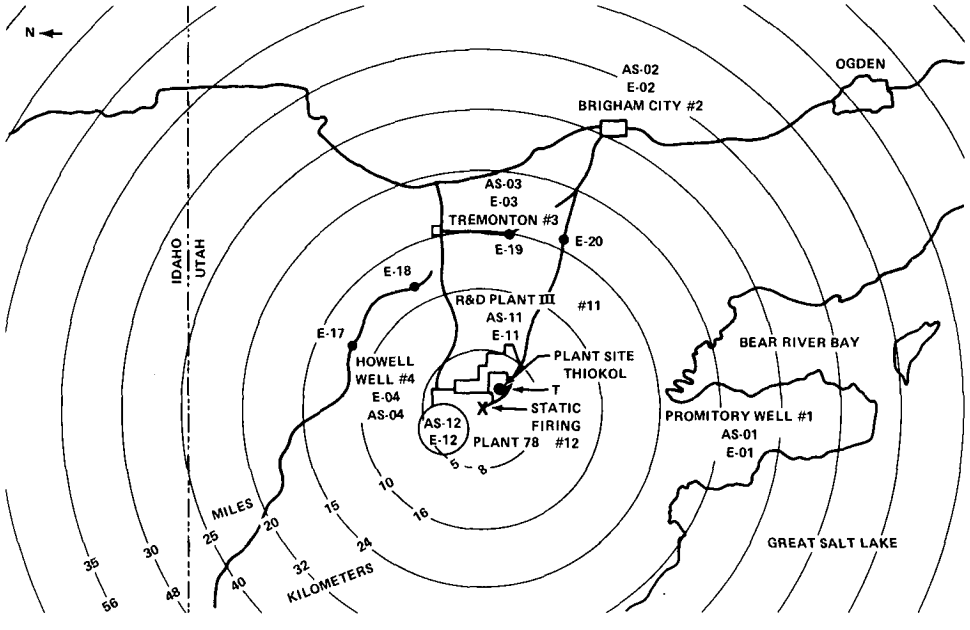
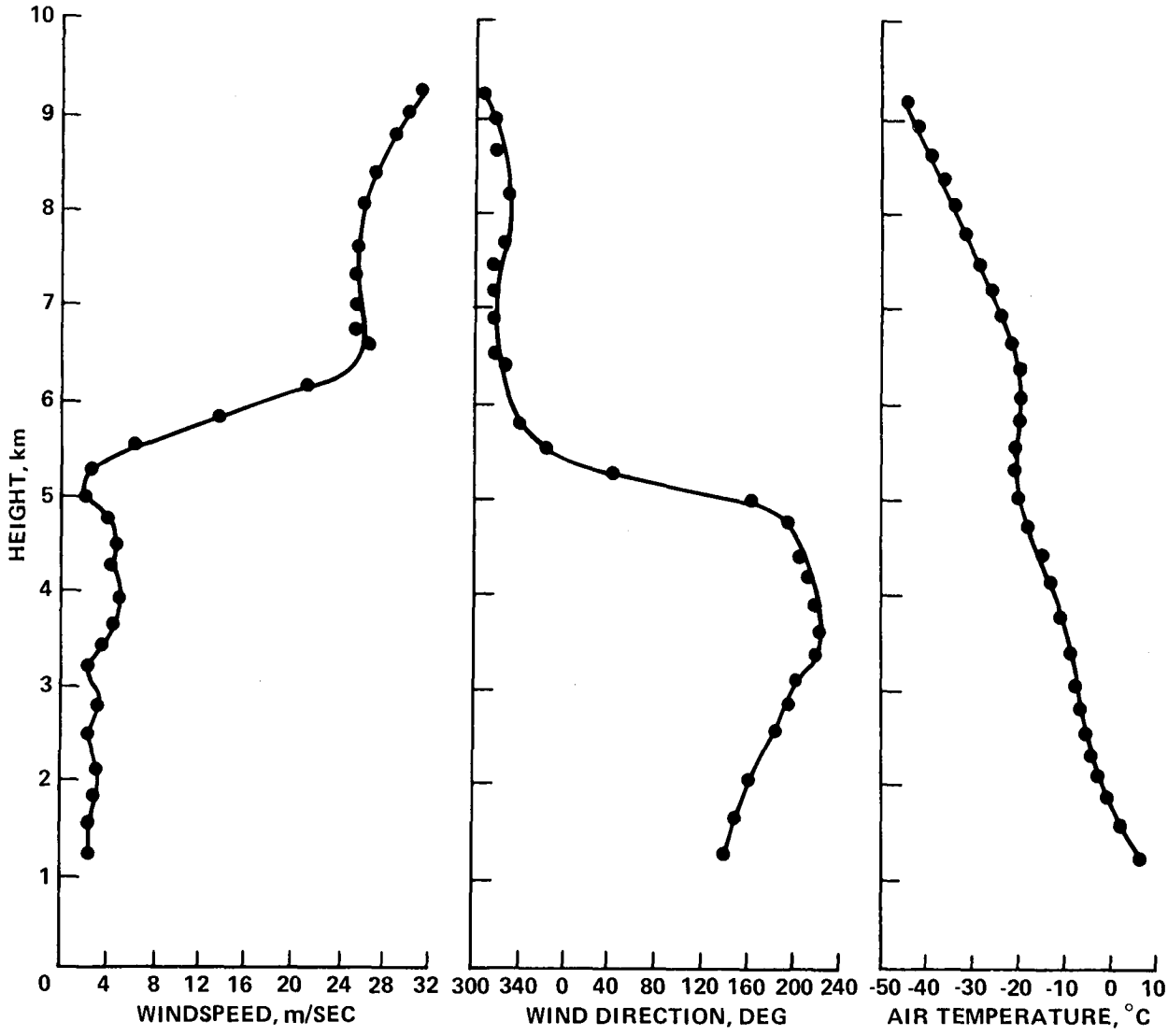


Figure 2.- Far-field location of Thiokol air samplers and MSFC electrets during DM-2 static test.



(a) Windspeed. (b) Wind direction. (c) Air temperature.

Figure 3.- Inputs to the MSFC multilayer diffusion model for DM-2 static test.