

# Dry Ice Sublimation Tests to Support Safe Shipment of SARS-CoV-2 Vaccines:

## Initial Findings

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**Federal Aviation  
Administration**

# Disclaimer

- **This document describes tests performed by the Fire Safety Branch of the William J. Hughes Technical Center at the Atlantic City International Airport in New Jersey (“Technical Center”) in Summer of 2021 in support of the FAA’s effort to aid in the safe shipment of SARS-CoV-2 vaccines.**
- **The tests were performed with high urgency due to the COVID-19 public health emergency, which did not allow for the time necessary to define a formal research program.**
- **The results and observations presented here should therefore be considered preliminary because:**
  - Strict control of initial conditions was not possible due to the state and availability of the laboratory equipment at the time of testing and the difficulty in obtaining large quantities of dry ice, as it was in high demand and supplies were limited.
  - A rigorous experimental design protocol was not followed due to the urgent need for test results.



# Disclaimer (cont.)

- **As additional tests are performed, the FAA will publish updated results and observations, as appropriate.**
- **The results and observations presented here should be considered together with other available information, including the specific details of particular operations. They do not relieve regulated parties of their independent obligations to analyze and appropriately manage safety risks to their operations.**
- **The sample vaccine thermal containers that the FAA used to conduct these tests are just a few examples of COVID-19 vaccine packaging; different packaging may affect dry ice sublimation differently.**



# Test Objective

- **Experiments were conducted in Summer 2021 to determine the effect that three variables had on dry ice sublimation rates**
- **Variables included:**
  - Test Environment Pressure
    - 10.9 psia (8,000 feet Simulated Altitude)
    - 14.7 psia (Mean Sea Level)
  - Dry Ice Pellet Size
    - 1/8", 1/4", 1/2", 5/8" (actual sizes varied)
  - Vaccine Container
    - Large Vaccine Thermal Container
    - Medium Vaccine Thermal Container 1
    - Medium Vaccine Thermal Container 2



# Experiment Setup

- **Containers were filled with dry ice and sealed per container manufacturer instructions**
- **For the 10.9 psia tests, containers were placed into a pressure chamber to simulate a reduced pressure environment (8,000 feet simulated altitude)**
- **All containers were placed on scales and the weight of the dry ice and containers were recorded throughout testing**
  - The ambient temperature and the temperatures within each container were recorded using thermocouples
- **Each test was eight hours in total duration**
- **The diameter, length and weight of 30 dry ice pellets were measured prior to every test**
  - Measurements revealed inconsistencies between the nominal pellet diameter size (what the distributor sold the pellets as) and the actual pellet diameter size (what was measured prior to testing).



# Results – Min, Max and Averages

- **Key preliminary results of Summer 2021 testing:**

- Large Vaccine Thermal Container had a higher average mass loss rate than either of the Medium Vaccine Thermal Containers, most likely due to having more initial dry ice stored
  - Large Vaccine Thermal container stores ~200 lbs compared to ~45 lbs for the Medium Vaccine Thermal Containers 1 + 2
- Medium Vaccine Thermal Container 2 had the highest average sublimation rate and the Large Vaccine Thermal Container had the lowest
- Based on the Summer 2021 test series:
  - For the Large Vaccine Thermal Container, the sublimation rate of dry ice ranged from .320 to .680%
  - For the Medium Vaccine Thermal Container 1, the sublimation rate of dry ice ranged from .430 to .740%
  - For the Medium Vaccine Thermal Container 2, the sublimation rate of dry ice ranged from .481 to .932%

	Large Vaccine Thermal Container		Medium Vaccine Thermal Container 1		Medium Vaccine Thermal Container 2	
	Mass Loss Rate	Sublimation Rate	Mass Loss Rate	Sublimation Rate	Mass Loss Rate	Sublimation Rate
Min	0.631	0.320	0.194	0.430	0.227	0.481
Avg	1.045	0.535	0.259	0.601	0.294	0.712
Max	1.329	0.680	0.344	0.740	0.344	0.932



Large Vaccine Thermal Container Comparisons							
Mass Loss Rate lb/hr	Pellet Size	10.9 psia			14.7 psia		
		Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
	1/8" [~0.1 Actual]	1.137	1.107		0.723	0.740	
	1/4" [~0.2" Actual]	1.078					
	5/8" [~.55 Actual]	1.019	1.098	1.052	1.279	1.329	0.631
1/2" [~.68" Actual]	1.016	1.008		1.224	1.227		
Sublimation Rate % mass loss/hr	Pellet Size	10.9 psi			14.7 psi		
		Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
	1/8" [~0.1 Actual]	0.585	0.569		0.367	0.376	
	1/4" [~0.2" Actual]	0.551					
	5/8" [~.55 Actual]	0.522	0.564	0.539	0.656	0.680	0.320
1/2" [~.68" Actual]	0.521	0.515		0.628	0.629		

Medium Vaccine Thermal Container 1 Comparisons							
Mass Loss Rate lb/hr	Pellet Size	10.9 psia			14.7 psia		
		Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
	1/8" [~0.1 Actual]	0.239	0.220		0.300	0.264	
	1/4" [~0.2" Actual]	0.210					
	5/8" [~.55 Actual]	0.206	0.247	0.244	0.344	0.304	0.333
1/2" [~.68" Actual]	0.201	0.194		0.324	0.258		
Sublimation Rate % mass loss/hr	Pellet Size	10.9 psia			14.7 psia		
		Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
	1/8" [~0.1 Actual]	0.616	0.533		0.68	0.66	
	1/4" [~0.2" Actual]	0.567					
	5/8" [~.55 Actual]	0.472	0.561	0.598	0.66	0.65	0.74
1/2" [~.68" Actual]	0.430	0.535		0.70	0.61		

\* Data points highlighted in yellow are the tests performed with the new containers. Old containers were replaced with new containers halfway through testing due to wear and tear.



Medium Vaccine Thermal Container 2 Comparisons							
Mass Loss Rate lb/hr	Pellet Size	10.9 psi			14.7 psi		
		Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
	1/8" [~0.1 Actual]	0.334	0.337		0.342	0.237	
	1/4" [~0.2" Actual]	0.232					
	5/8" [~.55 Actual]	0.227	0.230		0.344	0.326	0.227
1/2" [~.68" Actual]	0.290	0.292	0.316	0.337	0.343		
Sublimation Rate % mass loss/hr	Pellet Size	10.9 psi			14.7 psi		
		Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
	1/8" [~0.1 Actual]	0.914	0.882		0.932	0.570	
	1/4" [~0.2" Actual]	0.568					
	5/8" [~.55 Actual]	0.481	0.522		0.803	0.720	0.509
1/2" [~.68" Actual]	0.678	0.689	0.770	0.771	0.862		

**\* Data points highlighted in yellow are the tests performed with the new containers. Old containers were replaced with new containers halfway through testing due to wear and tear.**





# Observations

- **Mean sea level pressure (14.7 psia) appeared to have a slightly higher sublimation rate compared to 10.9 psia testing, until the new containers were used**
  - These tests revealed the influence of the condition of the containers on dry ice sublimation rates
  - Further tests need to be performed with containers of similar use history to evaluate the effect of ambient pressure on sublimation rate.
- **The size of dry ice pellets has an inverse relationship with mass loss and sublimation rate**
- **The condition of the containers had a significant impact on the sublimation rate of dry ice**
- **The Large Vaccine Thermal Container had a higher mass loss rate than Medium Vaccine Thermal Containers 1 + 2**
  - Most likely due to a larger amount of dry ice packed within the Large Vaccine Thermal Container
- **More testing may be needed to better understand trends for the sublimation rate of dry ice**

