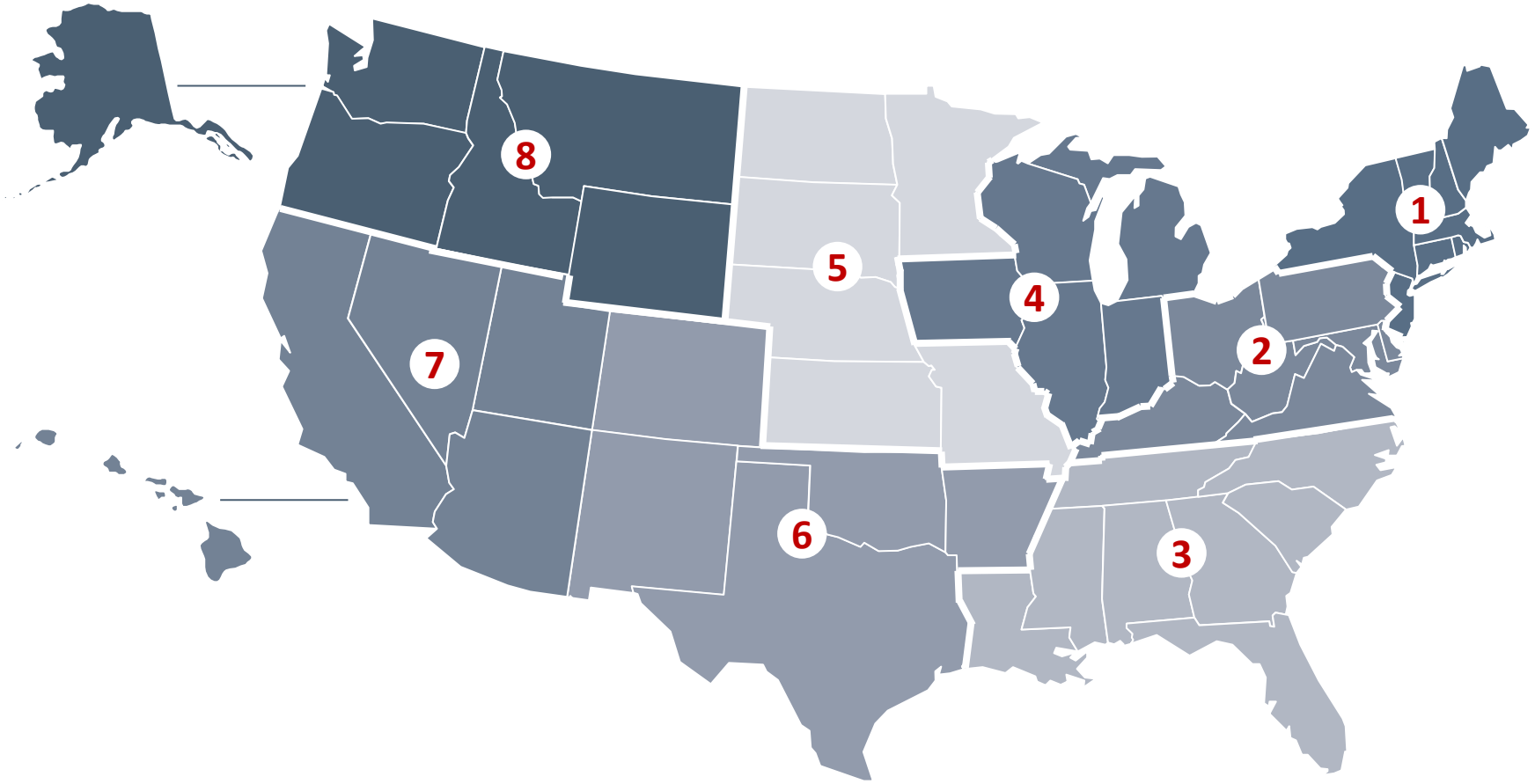
STUDY OF AEROSOL IN PERFORMING ARTS

National Federation of State
High School Associations

Dr. James Weaver
NFHS Director of Performing Arts and Sports
Performing Arts Aerosol Study Co-Chair

WHO IS THE NFHS

NFHS ACROSS THE NATION



STUDY CHAIRS

James Weaver - NFHS Director of Performing Arts and Sports

Mark Spede – CBDNA President, Director of Bands, Clemson University

LEAD FUNDERS

NAMM Foundation®

NFHS NATIONAL FEDERATION OF STATE HIGH SCHOOL ASSOCIATIONS

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CBDNA College Band Directors National Association

CONTRIBUTING ORGANIZATIONS

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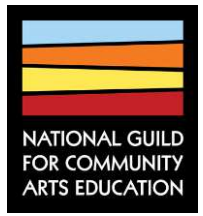

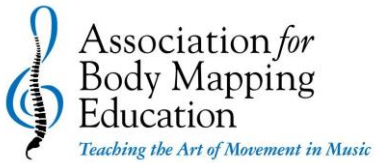

CONTRIBUTING COLLEGIATE CONFERENCE BAND ASSOCIATIONS AND UNIVERSITIES

Collegiate Conference Band Associations:
ACC Band Directors Association
Big 12 Band Directors Association
Big 10 Band Directors Association
PAC 12 Band Directors Association
SEC Band Directors Association

Individual School Band Programs:
Clemson University Bands
Linn-Benton Community College Bands
University of California Los Angeles (UCLA) Bands
University of Utah Bands

SUPPORTING ORGANIZATIONS

American School Band Directors Association (ASBDA)
American String Teachers Association (ASTA)
Arts Education in Maryland Schools (AEMS)
Association Européenne des Conservatoires/Académies de Musique et Musikhochschulen (AEC)
Buffet et Crampon
Bundesverband der deutschen Musikinstrumentenhersteller e.V
Chicago Children's Choir
Children's Chorus of Washington
Chorus America
Confederation of European Music Industries (CAFIM)
Drum Corps International (DCI)
Educational Theatre Association (EdTA)
European Choral Association - Europa Cantat
HBCU National Band Directors' Consortium
High School Directors National Association (HSBDNA)
International Conductors Guild
International Society for Music Education
League of American Orchestras
Louisiana Music Educators Association (LMEA)
MidWest Clinic
Minority Band Directors National Association
Music Industries Association
Musical America Worldwide
National Dance Education Organization (NDEO)
National Flute Association (NFA)
National Guild for Community Arts Education
Percussive Arts Society (PAS)
Save the Music Foundation
United Sound
WGI Sport of the Arts

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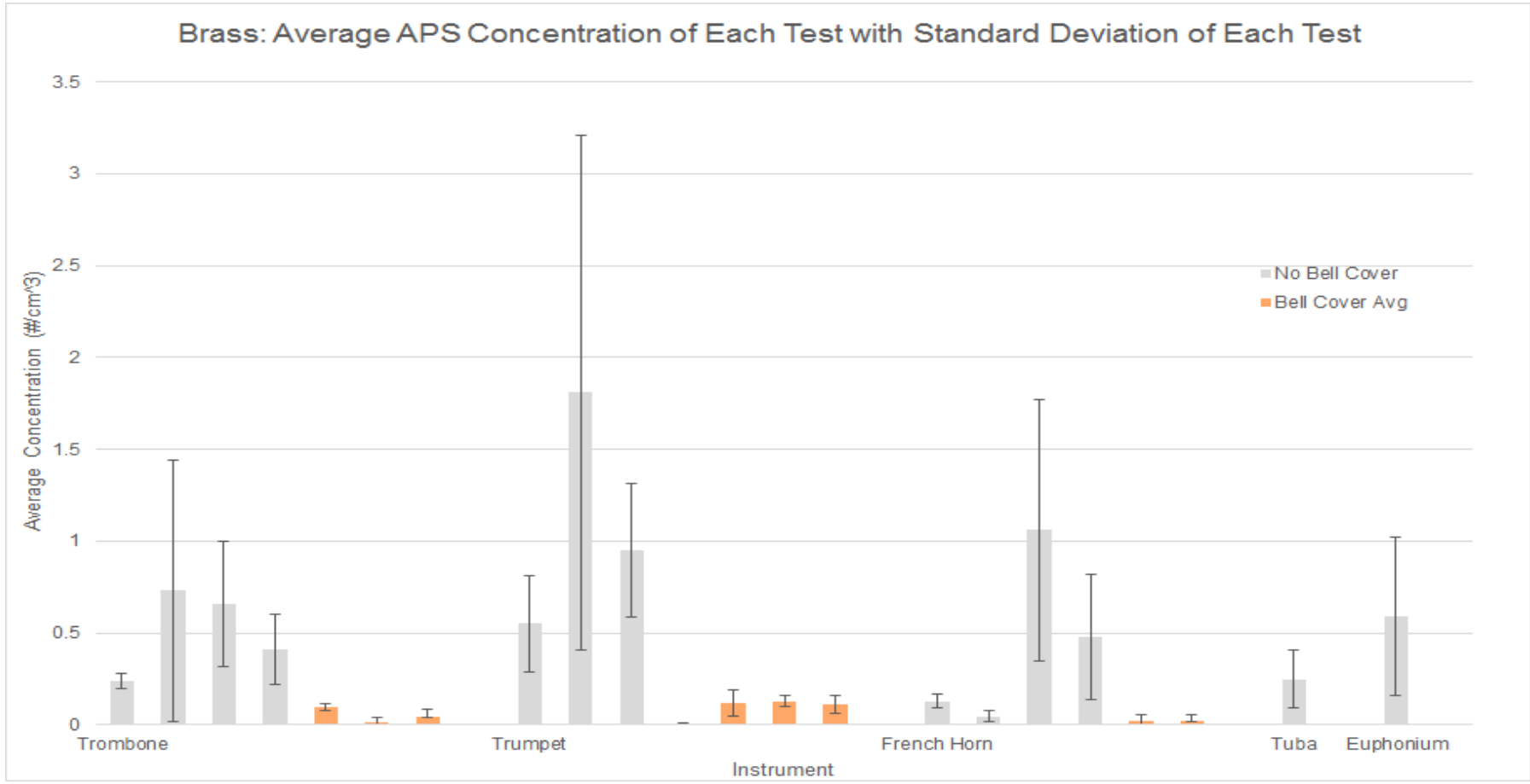
AEROSOL CONCENTRATIONS OVER TIME



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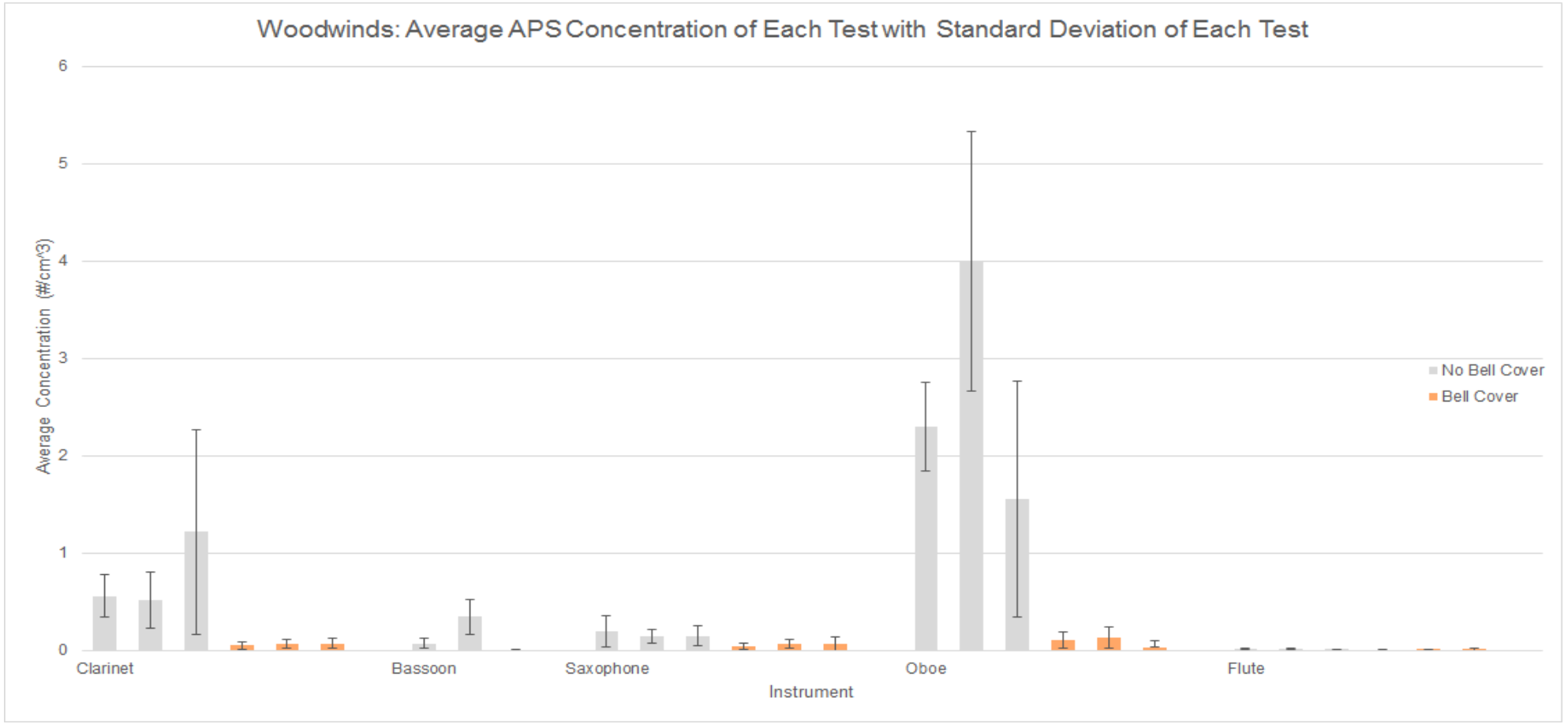

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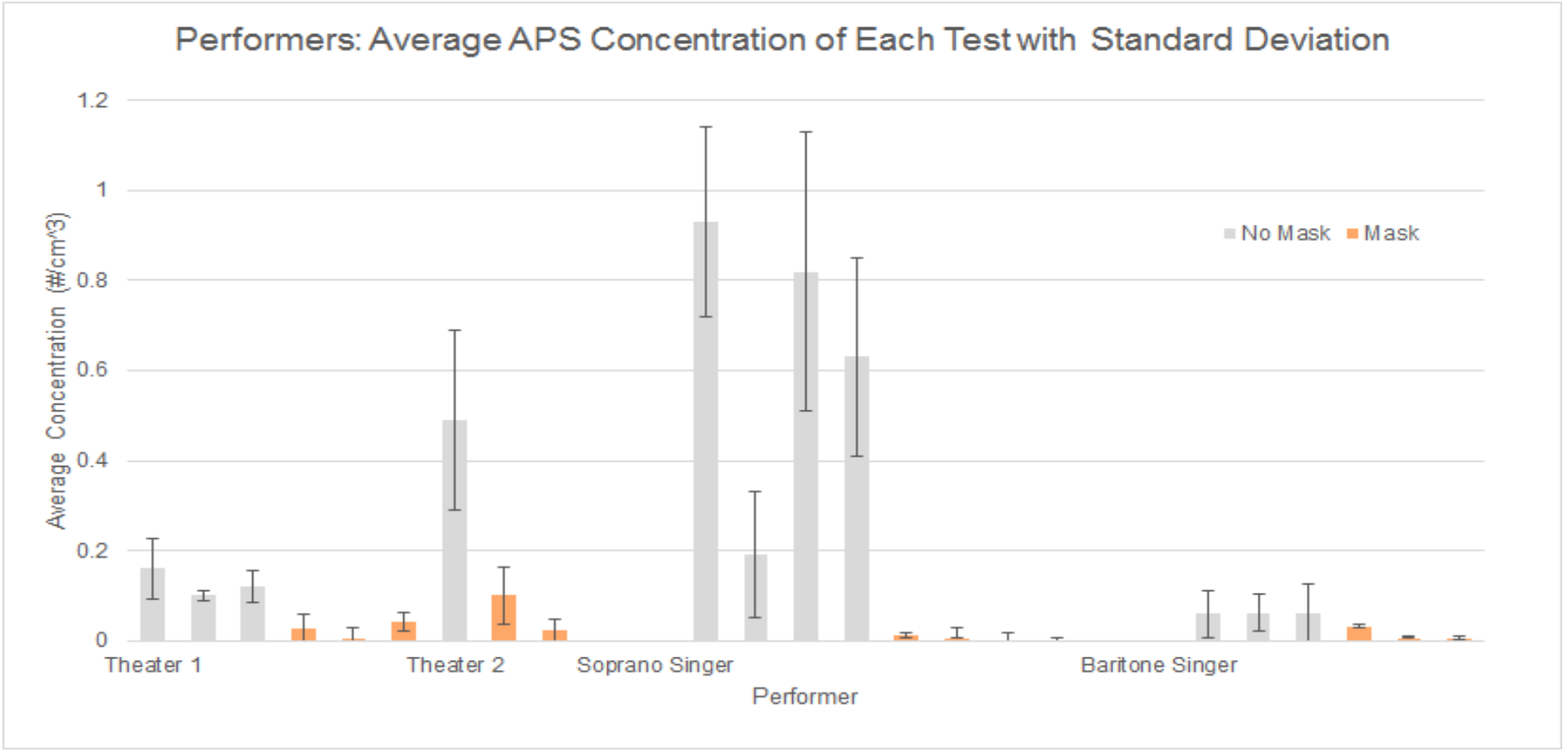


MITIGATION EFFECTIVENESS

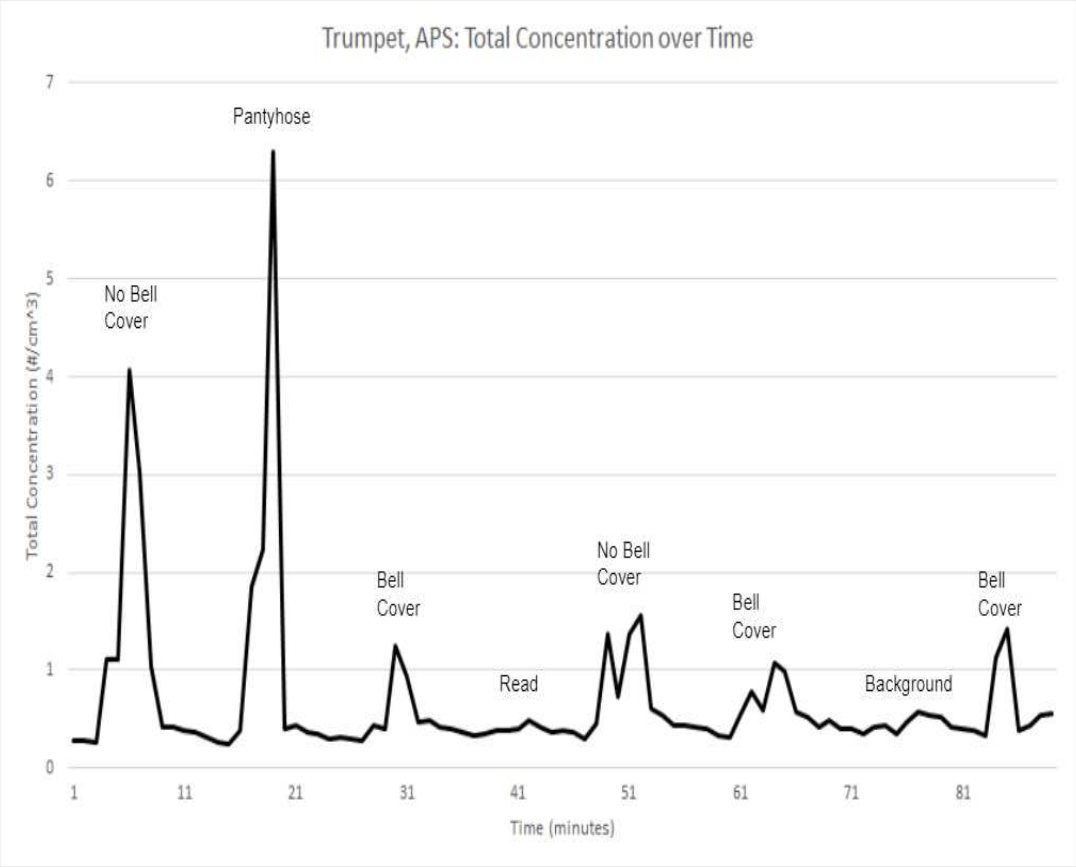
- Sampling performed at the bell does not take into account what is expelled at the keyholes. Bell covers diffuse the air coming out of an instrument bell, causing the plume to not be as concentrated. The samples are also not as concentrated as when playing without a bell cover. The efficiency percentages below are related to the aerosol produced in Appendix A. It is important to identify the reference to the background aerosol levels between Appendix C, to fully understand the depth of the mitigated aerosol release.

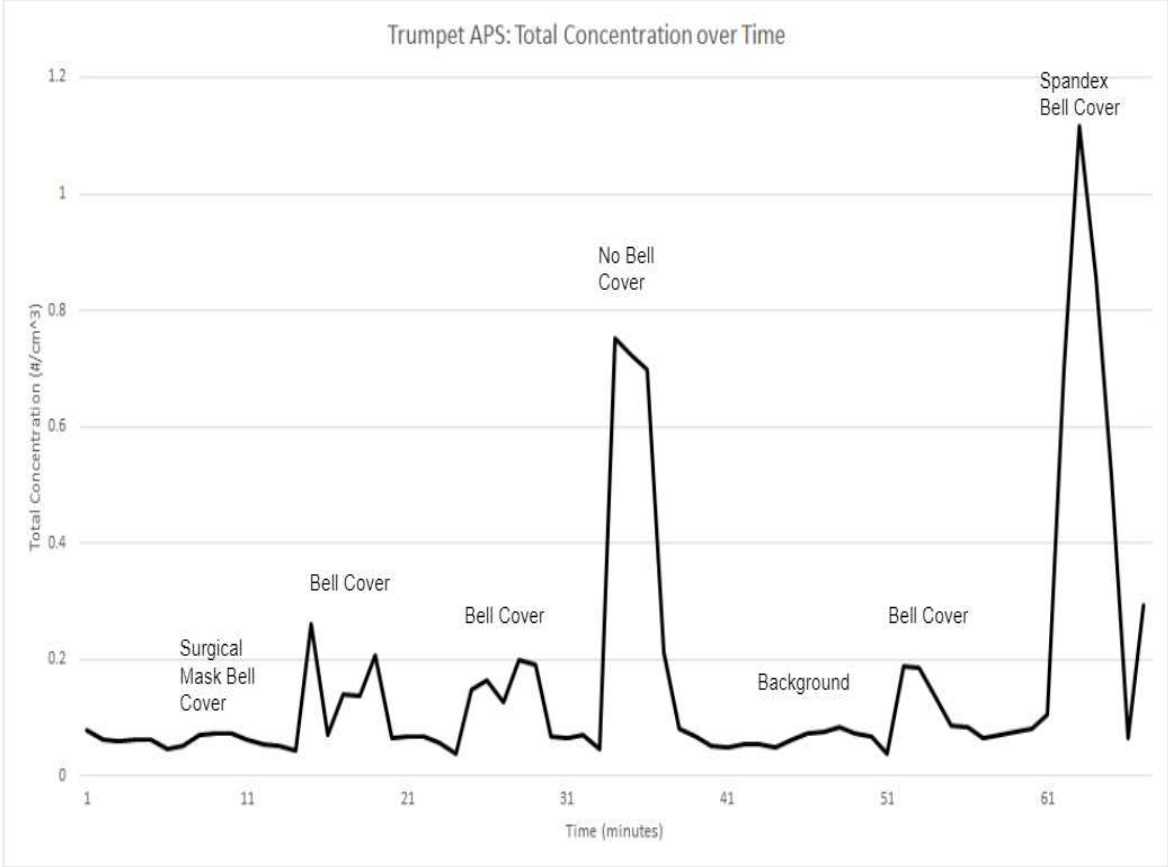
Example A: Saxophone has an overall aerosol release of 0.7 pp cm3 unmitigated and an aerosol release of 0.32 pp cm3 (64% reduction) with a bell cover, placing mitigated saxophone just above background levels of aerosol.

Example B: Oboe has an overall aerosol release of 4.00 pp cm3 unmitigated and an aerosol release of 0.5 pp cm3 (96% reduction) with a bell cover, placing mitigated oboe in line with other mitigated instruments and singers.

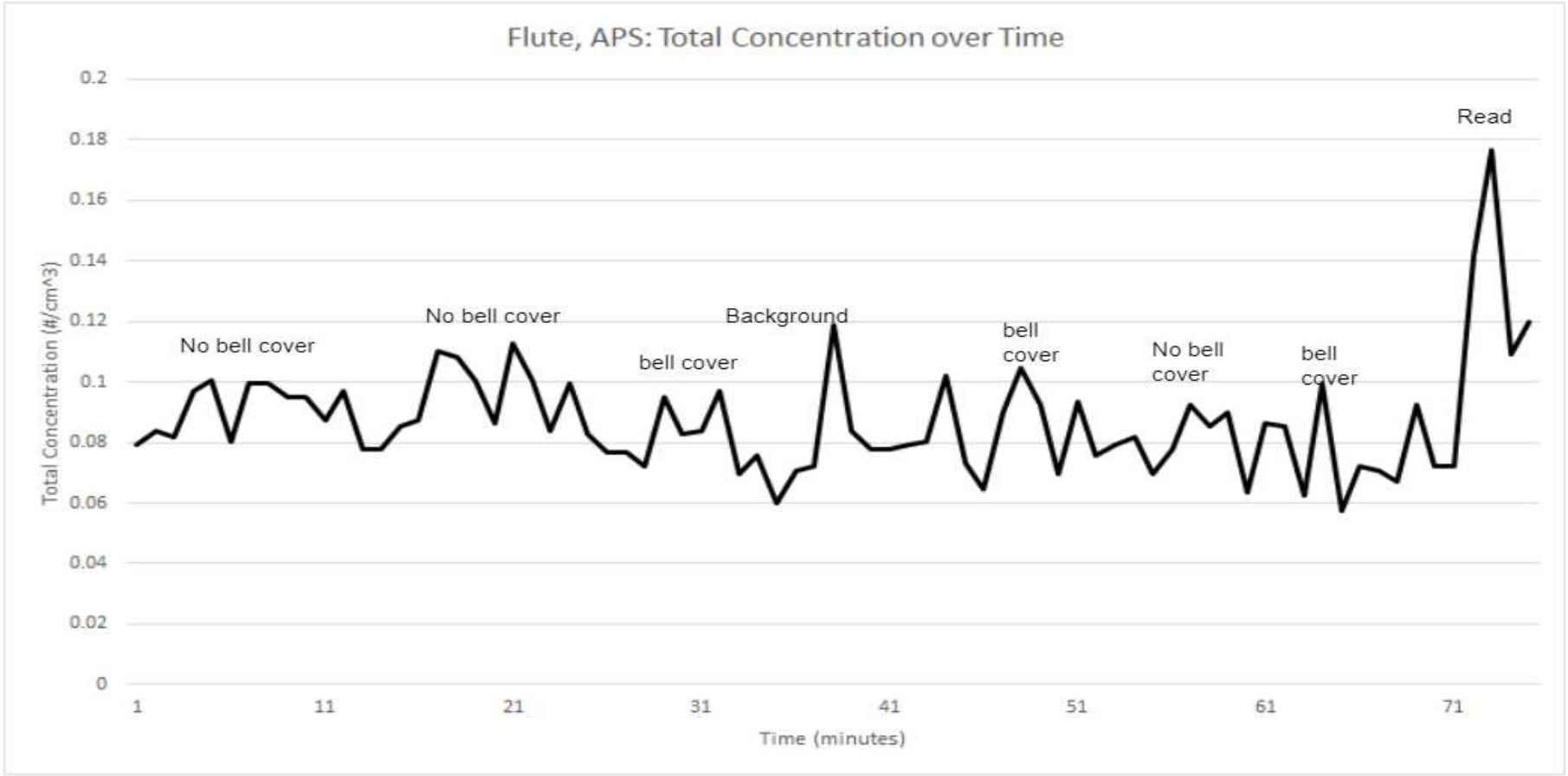
Instrument	Efficiency Calculated, Sampled at Bell / Mouth
Saxophone	64%
Flute	67%
Baritone Singer*	79%
Theater 1*	80%
Clarinet	87%
Theater 2*	88%
Bassoon	89%
Trombone	89%
Trumpet	92%
French Horn	95%
Oboe	96%
Soprano Singer*	98%

APS DATA OF AEROSOL EMISSIONS - TRUMPET

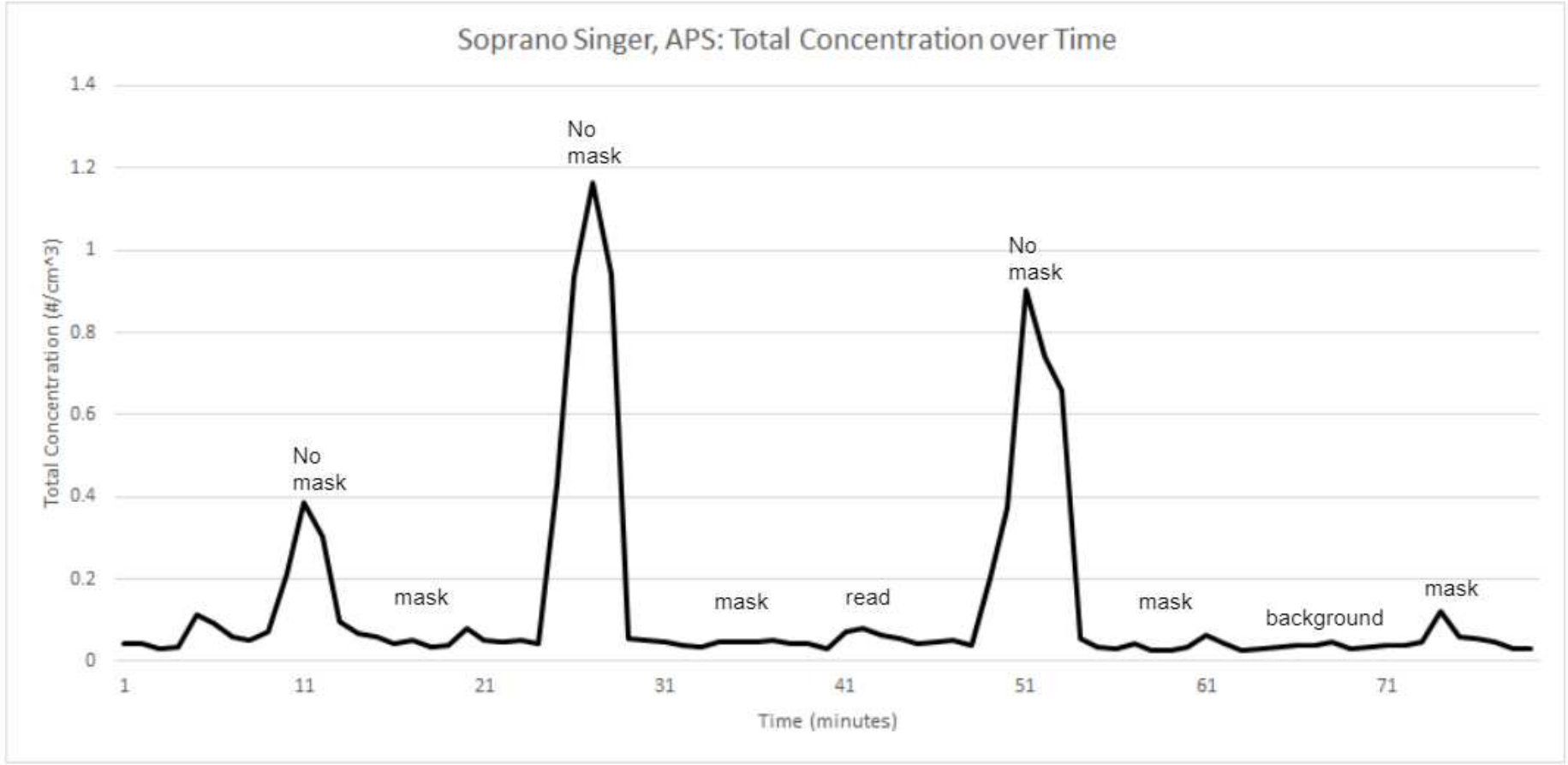




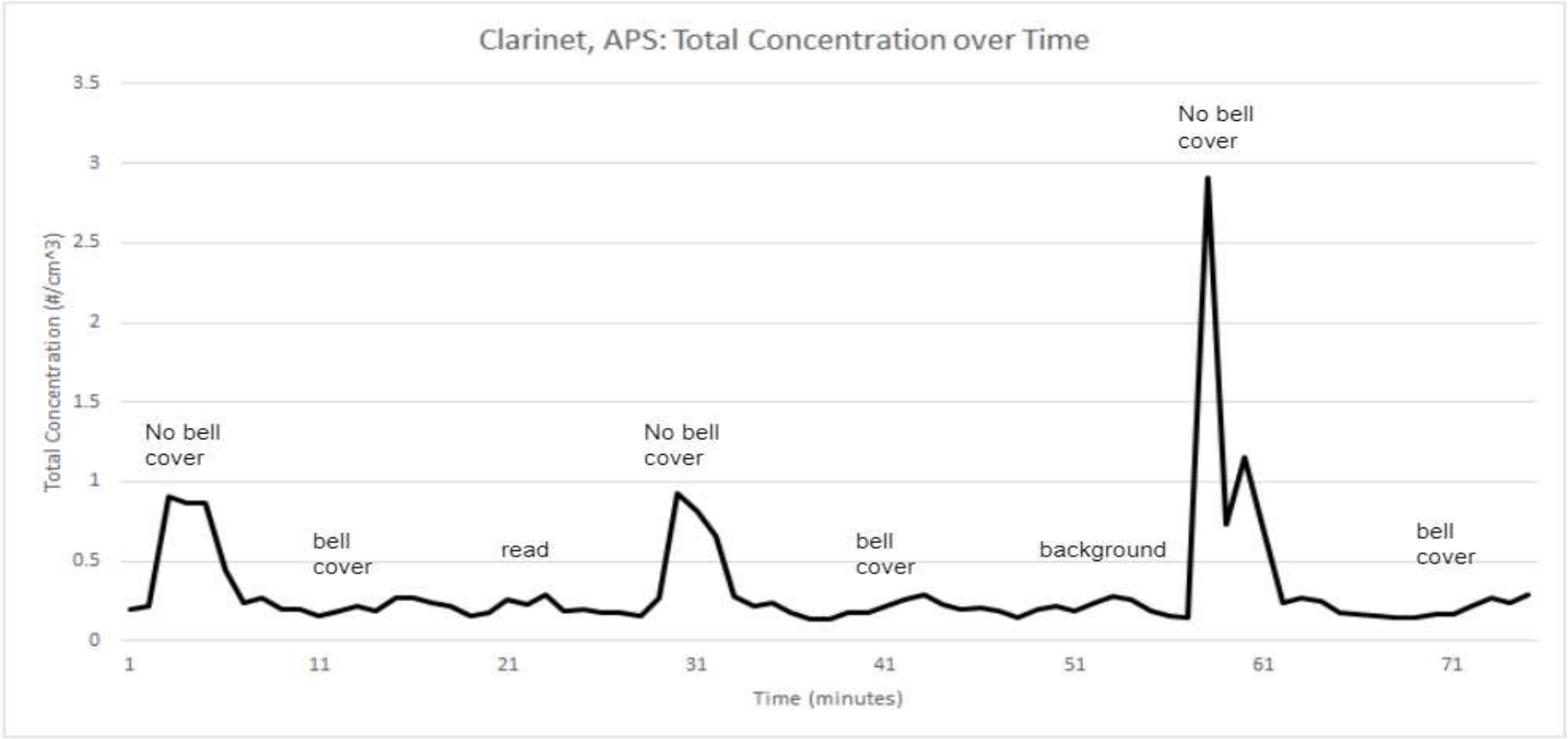
APS DATA OF AEROSOL EMISSIONS - FLUTE



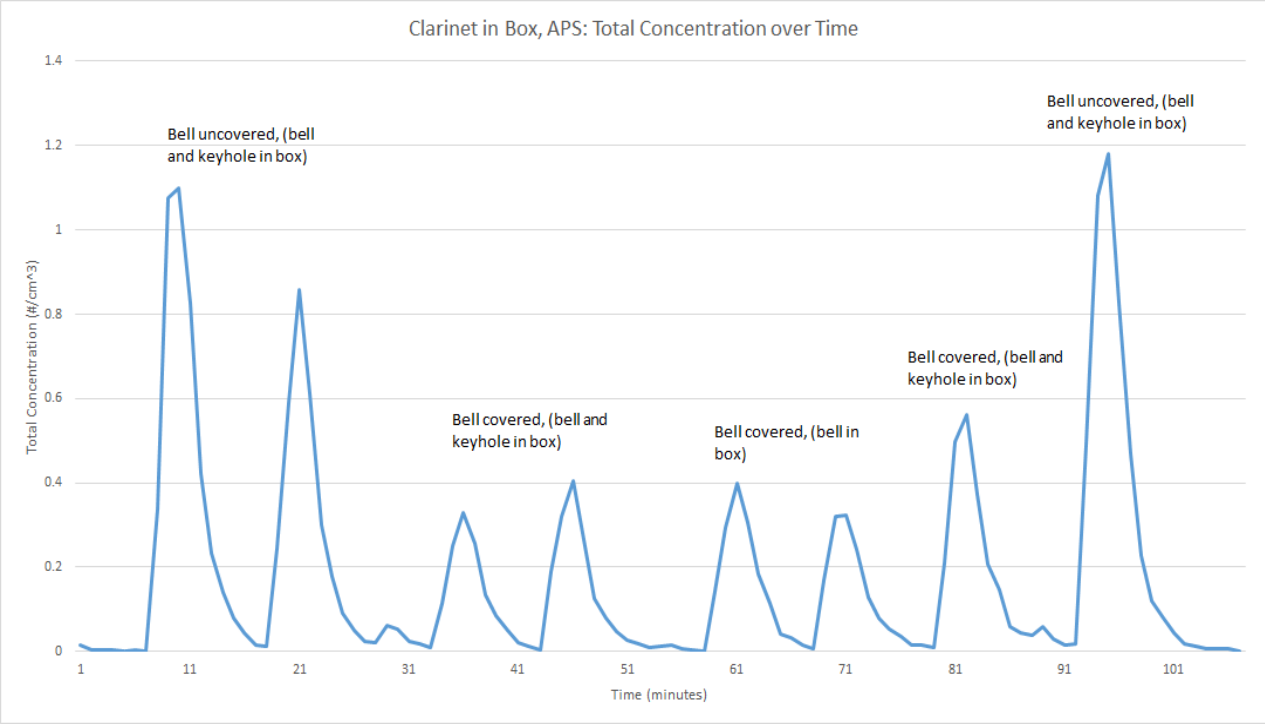
APS DATA OF AEROSOL EMISSIONS - SINGING

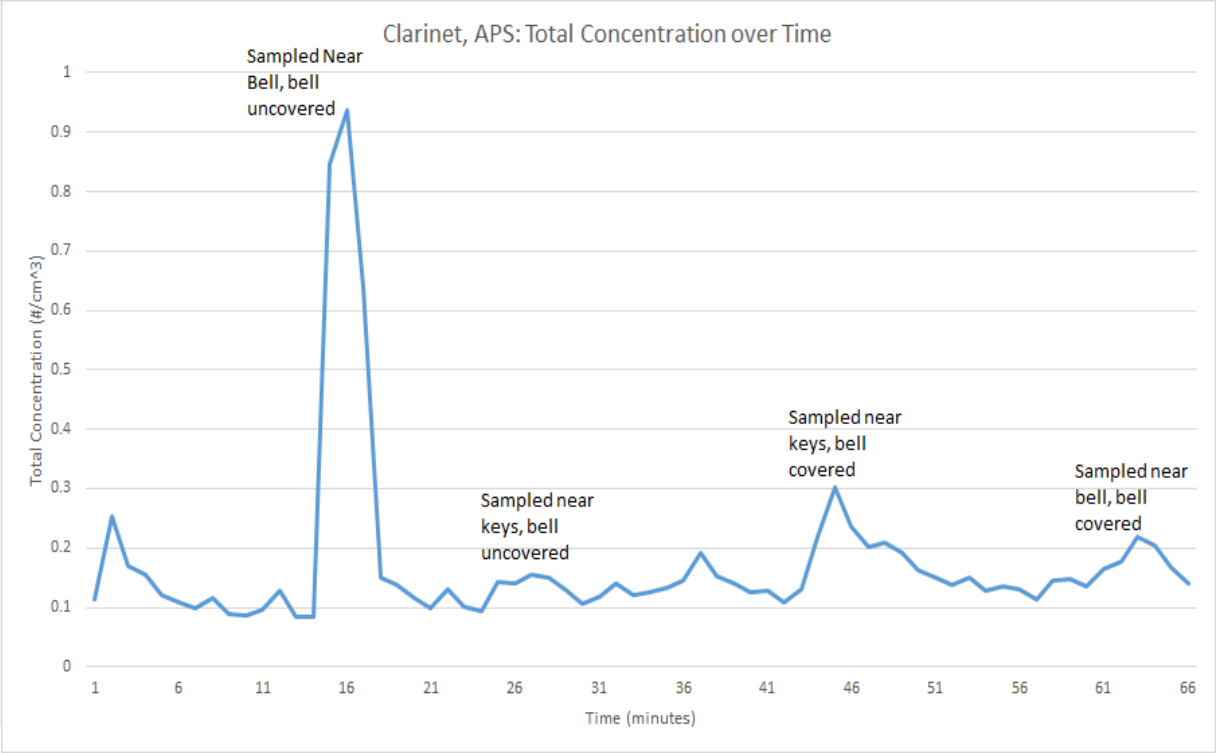


APS DATA OF AEROSOL EMISSIONS - CLARINET

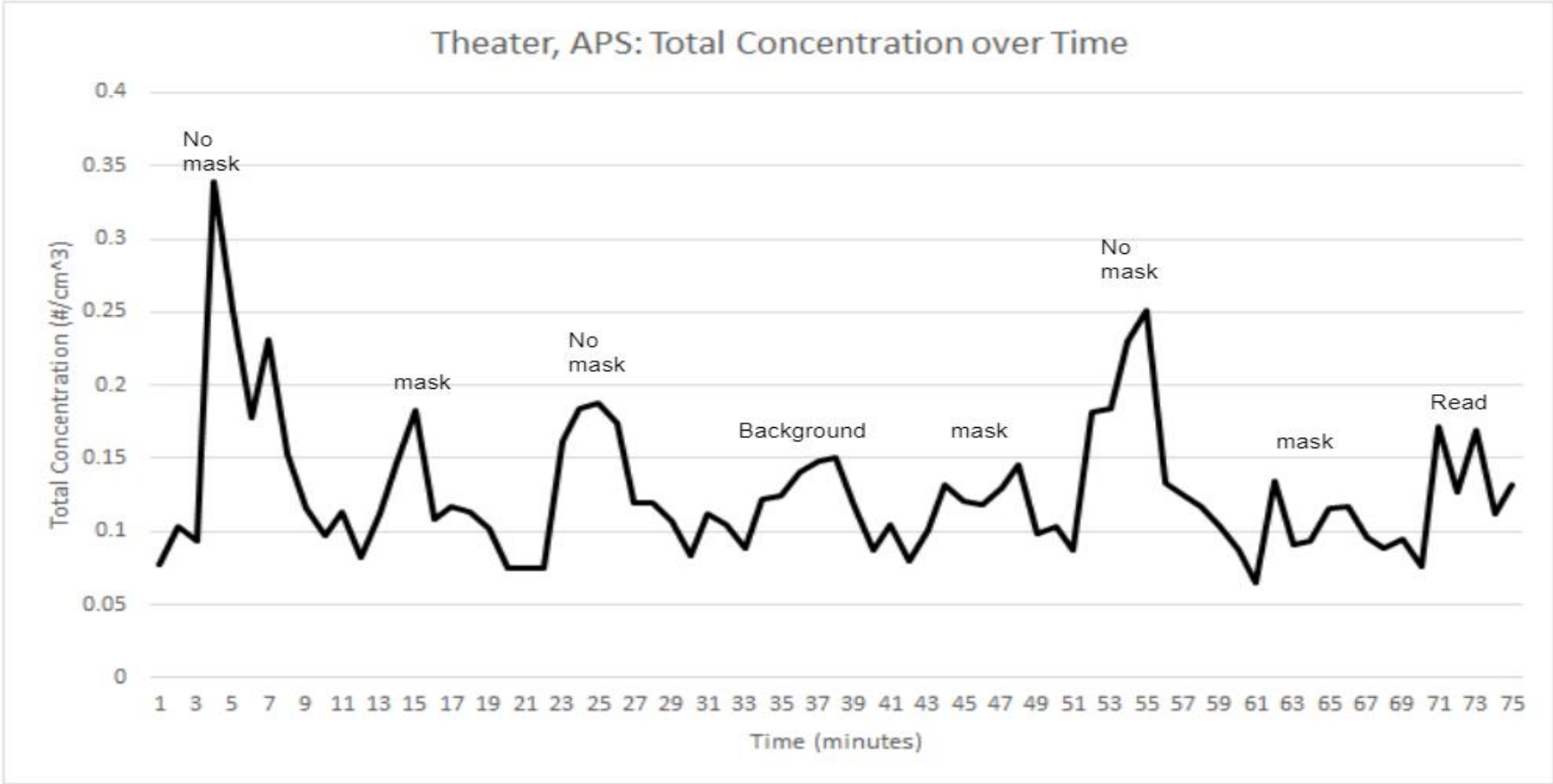


CLARINET KEYHOLE EMISSIONS



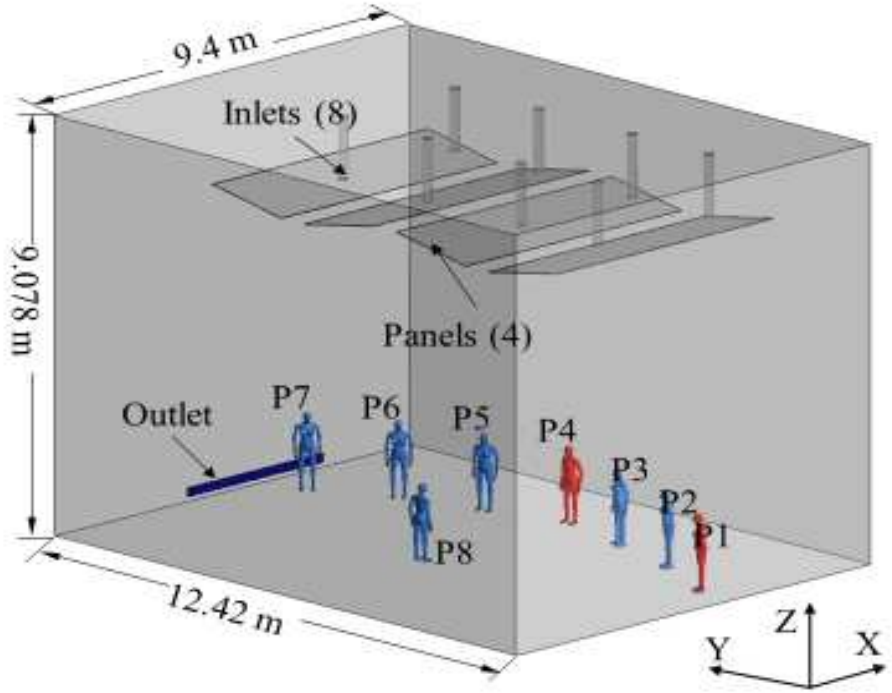


APS DATA OF AEROSOL EMISSIONS - THEATRE



CFD MODELING

Modeling of UC Rehearsal Hall with Singers



Rehearsal Hall Room:

- Inlet:
  $d = 0.2$ m, $v = 3.774$ m/s (3.2 ACH), $T = 22$°C (71.6°F)
- Outlet:
  3.6 m (X) × 0.2 m (Z)
- Walls & other solid surfaces:
  adiabatic

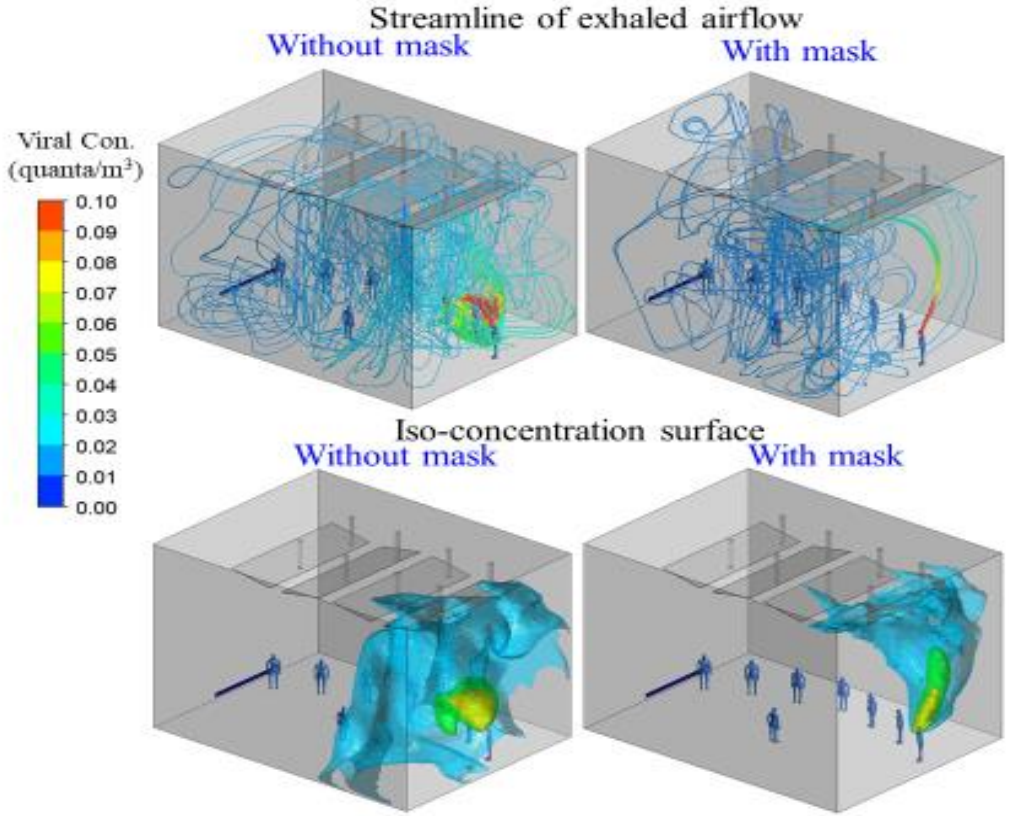
Human body:

- All body surface:
  convective heat flux = 23 W/m²
- Mouth of the infected singer (P1):
  $A = 3.8$ cm², $v = 0.56$ m/s, $T = 33$°C (91.4°F),
  $S = 48$ quanta/hr for COVID-19 virus
- Nostril of the susceptible singers & director:
  $A = 3.3$ cm², $v = 1.679$ m/s (14 L/min, 1.8 met)

❖ In the simulation, P1 was assumed to do constant exhalation with the susceptibles were assumed to do constant inhalation.

CFD MODELING

Spread of Viral Aerosols from P1



Infection risk for susceptible singers & director after 60 minutes (%).

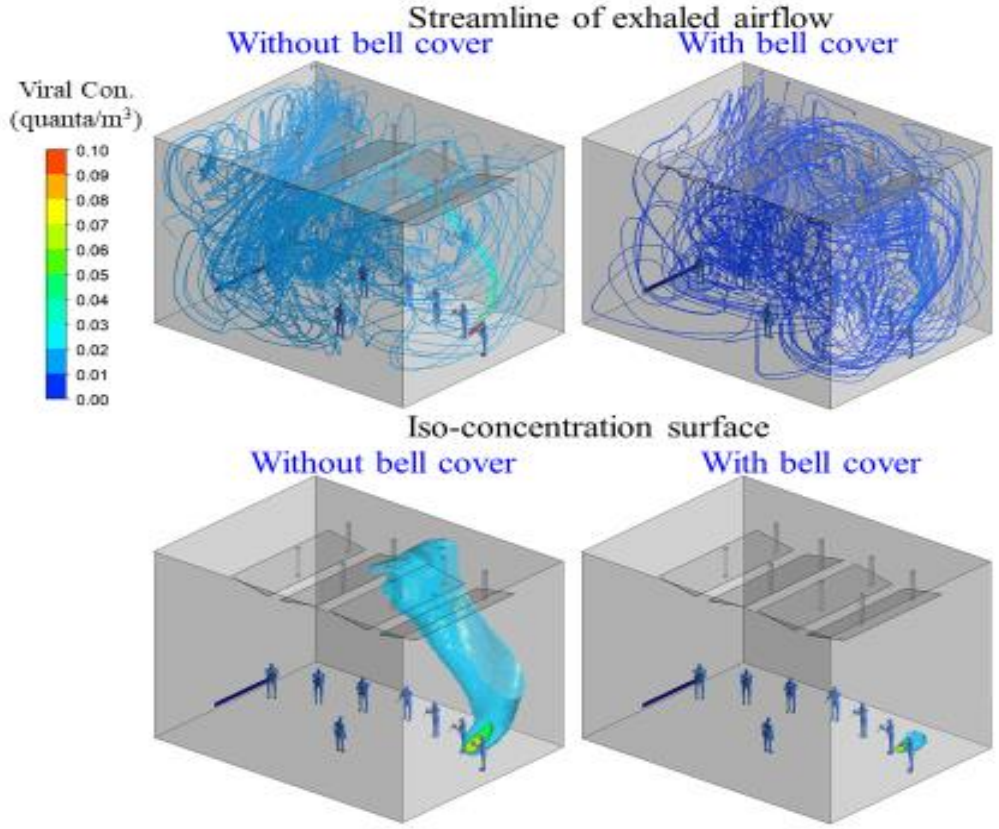
	P2	P3	P5	P6	P7	P8	Well-mixed
No mask	11	4	2	3	3	3	2.85e-04
With mask	2	1	1	1	1	1	5.25e-05
Reduction in risk	85%	61%	57%	60%	62%	58%	82%

- It is assumed that wearing a mask can filter 48.83% of aerosols for susceptible people.[1)]
- "Well-mixed" show the risk under the perfectly mixed ventilation conditions resulting in an underestimate of risk.

- **P2 has a high risk to be infected by P1 if not wearing a mask.**
- **Wearing a mask reduced the infection risk by over 57% for each susceptible person.**
- **However, indoor airflow rates could be increased to improve mixing and reduce the risk.**

CFD MODELING

Spread of Viral Aerosols from P1



Infection risk for susceptible clarinet players & director after 60 minutes (%).

Source	P2	P3	P5	P6	P7	P8	Well-mixing
No cover	3	3	3	3	3	3	2.85e-04
With cover	1	1	1	1	1	1	1.03e-04
Reduction in risk	56%	60%	59%	62%	64%	64%	64%

- The bell cover is assumed to have the same particle removal efficiency as a surgical mask: 64%.
- The susceptible people do not wear a mask.
- "Well-mixed" show the risk for the perfectly mixed ventilation resulting in an underestimate of risk.
- **Due to good air mixing in lower layers of room, with the same source strength, viral aerosols from playing clarinet resulted in a similar concentration distribution at the height of mouth as a whole, as well as the risk for the susceptible people except for P2.**
- **Using a bell cover greatly reduced the viral aerosol concentration at the height of month, resulting a reduction in infection risk by over 56%.**

5 PRINCIPAL RECOMMENDATIONS

Masks

- Student
- Instruments
- Materials

Distance

- 6-foot CDC guidance
- Applies indoors and outdoors
- 9x6 for trombone

Time

- 30-minute rehearsal
- Clear room for minimum 1 air change before next rehearsal period

Air Flow

- Outdoors is best
- HEPA Filtration
- ACH Rates

Hygiene

- Spit Valves
- Handwashing
- Storage Areas

KEY TAKEAWAYS

- We are entering month 5 of a 6-month study, utilizing two independent labs at the University of Colorado – Boulder and the University of Maryland
- Wind instruments and singing produce aerosol, which vary by instrument as well as intensity. The produced aerosol amount is, on average, similar across all instrument types and singing with the exception of the oboe. Most aerosol is being expelled from the bell of the instruments and from the mouth of the performers.
- At this time, it appears that if players wear surgical style masks with a slit for mouthpiece AND bell covers, aerosol emission is reduced between 60% and 90%.
- Flutes and recorders create a minimal amount of aerosol and it is recommended to play flute with the headjoint between their mouth and mask . Recorder should use the slitted mask used with woodwinds. Both the flute and recorder should use a cloth “mask” at the end of the barrel.

KEY TAKEAWAYS

- Bell covers for woodwinds and brass should be made with a multi-layer cover with the center layer being made of MERV-13 filter material, or a 3-layer surgical style mask using a standard such as GB/T32310.
- Singers produce aerosol at similar rates as woodwinds and brass. The amount of aerosol varies depending on consonants, vowels, intensity, and pitch. Singers wearing a well fit 3-layer surgical style mask reduces aerosol emission.
- Face shields are only effective at close range to stop large droplets; they do not prevent aerosol from being inhaled or released unless a mask is also worn.
- Plexiglass partitions or barriers between musicians are not recommended due to room HVAC system design limitations. "Dead zones" or areas where aerosol can build-up are a concern of plexiglass partitions are used.

REHEARSAL SPACE AND GENERAL PROCEDURES

- Rehearsal space recommendations in order of preference:
  - Outdoor rehearsals, using individual mitigation techniques described above.
  - Indoors with elevated outdoor air exchange rate from HVAC.
  - Indoors with typical outdoor air exchange rate from HVAC plus recirculation air through MERV 13 filters or addition of appropriately sized HEPA air cleaners.
  - Indoors with outdoor air exchange rate from open windows supplemented with appropriately sized HEPA air cleaners when airflow is reduced under certain outdoor wind conditions.

Please refer to the Association for Heating, Ventilating and Air-Conditioning Engineers (ASHRAE) guidance on ventilation during COVID-19: https://www.ashrae.org/technical-resources/resources

- General procedures (See Appendix G)
  - Masks must be worn at all times. Multi-layered bell covers must be used by all wind instruments
  - CDC guidelines for social distancing of 6x6 feet, with 9x6 for trombone players.
  - Indoors limited to 30 minutes followed by a minimum of one air exchange rate (ACH), preferably 3 ACH, to change the air indoors with outside air.
  - Increase ACH to HVAC maximum, add HEPA Filtration designed for the size of the room.
  - Practice good hygiene by washing hands, using sanitizers, and preventing uncontrolled spit valve release.
  - Next Steps

THANK YOU!

National Federation of State
High School Associations

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