National Personal Protective Technology Laboratory

Comparison of ISO work of breathing and NIOSH air flow resistance test methods for respiratory protective devices

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DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Personal Protective Technology Program (PPT)
National Personal Protective Technology Laboratory (NPPTL)

VISION: Our vision is to be a leading provider of quality, relevant, and timely PPT research, training, and evaluation.

MISSION: The mission of the PPT program is to prevent work-related injury, illness and death by advancing the state of knowledge and application of personal protective technologies (PPT).

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Background

- Work of breathing (WOB) was identified early on as a basis for breathing resistance limits for respiratory protective devices (RPDs).

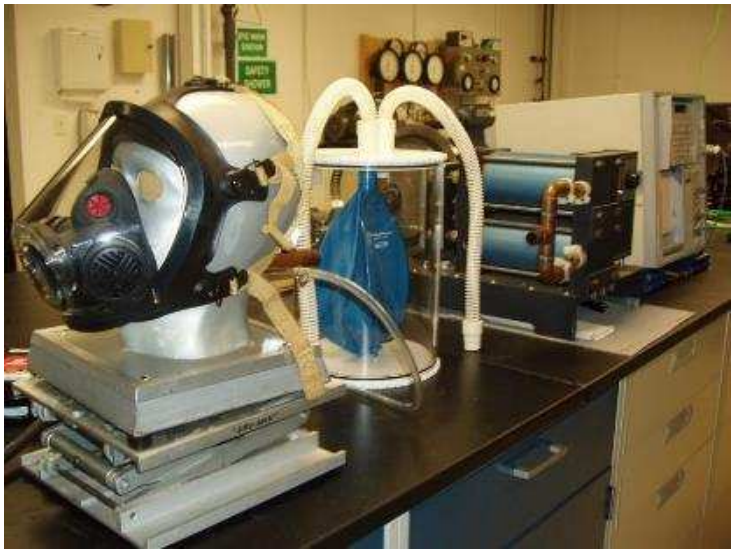
- WOB was adopted for underwater breathing apparatus in the 1970s, and was recently incorporated into new ISO standards for RPD.

- National Institute of Occupational Safety and Health (NIOSH) methods and requirements for breathing resistance, specified in 42CFR Part 84, currently do not include WOB.

NIOSH Methods for RPD Resistance

Photos courtesy of NPPTL

Air-purifying
Air-flow Resistance at constant flow (± 85 LPM)



Supplied-air
Peak pressures with 40 LPM breathing machine

Closed-circuit
Metabolic Simulator

Objectives

- Construct ISO WOB method at NPPTL
- Participate in ISO head form task group efforts to finalize standards.
- Measure WOB (and related parameters) for all classes (designs) of respirators.
- Determine how ISO WOB method compares to those from methods currently used by NIOSH for respirator evaluation under 42 CFR Part 84.
  - How do pass/fail rates compare?

Development of ISO Work of Breathing Method

ISO-16900-5 Tools

Headforms
Breathing tube
Breathing machine
Wave forms
Verification orifices, adapters, and procedure

Photos courtesy of NPPTL

ISO 16900-12 Method

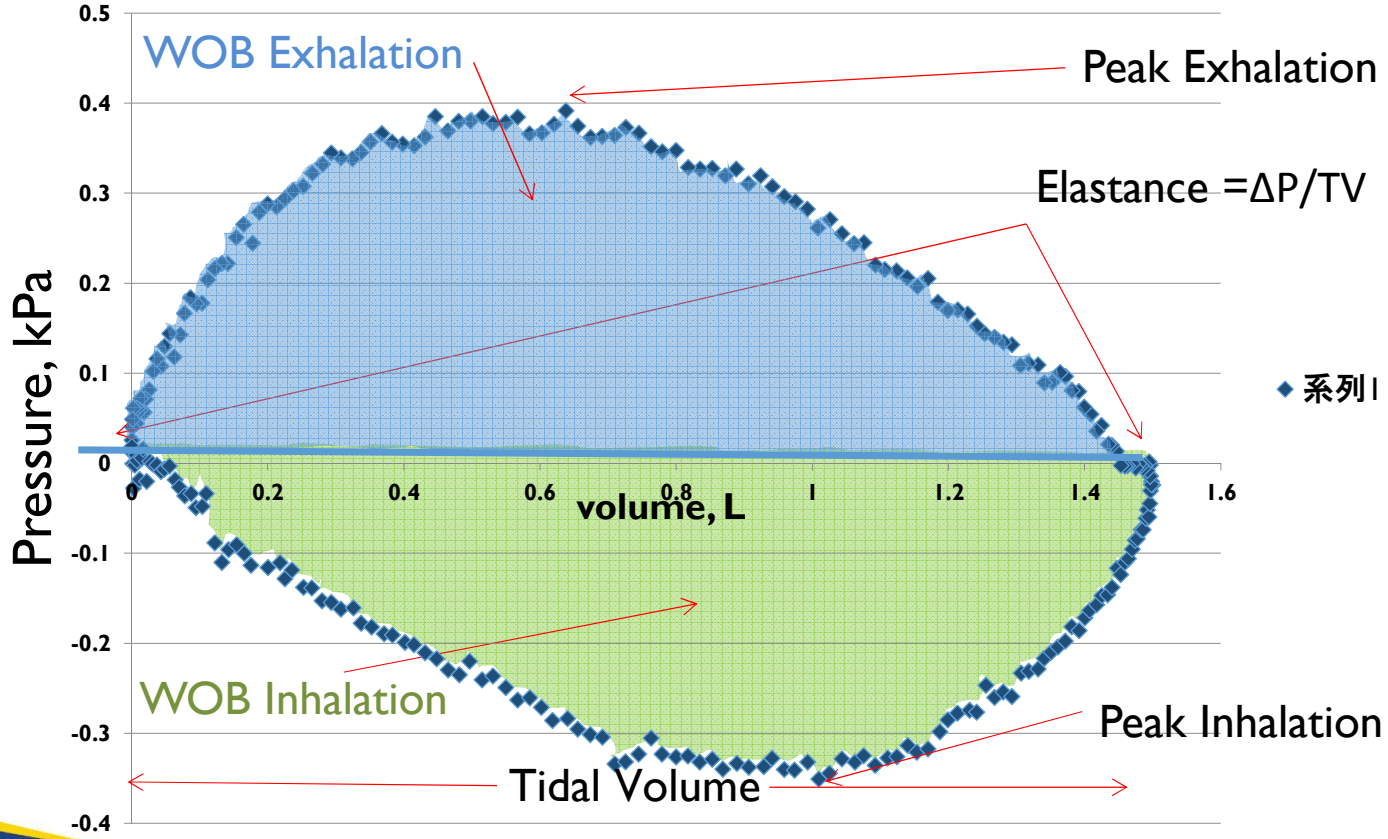
Verification requirements
All ISO waveforms including 4 ISO work rates
Method performance evaluated

Methods

- NIOSH resistance methods
  - STPs http://www.cdc.gov/niosh/npptl/stps/respirator_testing.html
- ISO WOB method
  - Standards 16900-5, 169000-12, 16900-13, 16976-4
- Fifty-four respirator models tested
  - Forty-five Air-Purifying (APR):
    - 17 filtering facepiece
    - 7 full-facepiece with CBRN canister
    - 11 elastomeric half-mask air-purifying respirator
    - 3 tight-fitting powered air-purifying (PAPR)
    - 7 loose-fitting PAPR
  - Nine Supplied-air (SAR):
    - 3 self-contained breathing apparatus
    - 4 constant-flow airline
    - 2 pressure-demand airline

Work of Breathing

Pressure-Volume (PV) results

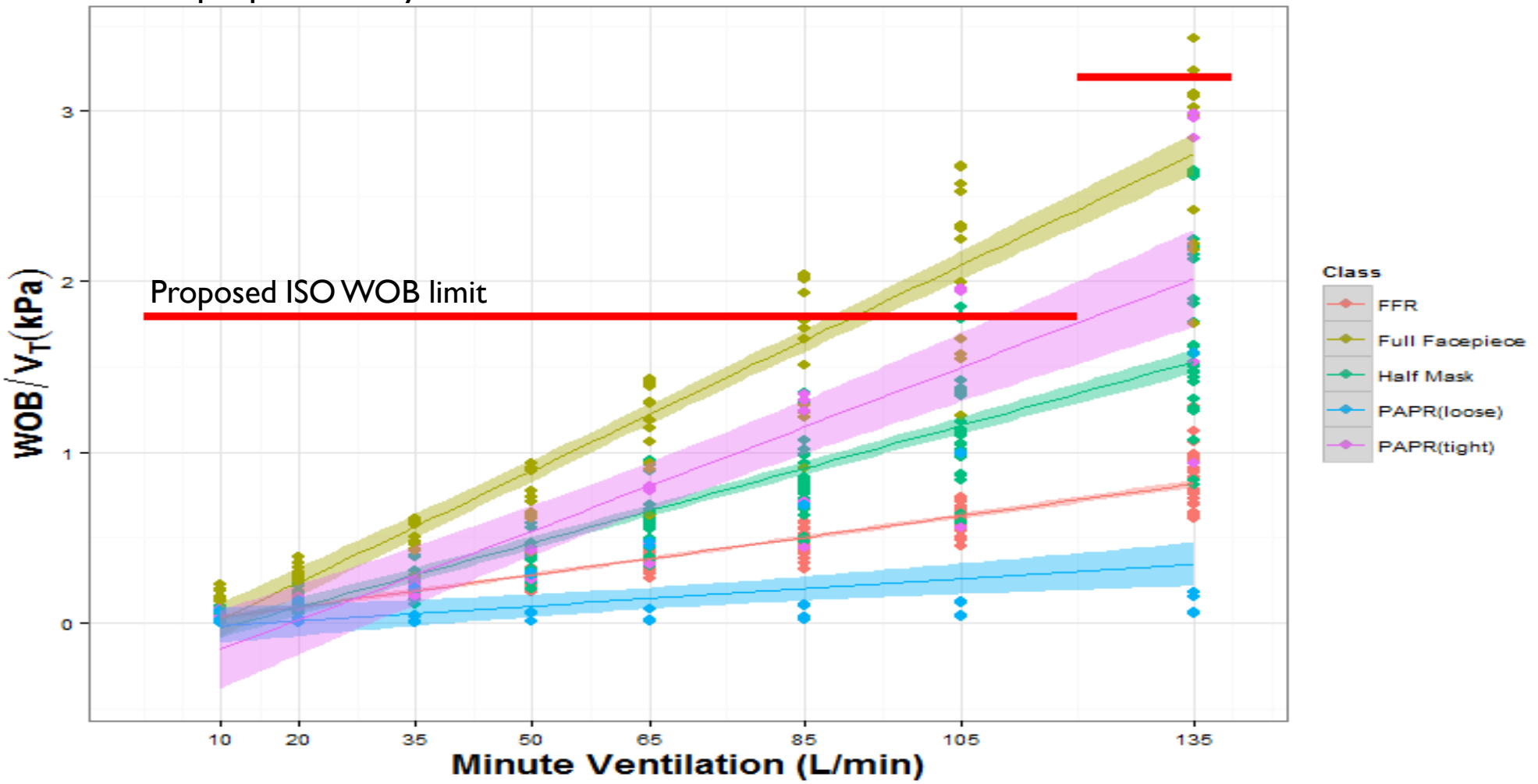


Example APR Results: Full-Facepieces with CBRN

Respirator	ISO WOB 35 LPM							NIOSH ΔP at 85 LPM	
	WoB total	WoB in	WoB ex	max P ex	min P in	elastance	tidal vol.	Inhalation	Exhalation
A	0.460	0.403	0.056	0.102	-0.519	-0.110	1.485	0.40	0.05
B	0.587	0.438	0.149	0.194	-0.579	-0.254	1.478	0.43	0.14
C	0.269	0.219	0.050	0.098	-0.302	-0.105	1.483	0.34	0.04
D	0.501	0.415	0.086	0.118	-0.556	-0.139	1.484	0.43	0.08
E	0.606	0.503	0.103	0.210	-0.669	-0.245	1.482	0.46	0.13
F	0.466	0.350	0.117	0.163	-0.459	-0.215	1.449	0.46	0.13
G	0.600	0.470	0.130	0.168	-0.612	-0.208	1.480	0.46	0.11

Total WOB versus Minute Volume for APR

General smooth proportionality with work rate



Comparison of results

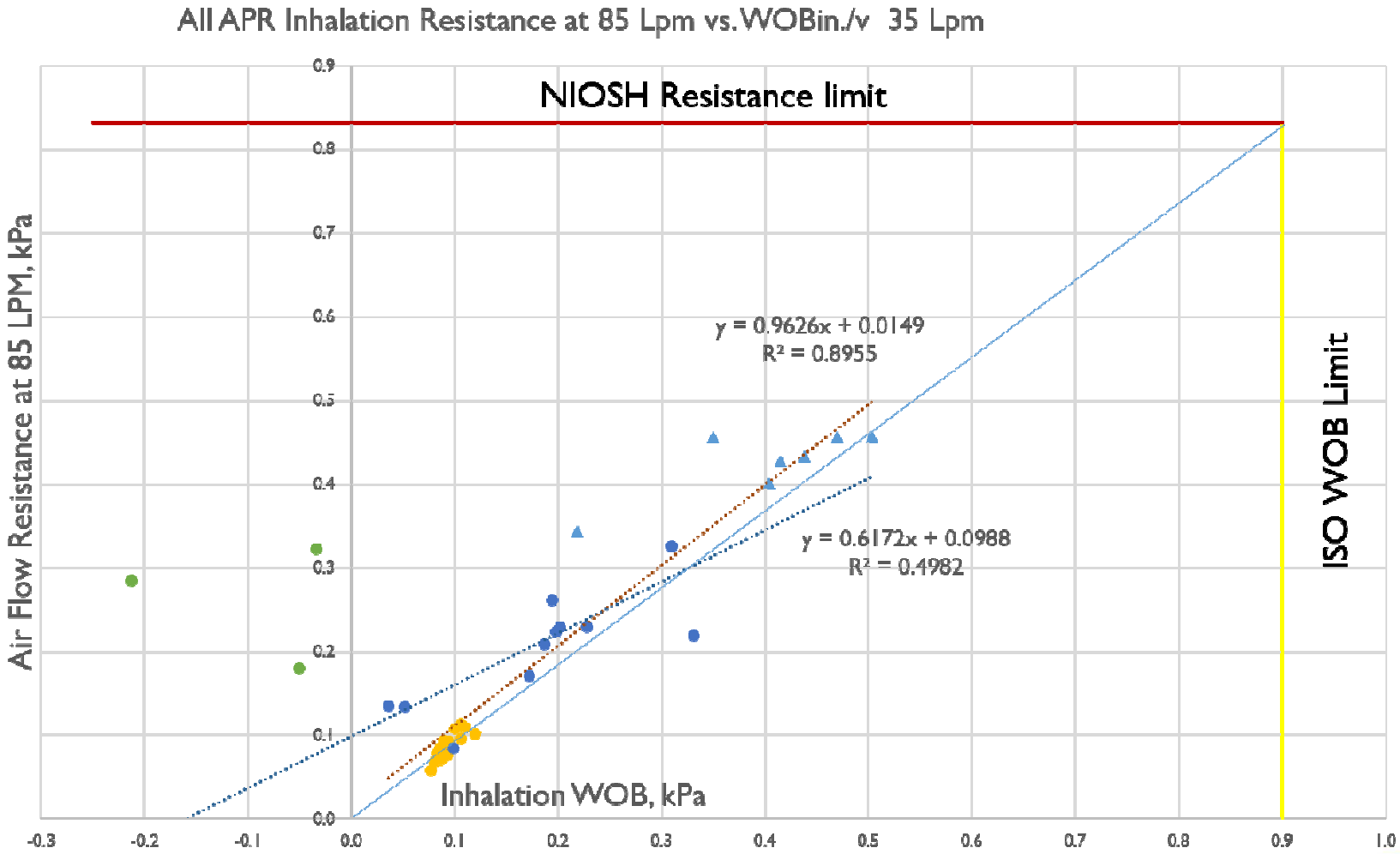
Regression of NIOSH resistance (Inhalation, Exhalation or Total) versus WOB parameters

All R-squared are above 0.50, those above 0.65 are highlighted.

Parameter		MV	All APR (n = 38)			w/o PAPR (n = 35)		
ISO WOB (Abscissa)	NIOSH (Ordinate)		M	b	R-squared	M	b	R-squared
WOBin	inhalation resistance	35	0.6172	0.0988	0.4982	0.9675	0.0149	0.8955
		65	0.3675	0.0573	0.733	0.4252	0.0197	0.9127
WOBex	exhalation resistance	35	0.5253	0.0364	0.7074	0.9826	-0.0002	0.7624
		65	0.4222	0.0073	0.7698	0.4198	0.0085	0.6982
WOBT/v	total resistance	35	0.9025	0.0503	0.6854	0.9758	0.0128	0.887
		65	0.4101	0.0495	0.7541	0.433	0.0213	0.9244
Min. in. P	inhalation resistance	35	-0.5457	0.0756	0.5846	-0.7478	0.0062	0.9033
		65	-0.2685	0.0654	0.6105	-0.2947	0.0419	0.7065
Max. ex. P	exhalation resistance	35	0.4885	0.0189	0.7123	0.5509	0.012	0.5828
		65	0.3362	0.0024	0.6803	0.2776	0.0156	0.6185

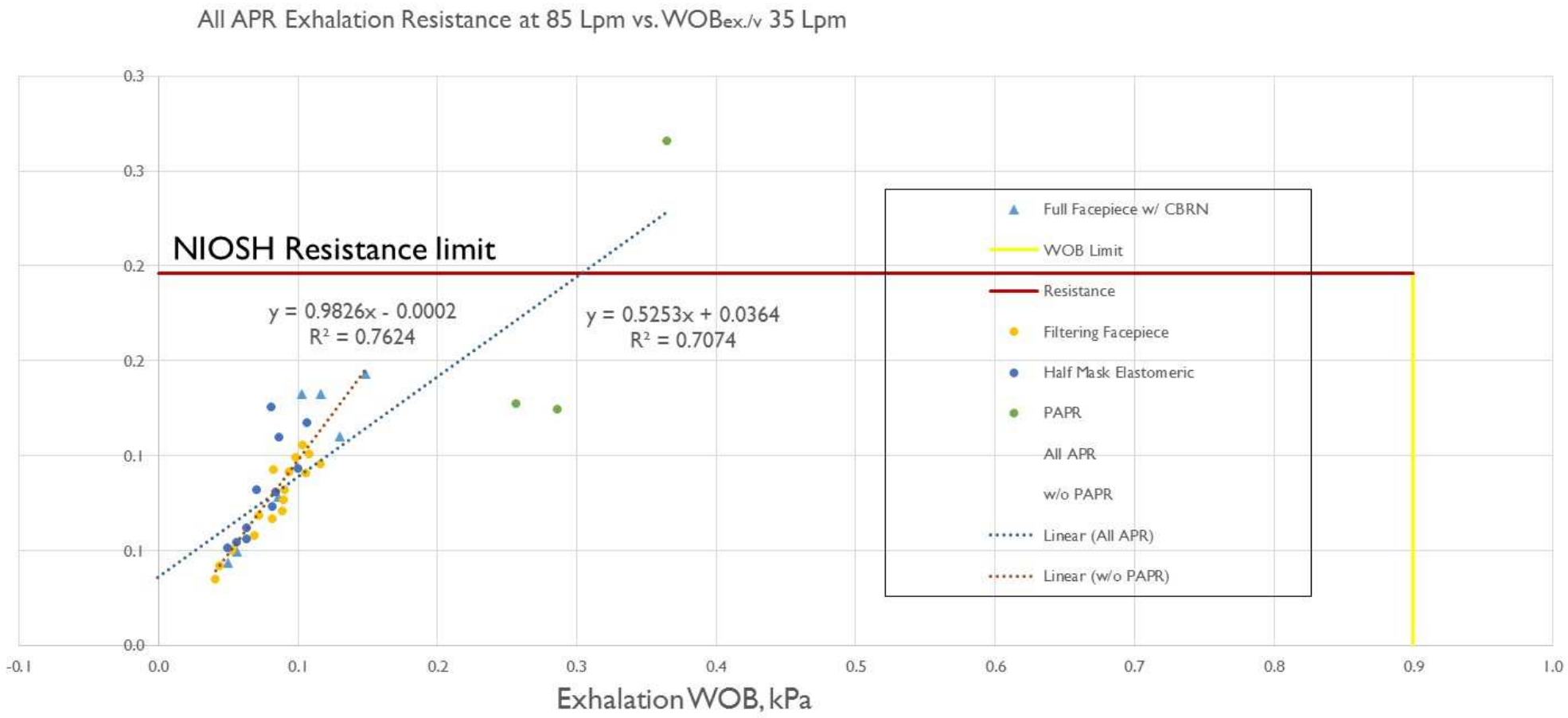
Resistance versus WOB for APR with limits

Comparing results versus limits for two methods



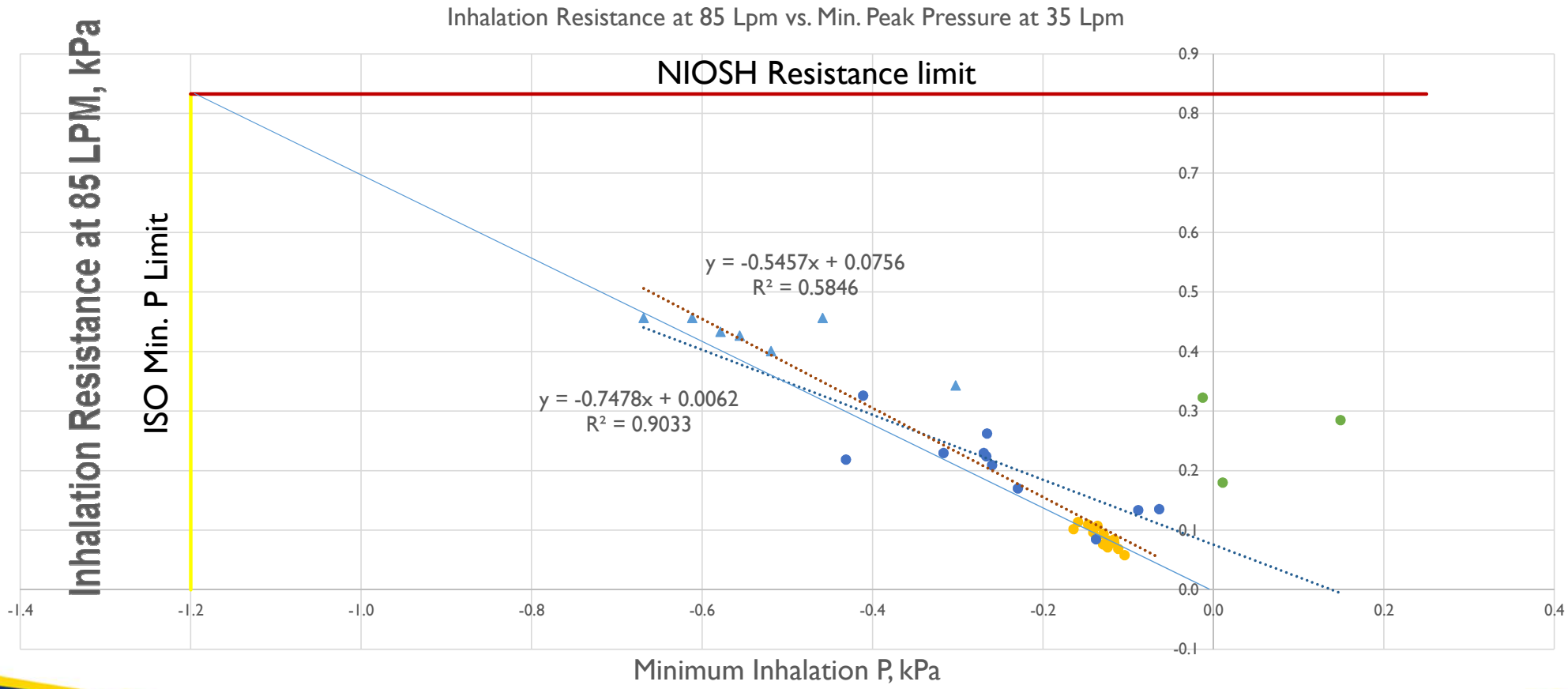
Resistance versus WOB for APR with limits

Compare result versus limit for two methods



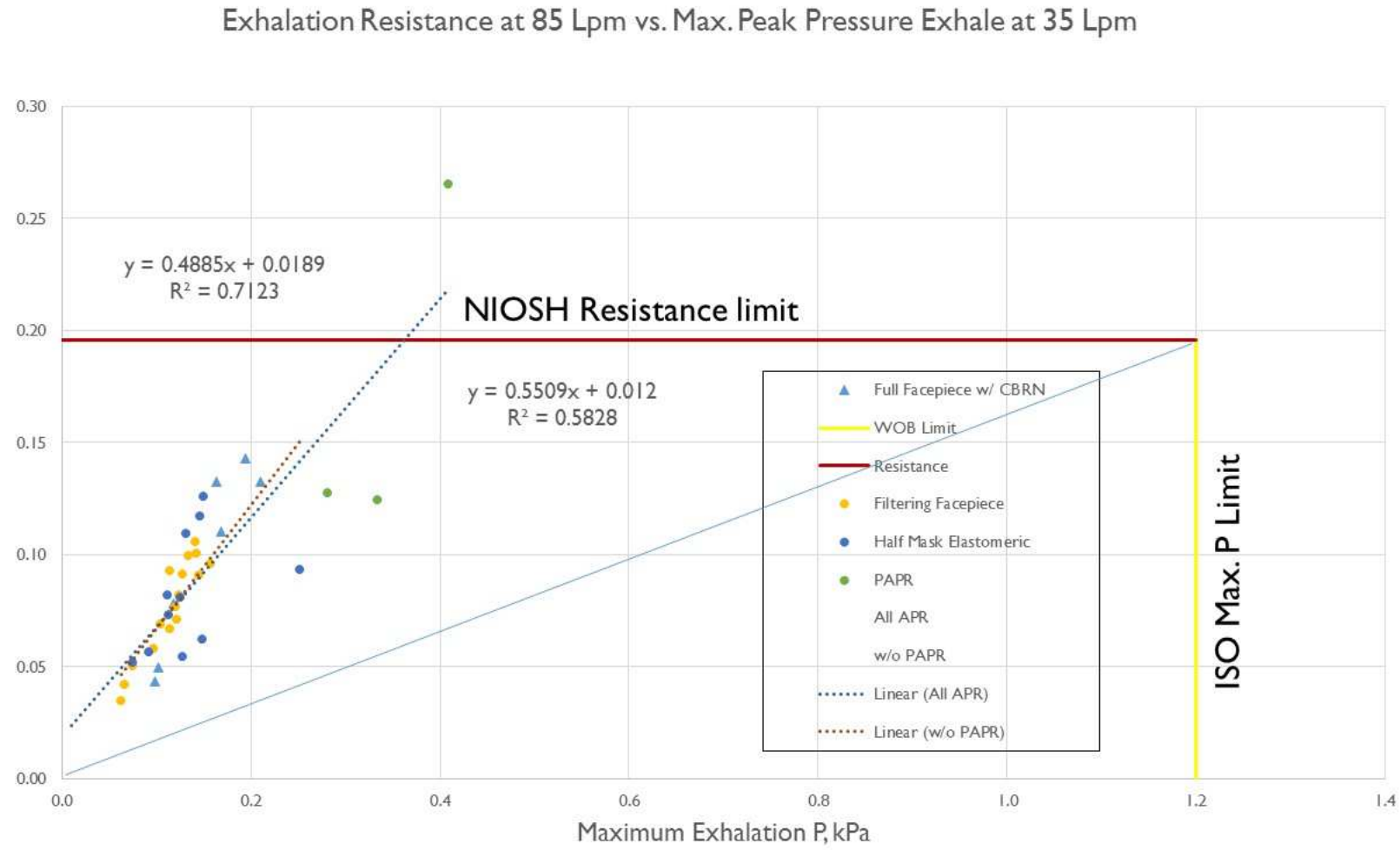
Resistance versus Peak P for APR with limits

Similar comparison



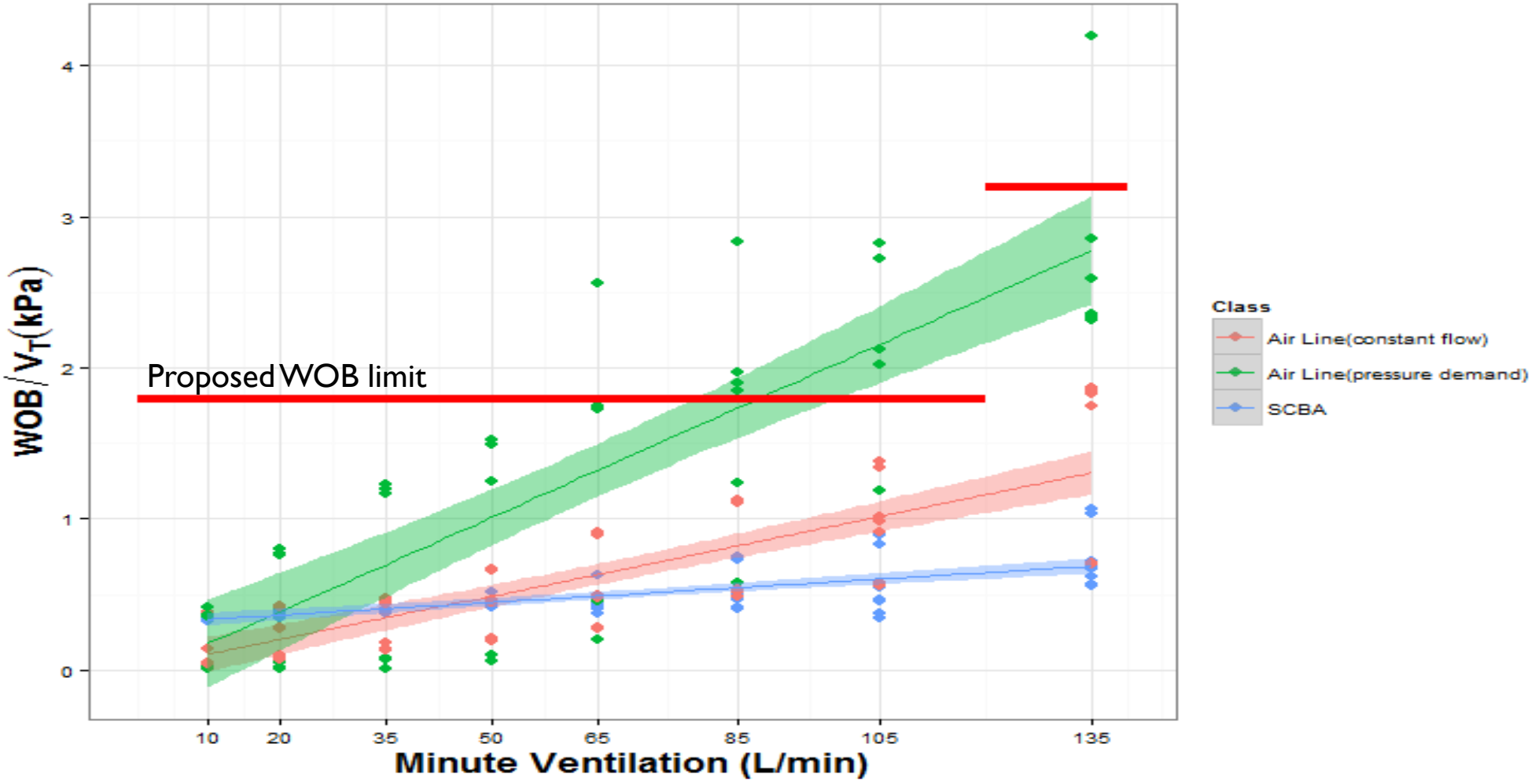
Resistance versus Peak P for APR with limits

Similar comparison



Total WOB versus Minute Volume for SAR

Fewer (nine) samples, Less proportionality with work rate



Conclusions

- WOB, peak pressures (and elastance) for all APR examined would likely meet the proposed ISO limits for ISO work rate 1 (35 lpm) and ISO work rate 2 (65 lpm)

- Likelihood of current APR results exceeding limits (e.g. Pass/Fail) are comparable for either method for inhalation. For exhalation, NIOSH resistance limits are more conservative than ISO WOB.

- For APR, Air-flow resistance at ± 85 LPM can be accurately predicted from WOB results and vice versa.

Remaining steps

- WOB for closed-circuit devices using ISO 16900-13
- Evaluate effect of headform size on WOB
- Related aspects:
  - inhalation and exhalation pressure (resistance) at 85 lpm,
  - maintenance of positive pressure
  - effect of flow (work rate)
  - valve behaviors (exhalation valve leakage and sticking)
  - Estimate of method uncertainty, U
- Publish method development experience, results and comparison of method(s)

Acknowledgements

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Photo courtesy of NPPTL

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Thank you

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