A Review of Self-Contained Self-Rescuer Research

Arthur T. Johnson, Ph.D.

Professor, Biological Resources Engineering Dept.

Self-Contained Self-Rescuer (SCSR)

- Provides oxygen for emergency escape
- Supposed to supply at least 60 minutes of oxygen

- **CSE SR-100**
  - Contains Potassium Superoxide (KO_2)
  - Chemical reaction that generates oxygen from moisture in exhaled breath (H_2O)

$$2KO_2 + H_2O \rightarrow 2KOH + 1.5O_2$$

  - Carbon Dioxide (CO_2) from exhaled breath reacts to form more water vapor, which reacts to form additional oxygen

$$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$$

- SCSR wearers are required to walk at a controlled pace so oxygen supply does not outpace the rate of oxygen use

- Enough oxygen is supplied to keep up with the rate of work **IF** **breathing air** is **proportional** to **oxygen demands**

- **What happens at high work rates?**
  - Breathing air is disproportionate to oxygen usage rate
  - Oxygen generating capacity is used up at a much faster rate
  - Extra oxygen is wasted to atmosphere

Two UMD Studies

1) How Far Can One Walk Wearing a Self-Contained Self-Rescuer?

- **Goal:** Determine the distance that can be walked when using SCSRs as intended
- **Discovered:**
  - Average Distance = 3.7 miles
  - Allows estimable distance to place additional SCSRs on route

2) Using Self-Contained Self-Rescuers at High Work Rates

- **Goal:** Examine effect of exercise intensity on performance time while wearing CSE SR-100
- **Discovered:**
  - SCSRs used outside of recommended range incur severe penalties

How Far Can One Walk Wearing a Self-Contained Self-Rescuer?

60 minutes of oxygen = what distance?

Answer (average result):

6.0 km (3.7 miles)

- 14 volunteer subjects
- PAR-Q health assessment form
- Maximum oxygen uptake in range of average fitness levels (2.7-3.2 L/min)
- Treadmill walking, 0% Grade
- Speed determined by subjects (had to meet rate of oxygen supplied)
- Instructed to walk as long as possible

CSE
CORPORATION
TRAINING UNIT
TRAINING

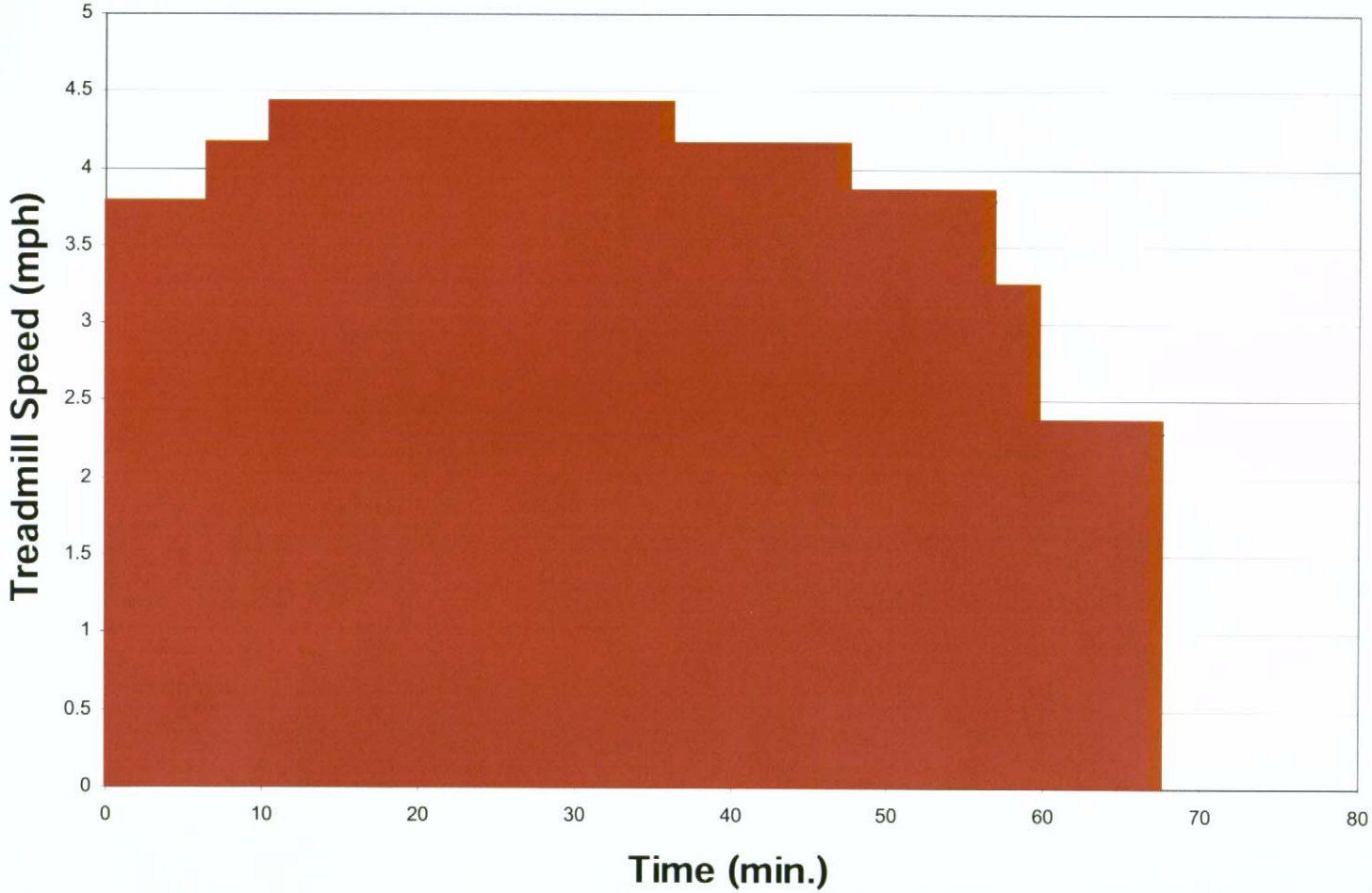
- **Results**
  - Distances
    - **Maximum** distance obtained = **9.2 km** (5.7 miles)
    - **Minimum** distance obtained = **2.1 km** (1.3 miles)
    - **Average** of **6.0 km** (3.7 miles)

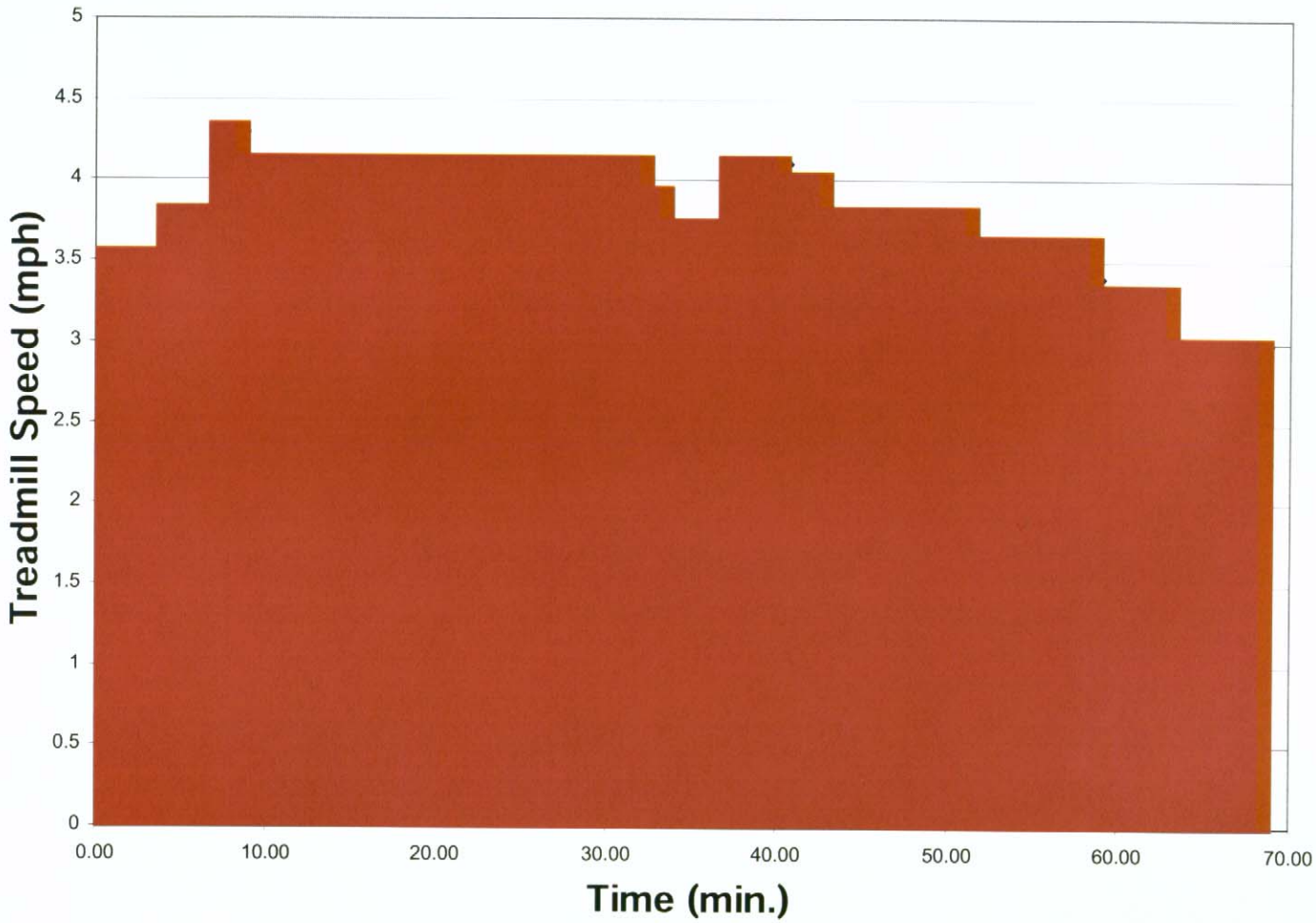
- **Results** ***(cont'd)***
  - Times
    - 30 minutes to 94 minutes
    - **Average** of **65 minutes**

Subject Performance Data

Subject	Time (min)	Distance (miles)	Termination Reason
1	57	2.9	insufficient air
145	59	3.5	none given
292	50	2.4	insufficient air
340	73	4.4	difficult to inhale
343	69	4.2	air too hot
358	67	4.3	air too hot
401	46	3	none given
402	75	4.2	none given
404	71	4.7	none given
406	30	1.3	insufficient air
409	69	3.7	difficult breathing
410	81	3.4	air too hot
411	90	5.6	difficult breathing
412	94	5.1	insufficient air
Avg.	65	3.7	

- **Results** ***(cont'd)***
  - Speeds
    - Began at 1.3 m/sec (3.0 mph) and adjusted for each subject
    - Found no correlation between speed and distance walked


Treadmill Speed (mph)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80
Time (min.)


Treadmill Speed (mph)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Time (min.)

- **Subject Complaints (SR-100)**
  - Unit gets very hot
  - Inhaled air uncomfortably warm
  - Inhaled fine, gritty material
  - High resistance toward end
  - Difficulty keeping nose clip on
  - Mouthpiece uncomfortable

- **Conclusion**
  - Additional SCSRs should be stationed at locations along route
  - Extra SCSRs should be available to carry from the beginning of the escape

- **Conclusion** ***(cont'd)***
  - Training is very important
    - Potential wearers should know about device limitations
    - Potential wearers should practice with the units
      - Become familiar with SCSR and aware of complaints listed
      - Additional practice would increase performance times and distance

Using Self-Contained Self-Rescuers at High Work Rates

With controlled pace walking, oxygen should be available for 60 minutes.

What happens…

High Speeds = X minutes Oxygen??

- One volunteer subject, $\dot{V}O_2 \max = 3.0 L/\min$
- Treadmill walking, 0% Grade
- Five testing sessions, each at varied intensities
  - 65, 70, 75, 80, and 85% $\dot{V}O_2 \max$
- Instructed to exercise until fatigue or until equipment limitations were reached

- **Results**
  - Performance times **decrease linearly** as oxygen consumption increased
  - No performance time reached 60 minutes
  - All work rates were **too high** for SCSR
  - Cause of exercise termination reported to be lack of supply from SCSR

Experimental Data

% VO2 Max	Performance Time (min)	Minute Volume (L/min)
65%	45.7	50
70%	40.5	56
75%	28.4	62
80%	10.4	68
85%	6.5	75

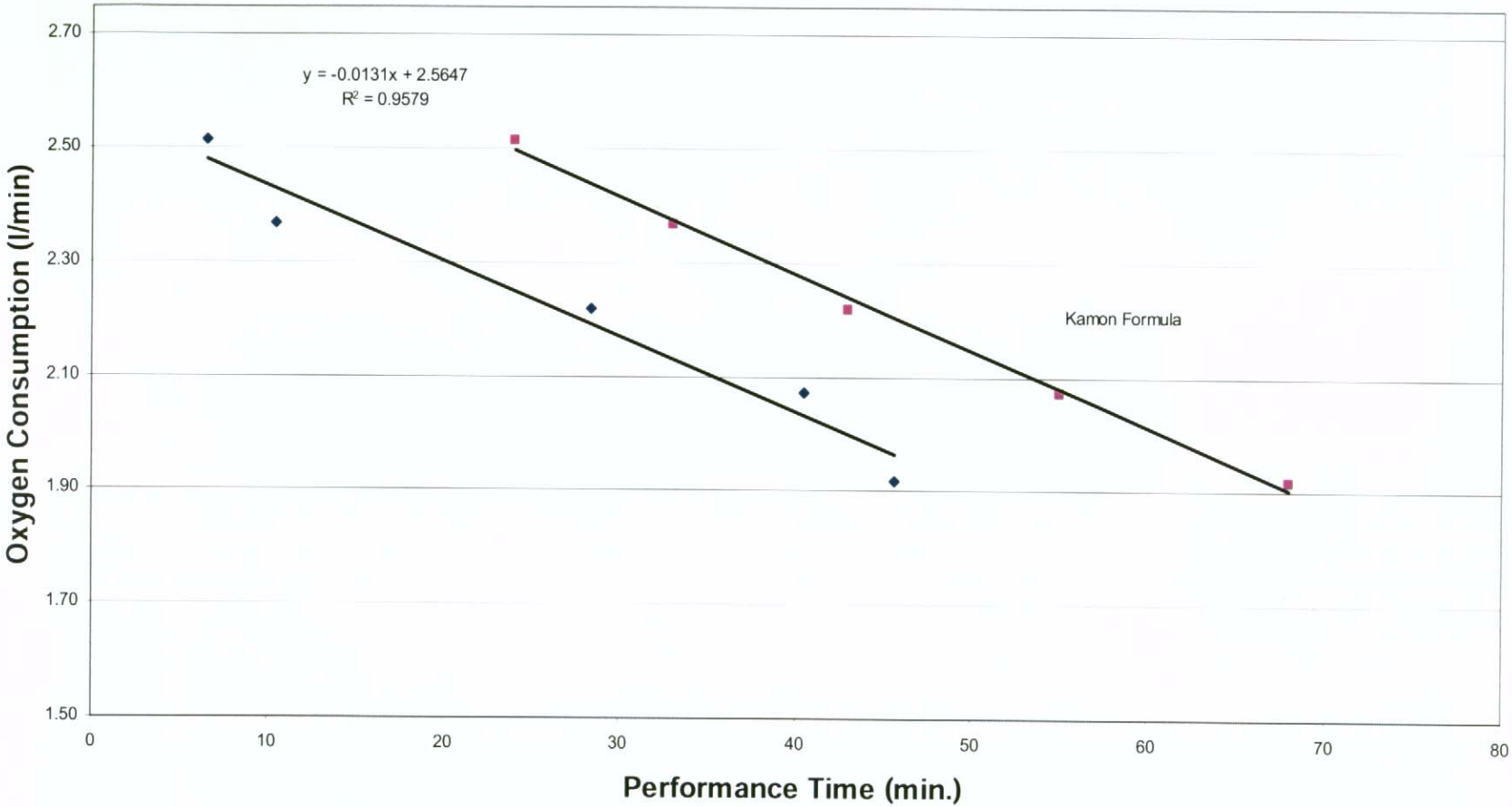
Experimental Data

% VO2 Max	RPE		BACS	
	6 min	term	6 min	term
65%	13	20	5	2
70%	12	19	5	0
75%	15	20	3	0
80%	15	19	2	0
85%	19	20	1	1

- **Calculated Data**
  - **Performance time** (Kamon Formula)

$$t_{\text{perf}} = 120\left(\frac{\dot{V}O_2\,\max}{\dot{V}O_2}\right) - 117$$

  - **Time penalty** = $t_{\text{penalty}} = t_{\text{perf}_{\text{calc}}} - t_{\text{perf}_{\text{meas}}}$
  - **Distance walked** = $(t_{\text{perf}_{\text{meas}}})(\text{treadmill speed})$
  - **Oxygen used** = $(\text{oxygen consumption})(t_{\text{perf}_{\text{meas}}})$


y = -0.0131x + 2.5647
R² = 0.9579
Kamon Formula
Oxygen Consumption (l/min)
2.70
2.50
2.30
2.10
1.90
1.70
1.50
0
10
20
30
40
50
60
70
80
Performance Time (min.)

- **Discussion**
  - **Emergency situation = panic = increased work rates**
  - **Penalty** for increased work rate:
    - SCSR much more uncomfortable
    - Effort more difficult
    - Much lower amount of accessible oxygen
    - Much shorter performance time
  - **Therefore**: **Use SCSR at low rates of work** (oxygen used is matched by oxygen generation)

- **Conclusion**
  - Inverse relationship exists between performance time and exercise intensity
  - Confirmed SCSR must be used as intended
  - Penalty can be expected if SCSR is used outside its range

Overall Conclusion

- In emergency situation, **DON'T PANIC!!!**
- Use SCSR as intended → at **LOW** work rates
- **TRAIN! TRAIN! TRAIN!** Become familiar and aware of SCSR limitations
- Additional SCSRs should be stationed at locations along route

AND/OR

- Extra SCSRs should be available to carry from the beginning of the escape