OAK RIDGE
NATIONAL LABORATORY

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ORNL/TM-2000/308

Detector Characterization Report

Response Related to Linear Movement and Radiation Levels for an Oak Ridge National Laboratory (ORNL)-Developed Ion Chamber and a Commercial Ion Chamber

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DETECTOR CHARACTERIZATION REPORT

RESPONSE RELATED TO LINEAR MOVEMENT AND RADIATION LEVELS FOR AN OAK RIDGE NATIONAL LABORATORY (ORNL)-DEVELOPED ION CHAMBER AND A COMMERCIAL ION CHAMBER

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CONTENTS

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1. BACKGROUND

Recent activities regarding the safeguarding of radioactive material have indicated there is a need to use radiation sensors to monitor intentional or unintentional material movement. Existing radiation detection systems were not typically designed for this type of operation since most of their use accounted for monitoring material while the material is stationary.

To ensure that a radiation monitoring system is capable of detecting the movement of radioactive material, a series of tests were needed. These tests would need to be performed in known radiological conditions, under controlled environmental conditions, and at known movement speeds. The Radiation Effects Facility (REF), located at the Radiation Calibration Laboratory, provided the necessary capabilities to perform these tests.

This report provides a compilation of the results from a characterization of two different sensors—a simple, air ionization chamber-based sensor developed at ORNL that consists of an ion chamber connected to a separate amplifier, and an Eberline model RO-7-LD. The RO-7-LD is also an air ionization chamber-based sensor, but the electronics are in the same physical package.

2. CHARACTERIZATION PROTOCOL

The evaluation process consists of establishing a sensor's nominal response at different horizontal positions along a flat plane perpendicular to a radiation beam followed by its response to the radiation field as it moves horizontally through the field. Although theoretical results are possible, real data obtained from actual exposures is more reliable and can be used to validate theoretical estimations. Since moving the source was undesirable, the test system was configured to move the sensor.

The characterization consisted of a) establishing the nominal response to a known radiation field from ^{137}Cs at fixed locations, b) moving the sensor through the radiation field, and c) tracking the response results.

A total of 600 readings over a period of one minute were taken to obtain each stationary response. Readings were obtained at 0.5 second intervals for each moving test. Movement speeds were 10 cm and 20 cm per second. The measured radiation level as provided by staff personnel at the REF was 50 mR/hr and 502 mR/hr.

The protocol followed is as follows:

1. Position the sensor on the track assembly.

2. Move the sensor to the nominal position (centered both horizontally and vertically in the radiation beam.
3. Expose the sensor to a 50 mR/hr ^{137}Cs radiation field and record a series of readings.
4. Determine and record the mean response.
5. Reduce the radiation field and move the sensor to the far end of the linear positioning system (in this test the position was 160 cm from the center position). Record the position from beam center.
6. Activate the radiation field and record the sensor's mean response.
7. Move the sensor in 20-cm increments and record the sensor's position (relative to beam center) and mean response.
8. Repeat step 7 until reaching the same distance on the other side of the beam.
9. Reduce the radiation field and reposition the sensor to the initial starting point.
10. Set the sensor movement speed to 10 cm/sec.
11. Activate the radiation field and initiate movement recording the detector response at 0.5-second intervals (max).
12. Plot the data to compare results from steps 6 through 8 with those results from step 11.
13. Repeat steps 10 through 12 using a speed of 20 cm/sec.
14. Repeat steps 2 through 13 at 500 mR/hr.

3. CHARACTERIZATION RESULTS

The results indicated that each detector responded to the change of activity at the speeds used. In addition, each detector's response approached 100% of the measured field value obtained from stationary measurements.

The ORNL sensor had a much lower relative response to radiation when compared to the RO-7-LD sensor. This was expected due to the design of the ORNL system. In addition, the ORNL sensor had a much greater contribution from "noise" as can be seen from the attached charts. This is much more apparent at the lower dose rate. Substantial increases in measured radiation levels can be seen from both sensors when exposed to the 502-mr/hr field. Additional evaluation of the response data will be required to determine maximum permissible movement speeds based on measured radiation levels. This should be done on a system as opposed to the component (the sensor), which was used for this evaluation.

4. DESCRIPTIONS OF ATTACHED CHARTS

Appendix 1A – ORNL sensor response as it moves through a 50-mR/hr field at 10 cm/second. Each measurement obtained from the stationary position is indicated on the chart. A direct comparison to the RO-7-LD is available in Appendix 1C. The measured response from the center position (mean response from +5 to –5 cm range) was 96% of the response obtained when the sensor was stationary.

Appendix 1B – RO-7-LD response as it moves through a 50-mR/hr field at 10 cm/second. The stationary measurement readings are identified on the chart. A direct comparison to the ORNL sensor is contained in Appendix 1C. The measured response from the center position (mean response from +5 to –5 cm range) was 100% of the response obtained when the sensor was stationary.

Appendix 1C – This chart displays the response comparison between the two sensors.

Appendix 2A – ORNL sensor response as it moves through a 50-mR/hr field at 20 cm/second. Each measurement obtained from the stationary position is indicated on the chart. A direct comparison to the RO-7-LD is available in Appendix 2C. It can be seen that the response is skewed due to the movement speed and response time. The measured response from the center position (mean response from +5 to –5 cm range) was 108% of the response obtained when the sensor was stationary.

Appendix 2B – RO-7-LD response as it moves through a 50-mR/hr field at 20 cm/second. The stationary measurement readings are identified on the chart. A direct comparison to the ORNL sensor is contained in Appendix 2C. As with the ORNL sensor, the response is skewed due to the movement speed and the response time of the sensor. The measured response from the center position (mean response from +5 to –5 cm range) was 93% of the response obtained when the sensor was stationary.

Appendix 2C – This chart displays the response comparison between the two sensors.

Appendix 3A - ORNL sensor response as it moves through a 502-mR/hr field at 10 cm/second. Each measurement obtained from the stationary position is indicated on the chart. A direct comparison to the RO-7-LD is available in Appendix 3C. The measured response from the center position (mean response from +5 to –5 cm range) was 98% of the response obtained when the sensor was stationary.

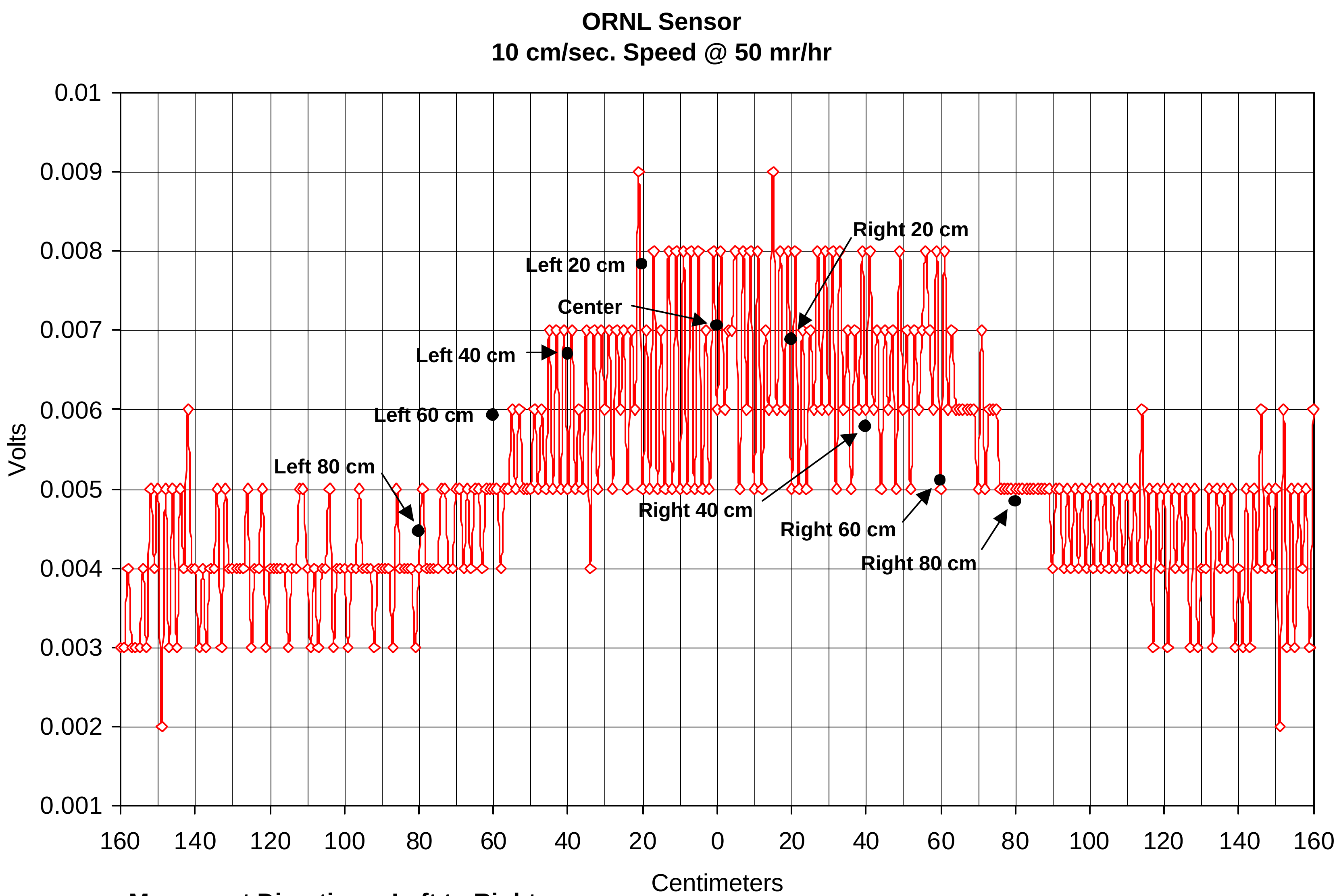
Appendix 3B – RO-7-LD response as it moves through a 502-mR/hr field at 10 cm/second. The stationary measurement readings are identified on the chart. A direct comparison to the ORNL sensor is contained in Appendix 3C. The measured response from the center position (mean response from +5 to –5 cm range) was 101% of the response obtained when the sensor was stationary.

Appendix 3C – This chart displays the response comparison between the two sensors.

Appendix 4A - ORNL sensor response as it moves through a 502-mR/hr field at 20 cm/second. Each measurement obtained from the stationary position is indicated on the chart. A direct comparison to the RO-7-LD is available in Appendix 4C. The measured response from the center position (mean response from +5 to –5 cm range) was 87% of the response obtained when the sensor was stationary.

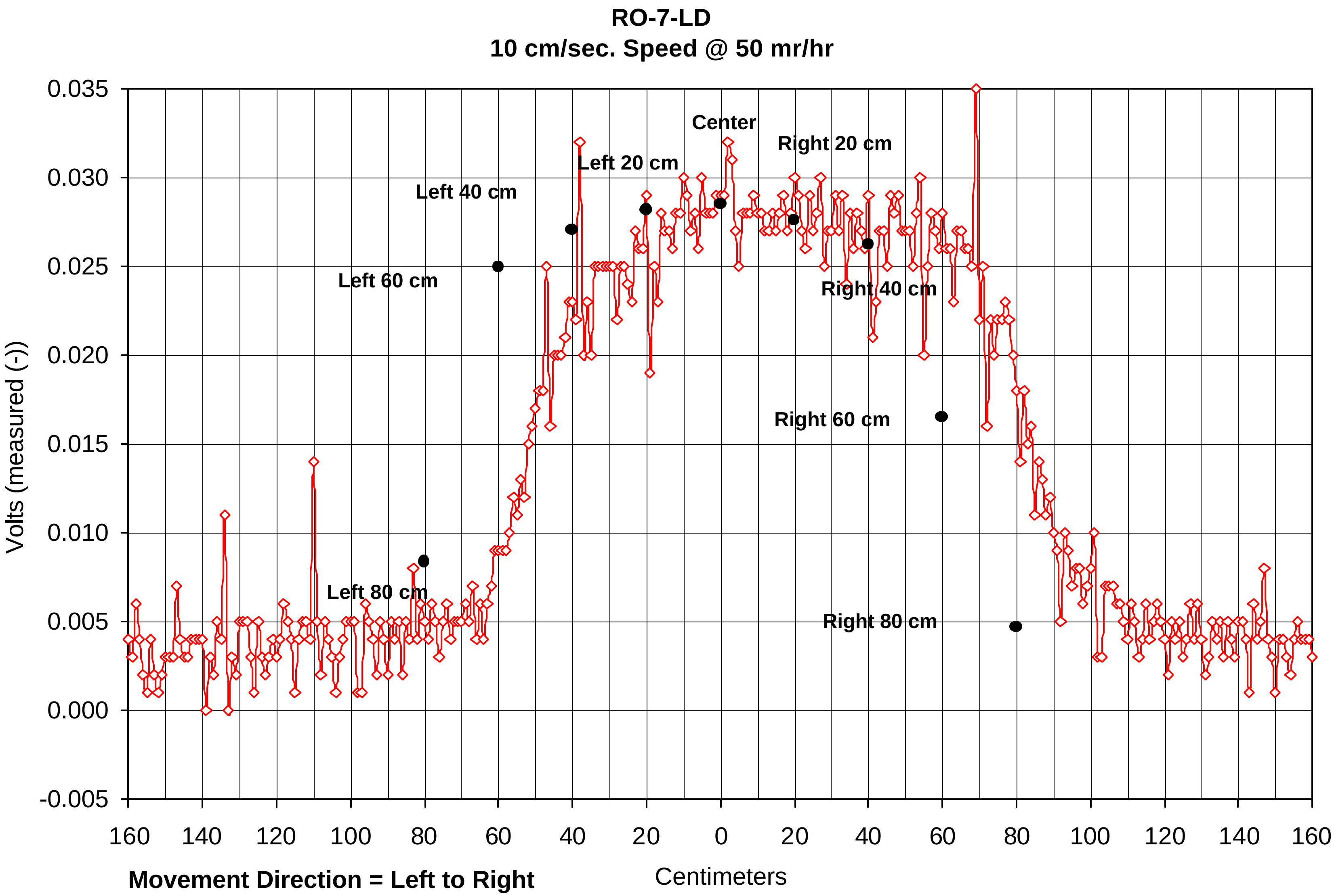
Appendix 4B – RO-7-LD response as it moves through a 502-mR/hr field at 20 cm/second. The stationary measurement readings are identified on the chart. A direct comparison to the ORNL sensor is contained in Appendix 4C. The measured response from the center position (mean response from +5 to –5 cm range) was 97% of the response obtained when the sensor was stationary.

Appendix 4C – This chart displays the response comparison between the two sensors.

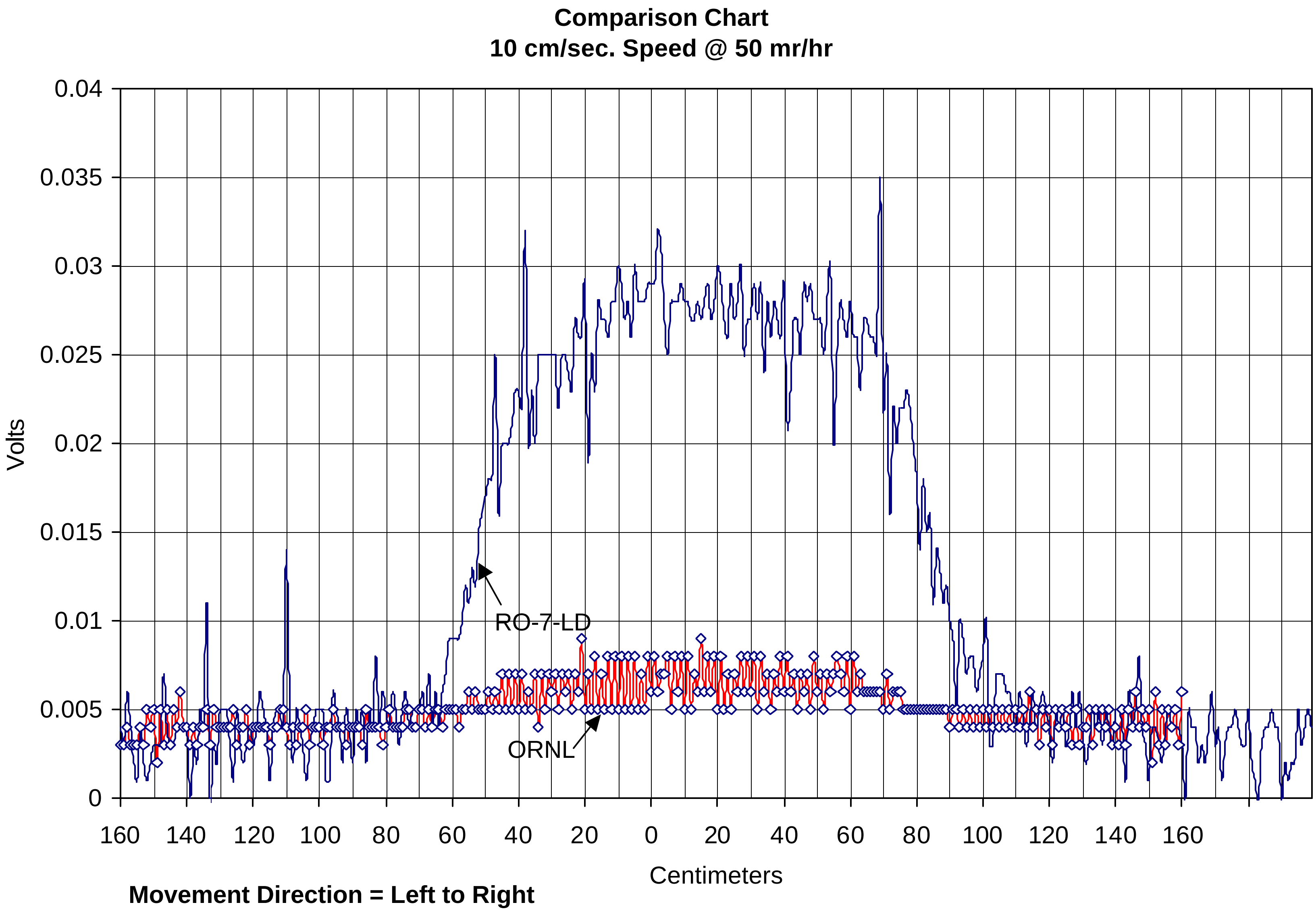


Movement Direction = Left to Right

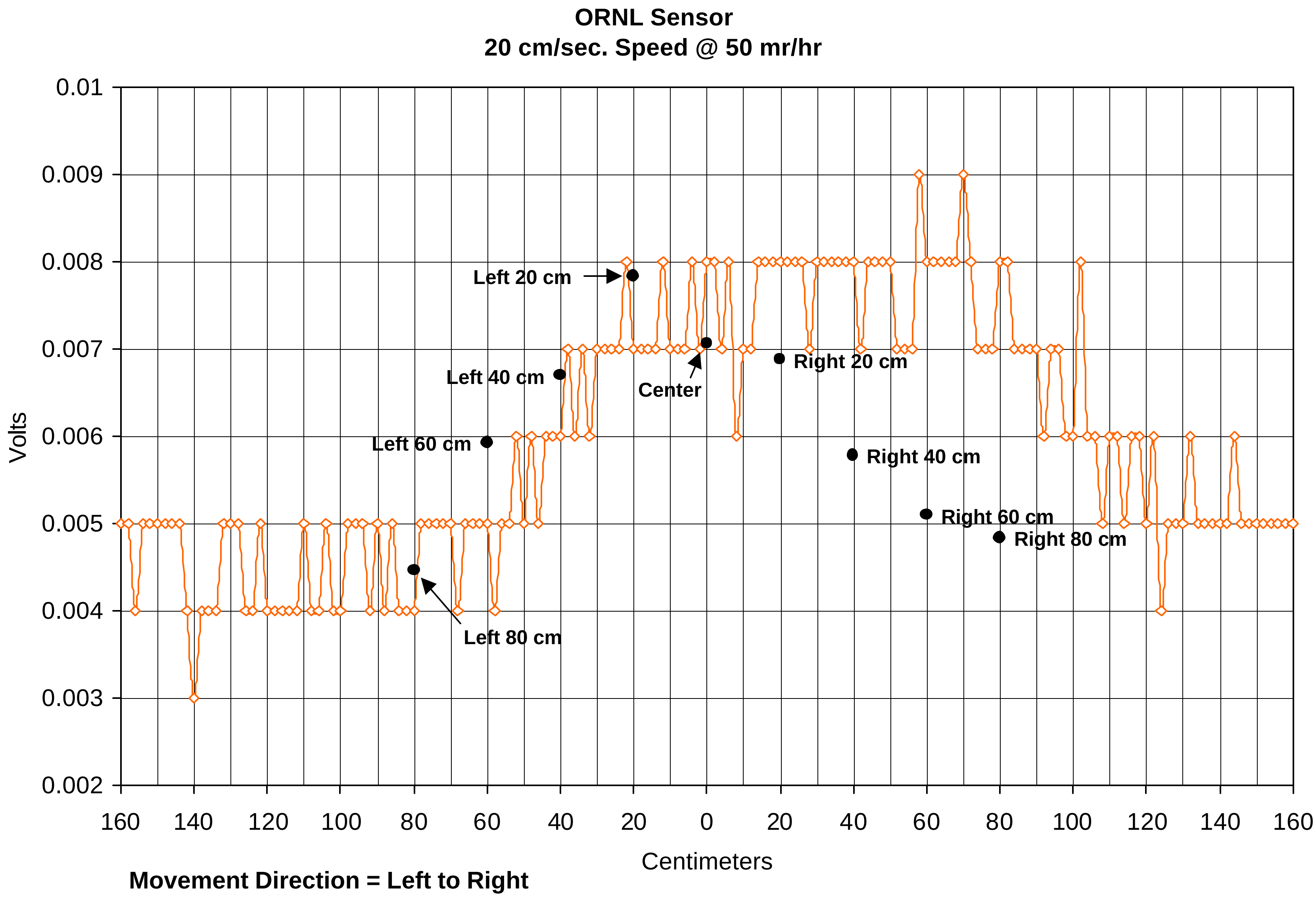
APPENDIX 1A


RO-7-LD
10 cm/sec. Speed @ 50 mr/hr
Volts (measured (-))
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
Center
Right 20 cm
Left 20 cm
Left 40 cm
Left 60 cm
Right 40 cm
Right 60 cm
Left 80 cm
Right 80 cm
160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160
Movement Direction = Left to Right
Centimeters

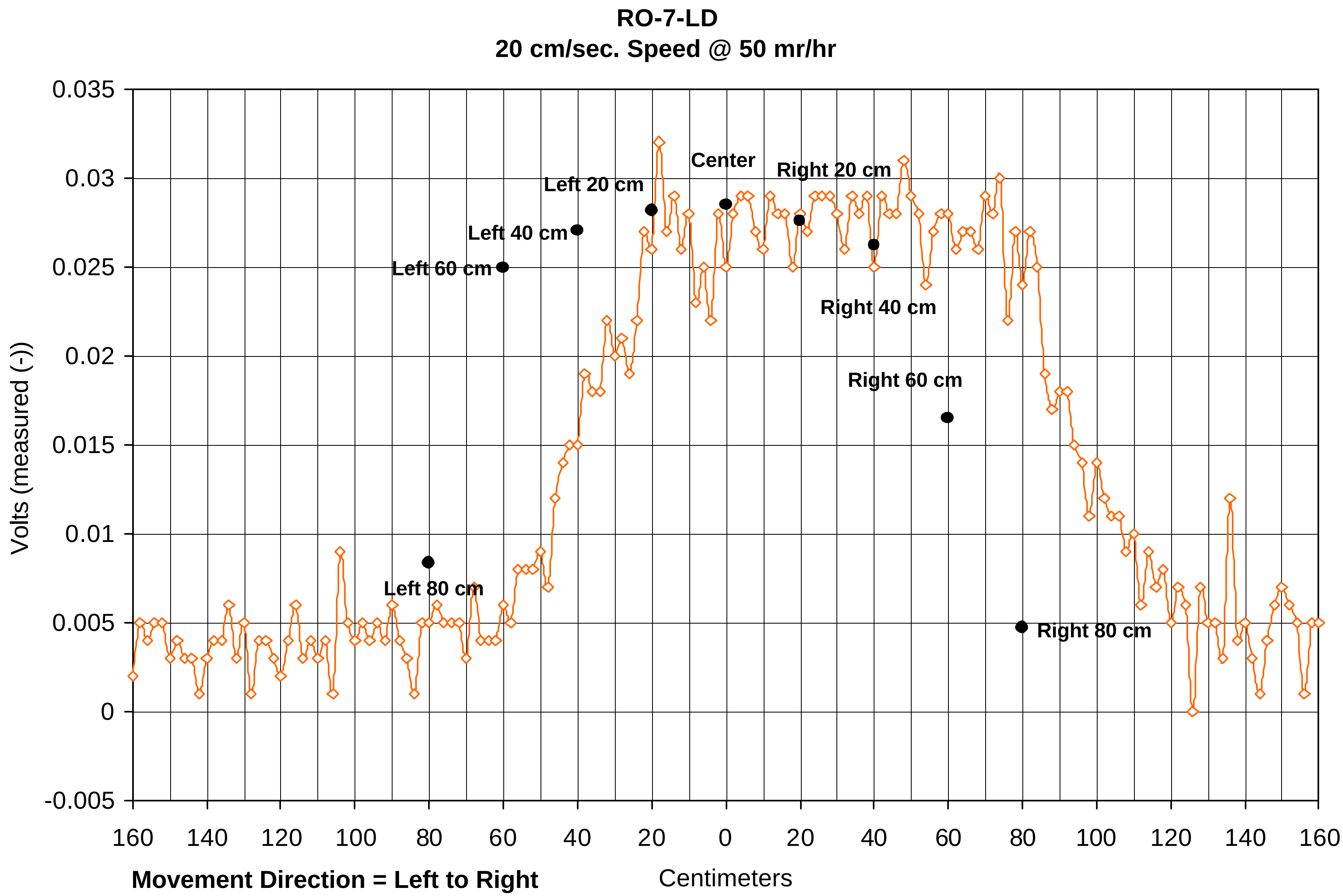
APPENDIX 1B


Comparison Chart
10 cm/sec. Speed @ 50 mr/hr
Volts
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
RO-7-LD
ORNL
160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160
Centimeters
Movement Direction = Left to Right

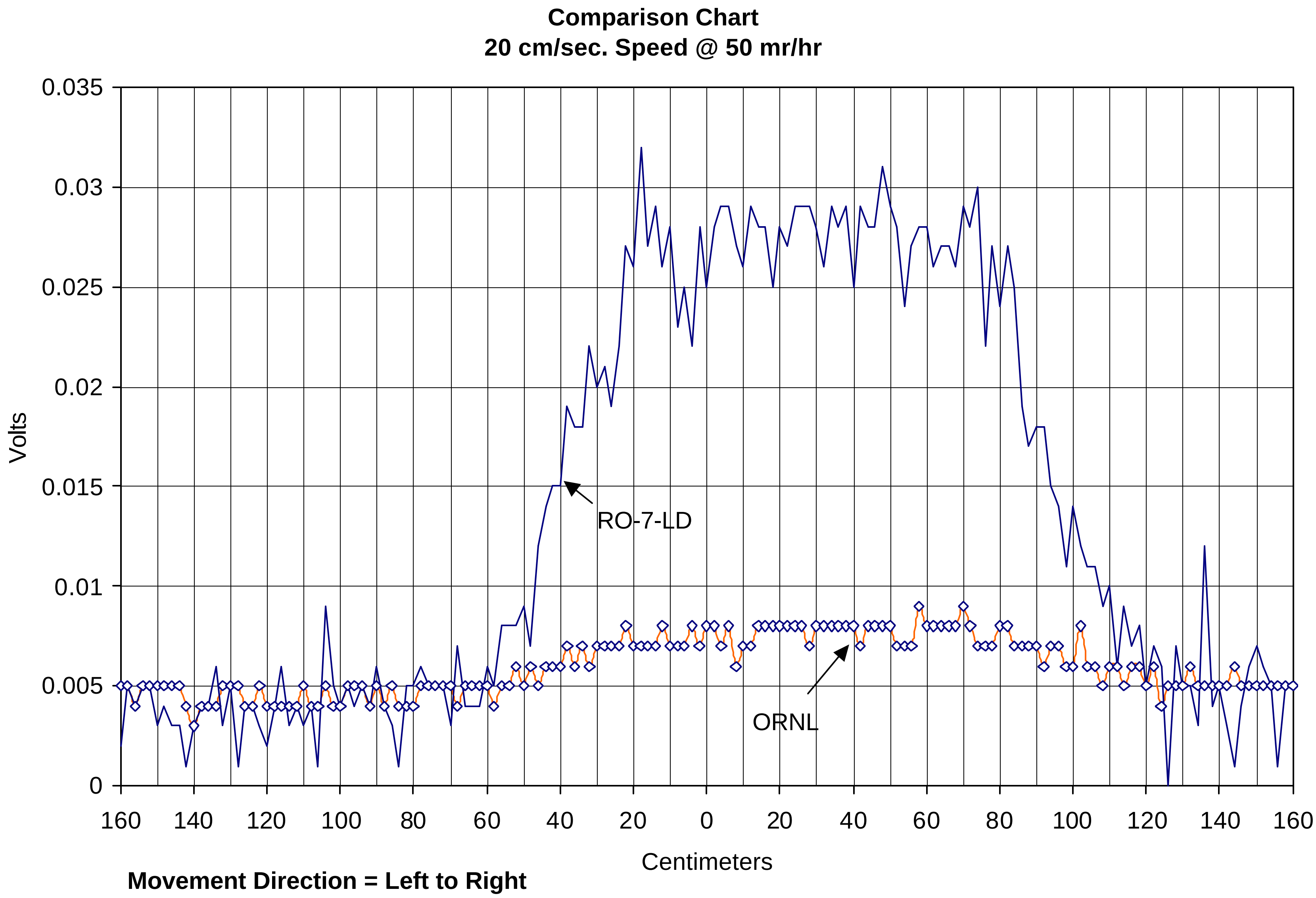
APPENDIX 1C


ORNL Sensor
20 cm/sec. Speed @ 50 mr/hr
Volts
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
Left 20 cm
Left 40 cm
Left 60 cm
Left 80 cm
Center
Right 20 cm
Right 40 cm
Right 60 cm
Right 80 cm
160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160
Centimeters
Movement Direction = Left to Right

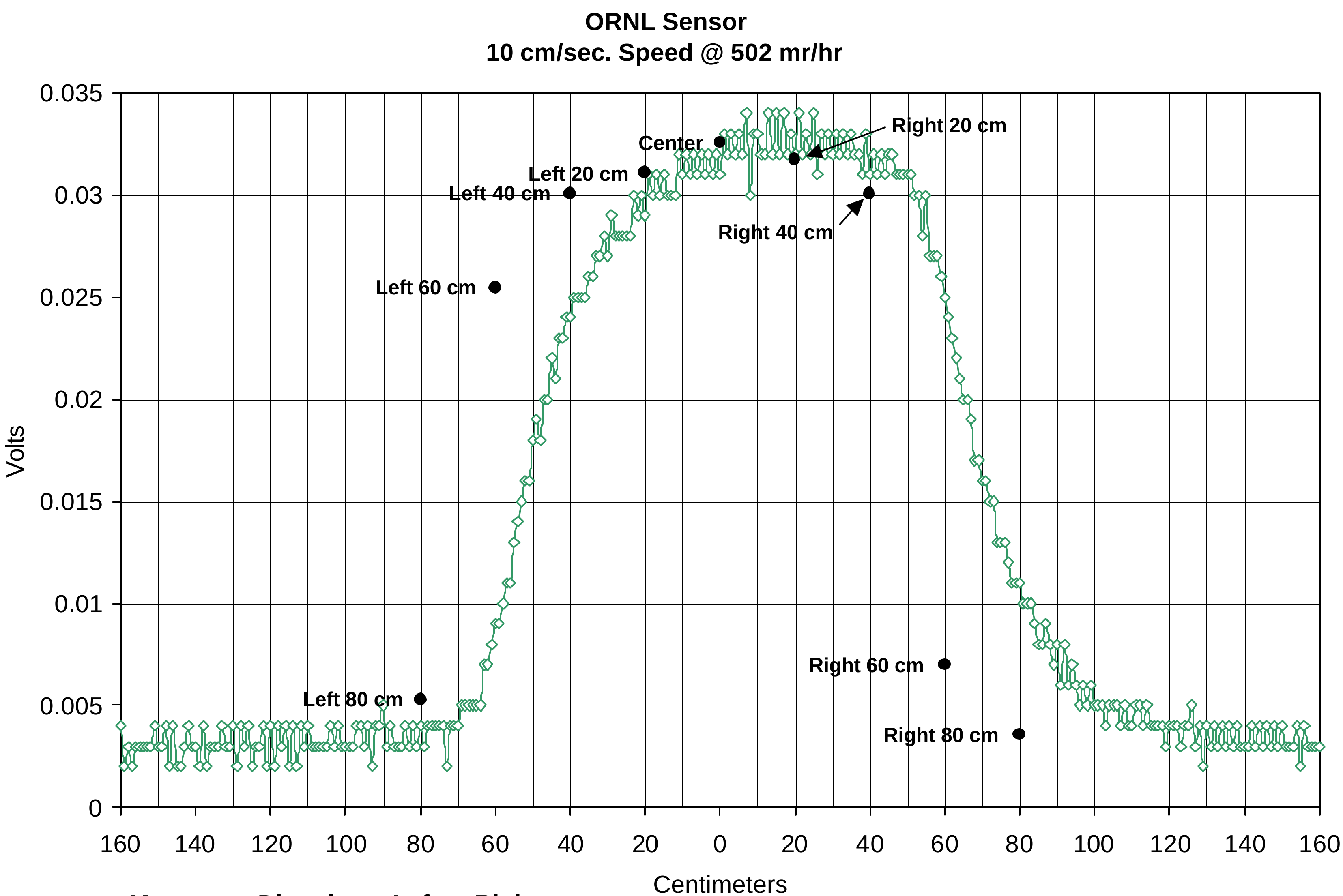
APPENDIX 2A


RO-7-LD
20 cm/sec. Speed @ 50 mr/hr
Volts (measured (-))
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
Center
Left 20 cm
Left 40 cm
Left 60 cm
Left 80 cm
Right 20 cm
Right 40 cm
Right 60 cm
Right 80 cm
160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160
Movement Direction = Left to Right
Centimeters

APPENDIX 2B

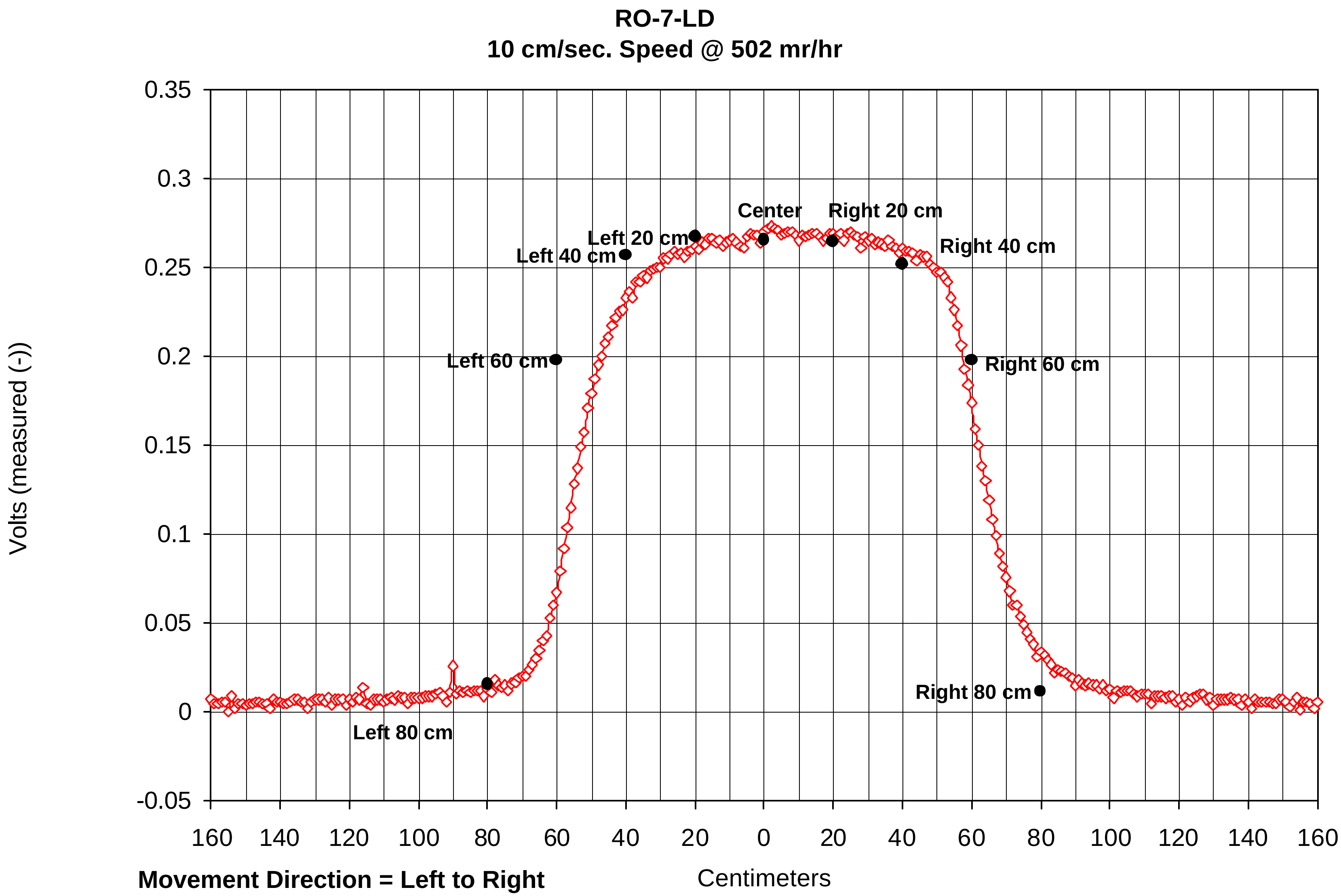

Comparison Chart
20 cm/sec. Speed @ 50 mr/hr
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Volts
RO-7-LD
ORNL
160
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
Centimeters
Movement Direction = Left to Right

APPENDIX 2C

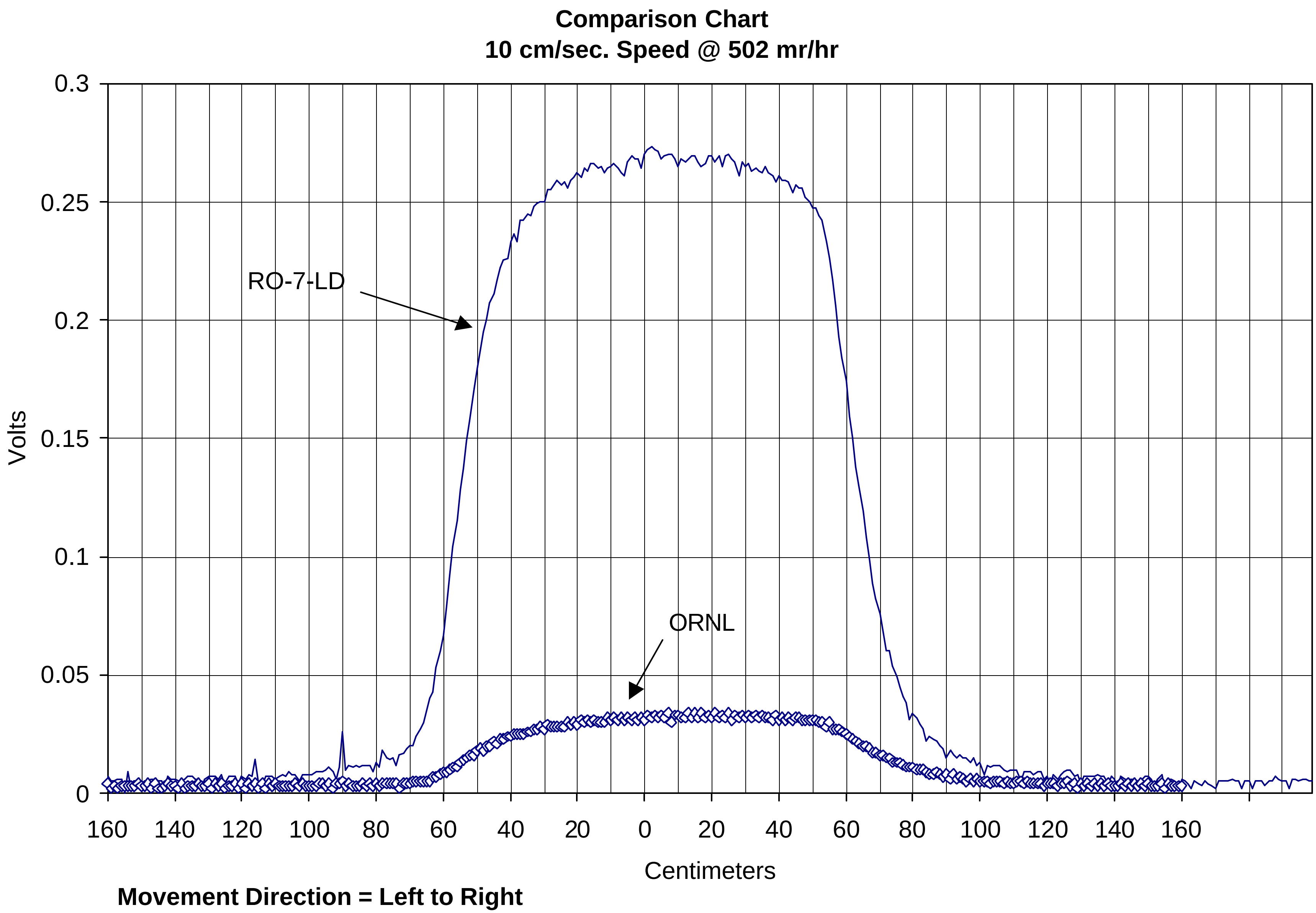


Movement Direction = Left to Right

APPENDIX 3A

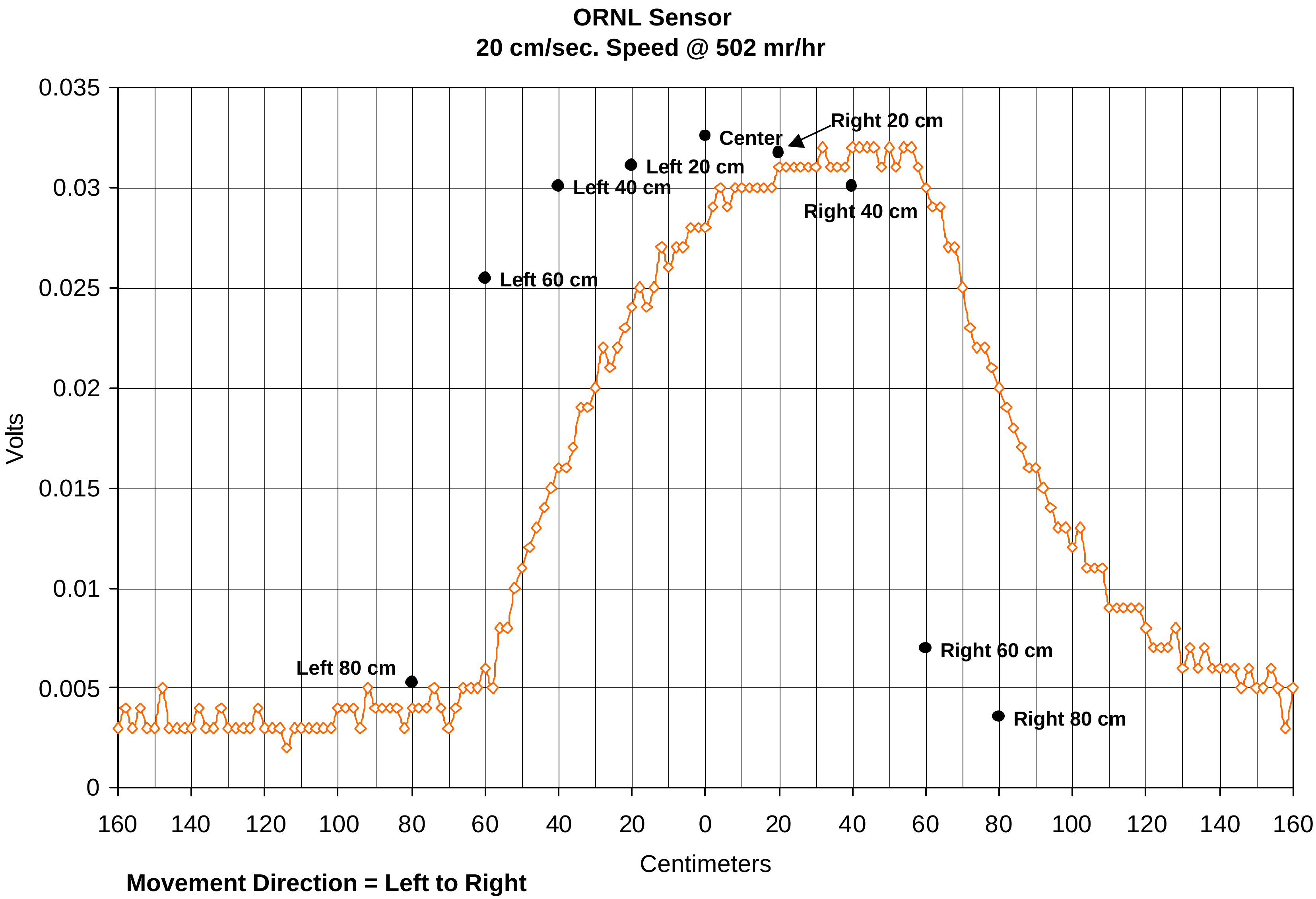

RO-7-LD
10 cm/sec. Speed @ 502 mr/hr
Volts (measured (-))
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
Center
Right 20 cm
Left 20 cm
Left 40 cm
Right 40 cm
Left 60 cm
Right 60 cm
Right 80 cm
Left 80 cm
160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160
Movement Direction = Left to Right
Centimeters

APPENDIX 3B

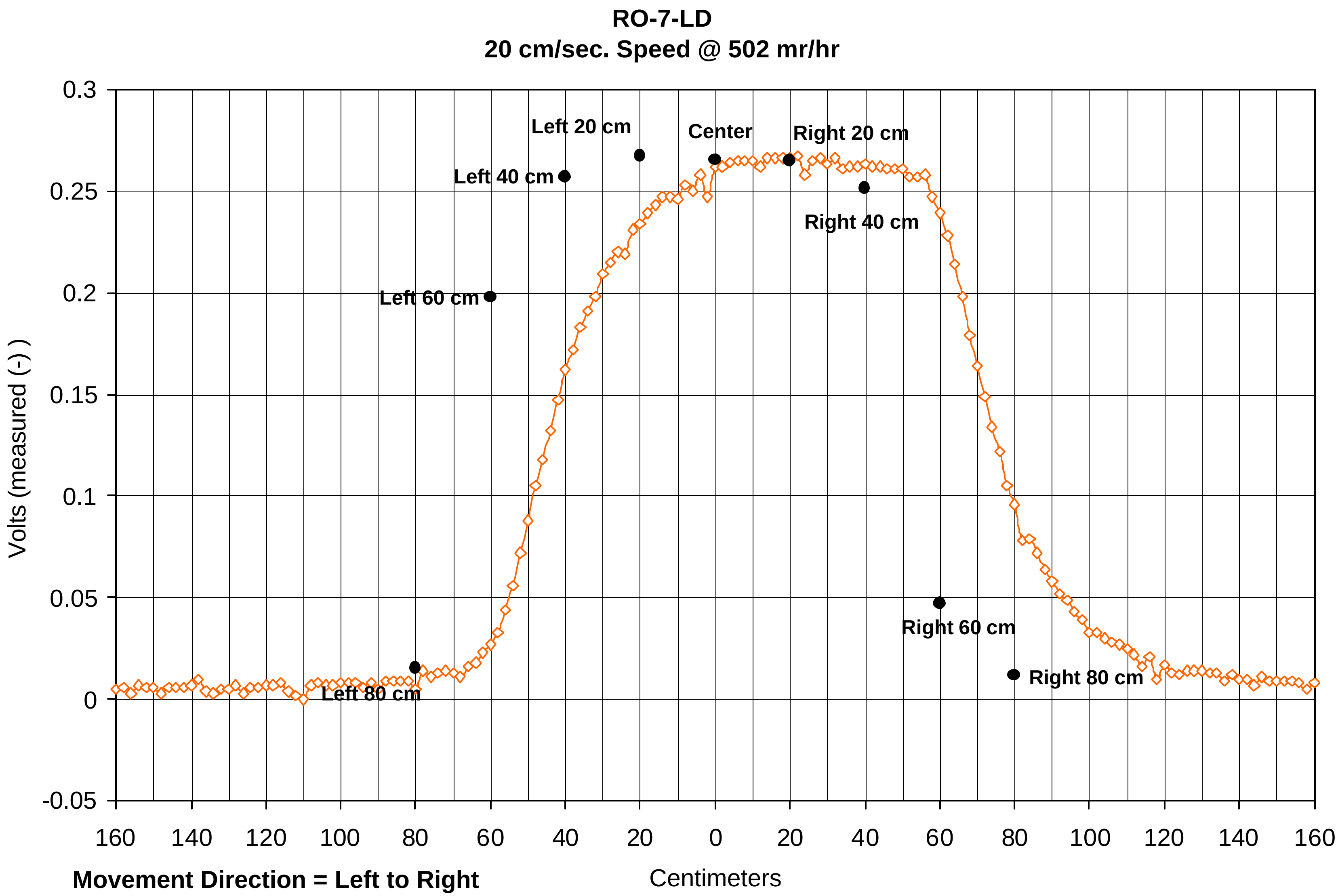


Comparison Chart
10 cm/sec. Speed @ 502 mr/hr
Volts
0.3
0.25
0.2
0.15
0.1
0.05
0
RO-7-LD
ORNL
160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160
Centimeters
Movement Direction = Left to Right

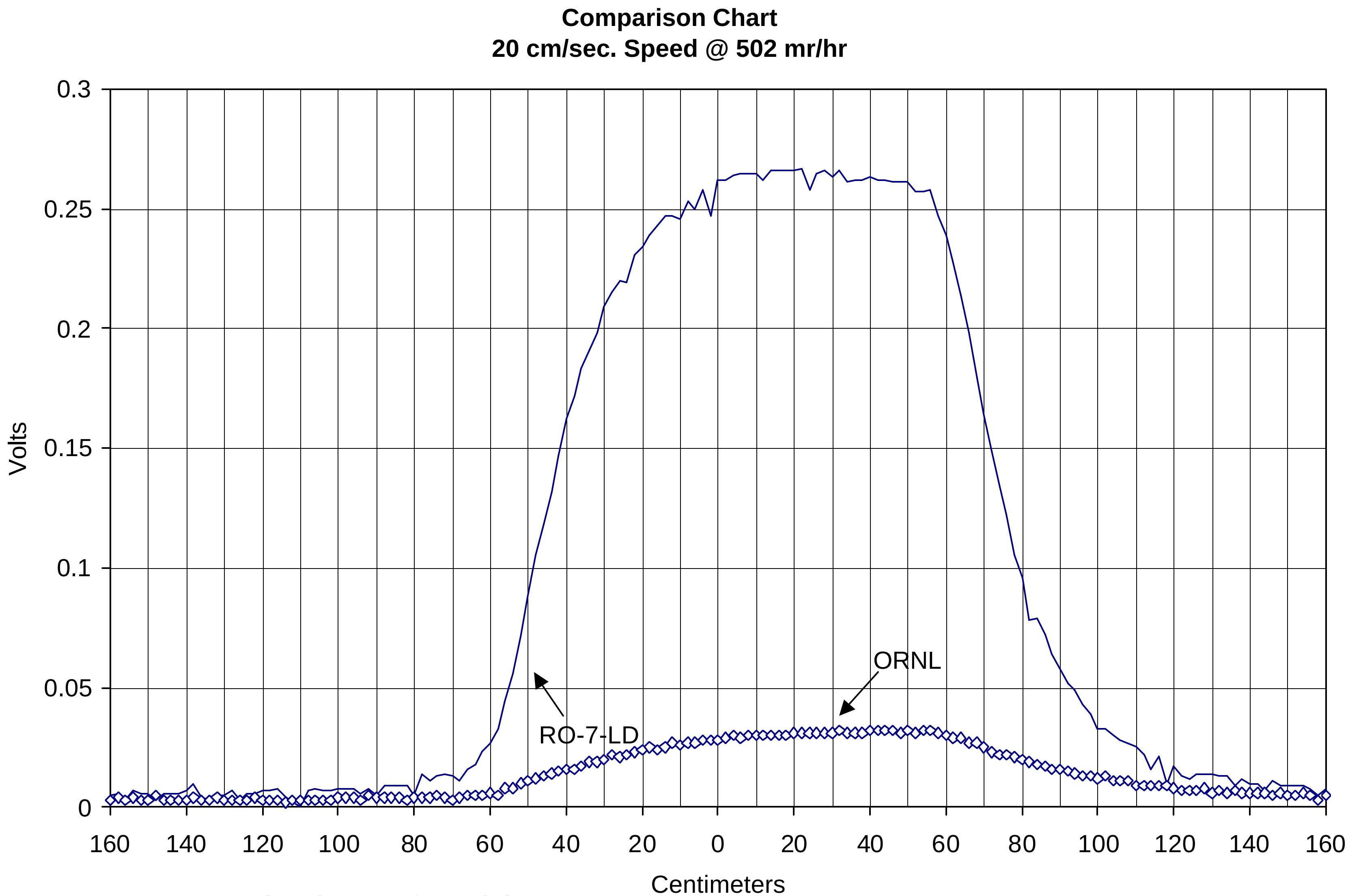
APPENDIX 3C


ORNL Sensor
20 cm/sec. Speed @ 502 mr/hr
Volts
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Center
Right 20 cm
Left 20 cm
Left 40 cm
Right 40 cm
Left 60 cm
Left 80 cm
Right 60 cm
Right 80 cm
160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160
Centimeters
Movement Direction = Left to Right

APPENDIX 4A


RO-7-LD
20 cm/sec. Speed @ 502 mr/hr
Volts (measured (-))
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
Left 20 cm
Center
Right 20 cm
Left 40 cm
Right 40 cm
Left 60 cm
Right 60 cm
Right 80 cm
Left 80 cm
160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160
Movement Direction = Left to Right
Centimeters

APPENDIX 4B



Movement Direction = Left to Right

APPENDIX 4C

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