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**Recommended algorithms for the computation of marine meteorological variables**

2015

**JCOMM Technical Report No.** **63**

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| **WORLD METEOROLOGICAL ORGANIZATION****\_\_\_\_\_\_\_\_\_\_\_\_\_** |  | **INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)\_\_\_\_\_\_\_\_\_\_\_** |

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NOTES

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**Regulation 42**

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

**Regulation 43**

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation on behalf of the constituent body when the matter is, in his opinion, urgent, and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

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**RECORD OF CHANGES**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Version*** | ***Version date*** | ***Prepared by*** | ***Main editor*** | ***Main changes*** |
| First version | February 2015 | SOT Task Team on Instrument Standards | Henry Kleta, DWD, Germany | n/a |

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**Recommended algorithms for the computation of marine meteorological variables**

**Introduction**

A range of variables observed under the Voluntary Observing Ship (VOS) scheme, and circulated over the Global Telecommunication System (GTS) in real-time (RT), or exchanged internationally in delayed mode (DM), may be computed shipboard or after receipt on shore. A general description of the different VOS variables and measurement methods can be found in the *Guide to Instruments and Methods of Observations* (WMO 2010; hereafter “WMO No-8”).

This publication presents a summarized version of the WMO No-8 information, focusing on the instruments used by the VOS, but breaks new ground in making specific recommendations (including providing software modules and test validation cases) on the algorithms to be used to compute “derived” variables. These derived variables can be required for reporting the data within the constraints of existing RT/DM code/format systems, or are required after the reported data are received by the climate data management and scientific communities, for purposes of a wide range of downstream science applications. Additionally, the algorithms recommended in this publication should in due course form the basis of developing more internationally consistent approaches to the calculation of derived marine meteorological variables. Examples where such an approach would be beneficial include in national publications of VOS observing instructions (e.g. US/NWS 2004, UK Meteorological Office 1995), and in the algorithms used in electronic logbook (e-logbook) software used to record, convert and format VOS observations (e.g. TurboWin; <http://www.knmi.nl/turbowin/>).

While VOS (and precursor historical) ship observations have been gathered systematically for well over a century, and some software has been developed internationally to handle computation requirements for the uniform handling of early historical ship observations (e.g. ICOADS 2004), this publication represents a first attempt by JCOMM to harmonize the specific computational practices for modern-day VOS, as an important step towards seeking general improvements in data homogeneity.

This JCOMM Technical Report No. 63 is not limited to humidity variables, but will be extended with further variables when the need arises. This publication was prepared by the Task Team on Instrument Standards (TT-IS) of the Ship Observations Team (SOT), in consultation with the Expert Team on Marine Climatology (ETMC), of JCOMM.

**PART I. Dewpoint Temperature and other humidity variables**

**I.1) Overview**

Humidity observations are required for most areas of marine meteorology and climatology, including air – sea interaction studies. A general description of the different humidity variables and measurement methods can be found in the *Guide to Instruments and Methods of Observations* (WMO No-8). This publication (as stated in the Introduction) presents a summarized version, focusing on the Voluntary Observing Ship (VOS) scheme, and makes recommendations on the algorithms to be used to calculate the derived humidity variables typically reported by the VOS, i.e. dew point temperature and relative humidity (of course it is dependent on the type of equipment used on the VOS which parameter is observed and reported).

.

**I.2) Measurement Methods**

**I.2a) Psychrometer**

The majority of the traditional manual VOS fleet use psychrometric methods to determine the humidity at sea, measuring the temperature difference between a dry bulb thermometer and a thermometer covered in a wetted wick. The difference (depression of the wet bulb temperature) is used to calculate the vapour pressure, from which other humidity variables can then be derived. The recommended formulae to calculate the vapour pressure are given by WMO No-8:

|  |  |  |
| --- | --- | --- |
|  | water | (1a) |
|  |  |  |

Where is the vapour pressure (hPa); the saturation vapour pressure (hPa) of moist air with regard to water at the wet bulb temperature; the dry bulb temperature (°C); the wet bulb temperature (°C); the pressure (hPa); and the psychrometric coefficient for the wet bulb.

|  |  |  |
| --- | --- | --- |
|  | ice | (1b) |
|  |  |  |

Where is the vapour pressure (hPa); the saturation vapour pressure (hPa) of moist air with regard to ice at the ice bulb temperature; the dry bulb temperature (°C); the ice bulb temperature (°C); the pressure (hPa); and the psychrometric coefficient for the ice bulb.

Note that in the psychrometric equations (1a and 1b) the saturation vapour pressure with regard to water (or ice respectively) at the wet bulb (ice bulb) temperature is used rather than at the dry bulb temperature.

The depression of the wet bulb thermometer relative to the dry bulb is a function of the humidity of the air, size and type of thermometers and flow rate past the thermometer bulbs (e.g. Folland 1977). This is reflected through a variable psychrometric coefficient in equation (1a and 1b). Flow rates through louvered marine screens are generally restricted to between 3 and 5 ms-1 depending on the design of the screen. Higher flow rates are generally achieved by artificial ventilation, either through the use of fans or whirling psychrometers. As a result, psychrometers housed in louvered screens generally require a higher psychrometric coefficient compared to other instruments. For example, the hygrometric tables published by the UK Met Office (1995) use a psychrometric coefficient of 0.799 x 10-3 for screens and 0.667 x 10-3 for psychrometers. The actual value to be used should be determined by the equipment manufacturers.

**I.2b) Electrical Resistive and Capacitive Hygrometers**

VOS Automatic Weather Stations (AWS) typically use electrical resistive or capacitive hygrometers to estimate the relative humidity directly. Both methods depend on the changes to the electrical properties of hygroscopic materials and give measurements of the relative humidity. The vapour pressure can be calculated from the relative humidity and dry bulb temperature with the following equations (ref. WMO No-8):

|  |  |
| --- | --- |
|  | (2) |

Where is the relative humidity (%).

**I.2c) Hair Hygristor**

Some VOS humidity observations are reported using hair hygrometers (or hygristors). These instruments measure the relative humidity using natural or synthetic hairs and more information can be found in WMO No-8. As with electrical hygrometers, the vapour pressure can be calculated using (2).

**I.3) Calculation of the Saturation Vapour Pressure**

The saturation vapour pressure is calculated as a function of dry bulb temperature and pressure (ref. WMO No-8):

|  |  |
| --- | --- |
|  | (3a) |
|  | (3b) |

Where is the saturation vapour pressure (hPa) in the pure phase with regard to water at the dry bulb temperature. The term adjusts for the pressure dependency of the saturation vapour pressure and is given by WMO No-8:

|  |  |
| --- | --- |
|  | (4) |

The saturation vapour pressure with regard to ice is given by:

|  |  |
| --- | --- |
|  | (5a) |
|  | (5b) |

Where is the saturation vapour pressure (hPa) in the pure phase with regard to ice at the dry bulb temperature.

**I.4) Calculation of the Dewpoint (or Frostpoint) Temperature**

The recommended formulae for calculating the dewpoint and frostpoint temperatures are given by (ref. WMO No-8):

|  |  |
| --- | --- |
|  | (6a) |
|  | (6b) |

Where and are the dewpoint and frostpoint temperatures (°C) respectively.

**I.5) Calculation of the Relative Humidity**

The recommended formulae for calculating the relative humidity are given by (ref. WMO No-8):

|  |  |
| --- | --- |
|  | (7a) |
|  | (7b) |

Where  and  are the relative humidity with regard to water and ice respectively.

**I.6) Applicability of Dewpoint vs. Frostpoint Calculations**

Following WMO No-8 (Part I, Annex 4.B) the dewpoint formulae are valid for the temperature range of -45°C to 60°C, whereas the frostpoint formulae are valid for the range of -65°C to 0°C. While those ranges overlap, presently WMO No-8 provides only limited guidance on their appropriate application, tied in with suggested variations in observing practices (i.e. in its sec. 4.2.1.4, *Operation of the wet bulb below freezing*). This situation apparently has lead to some variations in national practices (e.g. some Port Meteorological Officers have advocated that the observer shall use the psychrometer as long as it takes for the ice on the wet bulb thermometer to dissolve; therefore there is no ice, and the dewpoint formulas shall be used).

After international discussion however, our conclusion is to adopt another interpretation: In all cases the dewpoint shall be reported (in accordance with WMO No-306). When the wet bulb thermometer is iced, the dewpoint (and not the frostpoint) shall be calculated with vapour pressures with regard to ice (obtained from equation 1b).

The main reason behind this decision is that the dewpoint shall always be reported (in accordance with WMO No-306), and can be regarded at all times as a theoretical value describing the air when and where measured, and not the measurement itself. This approach is to some extent already standard with e.g. AWS’s calculating the dewpoint from measured humidity, and most hygrometers which are essentially responsive to the relative humidity indicate relative humidity with respect to water at all temperatures.

Nevertheless the better option is always to report the measured parameters, and not derived variables. This is consistent with regulation 12.3.6 from the Manual on Codes, part 1 and BUFR / CREX regulation B/C10 10.4.1.3.1.

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**I.7) Recommendations**

The TT-IS (with guidance from ETMC) recommends the following:

1) Measured variables shall be reported instead of (or additional to) derived / calculated variables when possible.

2) All relevant metadata (used instruments, methods of calculation of derived variables, etc) shall be made available.

3) When reporting the dewpoint temperature or relative humidity calculated from a dry bulb thermometer and a wet / ice bulb thermometer, the wet / ice bulb temperature shall be reported too when possible.

4) When reporting in the FM13 code form or BUFR the appropriate indicator shall be used to indicate whether the wet bulb is iced, sw from group 8swT­bT­bT­b in FM13 and 0 02 039 from BUFR.

5) Use of the algorithm described in Annex I for the computation of the dewpoint temperature.

6) When using the psychrometric equation to calculate the vapour pressure, the psychrometric coefficient appropriate to the instrumentation shall be used. Where necessary this shall be sought from the instrument manufacturer.

7) Use of all the test cases given in Annex II when testing own implementations of the recommended algorithm. Benchmark results for the test cases are available in Annex III, these shall be used to compare with the separately implemented results.

8) Own implementations of these algorithms shall be fully commented (in English). In addition the the source code shall be shared internationally through a proposed new collaborative JCOMM software repository.

9) The dewpoint temperature shall be reported (over GTS or in delayed-mode) to at least one decimal point (i.e. 0.1°C precision).

10) The pressure value used for the calculation of the dewpoint temperature shall be that observed closest to the height of the temperature / humidity measurements.

Where this value is not available, the pressure at mean sea level shall be used.

If no pressure observations are available the pressure of the ICAO standard atmosphere (1013.25 hPa) shall be used.

11) When calculating the relative humidity this should be done with respect to water at all temperatures as per WMO regulations (see Appendix B of WMO Technical Regulations (WMO-No. 49) Volume I) .

It should be noted that the values of the psychrometric coefficient used in the algorithm ( and in equations 1a and 1b) are dependent on the type of instrument used and the ventilation rate applied to the instrument. These values should be made available if possible.

\_\_\_\_\_\_\_\_\_\_\_\_

**Annex I**

**dewpoint algorithm: PSEUDOCODE**

Implementations of this algorithm can be found under the following URL: [link currently unknown, and to be added in a future revision of this Publication]

; function to calculate the dewpoint from the given values

; for pressure, dry-bulb and wet-bulb temperature

;

; all used formulae are taken from

; WMO-No.8, 2008 edition, updated 2010, Part I, Annex 4.B

;

; IN: pressure - pressure of moist air in hPa

; t\_dry - dry-bulb temperature in °C

; t\_wet - wet-bulb temperature in °C

; iced - measurements over ice yes / no

; OUT: Dewpoint - dewpoint in °C

;

Function Dewpoint(pressure, t\_dry, t\_wet, iced)

; psychrometric coefficient

; value is instrument dependent and should be given by manufacturer

; given value is for the Assmann psychrometer

;

If (NOT iced) then

 psychrometricCoeff = 0.000653

else

 psychrometricCoeff = 0.000575

endif

; interim values, for better readability of code

;

; pressure dependency

f\_p = 1.0016 + 0.00000315 \* pressure - 0.074 / pressure

; saturation and actual vapour pressure

If (NOT iced) then

 SatVapourPressure = f\_p \* 6.112 \* Exp(17.62 \* t\_wet / (243.12 + t\_wet))

 VapourPressure = SatVapourPressure - psychrometricCoeff \*

 (1 + 0.000944 \* t\_wet) \* pressure \* (t\_dry - t\_wet)

else

 SatVapourPressure = f\_p \* 6.112 \* Exp(22.46 \* t\_wet / (272.62 + t\_wet))

 VapourPressure = SatVapourPressure - psychrometricCoeff \*

 pressure \* (t\_dry - t\_wet)

endif

Dewpoint = (243.12 \* Log(VapourPressure / (6.112 \* f\_p))) /

 (17.62 - Log(VapourPressure / (6.112 \* f\_p)))

; return result

return Dewpoint

End Function

\_\_\_\_\_\_\_\_\_\_\_\_

**Annex II**

**dewpoint algorithm: RECOMMENDED TESTCASES**

; calculation of dewpoint with the formulae from

; WMO-No.8, 2008 edition, updated 2010, Part I, Annex 4.B

; "Formulae for the computation of measures of humidity"

;

; testcases defined by SOT TT-IS and ETMC, such that each new

; algorithm should be tested against all possible combinations

; of these numeric values, and the results compared against the

; benchmark results available in Annex III

; dry-bulb temperatures

t\_dry(0)=40.0

t\_dry(1)=30.0

t\_dry(2)=20.0

t\_dry(3)=10.0

t\_dry(4)=0.0

t\_dry(5)=-10.0

t\_dry(6)=-15.0

; wet-bulb temperatures

t\_wet(0)=35.0

t\_wet(1)=25.0

t\_wet(2)=15.0

t\_wet(3)=7.0

t\_wet(4)=3.0

t\_wet(5)=-2.0

t\_wet(6)=-5.0

t\_wet(7)=-12.0

t\_wet(8)=-17.0

; airpressure

pressure(0)=980.0

pressure(1)=1000.0

pressure(2)=1013.3

pressure(3)=1040.0

; psychrometric coefficient

psychrometricCoeff = 0.000653 (wet bulb)

psychrometricCoeff = 0.000575 (ice bulb)

\_\_\_\_\_\_\_\_\_\_\_\_

**Annex III**

**Dewpoint Algorithm: Benchmark results using recommended testcases**

Note: Invalid values resulting i.e. from a call of the logarithm function with a negative parameter are given here as –NaN. NaN stands for “Not A Number” and is the representation (in this case negative) of an invalid value given by the used software (here IDL) to clearly show that there was a problem while computing the values without stopping the computation.

 Case No. T\_dry T\_wet pressure Dewpoint

 1 40.0000 35.0000 980.000 33.9135

 2 40.0000 35.0000 1000.00 33.8908

 3 40.0000 35.0000 1013.30 33.8757

 4 40.0000 35.0000 1040.00 33.8453

 5 40.0000 25.0000 980.000 18.9258

 6 40.0000 25.0000 1000.00 18.7791

 7 40.0000 25.0000 1013.30 18.6808

 8 40.0000 25.0000 1040.00 18.4820

 9 40.0000 15.0000 980.000 -24.2691

 10 40.0000 15.0000 1000.00 -29.4747

 11 40.0000 15.0000 1013.30 -34.8902

 12 40.0000 15.0000 1040.00 -NaN

 13 40.0000 7.00000 980.000 -NaN

 14 40.0000 7.00000 1000.00 -NaN

 15 40.0000 7.00000 1013.30 -NaN

 16 40.0000 7.00000 1040.00 -NaN

 17 40.0000 3.00000 980.000 -NaN

 18 40.0000 3.00000 1000.00 -NaN

 19 40.0000 3.00000 1013.30 -NaN

 20 40.0000 3.00000 1040.00 -NaN

 21 40.0000 -2.00000 980.000 -NaN

 22 40.0000 -2.00000 1000.00 -NaN

 23 40.0000 -2.00000 1013.30 -NaN

 24 40.0000 -2.00000 1040.00 -NaN

 25 40.0000 -5.00000 980.000 -NaN

 26 40.0000 -5.00000 1000.00 -NaN

 27 40.0000 -5.00000 1013.30 -NaN

 28 40.0000 -5.00000 1040.00 -NaN

 29 40.0000 -12.0000 980.000 -NaN

 30 40.0000 -12.0000 1000.00 -NaN

 31 40.0000 -12.0000 1013.30 -NaN

 32 40.0000 -12.0000 1040.00 -NaN

 33 40.0000 -17.0000 980.000 -NaN

 34 40.0000 -17.0000 1000.00 -NaN

 35 40.0000 -17.0000 1013.30 -NaN

 36 40.0000 -17.0000 1040.00 -NaN

 37 30.0000 35.0000 980.000 36.0324

 38 30.0000 35.0000 1000.00 36.0529

 39 30.0000 35.0000 1013.30 36.0665

 40 30.0000 35.0000 1040.00 36.0938

 41 30.0000 25.0000 980.000 23.1851

 42 30.0000 25.0000 1000.00 23.1463

 43 30.0000 25.0000 1013.30 23.1205

 44 30.0000 25.0000 1040.00 23.0685

 45 30.0000 15.0000 980.000 2.52657

 46 30.0000 15.0000 1000.00 2.14296

 47 30.0000 15.0000 1013.30 1.88266

 48 30.0000 15.0000 1040.00 1.34686

 49 30.0000 7.00000 980.000 -NaN

 50 30.0000 7.00000 1000.00 -NaN

 51 30.0000 7.00000 1013.30 -NaN

 52 30.0000 7.00000 1040.00 -NaN

 53 30.0000 3.00000 980.000 -NaN

 54 30.0000 3.00000 1000.00 -NaN

 55 30.0000 3.00000 1013.30 -NaN

 56 30.0000 3.00000 1040.00 -NaN

 57 30.0000 -2.00000 980.000 -NaN

 58 30.0000 -2.00000 1000.00 -NaN

 59 30.0000 -2.00000 1013.30 -NaN

 60 30.0000 -2.00000 1040.00 -NaN

 61 30.0000 -5.00000 980.000 -NaN

 62 30.0000 -5.00000 1000.00 -NaN

 63 30.0000 -5.00000 1013.30 -NaN

 64 30.0000 -5.00000 1040.00 -NaN

 65 30.0000 -12.0000 980.000 -NaN

 66 30.0000 -12.0000 1000.00 -NaN

 67 30.0000 -12.0000 1013.30 -NaN

 68 30.0000 -12.0000 1040.00 -NaN

 69 30.0000 -17.0000 980.000 -NaN

 70 30.0000 -17.0000 1000.00 -NaN

 71 30.0000 -17.0000 1013.30 -NaN

 72 30.0000 -17.0000 1040.00 -NaN

 73 20.0000 35.0000 980.000 37.9563

 74 20.0000 35.0000 1000.00 38.0123

 75 20.0000 35.0000 1013.30 38.0495

 76 20.0000 35.0000 1040.00 38.1239

 77 20.0000 25.0000 980.000 26.6579

 78 20.0000 25.0000 1000.00 26.6902

 79 20.0000 25.0000 1013.30 26.7116

 80 20.0000 25.0000 1040.00 26.7546

 81 20.0000 15.0000 980.000 11.7671

 82 20.0000 15.0000 1000.00 11.6947

 83 20.0000 15.0000 1013.30 11.6463

 84 20.0000 15.0000 1040.00 11.5489

 85 20.0000 7.00000 980.000 -16.6585

 86 20.0000 7.00000 1000.00 -17.9315

 87 20.0000 7.00000 1013.30 -18.8511

 88 20.0000 7.00000 1040.00 -20.9187

 89 20.0000 3.00000 980.000 -NaN

 90 20.0000 3.00000 1000.00 -NaN

 91 20.0000 3.00000 1013.30 -NaN

 92 20.0000 3.00000 1040.00 -NaN

 93 20.0000 -2.00000 980.000 -NaN

 94 20.0000 -2.00000 1000.00 -NaN

 95 20.0000 -2.00000 1013.30 -NaN

 96 20.0000 -2.00000 1040.00 -NaN

 97 20.0000 -5.00000 980.000 -NaN

 98 20.0000 -5.00000 1000.00 -NaN

 99 20.0000 -5.00000 1013.30 -NaN

 100 20.0000 -5.00000 1040.00 -NaN

 101 20.0000 -12.0000 980.000 -NaN

 102 20.0000 -12.0000 1000.00 -NaN

 103 20.0000 -12.0000 1013.30 -NaN

 104 20.0000 -12.0000 1040.00 -NaN

 105 20.0000 -17.0000 980.000 -NaN

 106 20.0000 -17.0000 1000.00 -NaN

 107 20.0000 -17.0000 1013.30 -NaN

 108 20.0000 -17.0000 1040.00 -NaN

 109 10.0000 35.0000 980.000 39.7201

 110 10.0000 35.0000 1000.00 39.8060

 111 10.0000 35.0000 1013.30 39.8630

 112 10.0000 35.0000 1040.00 39.9769

 113 10.0000 25.0000 980.000 29.6028

 114 10.0000 25.0000 1000.00 29.6861

 115 10.0000 25.0000 1013.30 29.7413

 116 10.0000 25.0000 1040.00 29.8517

 117 10.0000 15.0000 980.000 17.7318

 118 10.0000 15.0000 1000.00 17.7832

 119 10.0000 15.0000 1013.30 17.8174

 120 10.0000 15.0000 1040.00 17.8857

 121 10.0000 7.00000 980.000 3.92109

 122 10.0000 7.00000 1000.00 3.85198

 123 10.0000 7.00000 1013.30 3.80587

 124 10.0000 7.00000 1040.00 3.71289

 125 10.0000 3.00000 980.000 -9.00001

 126 10.0000 3.00000 1000.00 -9.37989

 127 10.0000 3.00000 1013.30 -9.63818

 128 10.0000 3.00000 1040.00 -10.1712

 129 10.0000 -2.00000 980.000 -NaN

 130 10.0000 -2.00000 1000.00 -NaN

 131 10.0000 -2.00000 1013.30 -NaN

 132 10.0000 -2.00000 1040.00 -NaN

 133 10.0000 -5.00000 980.000 -NaN

 134 10.0000 -5.00000 1000.00 -NaN

 135 10.0000 -5.00000 1013.30 -NaN

 136 10.0000 -5.00000 1040.00 -NaN

 137 10.0000 -12.0000 980.000 -NaN

 138 10.0000 -12.0000 1000.00 -NaN

 139 10.0000 -12.0000 1013.30 -NaN

 140 10.0000 -12.0000 1040.00 -NaN

 141 10.0000 -17.0000 980.000 -NaN

 142 10.0000 -17.0000 1000.00 -NaN

 143 10.0000 -17.0000 1013.30 -NaN

 144 10.0000 -17.0000 1040.00 -NaN

 145 0.000000 35.0000 980.000 41.3502

 146 0.000000 35.0000 1000.00 41.4617

 147 0.000000 35.0000 1013.30 41.5355

 148 0.000000 35.0000 1040.00 41.6830

 149 0.000000 25.0000 980.000 32.1672

 150 0.000000 25.0000 1000.00 32.2893

 151 0.000000 25.0000 1013.30 32.3701

 152 0.000000 25.0000 1040.00 32.5313

 153 0.000000 15.0000 980.000 22.2060

 154 0.000000 15.0000 1000.00 22.3269

 155 0.000000 15.0000 1013.30 22.4068

 156 0.000000 15.0000 1040.00 22.5663

 157 0.000000 7.00000 980.000 12.5308

 158 0.000000 7.00000 1000.00 12.6266

 159 0.000000 7.00000 1013.30 12.6900

 160 0.000000 7.00000 1040.00 12.8166

 161 0.000000 3.00000 980.000 6.23055

 162 0.000000 3.00000 1000.00 6.29005

 163 0.000000 3.00000 1013.30 6.32950

 164 0.000000 3.00000 1040.00 6.40839

 165 0.000000 -2.00000 980.000 -5.68166

 166 0.000000 -2.00000 1000.00 -5.76682

 167 0.000000 -2.00000 1013.30 -5.82371

 168 0.000000 -2.00000 1040.00 -5.93858

 169 0.000000 -5.00000 980.000 -22.0754

 170 0.000000 -5.00000 1000.00 -22.7947

 171 0.000000 -5.00000 1013.30 -23.2967

 172 0.000000 -5.00000 1040.00 -24.3692

 173 0.000000 -12.0000 980.000 -NaN

 174 0.000000 -12.0000 1000.00 -NaN

 175 0.000000 -12.0000 1013.30 -NaN

 176 0.000000 -12.0000 1040.00 -NaN

 177 0.000000 -17.0000 980.000 -NaN

 178 0.000000 -17.0000 1000.00 -NaN

 179 0.000000 -17.0000 1013.30 -NaN

 180 0.000000 -17.0000 1040.00 -NaN

 181 -10.0000 35.0000 980.000 42.8667

 182 -10.0000 35.0000 1000.00 43.0005

 183 -10.0000 35.0000 1013.30 43.0889

 184 -10.0000 35.0000 1040.00 43.2655

 185 -10.0000 25.0000 980.000 34.4436

 186 -10.0000 25.0000 1000.00 34.5964

 187 -10.0000 25.0000 1013.30 34.6974

 188 -10.0000 25.0000 1040.00 34.8987

 189 -10.0000 15.0000 980.000 25.8145

 190 -10.0000 15.0000 1000.00 25.9810

 191 -10.0000 15.0000 1013.30 26.0910

 192 -10.0000 15.0000 1040.00 26.3098

 193 -10.0000 7.00000 980.000 18.2436

 194 -10.0000 7.00000 1000.00 18.4119

 195 -10.0000 7.00000 1013.30 18.5230

 196 -10.0000 7.00000 1040.00 18.7439

 197 -10.0000 3.00000 980.000 13.9300

 198 -10.0000 3.00000 1000.00 14.0933

 199 -10.0000 3.00000 1013.30 14.2010

 200 -10.0000 3.00000 1040.00 14.4154

 201 -10.0000 -2.00000 980.000 7.51632

 202 -10.0000 -2.00000 1000.00 7.66204

 203 -10.0000 -2.00000 1013.30 7.75823

 204 -10.0000 -2.00000 1040.00 7.94964

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 207 -10.0000 -5.00000 1013.30 2.85539

 208 -10.0000 -5.00000 1040.00 3.01668

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 218 -15.0000 35.0000 1000.00 43.7313

 219 -15.0000 35.0000 1013.30 43.8264

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 226 -15.0000 15.0000 1000.00 27.5769

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 236 -15.0000 3.00000 1040.00 17.3589

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 250 -15.0000 -17.0000 1000.00 -34.0688

 251 -15.0000 -17.0000 1013.30 -34.5801

 252 -15.0000 -17.0000 1040.00 -35.6826

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