

OPENTALLY FUNCTIONAL SPECIFICATIONS

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PART 1—PRELIMINARY

1. Introduction

- 1.1. These are the *OpenTally Functional Specifications*, which specify how an election is to be counted in a conforming implementation.

2. Scope

- 2.1. These specifications set out how the result of an election, namely the winning candidates and their order of election, are to be determined.
- 2.2. These specifications do not cover the input or validation of ballots. In particular, the following matters are outside the scope of these specifications and are implementation-defined:
 - (a) the format of ballots in input files,
 - (b) the checking of ballots for formality.
- 2.3. These specifications do not cover presentational matters or other matters which cannot impact the result of the election. In particular, the following matters are outside the scope of these specifications and are implementation-defined:
 - (a) the values of exhausted ballots,
 - (b) the votes lost by fraction,
 - (c) the votes credited to elected candidates after their surpluses are distributed,
 - (d) the presentation of results.

3. Method of counting

- 3.1. If *--method* is *wig*, *uig*, *eg*, *hare* or *ihare*, the ballots are to be counted according to section 4.
- 3.2. If *--method* is *meeek*, the ballots are to be counted according to section 21.

PART 2—METHODS OTHER THAN MEEK

Division 1—General

4. First stage

- 4.1. Take the transferable ballots in the input file, in the order each appears. Sort them into parcels, each of value 1, according to next available preference.
- 4.2. Transfer each parcel to the corresponding candidate, and credit the candidate with votes equal to the number of ballots in the parcel.
- 4.3. Calculate the *quota* according to section 29.
- 4.4. Apply section 5 to elect any continuing candidates who must be elected.
- 4.5. This is the *end of a stage*. Proceed to section 6.

5. Election of continuing candidates

- 5.1. This section applies in subsections 4.4, 8.5, 10.4, 16.3(b)(ii)(C), 17.4(c)(iii) and 19.3(b)(iii), to elect any continuing candidates who must be elected.
- 5.2. If *--quota-mode* is *ers97* and no candidates have been declared elected, recalculate the quota according to section 29.
- 5.3. If *--no-immediate-elect* is disabled:
- (a) If *--quota-mode* is *ers97* or *ers76*:
 - (i) Add:
 - (A) the sum of all continuing candidates' progress totals, plus
 - (B) the sum of all excluded candidates' progress totals, plus
 - (C) the total of any undistributed surpluses.Divide the sum by 1 more than the number of remaining vacancies. The quotient is the ***vote required for election***.
 - (ii) Declare elected any continuing candidate who meets the quota or the vote required for election, one by one in descending order of progress total, breaking any tie according to section 31.
 - (iii) If *--quota-mode* is *ers97* and any candidates were declared elected in subparagraph (ii), repeat this paragraph.
 - (iv) If *--quota-mode* is *ers76* and any candidates were declared elected in subparagraph (ii) due to meeting the quota, repeat this paragraph.
 - (b) If *--quota-mode* is *dynamic_by_total* or *dynamic_by_active*:
 - (i) Recalculate the quota according to section 29.
 - (ii) Declare elected any continuing candidate who meets the quota, one by one in descending order of progress total, breaking any tie according to section 31.
 - (iii) If any candidates were declared elected in subparagraph (ii), repeat this paragraph.
 - (c) If *--quota-mode* is *static*, declare elected any continuing candidate who meets the quota, one by one in descending order of progress total, breaking any tie according to section 31.

Early bulk election of sure winners

- 5.4. This subsection applies if *--early-bulk-elect* is enabled, and the continuing candidates with the highest progress totals, up to the number of remaining vacancies (the ***leading candidates***), each have a higher progress total than:
- (a) the sum of all other continuing candidates' progress totals, plus
 - (b) the sum of all excluded candidates' progress totals, plus
 - (c) the total of any undistributed surpluses.
- 5.5. If subsection 5.4 applies, immediately declare elected each of the leading candidates, one by one in descending order of progress total, breaking any tie according to section 31. The count is then complete.

6. Second or subsequent stages

- 6.1. If no more vacancies remain to be filled, the count is complete.
- 6.2. Otherwise, if 1 or more candidates have undistributed surpluses, and `--defer-surpluses` is disabled or the distribution of surpluses cannot be deferred under section 7, perform a surplus distribution according to section 8.
- 6.3. Otherwise, if the number of continuing candidates equals the number of remaining vacancies, declare elected all continuing candidates, one by one in descending order of progress total, breaking any tie according to section 31. The count is then complete.
- 6.4. Otherwise, perform an exclusion according to section 9.
- 6.5. Repeat this section until the count is complete.

7. Deferring surplus distributions

- 7.1. This section applies in subsection 6.2, if `--defer-surpluses` is enabled, to determine when the distribution of surpluses must be deferred.
- 7.2. If there are fewer than 2 continuing candidates, the distribution of surpluses must be deferred.
- 7.3. Otherwise, if `--bulk-exclude` is enabled and a bulk exclusion could be performed under section 30:
 - (a) If the total of all undistributed surpluses is less than the difference between the sum of the progress totals of the continuing candidates who could be bulk excluded, and the progress total of the continuing candidate with the next lowest progress total, then the distribution of surpluses must be deferred.
 - (b) Otherwise, the distribution of surpluses must not be deferred.
- 7.4. Otherwise, if the total of all undistributed surpluses is less than the difference between the progress totals of the 2 continuing candidates with the lowest progress totals, the distribution of surpluses must be deferred.
- 7.5. Otherwise, the distribution of surpluses must not be deferred.

8. Surplus distribution

- 8.1. This section applies in subsection 6.2 to distribute a candidate's surplus.
- 8.2. When this section applies, apply the following procedure to the candidate with an undistributed surplus, and if there are multiple such candidates:
 - (a) if `--surplus-order` is `by_size`, the one with the highest progress total (the ***elected candidate***), breaking any tie according to section 31.
 - (b) if `--surplus-order` is `by_order`, the one who was elected the earliest (the ***elected candidate***).
- 8.3. If `--no-immediate-elect` is enabled, declare that candidate elected.
- 8.4.
 - (a) If `--method` is `wig`, apply section 11 to the elected candidate.
 - (b) If `--method` is `uig`, apply section 12 to the elected candidate.
 - (c) If `--method` is `eg`, apply section 13 to the elected candidate.

(d) If *--method* is *hare* or *ihare*, apply section 14 to the elected candidate.

8.5. Apply section 5 to elect any continuing candidates who must be elected.

8.6. This is the *end of a stage*. Return to section 6.

9. Exclusion—generally

9.1. This section applies in subsection 6.4 to exclude 1 or more continuing candidates.

9.2. When this section applies:

(a) If it is the first time this section is applied, and 1 or more continuing candidates have a progress total equal to or lower than the value of *--min-threshold*, apply the following procedure to all those candidates.

(b) Otherwise, if *--bulk-exclude* is enabled and a bulk exclusion can be performed under section 30, apply the following procedure to the candidates to be bulk excluded.

(c) Otherwise, apply the following procedure to the continuing candidate with the lowest progress total, breaking any tie according to section 31.

9.3. Declare that candidate, or those candidates (the ***excluded candidates***), excluded.

9.4. If *--early-bulk-elect* is enabled, and the number of continuing candidates equals the number of remaining vacancies, declare elected all continuing candidates, one by one in descending order of progress total, breaking any tie according to section 31. The count is then complete.

9.5. If *--exclusion* is *reset_and_reiterate*, then apply section 20.

9.6. Otherwise:

(a) If *--exclusion* is *single_stage*, apply section 10 to all of the excluded candidates' parcels at once.

(b) If *--exclusion* is *by_value*:

(i) Aggregate the excluded candidates' parcels, in the order each was received, into 1 combined parcel for each value.

(ii) Apply section 10 to each combined parcel in turn, in descending order of value.

(c) If *--exclusion* is *parcels_by_order*, apply section 10 to each of the excluded candidates' parcels in turn, in the order each parcel was received by the excluded candidate.

9.7. Once all of the excluded candidates' parcels have been transferred under subsection 9.6, return to section 6.

10. Exclusion—each stage

10.1. This section applies in subsection 9.6 to transfer 1 or more parcels from excluded candidates (the ***parcels to transfer***).

10.2. (a) If *--method* is *wig*, *uig* or *eg*, apply section 18 to the parcels to transfer.

(b) If *--method* is *hare* or *ihare*, apply section 19 to the parcels to transfer.

10.3. If *--quota-mode* is *ers97*, and there are no elected candidates, recalculate the quota according to section 29.

10.4. Apply section 5 to elect any continuing candidates who must be elected.

10.5. This is the *end of a stage*. Return to subsection 9.7.

Division 2—Surplus distribution—Gregory method

11. Weighted inclusive Gregory method

11.1. This section applies in subsection 8.4(a), when *--method* is *wig*, to distribute the surplus of an elected candidate.

- 11.2. (a) If *--papers* is *both*, divide the elected candidate's surplus by their progress total.
- (b) If *--papers* is *transferable*, for each parcel held by the elected candidate, multiply the number of transferable ballots in the parcel by the parcel's value, and sum the products. Divide the elected candidate's surplus by the sum.
- (c) If *--papers* is *subtract_nontransferable*, for each parcel held by the elected candidate, multiply the number of non-transferable ballots in the parcel by the parcel's value, and sum the products. Subtract the sum from the elected candidate's progress total. Divide the elected candidate's surplus by the difference.

- 11.3. (a) If *--round-surplus-fractions* is disabled, the quotient is the **surplus fraction**.
- (b) If *--round-surplus-fractions* is enabled and *n* decimal places are requested, truncate the quotient to *n* decimal places. The result is the **surplus fraction**.

11.4. However, if the surplus fraction would be greater than 1, it is instead 1.

- 11.5. (a) If *--round-subtransfers* is *single_step* or *per_ballot*, apply subsection 11.6 to all of the elected candidate's parcels at once.
- (b) If *--round-subtransfers* is *by_value*:
- (i) Aggregate the elected candidate's parcels, in the order each was received, into 1 combined parcel for each value.
- (ii) Apply subsection 11.6 to each combined parcel in turn, in descending order of value.
- (c) If *--round-subtransfers* is *by_parcel*, apply subsection 11.6 to each of the elected candidate's parcels in turn, in the order each parcel was received by the excluded candidate.

Subtransfer of 1 or more parcels

11.6. This subsection applies to transfer 1 or more parcels as described in subsection 11.5.

- (a) For each of those parcels:
- (i) Multiply the parcel's value (the **original value**) by the surplus fraction.
- (ii) (A) If *--round-values* is disabled, the product is the **continued value**.
- (B) If *--round-values* is enabled and *n* decimal places are requested, truncate the product to *n* decimal places. The result is the **continued value**.
- (iii) Take the transferable ballots in the parcel, in the order each was added to the parcel. Sort them into further parcels, of value equal to the continued value, according to next available preference.

- (iv) Transfer each further parcel to the corresponding continuing candidate.
- (b) For each continuing candidate:
 - (i) (A) If *--round-subtransfers* is *per_ballot*, for each further parcel transferred to the continuing candidate, multiply the number of ballots in the further parcel by the continued value, and sum the products.
 - (B) If *--round-subtransfers* is not *per_ballot*:
 - (I) For each further parcel transferred to the continuing candidate, multiply the number of ballots in the further parcel by the original value, and sum the products.
 - (II) Multiply the sum by the surplus fraction.
 - (ii) (A) If *--round-votes* is disabled, credit the continuing candidate with votes equal to the result in subparagraph (i).
 - (B) If *--round-votes* is enabled and *n* decimal places are requested, truncate the result in subparagraph (i) to *n* decimal places. Credit the continuing candidate with votes equal to the result.

Completing the surplus distribution

- 11.7. Once all of the elected candidate's parcels have been transferred under subsection 11.5, proceed to subsection 8.5.

12. Unweighted inclusive Gregory method

- 12.1. This section applies in subsection 8.4(b), when *--method* is *uig*, to distribute the surplus of an elected candidate.
- 12.2. (a) If *--papers* is *transferable*, for each of the elected candidate's parcels, multiply the number of transferable ballots in the parcel by the parcel's value, and sum the products. If the sum is less than the elected candidate's surplus, this paragraph applies.
- (b) If paragraph (a) does not apply:
 - (i) (A) If *--papers* is *both*, divide the elected candidate's surplus by the total number of ballots in all of their parcels.
 - (B) If *--papers* is *transferable*, divide the elected candidate's surplus by the total number of transferable ballots in all of their parcels.
 - (ii) (A) If *--round-surplus-fractions* and *--round-values* are disabled, the quotient is the **transfer value**.
 - (B) If *--round-surplus-fractions* and/or *--round-values* is enabled and *n* decimal places are requested (and if both are enabled, however many decimal places is fewer), truncate the quotient to *n* decimal places. The result is the **transfer value**.
- 12.3. (a) If *--round-subtransfers* is *single_step* or *per_ballot*, apply subsection 12.4 to all of the elected candidate's parcels at once.
- (b) If *--round-subtransfers* is *by_value*:

- (i) Aggregate the elected candidate's parcels, in the order each was received, into 1 combined parcel for each value.
- (ii) Apply subsection 12.4 to each combined parcel in turn.
- (c) If *--round-subtransfers* is *by_parcel*, apply subsection 12.4 to each of the elected candidate's parcels in turn.

Subtransfer of 1 or more parcels

12.4. This subsection applies to transfer 1 or more parcels as described in subsection 12.3.

- (a) For each of those parcels:
 - (i) (A) If subsection 12.2(a) applies, take the transferable ballots in the parcel, in the order each was added to the parcel. Sort them into further parcels of the same value, according to next available preference.
 - (B) If subsection 12.2(a) does not apply, take the transferable ballots in the parcel, in the order each was added to the parcel. Sort them into further parcels, of value equal to the transfer value, according to next available preference.
- (ii) Transfer each further parcel to the corresponding continuing candidate.
- (b) For each continuing candidate:
 - (i) For each further parcel transferred to the continuing candidate, multiply the number of ballots in the further parcel by the further parcel's value, and sum the products.
 - (ii) (A) If *--round-votes* is disabled, credit the continuing candidate with votes equal to the sum.
 - (B) If *--round-votes* is enabled and *n* decimal places are requested, truncate the sum to *n* decimal places. Credit the continuing candidate with votes equal to the result.

Completing the surplus distribution

12.5. Once all of the elected candidate's parcels have been transferred under subsection 12.3, proceed to subsection 8.5.

13. Exclusive Gregory method

- 13.1. This section applies in subsection 8.4, when *--method* is *eg*, to distribute the surplus of an elected candidate.
- 13.2. In this section, ***last parcel*** means the the parcel most recently received by the elected candidate.
- 13.3. (a) If *--papers* is *transferable*, multiply the number of transferable ballots in the last parcel by the last parcel's value. If the product is less than the elected candidate's surplus, this paragraph applies.
- (b) If paragraph (a) does not apply:
 - (i) (A) If *--papers* is *both*, divide the elected candidate's surplus by the number of ballots in the last parcel.

- (B) If *--papers* is *transferable*, divide the elected candidate's surplus by the number of transferable ballots in the last parcel.
 - (ii) (A) If *--round-surplus-fractions* and *--round-values* are disabled, the quotient is the **transfer value**.
 - (B) If *--round-surplus-fractions* and/or *--round-values* is enabled and *n* decimal places are requested (and if both are enabled, however many decimal places is fewer), truncate the quotient to *n* decimal places. The result is the **transfer value**.
- 13.4. (a) If subsection 13.3(a) applies, take the transferable ballots in the last parcel, in the order each was added to the parcel. Sort them into further parcels of the same value, according to next available preference.
- (b) If subsection 13.3(a) does not apply, take the transferable ballots in the last parcel, in the order each was added to the parcel. Sort them into further parcels, of value equal to the transfer value, according to next available preference.
- 13.5. Transfer each further parcel to the corresponding continuing candidate.
- 13.6. For each continuing candidate:
- (a) Multiply the number of ballots in the further parcel transferred to the continuing candidate by the further parcel's value.
 - (b) (i) If *--round-votes* is disabled, credit the continuing candidate with votes equal to the product.
 - (ii) If *--round-votes* is enabled and *n* decimal places are requested, truncate the product to *n* decimal places. Credit the continuing candidate with votes equal to the result.
- 13.7. Proceed to subsection 8.5.

Division 3—Surplus distribution—Hare method

14. Hare method generally

- 14.1. This section applies in subsection 8.4(d), when *--method* is *hare* or *ihare*, to distribute the surplus of an elected candidate.
- 14.2. (a) If *--method* is *hare*, the parcel most recently received by the elected candidate is the **surplus parcel**.
- (b) If *--method* is *ihare*, aggregate all of the elected candidate's parcels, in the order each was received, into 1 combined parcel of value 1. The combined parcel is the **surplus parcel**.
- 14.3. (a) If *--sample* is *stratify*, apply section 15 to the surplus parcel.
- (b) If *--sample* is *by_order*, apply section 16 to the surplus parcel.
- (c) If *--sample* is *cincinnati*, apply section 17 to the surplus parcel.

15. Stratified sample

- 15.1. This section applies in subsection 14.3(a), when *--sample* is *stratify*, to transfer the surplus parcel of an elected candidate.

15.2. If *--papers* is *transferable* and the number of transferable ballots in the surplus parcel is less than the surplus:

- (a) Take the transferable ballots in the surplus parcel, in the order each was added to the parcel. Sort them into further parcels, each of value 1, according to next available preference.
- (b) Transfer each further parcel to the corresponding continuing candidate.
- (c) Credit each continuing candidate with votes equal to the number of ballots in the further parcel transferred to them.

15.3. Otherwise:

- (a)
 - (i) If *--papers* is *both*, divide the elected candidate's surplus by the number of ballots in the surplus parcel. The quotient is the **surplus fraction**.
 - (ii) If *--papers* is *transferable*, divide the elected candidate's surplus by the number of transferable ballots in the surplus parcel. The quotient is the **surplus fraction**.
- (b) For each continuing candidate, multiply the number of transferable ballots in the surplus parcel with a next available preference for that continuing candidate by the surplus fraction.
- (c) Round up to the next integer so many of the quotients as necessary, and round the rest down, such that the quotients sum to the surplus fraction.
- (d) The quotients to round up are those with the greatest fractional parts. If 2 or more quotients have the same fractional part, round up the quotient of the continuing candidate(s) with the higher progress total, breaking any tie according to section 31.
- (e) For each continuing candidate, where n is the candidate's quotient, select the n last ballots in the surplus parcel with a next available preference for that continuing candidate. Make a further parcel, of value 1, of those selected ballots.
- (f) Transfer each further parcel to the corresponding continuing candidate.
- (g) Credit each continuing candidate with votes equal to the number of ballots in the further parcel transferred to them.

15.4. Proceed to subsection 8.5.

16. By order

16.1. This section applies in subsection 14.3(b), when *--sample* is *by_order*, to transfer the surplus parcel of an elected candidate.

16.2. If *--papers* is *transferable* and the number of transferable ballots in the surplus parcel is less than the surplus:

- (a) Take the transferable ballots in the surplus parcel, in the order each was added to the parcel. Sort them into further parcels, each of value 1, according to next available preference.
- (b) Transfer each further parcel to the corresponding continuing candidate.
- (c) Credit each continuing candidate with votes equal to the number of ballots in the further parcel transferred to them.

16.3. Otherwise:

- (a) If *--sample-per-ballot* is disabled:
 - (i) (A) If *--papers* is *both*, select the n last ballots in the surplus parcel, where n is the elected candidate's surplus.
 - (B) If *--papers* is *transferable*, select the n last transferable ballots in the surplus parcel, where n is the elected candidate's surplus.
 - (ii) Take the selected ballots, in the order each was added to the surplus parcel. Sort those that are transferable into further parcels, of value 1, according to next available preference.
 - (iii) Transfer each further parcel to the corresponding continuing candidate.
 - (iv) Credit each continuing candidate with votes equal to the number of ballots in the further parcel transferred to them.
- (b) If *--sample-per-ballot* is enabled:
 - (i) For each continuing candidate, prepare a further parcel of value 1.
 - (ii) Repeat the following procedure until the number of ballots transferred from the surplus parcel equals the elected candidate's surplus, or until no more vacancies remain to be filled:
 - (A) (I) If *--papers* is *both*, take the ballot in the surplus parcel which was added the last.
 - (II) If *--papers* is *transferable*, take the transferable ballot in the surplus parcel which was added the last.
 - (B) If the ballot is transferable:
 - (I) Sort it to the further parcel corresponding to the continuing candidate who is its next available preference.
 - (II) Credit that continuing candidate with 1 vote.
 - (C) Apply section 5 to elect any continuing candidates who must be elected.
 - (iii) Transfer each further parcel that is not empty to the corresponding candidate.

16.4. Proceed to subsection 8.5.

17. Cincinnati method

17.1. This section applies in subsection 14.3(c), when *--sample* is *cincinnati*, to transfer the surplus parcel of an elected candidate.

17.2. Divide the number of ballots in the surplus parcel by the elected candidate's surplus. Disregard any fraction in the quotient. The result is the **skip value**.

17.3. If *--sample-per-ballot* is disabled:

- (a) Take the ballots in the surplus parcel, in the order each was added to the parcel. Examine every n -th ballot starting from the 1st, where n is the skip value. Select those which are transferable, until the number of selected ballots equals the elected candidate's surplus.

- (b) If subparagraph (a) does not select enough transferable ballots to equal the elected candidate's surplus, next examine every n -th ballot starting from the 2nd, then every n -th ballot starting from the 3rd, and so on. Continue until enough transferable ballots are selected to equal the elected candidate's surplus, or until all ballots in the surplus parcel are examined.
- (c) Take the selected ballots, in the order each was selected. Sort them into further parcels, of value 1, according to next available preference.
- (d) Transfer each further parcel to the corresponding continuing candidate.
- (e) Credit each continuing candidate with votes equal to the number of ballots in the further parcel transferred to them.

17.4. If *--sample-per-ballot* is enabled:

- (a) For each continuing candidate, prepare a further parcel of value 1.
- (b) For the purpose of paragraph (c), examine the ballots in the surplus parcel in the following order:
 - (i) Take the ballots in the surplus parcel, in the order each was added to the parcel. Examine every n -th ballot starting from the 1st, where n is the skip value.
 - (ii) If subparagraph (a) does not select enough ballots to examine, next examine every n -th ballot starting from the 2nd, then every n -th ballot starting from the 3rd, and so on.
- (c) Repeat the following procedure until the number of ballots transferred from the surplus parcel equals the elected candidate's surplus, until all ballots in the surplus parcel are examined, or until no more vacancies remain to be filled:
 - (i) (A) If *--papers* is *both*, take the next ballot in the order given by paragraph (b).
 - (B) If *--papers* is *transferable*, take the next transferable ballot in the order given by paragraph (b).
 - (ii) If the ballot is transferable:
 - (A) Sort it to the further parcel corresponding to the continuing candidate who is its next available preference.
 - (B) Credit that continuing candidate with 1 vote.
 - (iii) Apply section 5 to elect any continuing candidates who must be elected.
- (d) Transfer each further parcel that is not empty to the corresponding candidate.

17.5. Proceed to subsection 8.5.

Division 4—Exclusion

18. Gregory method

- 18.1. This section applies in subsection 10.2(a), when *--method* is *wig*, *uig* or *eg*, to transfer 1 or more parcels from excluded candidates (the ***parcels to transfer***).
- 18.2. (a) If *--round-subtransfers* is *single_step* or *per_ballot*, apply subsection 18.3 to all of the parcels to transfer at once.

- (b) If *--round-subtransfers* is *by_value*:
 - (i) Aggregate the parcels to transfer, in the order each was received, into 1 combined parcel for each value.
 - (ii) Apply subsection 18.3 to each combined parcel in turn.
- (c) If *--round-subtransfers* is *by_parcel*, apply subsection 18.3 to each of the parcels to transfer in turn.

Subtransfer of 1 or more parcels

18.3. This subsection applies to transfer 1 or more parcels (out of the whole set of parcels to transfer) as described in subsection 18.2.

- (a) For each of those parcels:
 - (i) Take the transferable ballots in the parcel, in the order each was added to the parcel. Sort them into further parcels of the same value, according to next available preference.
 - (ii) Transfer each further parcel to the corresponding continuing candidate.
- (b) For each continuing candidate:
 - (i) (A) If *--round-subtransfers* is *per_ballot*, for each further parcel transferred to the continuing candidate, multiply the number of ballots in the further parcel by the the further parcel's value, and sum the products.
 - (B) If *--round-subtransfers* is not *per_ballot*:
 - (l) For each further parcel transferred to the continuing candidate, multiply the number of ballots in the further parcel by the further parcel's value, and sum the products.
 - (ii) (A) If *--round-votes* is disabled, credit the continuing candidate with votes equal to the result in subparagraph (i).
 - (B) If *--round-votes* is enabled and *n* decimal places are requested, truncate the result in subparagraph (i) to *n* decimal places. Credit the continuing candidate with votes equal to the result.

Completing the transfer

18.4. Once all of the parcels to transfer have been transferred under subsection 18.2, proceed to subsection 10.4.

19. Hare method

19.1. This section applies in subsection 10.2(b), when *--method* is *hare* or *ihare*, to transfer 1 or more parcels from excluded candidates (the ***parcels to transfer***).

19.2. If *--sample-per-ballot* is disabled:

- (a) Aggregate the transferable ballots from the parcels to transfer, in the order each parcel was received. Sort them into further parcels, of value 1, according to next available preference.

- (b) Transfer each further parcel to the corresponding continuing candidate.
- (c) Credit each continuing candidate with votes equal to the number of ballots in the further parcel transferred to them.

19.3. If *--sample-per-ballot* is enabled:

- (a) For each continuing candidate, prepare a further parcel of value 1.
- (b) Aggregate the transferable ballots from the parcels to transfer, in the order each parcel was received. Sequentially for each transferable ballot:
 - (i) Sort it to the further parcel corresponding to the continuing candidate who is its next available preference.
 - (ii) Credit that continuing candidate with 1 vote.
 - (iii) Apply section 5 to elect any continuing candidates who must be elected.
- (c) Transfer each further parcel that is not empty to the corresponding candidate.

19.4. Proceed to subsection 10.4.

20. Reset and re-iterate

- 20.1. This section applies in subsection 9.5, when *--exclusion* is *reset_and_reiterate*, at the exclusion of 1 or more candidates.
- 20.2. Remove all parcels from all candidates, and set each candidate's progress total to 0.
- 20.3. Un-elect each elected candidate, so that all previously elected candidates become continuing candidates again (but all excluded candidates remain excluded).
- 20.4. Count the ballots again according to section 4.

PART 3—MEEK METHOD

21. First stage

- 21.1. Set the keep value of each continuing candidate to 1.
- 21.2. Distribute the ballots in the input file to the candidates according to section 22.
- 21.3. Calculate the quota according to section 29.
- 21.4. Apply section 23 to elect any continuing candidates who must be elected.
- 21.5. This is the *end of a stage*. Proceed to section 24.

22. Distribution of ballots

- 22.1. This section applies in subsections 21.2, 27.2(b) and 28.6, to distribute the ballots in the input file to the candidates.
- 22.2. Set each candidate's progress total to 0.
- 22.3. For each ballot in the input file, in the order each appears:

- (a) Set the ballot's **value** to 1.
- (b) For each preference listed on the ballot, from first to last:
 - (i) (A) Multiply the ballot's value by the corresponding candidate's keep value.
(B) If *--round-votes* is enabled, and n decimal places are requested, truncate the quotient to n decimal places, and if the result is inexact, add 10^{-n} .
 - (ii) Credit the candidate with votes equal to the result of subparagraph (i).
 - (iii) (A) Subtract the candidate's keep value from 1. Multiply the ballot's value by the difference.
(B) If *--round-surplus-fractions* is enabled, and n decimal places are requested, truncate the quotient to n decimal places, and if the result is inexact, add 10^{-n} .
 - (iv) Set the ballot's *value* to the result of subparagraph (iii).

23. Election of continuing candidates

- 23.1. This section applies in subsections 21.4, 27.3 and 28.8, to elect any continuing candidates who must be elected.
- 23.2. Declare elected any continuing candidate who meets the quota, one by one in descending order of progress total, breaking any tie according to section 31.

Early bulk election of sure winners

- 23.3. This subsection applies if *--early-bulk-elect* is enabled, and the continuing candidates with the highest progress totals, up to the number of remaining vacancies (the **leading candidates**), each have a higher progress total than:
 - (a) the sum of all other continuing candidates' progress totals, plus
 - (b) the sum of all excluded candidates' progress totals, plus
 - (c) the total of any undistributed surpluses.
- 23.4. If subsection 23.3 applies, immediately declare elected each of the leading candidates, one by one in descending order of progress total, breaking any tie according to section 31. The count is then complete.

24. Second or subsequent stages

- 24.1. If no more vacancies remain to be filled, the count is complete.
- 24.2. Otherwise, if 1 or more candidates have surpluses which exceed the surplus tolerance under section 25, and *--defer-surpluses* is disabled or the distribution of surpluses cannot be deferred under section 26, apply section 27 to recalculate the elected candidates' keep values.
- 24.3. Otherwise, if the number of continuing candidates equals the number of remaining vacancies, declare elected all continuing candidates, one by one in descending order of progress total, breaking any tie according to section 31. The count is then complete.
- 24.4. Otherwise, perform an exclusion according to section 28.

24.5. Repeat this section until the count is complete.

25. Surplus tolerance

- 25.1. This section applies in subsections 24.2 and 27.2, if 1 or more candidates have surpluses, to determine if those surpluses exceed the surplus tolerance.
- 25.2. If *--meek-surplus-tolerance* is a percentage, $n\%$, the surpluses exceed the surplus tolerance if and only if any of the surpluses is greater than $n\%$ of the quota.
- 25.3. If *--meek-surplus-tolerance*, n , is not a percentage, the surpluses exceed the surplus tolerance if and only if the total of all surpluses is greater than n .

26. Deferring surplus distributions

- 26.1. This section applies in subsections 24.2 and 27.2, if *--defer-surpluses* is enabled, to determine when the distribution of surpluses must be deferred.
- 26.2. If there are fewer than 2 continuing candidates, the distribution of surpluses must be deferred.
- 26.3. Otherwise, if:
- (a) the total of all undistributed surpluses is less than the difference between the progress totals of the 2 continuing candidates with the lowest progress totals, and
 - (b) if *--bulk-exclude* is enabled and a bulk exclusion could be performed under section 30, the total of all undistributed surpluses is less than the difference between the sum of the progress totals of the continuing candidates who could be bulk excluded, and the progress total of the continuing candidate with the next lowest progress total,
- the distribution of surpluses must be deferred.
- 26.4. Otherwise, the distribution of surpluses must not be deferred.

27. Recalculation of keep values

- 27.1. This section applies in subsections 24.2 to recalculate the elected candidates' keep values.
- 27.2. If 1 or more candidates have surpluses which exceed the surplus tolerance under section 25, and *--defer-surpluses* is disabled or the distribution of surpluses cannot be deferred under section 26:
- (a) For each elected candidate:
 - (i) (A) Multiply the candidate's keep value by the quota. Divide the quotient by the candidate's progress total.
 - (B) If *--round-values* is enabled and n decimal places are requested, truncate the quotient to n decimal places, and if the result is inexact, add 10^{-n} .
 - (ii) Set the candidate's keep value to the result of subparagraph (i).
 - (b) Distribute the ballots in the input file to the candidates according to section 22.
 - (c) Recalculate the quota according to section 29.

- (d) If *--no-immediate-elect* is disabled, and 1 or more continuing candidates meet the quota or subsection 23.3 applies, proceed immediately to subsection 27.3.
- (e) Otherwise, repeat this subsection until there are no surpluses exceeding the surplus tolerance under section 25, or if *--defer-surpluses* is enabled, the distribution of surpluses can be deferred under section 26.

27.3. Apply section 23 to elect any continuing candidates who must be elected.

27.4. This is the *end of a stage*. Return to section 24.

28. Exclusion

28.1. This section applies in subsection 24.4 to exclude 1 or more continuing candidates.

28.2. If *--meek-nz-exclusion* is enabled, apply subsection 27.2(a).

28.3. When this section applies:

- (a) If it is the first time this section is applied, and 1 or more continuing candidates have a progress total equal to or lower than the value of *--min-threshold*, apply the following procedure to all those candidates.
- (b) Otherwise, if *--bulk-exclude* is enabled and a bulk exclusion can be performed under section 30, apply the following procedure to the candidates to be bulk excluded.
- (c) Otherwise, apply the following procedure to the continuing candidate with the lowest progress total, breaking any tie according to section 31.

28.4. Declare that candidate, or those candidates, excluded, and set their keep values to 0.

28.5. If *--early-bulk-elect* is enabled, and the number of continuing candidates equals the number of remaining vacancies, declare elected all continuing candidates, one by one in descending order of progress total, breaking any tie according to section 31. The count is then complete.

28.6. Distribute the ballots in the input file to the candidates according to section 22.

28.7. Recalculate the quota according to section 29.

28.8. Apply section 23 to elect any continuing candidates who must be elected.

28.9. This is the *end of a stage*. Return to section 24.

PART 4—PROVISIONS APPLYING TO ALL METHODS

Division 1—General provisions

29. Calculation of quota

29.1. This section applies in subsections 4.3, 5.2, 5.3(b)(i), 10.3, 21.3, 27.2(c) and 28.7, to calculate the quota.

29.2. (a) If *--quota-mode* is *static*, *ers97*, *ers76* or *dynamic_by_total*:

- (i) If *--quota* is *droop* or *droop_exact*, divide the sum of all candidates' progress totals by 1 more than the number of vacancies.
- (ii) If *--quota* is *hare* or *hare_exact*, divide the sum of all candidates' progress totals by the number of vacancies.

- (b) If *--quota-mode* is *dynamic_by_active*:
 - (i) Add:
 - (A) the sum of all continuing candidates' progress totals, plus
 - (B) the sum of all excluded candidates' progress totals, plus
 - (C) the total of any undistributed surpluses.
 - (ii) If *--quota* is *droop* or *droop_exact*, divide the sum in sub-paragraph (i) by 1 more than the number of remaining vacancies.
 - (iii) If *--quota* is *hare* or *hare_exact*, divide the sum in sub-paragraph (i) by the number of remaining vacancies.

- 29.3. (a) If *--round-quota* is disabled, the quotient is the **quota**.
- (b) If *--round-quota* is enabled and *n* decimal places are requested:
 - (i) If *--quota* is *droop* or *hare*, truncate the quotient to *n* decimal places and add 10^{-n} . The result is the **quota**.
 - (ii) If *--quota* is *droop_exact* or *hare_exact*, truncate the quotient to *n* decimal places. If the result is exact, it is the **quota**. Otherwise, add 10^{-n} , and the result is the **quota**.

30. Bulk exclusion

- 30.1. This section applies in subsections 7.3, 9.2(b), 26.3(b) and 28.3(b), if *--bulk-exclude* is enabled, to determine which candidates (if any) can be bulk excluded.
- 30.2. In a bulk exclusion, select for exclusion as many of the continuing candidates with the lowest progress totals as possible, provided that:
 - (a) enough other continuing candidates remain to fill all remaining vacancies, and
 - (b) the sum of the progress totals of the selected candidates, plus the total of any undistributed surpluses, is lower than the progress total of the candidate with the next lowest progress total.

Division 2—Tie breaking

31. Tie breaking generally

- 31.1. In order to break a tie, apply each strategy listed in *--ties*, in the order listed, until a strategy is able to break the tie.
- 31.2. If the strategy is *backwards*, apply section 32.
- 31.3. If the strategy is *forwards*, apply section 33.
- 31.4. If the strategy is *random*, apply section 34.
- 31.5. If the strategy is *prompt*, apply section 35.

32. Backwards tie breaking

32.1. In the *backwards* strategy, if 2 or more candidates (***tied candidates***) have the equal highest progress total, and it is necessary to break the tie:

- (a) If 1 tied candidate had a higher progress total than any other tied candidate at the end of the previous stage, select that candidate.
- (b) If 2 or more tied candidates had (out of the tied candidates) the equal highest progress total at the end of the previous stage, each other tied candidate is no longer considered in the tie, and this subsection is applied to each preceding stage until 1 candidate is selected.
- (c) If no candidate can be selected under paragraphs (a) and (b), the tie cannot be broken under the *backwards* strategy.

32.2. In the *backwards* strategy, if 2 or more candidates (***tied candidates***) have the equal lowest progress total, and it is necessary to break the tie:

- (a) If 1 tied candidate had a lower progress total than any other tied candidate at the end of the previous stage, select that candidate.
- (b) If 2 or more tied candidates had (out of the tied candidates) the equal lowest progress total at the end of the previous stage, each other tied candidate is no longer considered in the tie, and this subsection is applied to each preceding stage until 1 candidate is selected.
- (c) If no candidate can be selected under paragraphs (a) and (b), the tie cannot be broken under the *backwards* strategy.

33. Forwards tie breaking

33.1. In the *forwards* strategy, if 2 or more candidates (***tied candidates***) have the equal highest progress total, and it is necessary to break the tie:

- (a) If 1 tied candidate had a higher progress total than any other tied candidate at the end of the first stage, select that candidate.
- (b) If 2 or more tied candidates had (out of the tied candidates) the equal highest progress total at the end of the first stage, each other tied candidate is no longer considered in the tie, and this subsection is applied to each subsequent stage until 1 candidate is selected.
- (c) If no candidate can be selected under paragraphs (a) and (b), the tie cannot be broken under the *forwards* strategy.

33.2. In the *forwards* strategy, if 2 or more candidates (***tied candidates***) have the equal lowest progress total, and it is necessary to break the tie:

- (a) If 1 tied candidate had a lower progress total than any other tied candidate at the end of the first stage, select that candidate.
- (b) If 2 or more tied candidates had (out of the tied candidates) the equal lowest progress total at the end of the first stage, each other tied candidate is no longer considered in the tie, and this subsection is applied to each subsequent stage until 1 candidate is selected.
- (c) If no candidate can be selected under paragraphs (a) and (b), the tie cannot be broken under the *forwards* strategy.

34. Random tie breaking

- 34.1. In the *random* strategy, a tie between 2 or more candidates is to be broken at random.
- 34.2. The method of breaking the tie at random is implementation-defined.

35. Tie breaking by prompt

- 35.1. In the *prompt* strategy, a tie between 2 or more candidates is to be broken as directed by the user.

Division 3—Numeric representation

36. Rational arithmetic

- 36.1. This section applies when *--numbers* is *rational*.
- 36.2. When this section applies, unless otherwise specified, all calculations must be performed without rounding, and the result represented exactly, as a fraction if necessary.

37. Fixed-point arithmetic

- 37.1. This section applies when *--numbers* is *fixed*.
- 37.2. When this section applies, unless otherwise specified:
 - (a) In subsections 11.2, 12.2(b)(i), 13.3(b)(i) and 15.3(a) (in the calculation of the surplus fraction or transfer value), the calculation must be performed without rounding, and the quotient represented exactly, as a fraction if necessary.
 - (b) For all other calculations, the result must be truncated to n decimal places, where n is given by *--decimals*.

38. Guarded fixed-point arithmetic

- 38.1. This section applies when *--numbers* is *gfixed*.
- 38.2. When this section applies, unless otherwise specified:
 - (a) In subsections 11.2, 12.2(b)(i), 13.3(b)(i) and 15.3(a) (in the calculation of the surplus fraction or transfer value), the calculation must be performed without rounding, and the quotient represented exactly, as a fraction if necessary.
 - (b) For all other calculations, the result must be truncated to $2n$ decimal places, where n is given by *--decimals*.
- 38.3. When this section applies, 2 numbers are considered equal, and neither greater or lesser than the other, if the difference between the 2 numbers is less than $\frac{10^{-n}}{2}$.

39. 64-bit floating-point arithmetic

- 39.1. This section applies when *--numbers* is *float64*.
- 39.2. When this section applies, unless otherwise specified:

- (a) In subsections 11.2, 12.2(b)(i), 13.3(b)(i) and 15.3(a) (in the calculation of the surplus fraction or transfer value), the calculation must be performed without rounding, and the quotient represented exactly, as a fraction if necessary.
- (b) For all other calculations, the calculation must be performed in accordance with the *IEEE Standard for Floating-Point Arithmetic* (IEEE 754) for double-precision binary floating-point (binary64) numbers, and the result represented as a binary64 number.

Division 4—Interpretation

40. Definitions

- 40.1. **ballot** means a record of a voter's preferences.
- 40.2. **continuing candidate** means a candidate who is not withdrawn, elected or excluded.
- 40.3. **end of a stage**: see subsections 4.5, 8.6, 10.5, 21.5, 27.4 and 28.9.
- 40.4. **meet**: a continuing candidate *meets* the quota (or vote required for election, as the case requires):
 - (a) if *--quota-criterion* is *gt*: if the candidate's progress total is higher than the quota (or vote required for election),
 - (b) if *--quota-criterion* is *geq*: if the candidate's progress total is higher than or equal to the quota (or vote required for election).
- 40.5. **next available preference**, of a ballot, means the continuing candidate highest on the ballot's preferences, if there is such a candidate.
- 40.6. **non-transferable ballot** means a ballot which does not have a next available preference.
- 40.7. **parcel** means a sequence of ballots, with an associated value.
- 40.8. **progress total**, of a candidate, means the total votes credited to the candidate.
- 40.9. **quota** means the quota calculated in section 29.
- 40.10. **surplus**, of an elected candidate who has a progress total higher than the quota, means the difference between the candidate's progress total and the quota.
- 40.11. **transferable ballot** means a ballot which has a next available preference.