APPENDIX B: OPM FLOW RELEASE HISTORY

APPENDIX TABLE OF CONTENTS

B.1 RELEASE 2023-10

We dedicate this OPM 2023-10 release to our colleague and friend David Baxendale. David passed away in late June 2023 after a short severe illness. Our thoughts are with his wife and son. The OPM community is very thankful for all his contributions to OPM and the fruitful discussions with him about issues with and advancements of the simulator.

David started contributing to OPM in 2016 as *OPMUSER* on github and continued his good work until his very last days. We owe the OPM Reference manual to him. He started this heroic effort in 2017 and it now has thousands of pages. We, his colleagues and friends, are and will be surely missing him with his reservoir engineering expertise and know-how, his enthusiasm, and humor.

The 2023-10 release consists of some new features and various improvements and bug fixes. Our main target was to support more keywords used for relevant fields and reduce differences between OPM flow and the commercial simulator. These improvements include:

- Added support for temperature (THERMAL) plus salt precipitation (PRECSALT) modeling in gas-water-brine (GAS-WATER-BRINE) systems.

- Added support for modeling dissolved gas in water (DISGASW) and vaporized water in the gas phase (VAPWAT) in the thermal-gas-water simulator.

- Support for modeling FOAM combined with SOLVENT.

- Partial support for WAGHYSTR keyword (Water-Alternating-Gas hysteresis).

- Improvements to many user-facing error messages.

- More graceful exits for problems in parallel runs.

- Temperature is output to the RESTART file if requested via RPTRST.

- Added support for WBP, WBP4, WBP5 and WBP9 in the SUMMARY section to output well block averaged pressures for open completions.

- Added support for initializing constant flux aquifers from a restart.

- Faster two-point flux-approximation introduced in the last release is now also used for linearizing gas-oil cases with energy (with diffusion) and gas-oil diffusion.

B.1.1 NEW AND DEPRECATED COMMAND LINE OPTIONS

The major command line changes made for this release are summarized in Table B.1

No.	Variable Name	Description	Default
OPM Flow 2023-10 New And Deprecated Command Line Options			
1	--linear-solver	Added option to use the experimental hybrid solver configuration. Valid options are: ilu0 (default), cprw, cpr (an alias for cprw), cpr_quasiimpes, cpr_trueimpes, amg or hybrid (experimental). Alternatively, you can request a configuration to be read from a JSON file by giving the filename here, ending with '.json.'.	ilu0
2	--linear-solver-print-json-definition	Added option to write the JSON definition of the linear solver setup to the DBG file.	true

No.	Variable Name	Description	Default
		OPM Flow 2023-10 New And Deprecated Command Line Options	
3	--linear-solver-reduction	The minimum reduction of the residual which the linear solver must achieve.	0.01
4	--local-domain-ordering-measure	Added parameter to specify the domain ordering measure as either residual or pressure when using the NLDD solver (#4738).	pressure
5	--local-domains-partitioning-imbalance	Subdomain partitioning imbalance tolerance for the NLDD solver. 1.03 is 3 percent imbalance.	1.03
6	--local-domains-partitioning-method	Subdomain partitioning method for the NLDD solver. Allowed values are 'zoltan', 'simple', and the name of a partition file ending with '.partition'.	zoltan
7	--local-solve-approach	Choose local solve approach for the NLDD solver. Valid choices are jacobi and gauss-seidel.	jacobi
8	--local-tolerance-scaling-cnv	Set lower than 1.0 to use stricter convergence tolerance for local solves when using the NLDD solver.	0.01
9	--local-tolerance-scaling-mb	Set lower than 1.0 to use stricter convergence tolerance for local solves when using the NLDD solver.	1
10	--local-well-solve-control-switching	Added trigger to enable (true) or disable (false) well control/status switching during local well equation solves when using the NLDD solver (#4895).	false
11	--max-local-solve-iterations	Max iterations for local solves with NLDD nonlinear solver.	20
12	--maximum-water-saturation	Maximum water saturation.	1
13	--network-max-iterations	Maximum number of iterations in the network solver before giving up.	200
14	--network-max-strict-iterations	Maximum iterations in network solver before relaxing tolerance.	100
15	--nldd-num-initial-newton-iter	Added option to specify number of global non-linear (Newton) iterations performed by the NLDD solver before starting the local non-linear iterations. The default value of 1 preserves the current behavior (#4922).	1
16	--nonlinear-solver	Choose nonlinear solver. Valid choices are newton or nldd.	newton

OPM Flow 2023-10 New And Deprecated Command Line Options			
No.	Variable Name	Description	Default
17	--num-local-domains	Number of local domains for NLDD nonlinear solver. Note this is an experimental feature in the current release 2023.10 that is expected to be more complete and tested by the 2024.10 release.	0
18	--save-step	Added new options to keep only the last step. Save serialized state to .OPMRST file. Either a specific report step, "all" to save all report steps or ":x" to save every x'th step. Use negative values of "x" to keep only the last written step, or "last" to save every step, keeping only the last (#4807).	""
19	--water-only-threshold	Cells with water saturation above or equal to this value are considered one-phase water only.	1
20	--load-file	FileName for .OPMRST file used to load serialized state. If empty (""), CASENAME.OPMRST is used.	""
21	--num-pressure-points-equil	Number of pressure points (in each direction) in tables used for equilibration (#4718).	2000
22	--save-file	FileName for .OPMRST file used for saving serialized state. If empty, CASENAME.OPMRST is used.	""
23	--use-average-density-ms-wells	Approximate segment densities by averaging over segment and its outlet.	false
24	--ecl-max-time-step-size-after-well-event	Maximum time step size after a well event (seconds). Default is equivalent to 1 year. Depreciated.	3.15576e+07
25	--ecl-restart-shrink-factor	Factor by which the time step is reduced after convergence failure. Depreciated	3

Notes:

1) Cells colored in green in the "No." column indicate a new command line option or a change to an existing option for this release.

2) Cells colored in orange in the "No." column indicate the command line option is available but is now "hidden" from the main help listing, --help. These options can be listed using the --help-all command line option, that lists all the command line options included in the release, including experimental, obsolete, hidden and deprecated options.

3) Cells colored in red in the "No." column indicate a deprecated command line option for this release.

Table B.1: OPM Flow 2023-10 New and Deprecated Command Line Options

B.1.2 NEW FEATURES

In addition to the above the following new features have been added to the simulator:

1) When the general well specification data is defined by the WELSPECS keyword in the SCHEDULE section the well can now be assigned directly to the FIELD group in item 2 GRPNAME (*#3485* and *#4608*). Previously there was a restriction preventing wells from being parented directly to FIELD. Although wells are now allowed to be parented directly to FIELD, this is discouraged and a warning message will be issued. Mixing wells and groups as children of a single group is still forbidden.

2) Added support for dissolved gas in water (DISGASW) in the gas-water simulator with salt precipitation (PRECSALT) and vaporized water in the gas phase (VAPWAT) (*#4623*). However, input of gas solubility in water is not currently supported so this option is only useful in combination with CO2STORE.

3) Added support for modeling dissolved gas in water (DISGASW) and vaporized water in the gas phase (VAPWAT) in the thermal-gas-water simulator (*#4661*).

4) Added support for temperature (THERMAL) plus salt precipitation (PRECSALT) modeling in gas-water-brine (GAS-WATER-BRINE) systems as specified in the RUNSPEC section (*#4650*). This has to date only been tested in combination with CO2STORE. Note that generally, if the PRECSALT keyword has been activated in the input deck then the VAPWAT keyword should also be activated.

5) Added support for modeling foam (FOAM) plus solvent (SOLVENT) in the simulator (*#4654*, *#3523* and *#805*). In addition, gas or water is now allowed as the transport phase for the foam as specified by FOAMOPTS item 1 (previously only gas was supported as the foam transport phase).

6) Added support for WVFPDP in the SCHEDULE section (*#4620* and *#3504*). The WVFPDP keyword modifies a well's Bottom-Hole Pressure ("BHP") estimated by the simulator by interpolation of the Vertical Flow Performance ("VFP") tables.

7) Added support for GCONPROD item 7 ACTION equal to NONE in the SCHEDULE section, which specifies that no action is to be taken if the oil, water, gas or liquid rate constraints are violated. Previously only the RATE option was supported by the simulator (*#4658*).

8) Added partial support for WAGHYSTR keyword in the PROPS section (*#4710* and *#3542*). This keyword defines the parameters for the Water-Alternating-Gas ("WAG") hysteresis option, when the hysteresis option has been activated by the HYSTER variable on the SATOPTS keyword in the RUNSPEC section. Only gas phase hysteresis is currently supported by the WAGHYSTR keyword. The residual oil modification fraction, which would only be active when the STONE1 three-phase oil relative permeability model is used, is not currently supported.

9) Support added for PPCWMAX to limit the maximum capillary pressure scaling when initializing the model using SWATINIT, and the option to modify the connate water saturation to match the input water saturation if the capillary pressure is exceeded (*#4707* and *#3570*).

10) Added support for WINJMULT in the SCHEDULE section to define pressure dependent injectivity multipliers for injection wells and can be used to approximate the change in injectivity due to hydraulic fracturing (*#4686*).

11) Added partial support for WPAVE and WWPAVE defining the method and parameters for calculating a well's block average pressures for either all wells or specific wells (*#4695*, *#4694* and *#4693*). Calculation of block averages pressures is currently only supported for OPEN completions (not for ALL completions) as specified in WPAVE item 4 and WWPAVE item 5.

12) Aquifer keywords have been enabled when H2STORE is specified in the RUNSPEC section with brine modeled by the OIL phase (*#4791*). This is similar to the behavior when CO2STORE is specified.

13) Added a model for formation damage due to suspended solids in the injection water (*#4346* and *#3313*). New OPM specific well keywords WINJDAM, WINJFCNC and WINJCLN have been added to the SCHEDULE section. WINJDAM sets up the filter cake properties for the specified water

injection well, WINJFCNC defines the filtrate concentration in the injection water, and WINJCLN specifies that a fraction of the filter cake has been cleaned up.

14) User defined arguments (UDA) have been enabled for the WINJFCNC keyword item 2 (FCONCPPM) the injection concentration parameter (*#4763* and *#3614*).

15) Added partial support for GRUPNET, which defines the standard group network parameters used to model the flow and pressure behavior within the network (*#4760*, *#3609*, *#4815* and *#3651*). GRUPNET item 5 OPTION1 equals NO only is supported (defines how the groups production target should be achieved). Item 6 OPTION2 equals NO or FLO is supported but ALQ is not supported (defines how gas lift gas flows through the group's pipeline). Item 7 OPTION3 equals NONE only is supported (defines if the ALQ-PIPE variable should be reset).

16) Added partial support for GECON (*#4819* and *#3657*). Item 7 WORKOVER only supports NONE, workover procedures are not currently implemented. Item 8 ENDRUN only supports NO, end run is not currently implemented. Item 9 MXWELLS is not supported and must be defaulted.

17) Support has been added for the CSKIN keyword in the SCHEDULE section to modify the connection skin factor (*#4871* and *#3681*).

18) Support for WSF and GSF keywords in the PROPS section has been added for H2STORE runs (as for CO2STORE) (*#4528*). The WSF and GSF keywords define the water relative permeability data versus water saturation tables and the gas relative permeability data versus gas saturation tables for when only gas and water are present in the input deck. These keywords can only be used with either the CO2STORE or H2STORE models.

19) Support has been added for setting the WGRUPCON keyword Item 2 STATUS in the SCHEDULE section equal to NO (*#4575*).

20) Support has been added for setting the PINCH item 2 PINCHOPT parameter equal to NOGAP in the GRID section. This parameter is now fully supported by the simulator. Previously only the default GAP option was supported (*#4603*).

21) Added support for initializing constant flux aquifers from a restart (*#4520* and *#4519*). In particular, form constant flux aquifer objects from the restart step's collection if available and properly initialize their total produced volume.

22) Added support for gas-water-solvent systems (*#4568* and *#4548*).

23) Added partial support for setting items 11, 12 and 13 of GCONPROD in the SCHEDULE section: ACTWAT, ACTGAS and ACTLIQ respectively define the action to be taken if the water rate (WRAT), gas rate (GRAT) and liquid rate (LRAT) constraints defined by GCONPROD are violated. Supported options are now NONE or RATE. Options CON, +CON, WELL, and PLUG are not currently supported (*#4748*).

24) Added support for Non-linear Domain Decomposition (NLDD) as the non-linear solver.

25) The option has been added to allow well control or well status to be updated during the iteration process during local solve for the well equations (*#4895*). In this way the converged well is given the correct control/status for the current reservoir state. A command line argument *–local-well-solve-control-switching=true* has been added to trigger the use of the function (this is *false* by default).

B.1.3 IMPROVEMENTS

Improvements include:

1) The correct version of flow is now selected for two-phase gas-water systems with either water vaporized in the gas phase (VAPWAT) and/or gas dissolved in the water phase (DISGASW) as defined in the RUNSPEC section (*#4592*). Previously the wrong version of flow was selected for gas-water systems with water vaporized in the gas phase (but no gas dissolved in the water phase).

2) The boundary conditions keyword BC has been deprecated and been split into two parts: BCCON in the GRID section where the block indices and direction are set, and BCPROP in the SCHEDULE section where the type and value of the boundary condition are set (*#3482*, *#802* and *#949*).

3) The maximum number of allowable EQLNUM regions has been increased from 255 to 65525 (*#4726*).

4) A stricter convergence tolerance has been imposed on standard (not multi-segment) wells with a zero rate target. This change improves the results of a reported case with zero reservoir volume rate (RESV) control and potentially improves the material balance of the whole system (*#4572*).

5) When testing a gas lift well under THP control, if the well does not converge with the maximum artificial lift quantity (ALQ) then the simulator will now try to reduce ALQ in increments to check if the well equations converge with a smaller ALQ (*#4579*).

6) The bisection algorithm has been updated to keep track of the size of its search interval. The algorithm will now stop iterating if the minimum interval size is reached (*#4617*).

7) The simulator has been modified to ensure that THP constraints are only applied to prediction wells and not history match wells (*#4615*).

8) The simulator has been updated to avoid requesting the ALQ value for injectors, the ALQ value is only requested for producers (*#4648*).

9) The simulator has been modified to output temperature information to the restart file if TEMP is specified in the RPTRST keyword or if THERMAL is set in the RUNSPEC section even if the command line option *--enable-opm-rst-file=false* is set (*#4646*). The command line option *--enable-opm-rst-file* is a Boolean value that controls the output of OPM specific data sets to the commercial simulator's restart file to enable restart of OPM Flow runs by OPM Flow (*true*), or not to output the data (*false*).

10) Update the calculation of immobile gas saturation to take into the account trapped saturation (calculated when the hysteresis model is used) in the calculation of mobile and immobile fluid volumes in place (*#4642* and *#3517*). The hysteresis model is activated by the specifying the HYSTER parameter of the SATOPTS keyword in the RUNSPEC section.

11) An error message will now be generated if invalid region numbers SATNUM, PVTNUM, IMBNUM or EQLNUM are input (*#4705*). Valid region numbers are positive integers less than or equal to the maximum number of regions specified in the RUNSPEC section.

12) Added setVapPars() at the start of the report step to properly handle oil vaporization parameters (VAPPARS) updates in the SCHEDULE section (*#4677*).

13) If vaporised water (VAPWAT) is present in the model but the initial equilibrium vaporized water in gas ratio (RVW) for an equilibration region is not explicitly defined by a value versus depth table (RVWVD), and the datum depth is not at either the gas-oil contact (if oil is present) or the gas-water contact (if oil is not present) then the values of RVW will be initialised to zero (*#4647* and *#4688*). This makes it easier to include VAPWAT in CO2STORE cases.

14) The mass balance limit (XXXMBE) from the keyword TUNING is now used if it is explicitly specified (not defaulted) and the command line argument *--enable-tuning=true* is used (*#4621* and *#3522*).

15) The simulator now gives a more informative error message if the input grid has no active cells at all. Often this points to an error in the input data and this change might help in finding the problem (*#4735*).

16) A more user-friendly error message is now reported when the time step is cut too often or too much. (*#4746*).

17) Perform a more graceful exit instead of MPI_Abort for expected exceptions in parallel runs. Instead of unconditionally issuing MPI_Abort if a fatal exception is encountered, the simulator will try to test whether all processes have experienced this exception and if this is the case just terminate normally with an exit code that signals an error. MPI_Abort is still used if not all processes get an exception as

this is the only way to ensure that the program aborts (#4750). This approach also works around issues in some MPI implementations that might not correctly return the error.

18) Hydrostatic and acceleration pressure losses have been included for well segments representing an inflow control device (ICD) (#4824). Valves may be placed in long segments with significant depth differences (for example, at branch inlets), where the hydrostatic contribution in particular may be significant.

19) An error message is now reported if a negative oil or water saturation is passed to the RV and RVW initialization routine (#4675).

20) When approximately zero well rates are encountered during iterations (pre-convergence), gas/water fractions become highly inaccurate which in turn may lead to the solver getting stuck or the well getting shut prematurely. The code has been updated to switch to explicit VFP table lookup whenever the rate drops below the lowest value in the table. The logic around explicit lookup is also updated so that this approach also works for just opened wells (#4669).

21) Information about linear system sizes is now output to the DBG file (#4734 and #4754).

22) For stopped or zero-rate-target wells the *alternative_well_rate_init* procedure previously returned unscaled well-rates resulting from a zero-bhp condition. This could lead to convergence failures for network balancing since the initialized rates could be off by orders of magnitude. The code now skips this procedure for stopped or zero-rate-target wells reducing the risk of convergence failures (#4817).

23) The two-point flux-approximation (TPFA) has been added as a linearizer for gas-oil cases with energy (with diffusion) and gas-oil diffusion (#4825 and #4816). All energy cases now have diffusion enabled.

24) Added RESTART file output for the geomechanical module (#4803 and #4588).

25) Relaxation factors slightly outside the interval [0, 1] in the standard well model are reset to the interval limits, while keeping the assertion for factors further outside the interval to possibly pick up failure cases (#4862).

26) Connections between reservoir cells and numerical aquifer cells, or between numerical aquifer cells when multiple such cells define a single numerical aquifer, are now always treated as NNCs for output purposes (#4821).

27) Regional transmissibility multipliers such as those entered in the MULTREGT keyword are now applied to explicit input non-neighbor connections (NNC). This now implements all known connection behaviors for inter-region connections. In the commercial simulator, if the region numbers specified in MULTREGT items 1 and 2 are equal and positive then the transmissibilities within the region as well as any transmissibilities connecting any other regions are multiplied by the given value. The option to specify transmissibility multipliers in this way using MULTREGT is not yet supported (#4822 and #4821).

28) The name of the missing OPM restart file is reported in the error message when it cannot be located (#4870).

```
Error locating serialized restart file PATH/FILENAME.OPMRST
```

29) Added PRT file output when group economic criteria for production groups GECON is activated (#4866).

30) Reduced repetitive output of network information when running in parallel (#4879).

31) The lower limit for bottom hole pressure (BHP) in Newton updates has been reduced slightly from 1 bar. This allows for cases that might have a defaulted BHP constraint of 1 bar (#4877).

32) The region set name matching algorithm has been changed to using unique prefixes. This enables the simulator to recognize that the region set name FIPUNI should match the user defined region name FIPUNIT (*#4868*).

33) Debug output sent to the DBG file is no longer also echoed to the console as well (*#4955* and *#4941*).

34) Updated the derivatives and also the Jacobian matrix for the multisegment well pressure equations (*#4640*).

35) The intensive quantities for $timeIdx==1$ corresponding to the start of the current timestep are now updated if we do not use the storage cache, or if we cannot recycle the first iteration storage (*#4662*).

36) Improved message issued when shutting a well because it fails to converge (*#4741*).

37) Damaris was updated in version 1.8.0 to support the HDF5 *H5Sselect_elements()* capability to rewrite data in memory to another order on disk. This allows (MPI decomposed) local simulation data to be written back to its original global position on disk. To support this a new element was added to the Damaris XML <variable...> type, named "select-file", along with some other options (not required by OPM Flow). This keyword is added to the basic in-built Damaris XML file of OPM Flow (*#4830*).

In addition, the following new SUMMARY keywords are now recognized as described by the comments in Table B.2.

No.	Summary Keyword	Comment
1	WBP, WBP4, WBP5 and WBP9	Added support for SUMMARY vectors to output well block averaged pressures for open completions (*#4695*, *#4694* and *#4693*).
2	WINJFVR, WINJFVT and WINJFC	Added support for SUMMARY keywords relating to filtration injection modelling (*#4790*, *#3628* and *#3626*). Added injection well SUMMARY vectors for filtrate volume injection rate (volume rate), filtrate volume injection total (volume), and filtrate injection concentration (ppm).
3	CINJFVR, CINJFVT, CFCSKIN, CFCWIDTH, CFCPERM, CFCPORO, CFCRAD and CFCAOF	Added support for SUMMARY keywords relating to filtration injection modelling (*#4790*, *#3628* and *#3626*). Added injection well connection SUMMARY vectors for filtrate volume injection rate (volume rate), filtrate volume injection total (volume), skin factor due to filtration (dimensionless), thickness of filter cake (Length), permeability of filter cake (MD), porosity of filter cake (dimensionless), well bore radius used in the filtration modeling (Length), and well bore area of flow used in the filtration modeling (Area).
4	SxDEN, SDENM and SMDEN	Added support for SUMMARY vectors to output fluid densities at the block and well segment levels (*#4744*, *#3594* and *#3593*). Added well segment SUMMARY vectors for phase density of phase x (segment conditions), fluid mixture density weighted by phase flowing fractions, and fluid mixture density weighted by phase flowing fractions with exponents. Phase x is one of O (oil), G (gas), or W (water).
5	BxDEN and BDENx	Added support for SUMMARY vectors to output fluid densities at the block and well segment levels (*#4744*, *#3594* and *#3593*). Added block SUMMARY vectors for phase density of phase x. Phase x is one of O (oil), G (gas), or W (water).
6	BFLOWI, BFLOWJ, and BFLOWK	Added support for SUMMARY vectors BFLOWI, BFLOWJ and BFLOWK to request block oil/gas/water flow rates at surface conditions (*#4867*, *#3675* and *#827*). This does not require FLOWS to be specified in RPTRST.

Table B.2: New SUMMARY Keywords for the 2023-10 Release

B.1.4 BUG FIXES

The following bug fixes and improvements have been incorporated into this release.

1) Fixed the issue of incorrectly using the gas-oil contact depth for initialization of vaporized water (RVW) in the special case of a two-phase gas-water system. The gas-water contact depth is now used in this case (*#4688* and *#4647*).

2) Fixed a bug in the group pressure maintenance (GPMAINT) code (*#4664*). Previously, if negative group pressure maintenance rates were calculated, they would first be used to incorrectly update the GPMAINT error integral, before the rates were later set to zero. Now the simulator only calculates rates for injectors if the pressure is below the regional pressure target (or for producers if the pressure is above the regional pressure target).

3) Bug fixes related to the handling of gas dissolved in water ratio (RSW) and water vaporized in gas ratio (RVW) in the standard well model (*#4591*).

4) The max size of the next time step is now only used when specified in TUNING or NEXTSTEP (*#4660*).

5) If the data file contains the CPR keyword then the "CPR" preconditioner should be used unless it is overridden by a command line argument. Previously this was incorrectly overridden by the command line argument --linear-solver-max-iter, the correct command line argument --linear-solver is now used (*#4700*).

6) The user is now able to specify any number of threads, this prevents only one thread being used on some hardware where the number of processors would always be reported as one when using MPI and OpenMP (irrespective of the actual number). The behaviour is now: (a) if nothing is specified then 2 threads are used, (b) if OMP_NUM_THREADS is specified then this number is used regardless of the hardware and the command line argument --threads-per-process is ignored, and (c) if --threads-per-process is used and OPM_NUM_THREADS is not set then the number specified on the command line is used (*#4709*). There is a check to make sure that the number of threads used by the linearizer is consistent (*#811*).

7) Fixed a bug related to indexing in the temperature boundary condition (*#4761*).

8) Gas dissolved in oil (RS) and oil vaporized in gas (RV) ratio initialized using value versus depth tables (RSVD, RVVD) should be limited by their respective saturated values. Fixed a bug where this limit was not applied at depths outside the range of depths in the RSVD or RVVD table (*#4723*).

9) For producers where all perforations have zero rates the perforation mixture fraction is approximated using the (inverse formation volume factor times mobility) ratio, and weight the perforation rates using the well transmissibility. The perforation mixture fraction was previously approximated using only the mobility ratio (*#4681*).

10) A case under investigation has some cells containing only oil and water (zero gas saturation), which have zero relative permeability (and mobility) for all the three phases. This caused problems in part of the code which assumed the total mobility was non-zero. For perforations having zero mobility for all the phases, the simulator now uses a small value to generate small perforation rates for those perforations, at the same time, the simulator can use these rates to recover the mixing ratios for those perforations (*#4682* and *#4681*).

11) The correct formation volume factors are now used in the case of zero phase rates resulting in zero RS, RV, RSW or RVW. Previously the saturated formation volume factor was used in these cases (*#4590*).

12) The reservoir volume rate constraint (RESV) in GCONPROD was not honoured. This has been fixed (*#4687*).

13) Previously, in the case of zero threshold pressure and zero pressure difference, the code would set the pressure difference explicitly to zero. This would also set any derivatives to zero, which could disconnect the corresponding matrix rows. The code no longer sets the pressure difference to zero when not necessary (#4701).

14) Code has been updated to avoid dividing by zero when scaling the well rates in updateWellStateRates() (#4715 and #4649).

15) The code has been updated to avoid round off errors in phase saturations leading to the initialization of dissolved or vaporized fluid ratios (for example saturated RS) with saturated values instead of taking values from the input ratio versus depth table (for example RSVD) (#4720).

16) Code has been updated to avoid writing beyond array limits (#4753).

17) The well closure reason is now set to GROUP rather than ECONOMIC if a group economic constraint (GECON) is reached. This prevents the closed well being reopened with WTEST item 3 TEST equal to 'E' (#4854).

18) The simulator now sets the well THP to be zero in the WellState only if there is no VFP table associated with the well (#4932). Previously, this would be done if the well had no target THP or THP limit.

19) The code now checks whether LIFTOPT is active first to avoid unnecessarily running routines relating to gas lift optimization (#4956).

20) MPI is now initialized before creating the communicator and a couple of fields are now set to ROOT_ONLY in *opmrst_inspect()* (#4601).

21) The *updateWaterMobilityWithPolymer()* method updates values, it does not rewrite them. Hence we have to feed it the scalar values not zeros. Scalar values are now used (#4655).

22) The restriction on the length of the next timestep following an event will now be applied following production or injection updates (WCONPROD, WCONINJE keywords) (#4781). The maximum length of the next timestep following an event can be set using either the TUNING keyword item 10 (TMAXWC) with the command line argument *--enable-tuning=true*, or by using the command line argument *--time-step-after-event-in-days=x* (where *x* is the number of days).

23) Added perforation data (perf_data) comparison in the equality operator for SingleWellState (#4783).

24) Added check that rock compaction table indices (ROCKNUM) are within the bounds of the tables defined by ROCKTAB (#4788).

25) Code modified to avoid a possible segmentation fault in the cleanup routine if the simulator has not been set up (#4794).

26) Fixed a bug where the code could attempt to access entries in a zero element array due to not dereferencing a pointer to inspect array elements when deciding whether to apply TRANX, TRANY, etc. keywords (#4801).

27) Code has been modified to prevent slightly negative oil fractions in well segments occurring due to round-off. This could have lead to failure if the segment represented for example an autonomous Inflow Control Device (ICD) valve in a multi-segment well (#4834).

28) Fixed a bug with the DIRICHLET option in the boundary condition property definition (BCPROP) not working in gas-water runs. Additionally, fixed a bug where BCPROP had to be defined at every report step (#4835).

29) If a well was SHUT due to economic or physical reasons the well-state quantities were mostly set to zero (including the BHP). The code has been modified to set the BHP to the BHP limit when its value has not been initialized when under well target rate control (#4841). This helps to prevent the Newton update from stagnating under certain circumstances (for example, a reported issue introduced by #4772).

30) Fixed a bug which occurred when using non-neighbor connections (NNC) in thermal simulations (*#4900*).

31) Fixed computation of temperature for distributed wells (*#4888*). This was not an issue for non-distributed wells.

32) Code has been modified to always allocate buffers for storing flows if BFLOWI, BFLOWJ or BFLOWK is requested. This fixes a segmentation fault that occurred if these keywords were requested without RPTRST in the SOLUTION section (*#4904*).

33) Code has been modified so that there will be no vertical connection between cells if the layers in between are inactive or collapsed unless the PINCH keyword has been specified (*#4901*).

34) Fixed a bug which occurred in parallel runs where all processes other than rank zero would keep iterating beyond the maximum number of allowed iterations (*#4909*).

35) Fixed a bug where regional multipliers (MULTREGT) were applied twice to non-neighbor connections entered in EDITNNC (*#4921*).

36) Fixed a bug where if *--enable-vtk-output=true* and *--enable-write-all-solutions=false* (it is false by default), then Visualization Toolkit (VTK) files were written for all solutions. The code has been modified so that VTK files are only written for report steps (unless *–enable-write-all-solutions=true*) (*#4916*).

37) After DUNE version 2.7, the method *getCollectiveCommunication()* was changed to *getCommunication()*. The *getCollectiveCommunication()* method issues the deprecation warning and assumes all process take part in the communication. However, this might not be the case, namely, only a subset might be used. This fix consists of getting the communication object used by the grid as this uses only processes that are actually computing and not only outputting (*#4962*).

38) Fixed computation of dissolved gas in water ratio (Rsw) used in calculation of wellbore density for standard wells (*#4976*).

B.1.5 KNOWN ISSUES

1) There is an error with the RSM header for summary vectors whose NUMS entry in the SMSPEC file is derived from more than a single number source (e.g., single region or segment ID). This applies to all block vectors (BGPV, BOPV, BWPV, etc.), connection level quantities (COPT, etc.), and inter-region flows such as ROFT etc (*#3078*). The work around is to plot the data in OPM ResInsight and right-click on the plot to view and copy the data.

2) OPM Flow does not support using LIQ as a well's preferred phase with the WELSPECS. keyword, that is WELSPECS(TYPE) equals LIQ. This is a long-standing bug/omission in the simulator stemming from a somewhat naive internal notion of phases so we don't have an entry for a liquid phase, only for the distinct oil and water phases. For producing wells this mostly matters if you plot the WPI summary vector (productivity index for well's preferred phase). In the current treatment WPI will not have contributions from the water phase if the declared preferred phase is LIQ. For injecting wells WELSPECS's preferred phase doesn't really matter at all since the preferred phase is (typically) reset to the injected phase in WCONINJE/WCONINJH anyway. See issue *#3075*.

3) If the simulator finds well connection being declared as connections via the COMPDAT keyword in the SCHEDULE section, then it writes out a warning message:

```
Warning: Problem with COMPDAT keyword
In SIM_PEE_Basic_Simulator.DATA line 535
The cell (0,6,4) in well INJ1 is not active and the connection will be ignored

Warning: Problem with COMPDAT keyword
In SIM_PEE_Basic_Simulator.DATA line 535
The cell (16,0,4) in well INJ2 is not active and the connection will be ignored
```

However, the reported cell references are offset by minus one, meaning the correct warning messages should be:

```
Warning: Problem with COMPDAT keyword
In SIM_PEE_Basic_Simulator.DATA line 535
The cell (1,7,5) in well INJ1 is not active and the connection will be ignored

Warning: Problem with COMPDAT keyword
In SIM_PEE_Basic_Simulator.DATA line 535
The cell (17,1,5) in well INJ2 is not active and the connection will be ignored
```

See issue *#3167* for details.

4) The GDFILE keyword in the GRID section loads a grid file in various formats, with the FMTOPT parameter setting the format type of the file. If the variable FMTOPT is omitted then the default is for binary file input for the commercial simulator; whereas, OPM Flow derives FMTOPT from the file extension (*.EGRID or *.FEGRID), making FMTOPT superfluous. However, if the extension is lower case then OPM Flow may incorrectly determine the file type. The work around is change the extension to upper case.

5) As per previous releases of the radial model, the COORDSYS keyword item three must be set to COMP to complete the circle, this has not been implemented in this release. Also there appears to be a bug for full radial models when a well goes on BHP control that causes the well not to respect the BHP constraint, this eventually causes the well to die prematurely. See *#2640* for a discussion on the topic.

6) As in previous releases there are some issues with the OPERATE and OPERATER keywords associated with the input parsing; for various reasons a few of the fields require special case treatment in the grid processing, including (at least) MULTZ, PORV and ACTNUM, and for those keywords the OPERATE/OPERATER keyword doe not work. The work around is to use the MULTIPLY keyword instead.

7) For the UDQ ASSIGN operator after the terminating "/" normally any comments can be entered; however, if there is "/" within the comment field, as per:

ASSIGN FUNGLYLD 1.196   /   Condensate Yield (63.5/56.7)/(1.0 – 0.065)

then the simulator will abort. The work around is to manually place the comment characters "--" after the ASSIGN terminating "/", like so:

ASSIGN FUNGLYLD 1.196   / -- Condensate Yield (63.5/56.7)/(1.0 – 0.06)

8) At the moment, one cannot initialize tracers using the EQUALS keyword. Instead use the array format, that is the keyword followed by the required number of values, or the TVDP keyword in the SOLUTION section to set the initial tracer concentrations as a function of depth.

9) Currently, gas tracers cannot be used if the dissolved gas phase, as per the DISGAS keyword in the RUNSPEC section, is active in the model.

10) The summary vector RTIPTHEA, that defines the energy in-place between the initial and the current time for regions, is not supported unlike the FTIPTHEA and BTIPTHEA vectors. Secondly, the error message:

```
Warning: Problem with summary keyword RTIPTHEA
In RSM-THERMAL.data line 492
FIP region FIPHEA not defined in REGIONS section - RTIPTHEA ignored
```

is incorrect, as the message indicates that it is being treated like a named region, as per the FIP keyword, when it is actually a SUMMARY vector (*#3870*).

11) If there are cells that are very distorted, which can occur near fault planes, then the simulator may abort because it cannot calculate the pore volume of such cells. The work around is to re-generate

the grid in the static model, taking care that the cells around the fault planes are more or less orthogonal (*#2992* and *#3770*).

12) Currently the OPERATER keyword in the EDIT section does not work with the DEPTH, TRANX, TRANY and TRANZ property arrays (*#2994* and *#748*).

13) If a standard well is fully declared in an ACTIONX block which is then activated at a later date, and later the well is modified to be a multi-segment well using the WELSEGS and COMPSEGS keywords, then this will cause the simulator to abort with an assert failure. The solution to this issue is to not use this type of work flow in declaring wells (*#2891* and *#2895*).

14) Although the ACTIONX EXIT command works as expected, it does not write out the requested RSM file at the end of the run. However, the other SUMMARY and RESTART files are written out (*#2877*).

15) Although the GCONSUMP keyword in the SCHEDULE section is fully implemented as documented, it is not possible to verify the output as the associated SUMMARY vectors are not written out, that is the SUMMARY sales gas vectors FGSR, FGST, GGSR and GGST, and fuel vectors FGCR, FGCT, GGCR, and GGCT have not been implemented (*#2679*).

16) There are small differences in the behavior of the NEXTSTEP keyword in the RUNSPEC section between OPM Flow and the commercial simulator that remain unresolved (*#3745*).

17) **There is a unit handling issue associated with OPERATE keyword. If the OPERATE(X) parameter has units, as for example PERMX, then the conversion is always done in SI units, despite the input deck declaring the deck to be fields units, as per FIELD keyword in the RUNSPEC section. Note that OPM Flow performs all of its calculations internally in SI and performs unit handling only when inputting the *.DATA file and when outputting result files. Thanks to *Irijkels* for reporting the issue. See *#4597* for details.**

18) There is an issue associated with restarting from a restart file with the solution gas (Rs) maximum rate of increase, as defined by the DRSDT keyword in the SCHEDULE, that has been set to zero. This is because, the simulator does not save/restore this setting in simulator's restart files, which means that simulator misses the essential value zero upon restarting the case. As a work-around one can use the option --sched-restart=true, when running the restart case. This will initialize the restarted simulation based on information from the complete SCHEDULE section, instead of just the parts that we're going to simulate and the rest from the restart file. Thanks to *goncalvesmachadoc* for reporting the issue. See *#4272* for details.

19) OPM cannot be built with dune-fem version 2.9 or later. Please use a previous version.

20) The simulator uses an irregular corner-point grid geometry with adjusted pore volumes to represent radial grids so it is not possible to create a full ring (360 degree disk) with only one cell in the theta direction (NY=1). The work around is to model a slice (say DTHETA=60 degrees). Note that as the angle increases larger pore volume adjustments are required (*#4755*).

21) In principle the PYACTION code can control anything, however the simulator generally deals poorly with wells not explicitly controlled by the input file (for example opening or closing wells). It is recommended to utilize the normal ACTIONX machinery for well controls by constructing an ACTIONX block in the Python code and then passing that back to the Schedule object (*#4810* and *#4813*).

22) If the *--save-step* command line option is used to request the serialized state is saved to an .OPMRST file and HDF5 support is missing then an error is generated at the report step where the save was requested. This error should be generated during startup to save time and resources (*#4812*).

23) In some cases with the network option the simulator can wrongly report that a well has no THP constraints, for example

```
GLIFT WTEST: Well S-3H does not have THP constraints
```

when THP constraints have been defined (*#4887*).