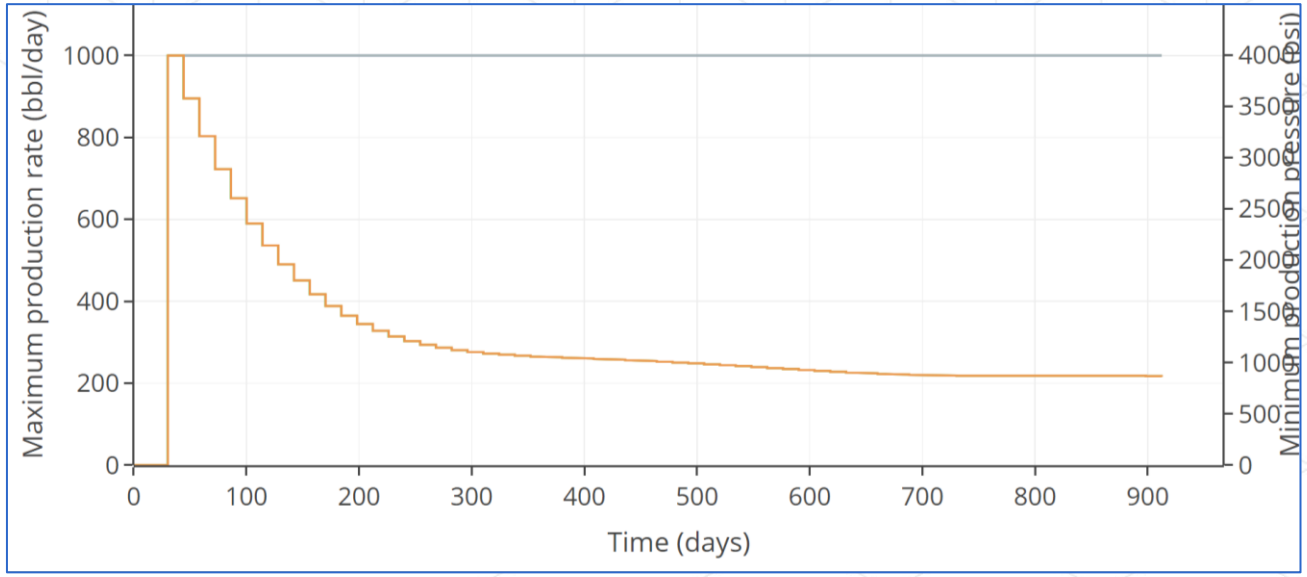
ResFrac

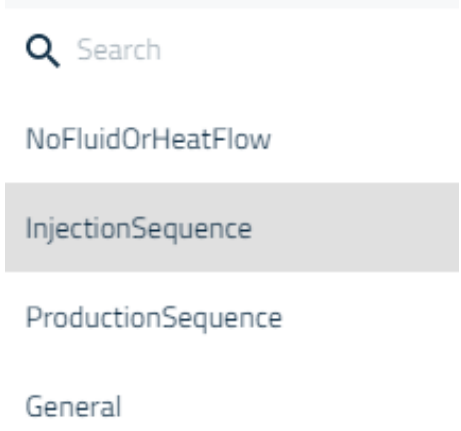


1. Injection Sequence	Start time: 0 Minutes	Duration: 149 Minutes	Number of controls: 17	Proppant stage 1: 1712.1 lbs/ft	Fluid stage 1: 42.265 bbl/ft
2. Shut-in	Start time: 2.4833 Hours	Duration: 720 Hours	Number of controls: 1		
3. Production Sequence	Start time: 722.48 Hours	Duration: (Blank) Hours	Number of controls: 64		

Boundary Conditions

How to set up well controls

Boundary Conditions – Well Controls



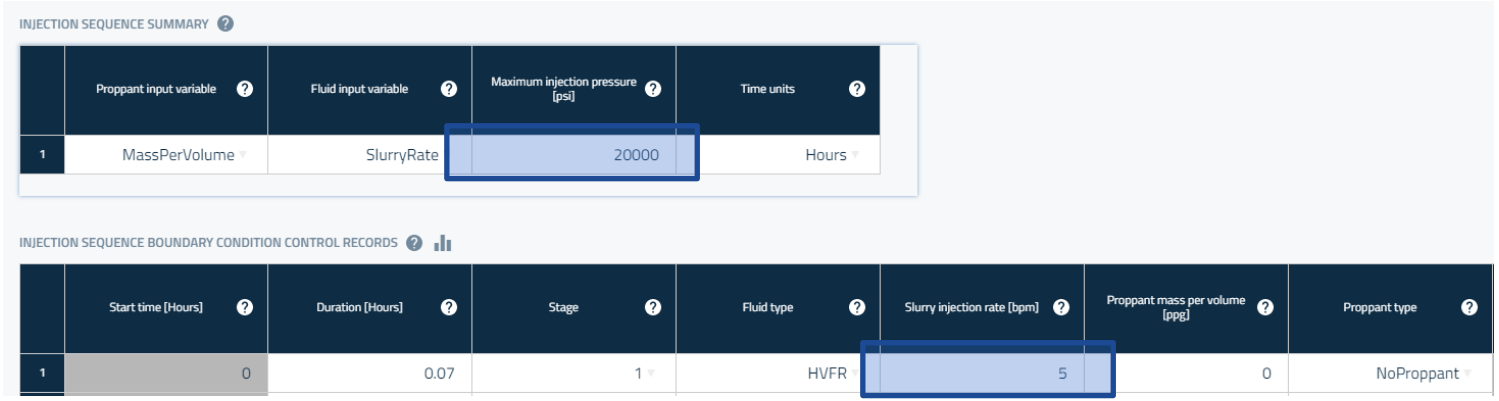
There are four types of boundary conditions that you can choose for your wells.

Remember, all times in ResFrac are referenced back to zero. You will need to set up a combination of boundary conditions such that wells are frac'd, shut in and produced in the correct sequence.

INJECTION SEQUENCE BOUNDARY CONDITION CONTROL RECORDS

	Start time [Hours]	Duration [Hours]	Stage	Fluid type	Slurry injection rate [bpm]
1	0	0.07	1	HVFR	5
2	0.07	0.01	1	PureWater	30
3	0.08	0.25	1	HVFR	85
4	0.33	0.16	1	HVFR	85
5	0.49	0.15	1	HVFR	85

Boundary Conditions – How ResFrac Handles Rate and Pressure

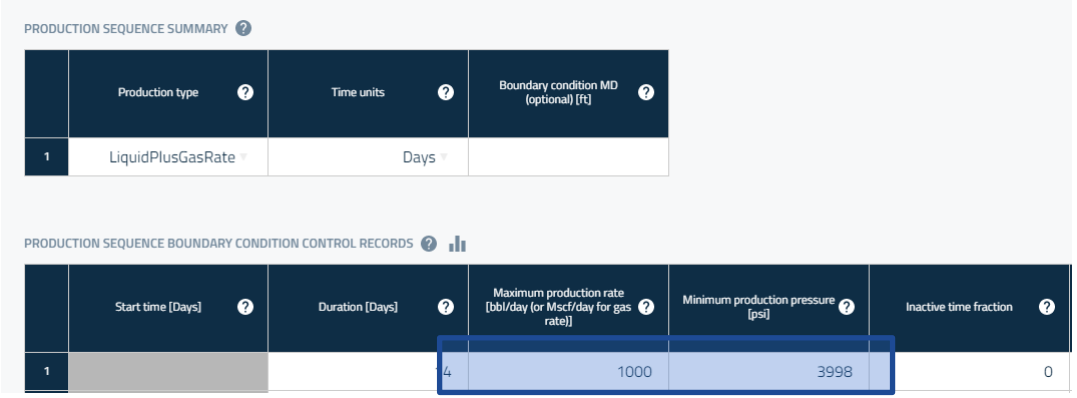


INJECTION SEQUENCE SUMMARY

	Proppant input variable	Fluid input variable	Maximum injection pressure [psi]	Time units
1	MassPerVolume	SlurryRate	20000	Hours

INJECTION SEQUENCE BOUNDARY CONDITION CONTROL RECORDS

	Start time [Hours]	Duration [Hours]	Stage	Fluid type	Slurry injection rate [bpm]	Proppant mass per volume [ppg]	Proppant type
1	0	0.07	1	HVFR	5	0	NoProppant



PRODUCTION SEQUENCE SUMMARY

	Production type	Time units	Boundary condition MD (optional) [ft]
1	LiquidPlusGasRate	Days	

PRODUCTION SEQUENCE BOUNDARY CONDITION CONTROL RECORDS

	Start time [Days]	Duration [Days]	Maximum production rate [bbl/day (or Mscf/day for gas rate)]	Minimum production pressure [psi]	Inactive time fraction
1		14	1000	3998	0

In ResFrac you can specify both the rate and pressure.

It is important to understand that these are ***LIMITS THAT WORK TOGETHER***! Once one limit is reached the simulator will automatically adjust the other limit to compensate. ***Do not constrain both!*** This is essentially forcing an answer.

For example…

While injecting set your maximum pressure high, so that WHP can be tuned. Setting it low can lead to jobs that are not completely pumped.

While producing using a bottom hole pressure control, set the max rate high so the permeability can be tuned. If using a rate control, set the pressure very low.

ResFrac

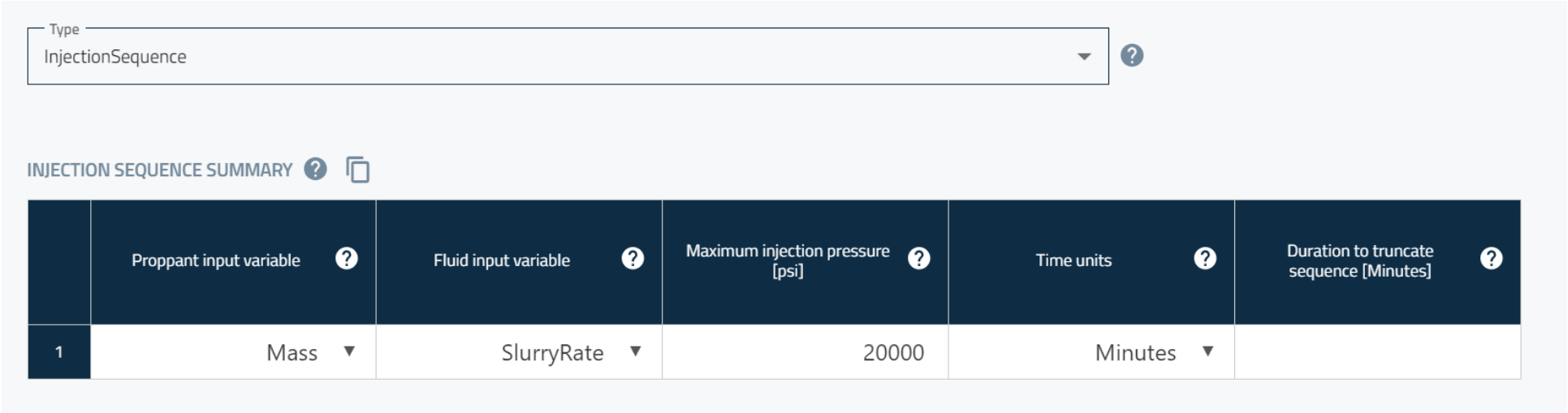
Injection Sequences

Injection Sequences – Summary

‘Proppant input variable’ and ‘Fluid input variable’ specify how the injection sequence should be defined. More on that in following slides.

The ‘Maximum injection pressure’ specifies the maximum pressure that can be reached before ResFrac will start to limit the rate. Set this to a higher number than you would expect so that the job pumps to conclusion. You don’t want to ‘screen out’ and not catch the problem. The WHP can be tuned later.

The ‘Duration to truncate sequence’ is intended to be used with a decision support workflow to, for example, allow you to control the length of the production period. Control sequence records that occur after this value will be cut off in this block. Leave this value blank (nan) to not apply any cutoff.



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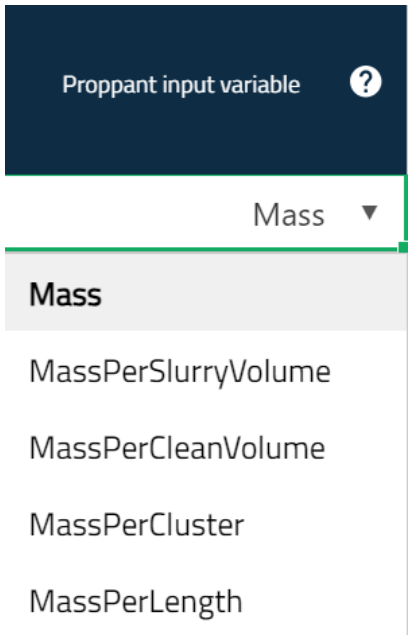
Injection Sequences – Proppant input variable



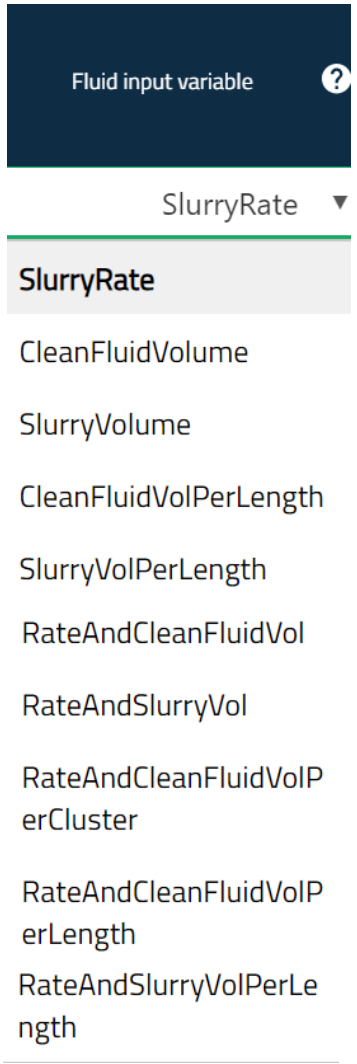
The proppant input variable refers to how the proppant concentration is reported in the frac summary report.

- Mass – pounds of proppant
- MassPerSlurryVolume – refers to pounds of proppant in one gallon of slurry (ppg)
- MassPerCleanVolume – refers to pounds of proppant added to one gallon of clean fluid (ppa)
- MassPerCluster – pounds of proppant / # of clusters in stage
- MassPerLength – pounds of proppant / stage length

It is important to understand how the job was specified in the frac report.

The final two input methods are useful when running sensitivities on stage length or cluster spacing.

Injection Sequences – Fluid input variable



It's is very important to understand exactly how the injected volume was reported.

Additionally, there are lot of options that are specific to doing optimizations and sensitivities.

For the following input types, the duration of each step needs to be input:

- SlurryRate – pump rate of dirty fluid (most common, both in designs and job reports)
- CleanFluidVolume – volume of clean fluid for each step (common in designs)
- SlurryVolume – volume at dirty fluid for each step
- CleanFluidVolPerLength – volume of clean fluid for each step / stage length
- SlurryVolPerLength – volume of dirty fluid for each step / stage length

These input types as similar as above, except SlurryRate also needs to be specified and "Duration" will be calculated:

- RateAndCleanFluidVol
- RateAndSlurryVol
- RateAndCleanFluidVolPerCluster
- RateAndCleanFluidVolPerLength
- RateAndSlurryVolPerLength

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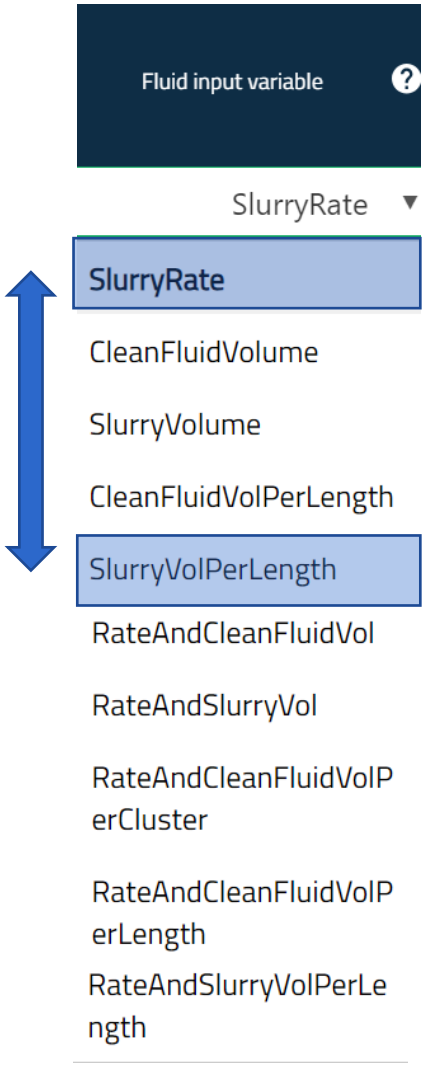
Injection Sequences – Fluid input variable



Once the original data has been entered, you can toggle between different fluid input variables to change the rate type. ResFrac will recalculate the table based on the input.

For instance, if you wanted sensitize on volume/ft then you might start by entering the 'slurry rate', converting it to 'slurry volume per length'. Changing the 'slurry volume per length' will change the slurry rate accordingly.

The same goes for changing the 'Proppant input variable'. You can swap between mass and concentration depending on what is most convenient.

Slurry injection rate [bpm]	Slurry volume per (estimated) length [bbl/ft]
5	0.0800958724278748
30	0.120143808641812
85	5.10611186727702
85	3.40407457818468

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Boundary Conditions – Injection Sequences Summary

INJECTION SEQUENCE BOUNDARY CONDITION CONTROL RECORDS

	Start time [Hours]	Duration [Hours]	Stage	Fluid type	Slurry injection rate [bpm]	Proppant mass per volume [ppg]	Proppant type
7	0.79	0.12	1	HVFR	85	1.25	100M
8	0.91	0.12	1	HVFR	85	0.25	40/70M
9	1.03	0.12	1	HVFR	85	0.5	40/70M

Clean fluid volume [bbl]	Slurry volume [bbl]	Proppant mass added per volume [ppa]	Proppant mass [lbs]	Total slurry mass [lbs]
577.317572997477	612	1.32509390980091	32130.0171156498	234483.860004589
605.063514599495	612	0.252866015398853	6426.00342312997	218504.992696562
598.12702919899	612	0.511597010437388	12852.0068462599	222499.709523569

Once the injection table is set up, this table is straightforward. Just remember, the fluid and proppant types are the *mixtures* that were set up previously. Finally, ResFrac calculates total mass, volumes etc. Check these against your frac report and check again in the UI to ensure that everything was pumped correctly (along with your pressure). Screen outs can happen in ResFrac , just like in real life, so verify in the UI that the job pumped to completion.

ResFrac

PRO TIP!

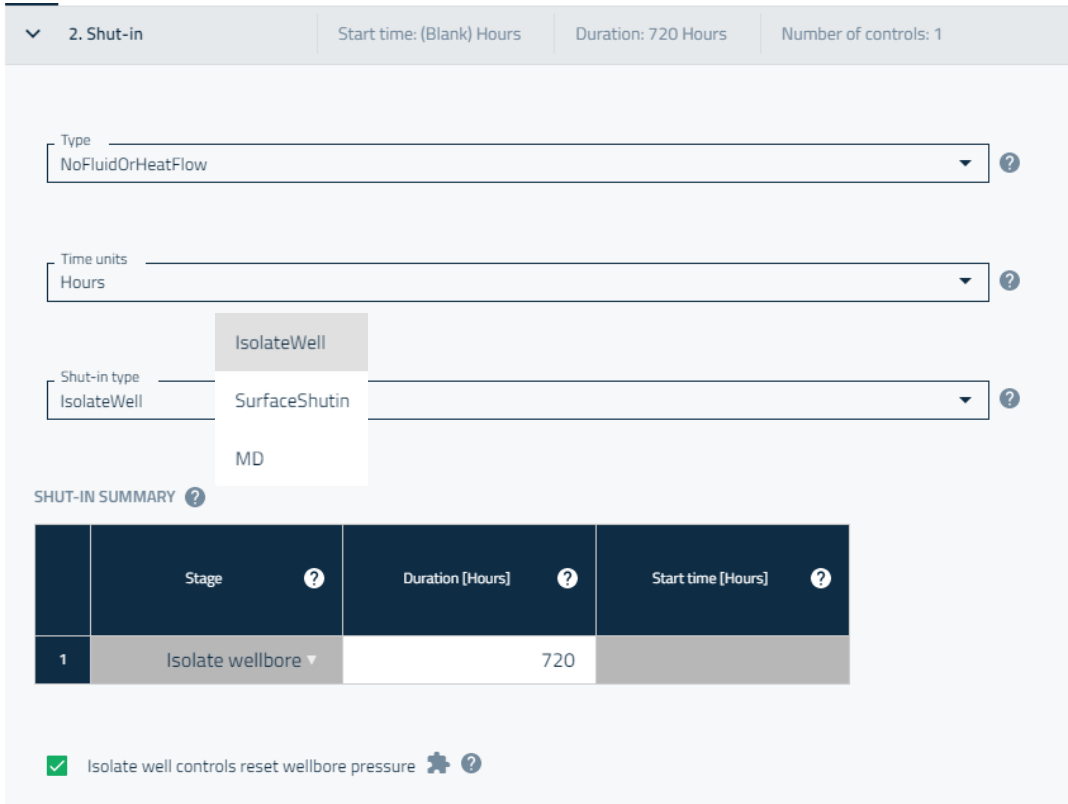
Include a step after injection (10-15min) with zero volume or zero rate. This is equivalent to a surface shut-in; WHP is reported so you can record the ISIPs.

	Start time [Minutes]	Duration [Minutes]	Stage	Fluid type	Slurry injection rate [bpm]	Proppant type	Proppant mass [lbs]
1	0	0.793650666666667	1	HVFR 20cP	30	NoProppant	0
2	0.793650666666667	2.64550222222222	1	HVFR 20cP	90	NoProppant	0
3	3.43915288888889	4.30476711386494	1	HVFR 20cP	90	40/70 Mesh White	6000
4	7.74392000275382	18.2519115858476	1	HVFR 20cP	90	40/70 Mesh White	66000
5	25.9958315886015	22.9387551840875	1	HVFR 20cP	90	40/70 Mesh White	159000
6	48.9345867726889	5.00709001950626	1	HVFR 20cP	90	40/70 Mesh White	42500
7	53.9416767921952	4.23280444444444	1	HVFR 20cP	90	NoProppant	0
8	58.1744812366396	15	1	HVFR 20cP	0	NoProppant	0

Shut-Ins

‘NoFluidOrHeatFlow’

Shut-Ins or ‘NoFluidOrHeatFlow’



Isolate wellbore – Literally isolates the wellbore from the exchanging fluids in the fractures and the matrix. Because the wellbore is isolated a pressure will not be reported in the tracking files. Most often used between stages while frac’ing when there are plugs.

Surface shut in – Shuts the well in at surface. A pressure is reported and fluids from the fractures, matrix and well are now being exchanged. Used most often for ISIP reporting and wells that have already been producing and are shut in for build ups and parent wells that have been shut in for child well fracs.

MD – Measured depth boundary conditions are discussed on the next slide.

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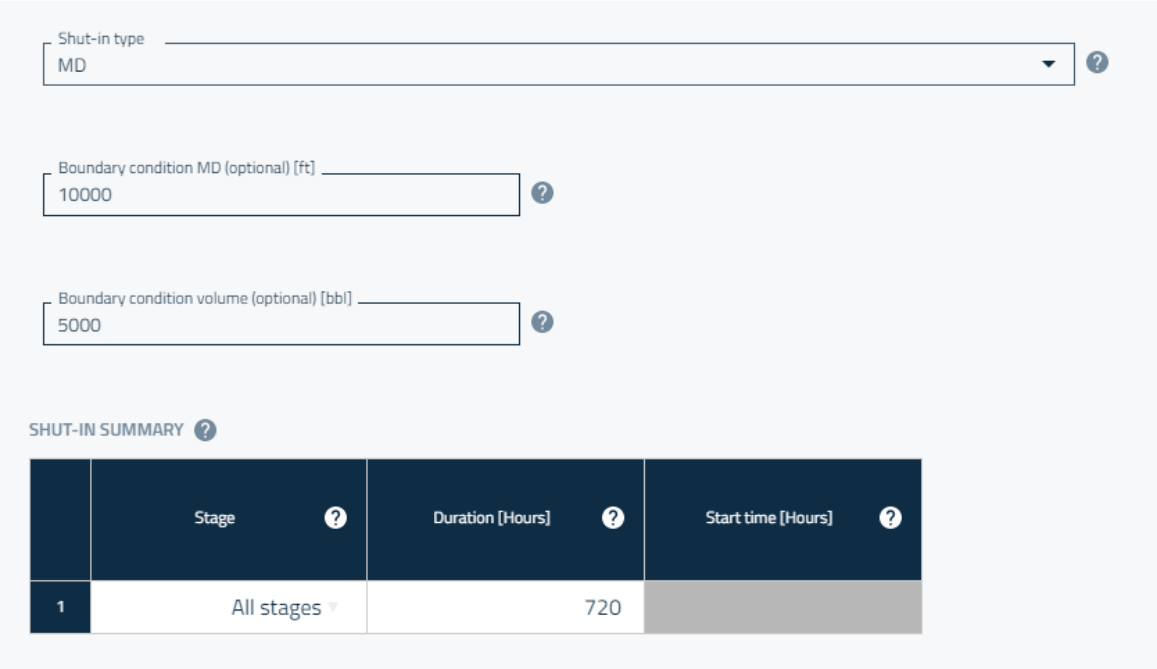
Shut-Ins or ‘NoFluidOrHeatFlow’– Measured Depth BC



Measured depth boundary conditions allow you to set the depth at which you want the boundary condition reported. This is most often used for reporting and ‘calibrating’ frac hits. The boundary condition is most often set outside the matrix just a few hundred feet up hole (towards the heel).

Fluid will be allowed to flow into and out of the boundary condition. The boundary condition itself is treated like a tank with an associated volume. This volume can be used to simulate the intensity and crossflow that occurs during frac hits. A larger volume will ‘mute’ the intensity of the frac hit.

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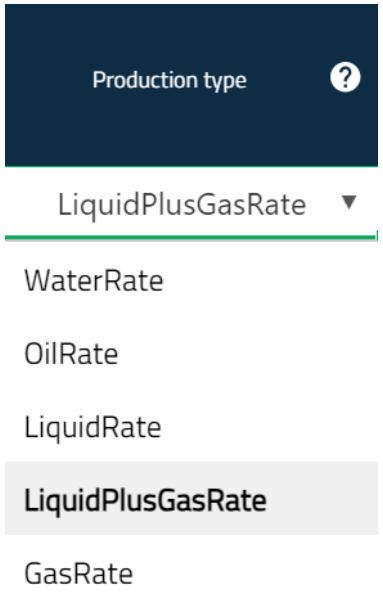
Production Sequence

Production Sequence - Summary

	Production type	Time units	Boundary condition MD (optional) [ft]	Duration to truncate sequence [Days]	Optional secondary production type
1	LiquidPlusGasRate	Days			WaterRate



Production sequences are specified by ‘rate’.

The ‘liquidplusgasrate’ is the most often used. When using this control, it is important to understand that unlike the other rate controls, the ‘liquidplusgasrate’ has nonsensical units. It is BBLS Oil + BBLS H2O + Mscf.

Even if you intend to use pressure as your control, you must specify which production type you intend use.

Once again, there is an option to specify a MD boundary condition. The is generally used to model artificial lifts such as an ESP or rod pump in a vertical.

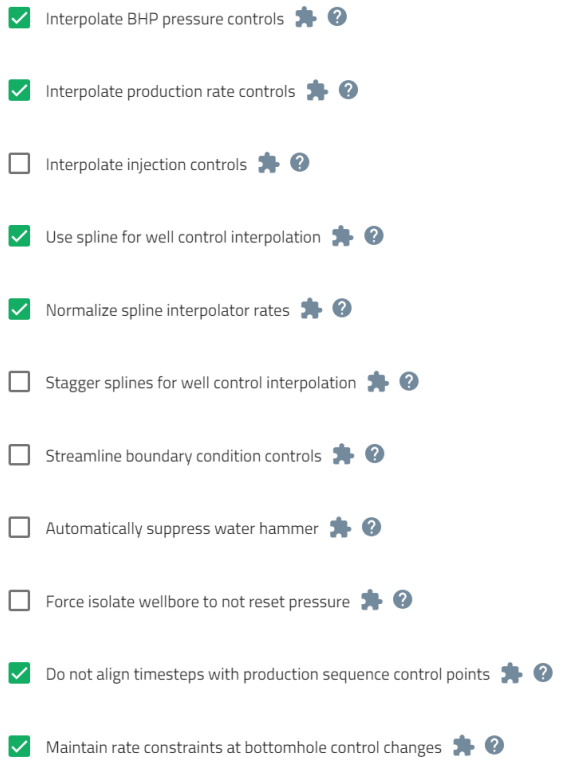
Production Sequence – Records Table

PRODUCTION SEQUENCE BOUNDARY CONDITION CONTROL RECORDS

	Start time [Days]	Duration [Days]	Maximum production rate [bbl/day (or Mscf/day for gas rate)]	Minimum production pressure [psi]	Inactive time fraction
1	30.2548333333333	14	1000	3998	0
2	44.2548333333333	14	1000	3580	0

Use the wizard to consolidate boundary condition controls.

At every boundary condition change ResFrac will take smaller timesteps. So, fewer boundary condition changes will result in faster run times. In most cases, check the boxes shown to the right to facilitate a smooth transition and minimize boundary condition changes.



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Production Sequence - Wizard

Well name: Well_High Noon

Specify the well and when the production control is supposed to start.

Production sequence start time [days]: 30.25

Averaging duration [days]: 30

Specify the averaging duration. Remember, less boundary condition changes equals faster run times.

Default minimum BHP [psi]: 500

Default maximum rate [BPD]: 1500

Both minimum production pressure and maximum production rate need to be specified. This sets the final production controls sequence and when the 'default to rate or BHP' control is used, ResFrac will set the one not used to this number.

Production tubing ID (optional) [in]

Specify the production tubing (optional).

Default to rate or BHP: BHP

Specify BHP or Rate control.

Add BHP to tracking file: Yes

Specify BHP or Rate and BHP to the tracking file.

Force wizard to honor shut-ins: Yes

If zero production is noted, then the wizard will change the maximum rate to zero to honor the shut in.

PRODUCTION TABLE

	Time from sequence start [days]	Water rate [STB/day]	Oil rate [STB/day]	Gas rate [Mscf/day]	BHP [psi]	WHP [psi]
1	1	5	5	5	5000	
2	2	10	10	10	4000	
3	3	20	20	20	3000	

Copy and paste the actual production table into this table and click apply. Note, that in this instance, the production controls are not starting at 'time zero'. Day 1 refers to the day production started.

The WHP column is normally left empty, unless your well is producing without artificial lift, and you want ResFrac to calculate the BHP.

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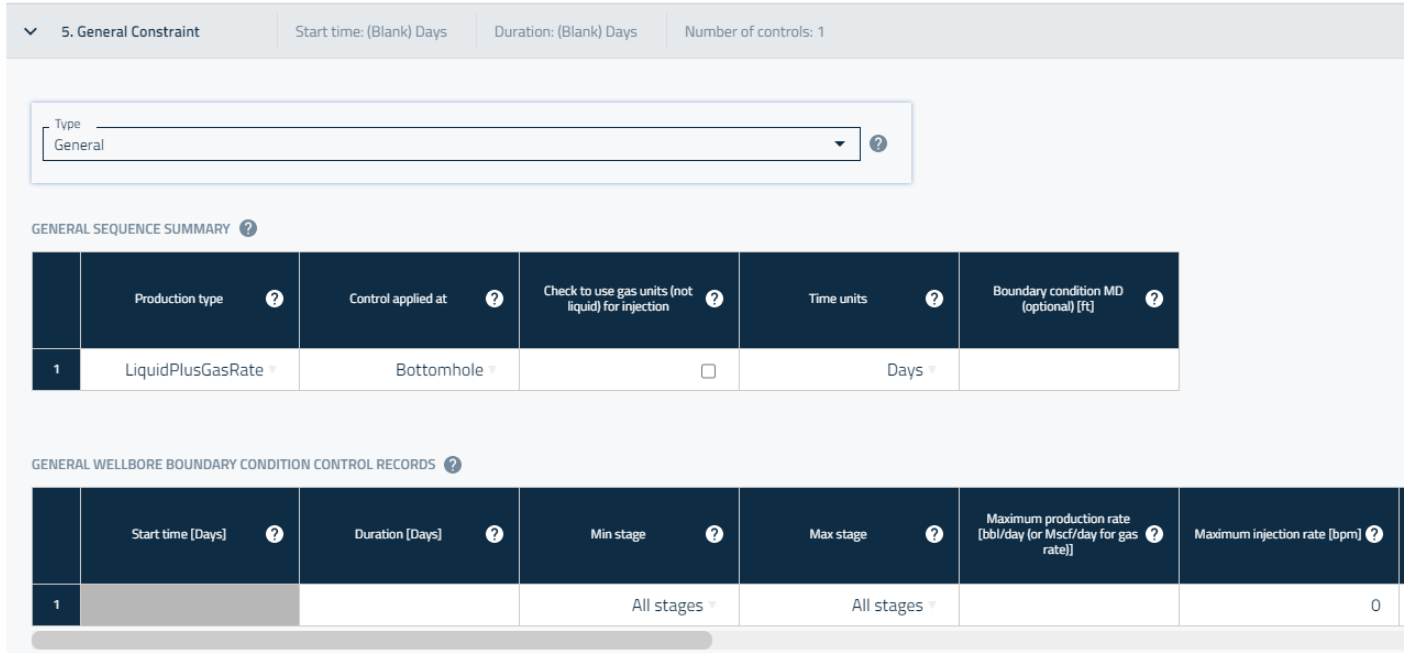
General Constraints

General Constraints - Summary



Etc.

In most cases general constraints are not necessary and injection, production and shut-in constraints are used. A general constraint can do everything the other constraints can do but are a lot more tedious to set up. However, there might be cases that a more 'general constraint' is necessary. For instance, the injection sequence assumes that a water based frac fluid is being pumped, but if you were to inject a hydrocarbon or gas (huff n puff), then this type of constraint would be necessary.

Thank You!

Chris Ponners
cponners@resfrac.com

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