



Technology for Real-World Solutions

QuARTIC®

Qualified Automated Reporting Tool for Inputs and
Calculation Notebooks

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Research, Development, & Engineering Solutions

Energy & Space Solutions

Products & Manufacturing

A Culture of Quality



Following world war II, Japan needed to rebuild their economy. Japanese manufacturing was not known for quality products. American academics Edward Deming, Joseph Juran, and Walter Shewhart had been doing research into how to **improve product quality** and at the same time **reduce cost**.

US businesses were not interested in the type of cultural change required, but Japan adopted the new ideas, which were later coined as **Lean Six Sigma**. A little car company named Toyota integrated these new practices and by the 1980's became the world standard for vehicle quality.

Lean Six Sigma



The objective of Lean Six Sigma is to improve product quality while reducing cost.

- **Lean** - reducing waste to gain efficiency and reduce cost. Waste includes repetitive or routine tasks that could be eliminated or automated.
- **Six Sigma** - eliminating sources of variation and error in producing a product to meet the highest quality standards.

Safety Analysis Model Development Level of Effort



Development of qualified RELAP5-3D safety analysis model is a major effort.

- Typical effort ranges from 8 to 14 months - 300 to 600 pages of calculations for large full-scale plant models
- Review / checking commonly takes 3 to 5 months
- Revisions of the calculation notebook typically takes months of effort

The large level of effort presents significant opportunity to improve the process.

Making Model Development Faster and Better



QuARTIC® arose out of looking at the model development process from the perspective of Lean Six Sigma:

How can the model development process be adapted to increase quality and reduce effort?

Measures of Model and Document Quality



There are a few key measures of Quality for a model and its documentation.

- **Traceability** – Are model parameters traceable to valid source data?
- **Readability** – Are calculations documented in a way that can be clearly followed and understood?
- **Consistency** – Are values consistent between calculation document, model, and references.
- **Verifiability** – Are the calculations clear and easy to verify?
- **Accuracy** – Are appropriate calculations applied and free of error?

Standard Model Development Process



The most common model development process uses the following tools:

- **Excel** is used to collect reference data and perform calculations.
- **Word** is used to document calculations.
- **SNAP[®]** is used to construct the RELAP5-3D model.



Standard Model Development Process



How do Excel, Word, and SNAP[®] stack up in terms of **traceability, readability, consistency, verifiability** and **accuracy** of models and documentation?

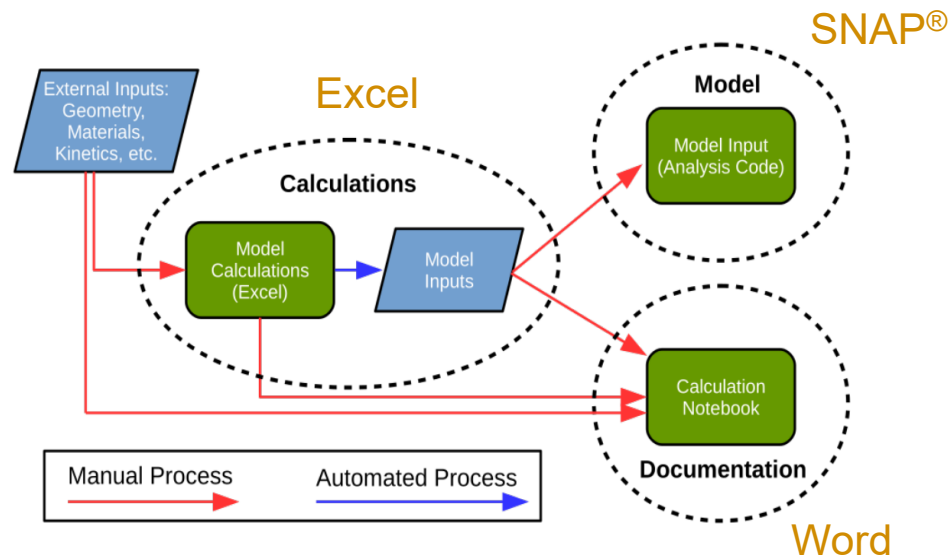
- Significant **manual** effort / time required to maintain quality.
- Verification is labor intensive due to significant potential for inconsistencies.
- Tools not designed to integrate well to address quality concerns.

QuARTIC[®] Process

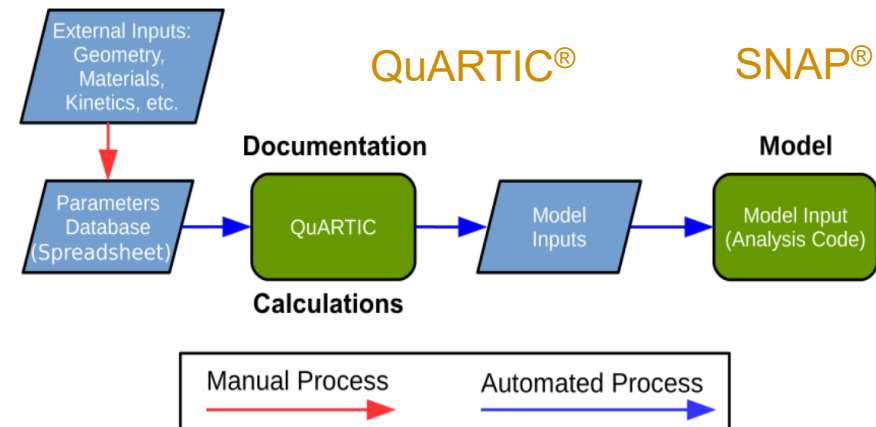


QuARTIC[®] was designed to increase quality, reduce effort, and simplify the model development process by automating important aspects of quality.

Standard Process



QuARTIC[®] Process



What is QuARTIC[®]



QuARTIC[®] is a documentation tool, computer algebra system, and automation tool that understands RELAP5-3D models.

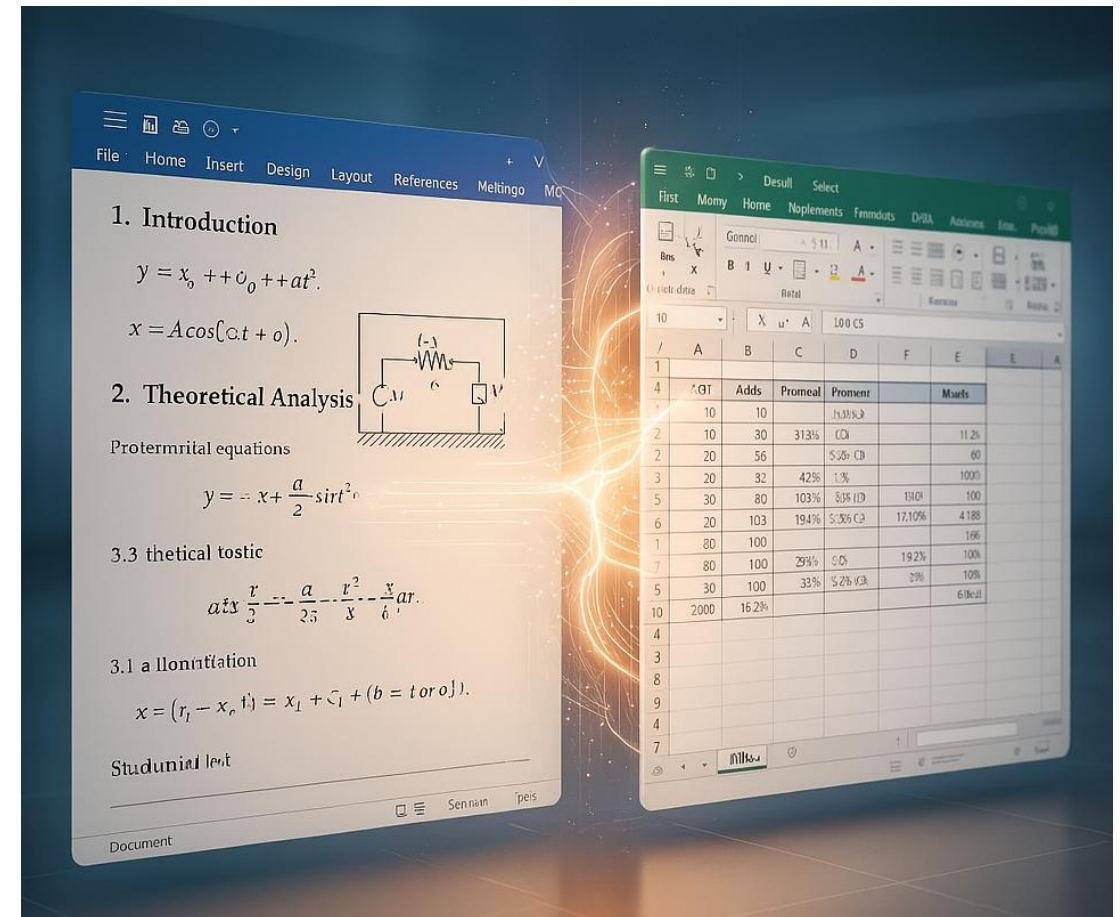
- Documents written in LaTeX format. Processed to generate a PDF document.
- QuARTIC[®] commands (such as calculations) are embedded in a LaTeX document to add computer algebra and other automation capability.
- QuARTIC[®] can read RELAP5-3D input files and verify that document calculations match RELAP5-3D inputs. It can also auto-document components from the input file.

Since QuARTIC[®] is both a

- **Documentation tool**
- **Computer algebra system**

No separation of calculation and document tools (as with Word and Excel) **eliminates significant duplicate effort!**

Consistency of the calculation and document is inherent which aids **Accuracy.**



Parameter Database



QuARTIC® uses a parameter database (excel spreadsheet) that contains all input parameters used in the calculation document. For **readability** and **traceability** each parameter has:

- A unique variable name (used in calculations)
- A value with units
- Reference information and description

Parameter	Name	Value	Units	Ref	Loc	Desc
	L_FlangeD620	4 5/8	in	EPRI-NP-2479	Figure A-14	Length of inlet flange to discharge downcomer
	L_Spool73_D622	69.75	in	EPRI-NP-2479	Figure A-14	Length of main 6" pipe of discharge downcomer
	L_Spool73_Reducer	6	in	EPRI-NP-2479	Figure A-14	Length of 8" to 6" reducer in discharge downcomer
	L_Spool73_D624	5 3/8	in	EPRI-NP-2479	Figure A-14	Length of 8" flange at outlet of discharge downcomer
	L_Spool_5	7.25	in	EPRI-NP-2479	Figure A-2	Length of 8" Grayloc reducer
	L Spool 6	13' 1/8"		EPRI-NP-2479	Figure A-3	Overall length of vertical 12" downcomer

Symbolic Calculations



Calculations written symbolically using parameter names - expanded automatically with parameter database values - results in excellent **readability** to help reviewers verify **accuracy**. Variables are unique and searchable leading to excellent **traceability**.

@\$\$

$$L_{300_c1 \times 2} = (L_{IHT_HL_1} + 0.5 \cdot L_{elbow_IHT_HL}) / 2$$

$$L_{300_c3 \times 4} = (L_{IHT_HL_2} + L_{elbow_IHT_HL}) / 2$$

$$L_{300_c5} = L_{IHT_HL_3} + 0.5 \cdot L_{elbow_IHT_HL}$$

\$\$@

$$\begin{aligned} L_{300.c1-2} &= \frac{(L_{IHT.HL.1} + 0.5 \cdot L_{elbow.IHT.HL})}{2} \\ &= \frac{(15.65 \text{ m} + 0.5 \cdot 0.8839 \text{ m})}{2} \\ &= 8.0458 \text{ m} \end{aligned}$$

$$\begin{aligned} L_{300.c3-4} &= \frac{(L_{IHT.HL.2} + L_{elbow.IHT.HL})}{2} \\ &= \frac{(18.88 \text{ m} + 0.8839 \text{ m})}{2} \\ &= 9.8844 \text{ m} \end{aligned}$$

$$\begin{aligned} L_{300.c5} &= L_{IHT.HL.3} + 0.5 \cdot L_{elbow.IHT.HL} \\ &= 2.896 \text{ m} + 0.5 \cdot 0.8839 \text{ m} \\ &= 3.3376 \text{ m} \end{aligned}$$

Automatic Reference Tables



Parameters used are *automatically tracked*. Reference tables that contain used parameters and reference information are autogenerated making **traceability** simple and automatic.

Table 19: Inputs from References

Parameter	Value	Reference	Description
$CLL_{SW663.and.665}$	18 inch (0.4572 m)	Ref [1], Figure A-6	Total length from centerline of inlet to centerline of outlet for bends SW663 and SW665 of spool piece 27
$L_{Bend1Inlet}$	30.688 inch (0.7795 m)	Ref [1], Figure A-6	Total length of piping from flange SW660 inlet to top of U-bend (SW663)
L_{SW661}	9.5 inch (0.2413 m)	Ref [1], Figure A-6	Length of SW661
L_{SW662}	6 inch (0.1524 m)	Ref [1], Figure A-6	Length of SW662 reducer
$L_{SW664.and.666}$	2 ft (0.6096 m)	Ref [1], Figure A-6	Total length of the straight pipe sections SW664 and SW666 of spool piece 27

Automatic Unit Conversion



Preferred units can be specified. QuARTIC[®] converts parameters to preferred units for calculations. Autogenerated reference tables show original units and converted units and specific source location for easy **verifiability** and excellent **traceability**.

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Symbolic Calculations



When input parameters are updated or calculations are modified to use different parameters:

- Numeric values in symbolic calculations and dependent calculations are automatically updated.
- Reference tables are automatically updated to reflect changes in parameters used.
- The bibliography is also auto-updated to reflect changes in reference documents.
- Helps ensure **consistency** and **accuracy** of calculations.

Autogenerated Component Doc



QuARTIC[®] can read RELAP5-3D input files and autogenerate documentation of components.

Range	Length (<i>m</i>)	Area (<i>m</i> ²)	Volume (<i>m</i> ³)	Elevation Change (<i>m</i>)	Vert Angle (<i>deg</i>)	Azim Angle (<i>deg</i>)
1	0.23939	0.065552	0.015692 ^a	0.086888	22.5	0.0
2	0.23939	0.065552	0.015692 ^a	0.16055	45.0	0.0
3	0.23939	0.065552	0.015692 ^a	0.20977	67.5	0.0

^a Specified as 0.0 - value is calculated

Range	Therm. Strat. Model	Mixture Level Tracking	Water Packing Scheme	Vert. Strat. Model	Interphase Friction Model	Wall Fric.	Equilibr. Option
1 - 3	0 (off)	0 (off)	0 (on)	0 (on)	0 (pipe)	1 (off)	0 (nonequilib.)

Calculated Value vs Model Input Verification



QuARTIC[®] automates **verification** of calculated values against RELAP5-3D model inputs and reports differences. Thus, checking **consistency** is fast, accurate, and repeatable (reducing effort from days to seconds).

Param	Value	Units	Card	Cmp ID	Cells	R5 Field	vol-jun-node	R5 Value	% Diff	# Mismatch or Fails = 4
L_1	6.042821	m	10101	tmdpvolf 1		length		6.0428	0.00017	
V_1	14.15842	m^3	10101	tmdpvolf 1		volume		14.158	0.00149	
A_2	0.023554	m^2	20101	sngljun 2		area		0.023554	0.00076	
K_FWD_2	1		20101	sngljun 2		fwd_loss		0.04	92.30769	mismatch
K_REV_2	0.4		20101	sngljun 2		rev_loss		1	42.85714	mismatch
L_3c1x6	0.160867	m	30301	pipe 3	valid 1-6	x_length	6	0.16087	0.00104	
A_3c1x6	0.023554	m^2	30101	pipe 3	valid 1-6	x_area	6	0.023554	0.00076	
DZ_3c1x6	0.160867	m	30701	pipe 3	valid 1-6	x_elev	6	0.16087	0.00104	
L_5c1x2	0.11503	m	50301	pipe 5	valid 1-2	x_length	2	0.15716	15.47805	mismatch
L_5c3	0.1524	m	50302	pipe 5	valid 3	x_length	3	0.1524	0	
L_5c4x9	0.119695	m	50303	pipe 5	valid 4-9	x_length	9	0.11969	0.00195	
L_5c10x14	0.12192	m	50304	pipe 5	valid 10-14	x_length	14	0.12192	0	
L_5c15x20	0.119695	m	50305	pipe 5	valid 15-20	x_length	20	0.11969	0.00195	
L_5c21x26	0.390525	m	50306	pipe 5	valid 21-26	x_length	26	0.13017	50.00144	mismatch

Calculation

RELAP5-3D Input

Customizable RELAP5-3D Input Processing

Vendors sometimes add new input cards to RELAP5-3D or modify existing cards.

QuARTIC[®] can be customized to handle vendor modifications to the input file format and to include these changes the autogenerated component documentation.

Parallel Model Development



QuARTIC® makes it relatively simple to have multiple engineers work in parallel on different parts of a model.

- QuARTIC® documents are text based.
- Modifications can be easily tracked in a version control system such as git.
- Word and Excel can be hosted on Sharepoint or Office 365 for parallel development, but experience suggests this is not always robust. Change history over time is more difficult to track.

QuARTIC[®] is a scripting environment. Documentation tasks that are repetitive can be automated.

- Auto-documentation of components is an example of this.
- QuARTIC[®] has a TRACE module for auto-documenting homologous pump curves given pump characteristics (not available for RELAP5-3D at present).
- If calculation processes are well defined, documentation tasks can be automated for efficiency.

Document Flexibility



While QuARTIC® does allow automation of routine tasks, it leaves full control of the structure and content of the document in the hands of the engineers building the model. Automation commands are added to the document where useful.

Thus, QuARTIC® documents can be adapted to vendor documentation requirements, while applying automation where it makes the process more efficient.

QuARTIC[®] Reduces Effort



QuARTIC[®] was designed to reduce model documentation effort. For example:

- QuARTIC[®] merges documentation and calculation to eliminate a major documentation step.
- QuARTIC[®] equations are easy to both write and read and make document review much faster. Reviewers check for correct methodology rather than consistency and accuracy.
- QuARTIC[®] autogenerates reference tables to simplify traceability.
- Unit conversions are automated to reduce calculation and review effort.
- Comparison of calculation parameters against model inputs is automated.

QuARTIC[®] increases Quality



QuARTIC[®] was designed to increase Document Quality. For example:

- QuARTIC[®] equations are shown symbolically and numerically for readability and verifiability.
- QuARTIC[®] calculated parameter names are unique and searchable for traceability.
- QuARTIC[®] parameter reference tables are autogenerated for traceability, consistency, and completeness.
- QuARTIC[®] allows automated verification of calculation parameters against model inputs for accuracy and consistency.

Summary



QuARTIC® automates time consuming tasks related to traceability, readability, accuracy, consistency, and verifiability to produce high quality model documentation with less effort.

QuARTIC® improves engineering efficiency and provides significant time savings; most notably at the end of the project when quality and schedule compete.

QuARTIC® frees engineers to do what they do best – ensure engineering practices are applied correctly – and lets QuARTIC® handle the tedious consistency, bookkeeping, and verification tasks.