Department of Energy
Washington, DC 20585

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Mr. David L. Meyer, Chief
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Dear Mr. Meyer:

Enclosed are the U.S. Department of Energy (DOE) comments on the U.S. Nuclear Regulatory Commission (NRC) draft Staff Technical Position (STP) on "Geologic Repository Operations Area Underground Facility Design -- Thermal Loads", published for public comment on July 22, 1991, (56 FR 33478). DOE is concerned with the far-reaching implications of the staff's expectation that DOE employ "fully coupled" models that combine thermal, mechanical, hydrological, and chemical inputs into performance models without, (1) defining what "fully coupled" means, or (2) without the requirement in 10 CFR 60 for such a demonstration. Our itemized comments point out that it was NRC's stated concern about the technical feasibility, defensibility, and inherent uncertainties of extensively coupled system models that led to 10 CFR 60 remaining silent in this regard.

The staff's expectations regarding the use of "fully coupled" models, as that concept appears to have been adopted by the staff, far exceed the existing state-of-the-art for process modeling. DOE, consequently, will not likely to be able to comply with a requirement to develop, verify, and validate a coupled physical system model(s) for an underground geologic repository operations area of the breadth and depth anticipated by the staff.

Use of simplified process models and a progression to more complex models, coupled to the extent feasible, is DOE's current strategy and approach. DOE's intended use of such models assume the availability of a robust empirical data base and thorough explanation and defense of input assumptions and boundary conditions. We do not believe that the STP contains a workable approach. NRC's adoption of a containment period and the concept of a disturbed zone in 10 CFR 60 was explicit recognition of the infeasibility of highly complex, and possibly unattainable modeling applications. We strongly advise that NRC staff avoid imposing overly prescriptive expectations. We believe that DOE can successfully act upon the requirements as expressed in 10 CFR 60.

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If you have any questions, please contact Priscilla Bunton at 202-586-8365.

Sincerely,

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Enclosure:
DOE Comments on NRC's Draft Staff Technical Position Geologic Repository Operations Area Underground Facility Design -- Thermal Loads

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**DOE Comments on NRC's Draft Staff Technical Position
Geologic Repository Operations Area
Underground Facility Design -- Thermal Loads**

General Comments

Over the past ten years, the U.S. Nuclear Regulatory Commission (NRC) staff has urged the U.S. Department of Energy (DOE) to assess the coupled thermal (T), mechanical (M), hydrological (H), and chemical (C) [(T-M-H-C)] responses associated with a geologic repository. In response, the Yucca Mountain Site Characterization Plan (SCP) stated that although not completely defined, tests will investigate coupled interactions (page 8.3.2.1-14). Also, in our Exploratory Shaft Facility (ESF) Alternatives Study, we examined different testing layouts and chose one that would accommodate most testing programs, including tests for coupled interactions. Test Planning Packages and the Title II design of the ESF should give the NRC staff more information, but we have no immediate plans to examine coupled interactions at the level of detail that the draft Staff Technical Position (STP) recommends.

The STP outlines a step-wise approach by which the T-M-H-C assessment would be accomplished. It is a demanding approach entailing many computer codes whose development will push DOE well beyond the state-of-the-art. Ultimately, the NRC staff expects DOE to "demonstrate a comprehensive, systematic, and logical understanding of the coupled T-M-H-C responses associated with a particular geologic repository operations area (GROA) underground facility design." (page 1). We seriously doubt that the staff's expectations will be realized, at least within the next five to ten years.

The STP does not convince us that a fully coupled model is needed for demonstrating compliance with 10 CFR 60.133(i) or, for that matter, any requirement in 10 CFR 60. We believe that simplified models would work as well, if not better. The STP does not explain what makes a model "fully coupled". An example would be helpful. The STP voids the NRC's justification for requiring a disturbed zone and a containment period. Both were justified because they permitted simplified analyses, not the highly complex and possibly unattainable analyses that the STP expects.

We suggest that the NRC staff limit this STP to one-way thermomechanical coupling as the title suggests, as other NRC guidance (NUREG/CR-5428) has done, and as 10 CFR 60.133(i) requires. We discourage the staff from pursuing fully coupled models at least until the staff and DOE know more about them.

The STP lacks a regulatory basis. It cites the requirements that supposedly require an assessment of coupled processes, yet the terms "coupled processes" or "fully coupled models" never appear in 10 CFR 60, in the draft rule, or in the supplementary and background information. To the contrary, NRC sought to avoid analyses of these highly complex and uncertain interactions. To do so, NRC confined thermally driven phenomena to the "disturbed zone"; a portion of the host rock for which DOE could not take credit. Likewise, NRC required containment until the thermal loads subside. By doing so, NRC sought to simplify DOE's evaluation of the repository's performance. In short, by requiring a "comprehensive, systematic, and logical understanding of the coupled T-M-H-C responses", this STP voids NRC's justification for requiring a disturbed zone and a containment period.

The STP is too generic and lacks pertinent details to meet its stated purpose. The acceptable methodology for demonstrating compliance with 10 CFR 60.133(i), as described on pages 7-10, is incomplete and lacks some crucial details of acceptable methods for decision making, especially in the case where the available information will reflect large uncertainty at the programmatic and technical decision points shown in Figure 1.

On pages 1-5 of the STP, the expectations of the NRC staff at each stage of the program such as Construction Authorization, Construction, Waste Acceptance, Performance Confirmation Monitoring, and Closure, are not clearly stated. The text switches back and forth between these various stages of the program leaving the reader somewhat confused about the various expectations. It would be useful to the designers and modelers of the repository if the expectations of the NRC staff were stated clearly at each stage of the program.

Specific Comments

1. Page iii, ABSTRACT

The NRC staff anticipates that the methodology to demonstrate compliance with 10 CFR 60.133(i) "will require development of fully coupled models." No such requirement appears in 10 CFR 60 nor has this STP justified the need for one. Moreover, STPs cannot "require" but may recommend or suggest a particular approach.

2. Page 2, Section 1.1, Background

The STP states, "One must also understand the uncertainties associated with predicting the thermal loading and corresponding rock and groundwater responses so that these uncertainties can be accommodated by the design." According to 10 CFR 60.2, thermal loads that "may have a significant effect on the performance of the geologic repository" are confined to the "disturbed zone". Provisions at 10 CFR 60.113(a)(2) exclude this thermally disturbed rock from the calculation of ground water travel time, i.e., the calculation cannot take credit for the rock within the disturbed zone.

By creating a disturbed zone, NRC relieved DOE from having to understand the uncertainties associated with predicting thermal loads. NRC justified a disturbed zone because physical and chemical processes therein "are especially difficult to understand in the area close to the emplaced wastes because that area is physically and chemically disturbed by the heat generated by those wastes." (NRC, 1981).

Likewise, NRC requires containment for at least 300 to 1,000 years because during this time, decay heat would drop three orders of magnitude. (Ibid) NRC wanted containment "during the period when the thermal conditions around the waste packages are most severe ... [so that] ... evaluation of repository performance ... [would be] ... greatly simplified...." (Ibid). The rationale for 10 CFR 60 elaborates,

> "During this critical [thermal] period the uncertainties in predicting release rates are very great. Even if we did understand the mechanisms completely, the data scatter increases with temperature so that test programs to gather the data to narrow the uncertainties to reasonable bounds are very cumbersome." (NRC, 1983, page 472).

This STP burdens DOE with the types of assessments that NRC sought to avoid. The STP would have DOE assess the fully coupled thermal, hydrological, mechanical, and chemical processes, plus all uncertainties. But NRC sought to avoid these assessments by confining these processes to a disturbed zone and by requiring that the waste be contained until the processes have attenuated. If DOE must provide the information that this STP requests, there is no longer any justification for 10 CFR 60 to require a disturbed zone or a containment period.

It is also worthwhile to note that other uncertainties in the overall systems, such as the model and parameter uncertainties and the highly uncertain probability and consequences of human intrusion, far outweigh the uncertainties resulting from the use of uncoupled or partially coupled models.

The NRC staff should state that this STP does not apply to the rock within the disturbed zone nor does it apply during the containment period. The disturbed zone includes "that portion of the controlled area the physical or chemical properties of which have changed as a result of ... heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository." (10 CFR 60.2). The containment period would last, at the minimum 300 to 1,000 years.

We must add, however, that if the STP applies after the containment period and only to the rock beyond the disturbed zone, most of the guidance would be irrelevant. When attenuated in time and space, thermal loads and gradients as well as fully coupled T-M-H-C processes would not significantly affect the repository's long-term performance.

3. Page 3, Section 1.1, Background

In line 5 and elsewhere the STP references heat-induced effects on groundwater flow. The STP should also acknowledge the possibility for steam generation and water-vapor transport. Otherwise, the term "groundwater" could be interpreted narrowly to mean only liquid-phase transport.

4. Pages 3 and 4, Section 1.1, Background

The STP states that for "repository-generated thermal regimes that are beyond the range of current engineering experiences," the use of existing models as a first step in establishing an expected range of effects of thermal loads is "not satisfactory" unless there is "a programmatic need for evaluation of such thermal loads."

This STP should not discourage the use of established models in preliminary programmatic evaluations of thermal loadings. Some established models would be useful in sensitivity and tradeoff studies.

Also, the above passage contradicts statements made on page four that state that an initial understanding of thermally induced phenomena is expected to be gained from the use of models that are reasonably available.

The guidance stated above is hardly new, and does not contribute to a demonstration of compliance. There is a need to demonstrate what the thermal loads are, the effects of those loads, and whether the effects are significant to performance and/or design. (Thermomechanical testing is described in SCP section 8.3.1.15.)

5. Page 3, Section 1.1, Background

In the second paragraph, the authors of the STP appear to believe that DOE will make a decision that results in an extraordinarily high repository-generated thermal regime. This may be a reflection of NRC using available but outdated information on repository conceptual design in the Conceptual Design Report or SCP chapters 6 and/or 7. Currently, there is no reference waste package design or heat load. DOE is currently reviewing EBS concepts. Even if this assumption was true and DOE developed "state-of-the-art" models, how would NRC independently evaluate the unproven methodology.

6. Page 4, Section 1.1, Background

The second sentence states, "If, at any time, reliable information is gathered to convincingly demonstrate that further development of predictive models and codes would be unwarranted, nothing in this STP should be interpreted to suggest that the staff would expect that additional unnecessary steps would, nevertheless, be performed."

This statement gives DOE flexibility, but it is inconsistent with the rest of the STP. Overall, the STP implies that fully coupled models and an understanding of fully coupled processes are required. For example, the STP recommends a methodology which "is based on an expected understanding of the fully coupled effects of thermally induced phenomena." (Section 3.0). Apparently, the staff believes that only fully coupled models can produce reliable information. We believe that reliable information can be obtained from simplified uncoupled or partially coupled models and codes.

7. Page 4, Section 1.2, The Use of Models in Thermal-Response Predictions

The third sentence of the first paragraph states, "the NRC staff finds that predictive models based on approximations of coupled formulations of T-M-H-C responses may have to be used for demonstrating compliance with 10 CFR 60.133(i) at the construction authorization stage of the repository licensing process." The staff expects fully coupled models "by the time of application for the license to receive, possess, and emplace waste...."

If NRC finds, with reasonable assurance, that the models are sufficient at the time of construction, there is no reason to develop fully coupled models at the time of licensing. Up until the repository is closed, we will continue improving our models and our understanding of coupled responses. But is it premature for the staff to expect that the processes will ever be fully understood and that these models will be fully coupled.

8. Page 7, Section 3.0, STAFF TECHNICAL POSITIONS

The fourth sentence states that the staff's approach for demonstrating compliance with 10 CFR 60.133(i) "is based on an expected understanding of the fully coupled effects of thermally induced phenomena."

The protection of public health and safety and compliance with 10 CFR 60 do not necessarily depend on understanding the fully coupled effects of thermally induced phenomena. The restricted spatial and relatively short temporal extent over which the coupled effects are significant combined with other precautions mandated by the regulations (i.e., the disturbed zone and a containment period) remove the necessity to fully understand coupled effects. From our reading of the regulations, we conclude that a safety analysis need only demonstrate that thermal loads will not adversely affect the design of the underground facility, and that the design will not preclude compliance with the performance objectives.

9. Pages 8 to 10, Section 3.1, Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)

This section suggests a step-wise approach for developing a fully coupled model which, according to the STP, is needed to demonstrate compliance with requirements for the underground facility at 10 CFR 60.133(i).

Before requesting a fully coupled model, this STP should establish that the model is needed to design an underground facility. The recommended approach does not establish the need for a fully coupled model nor does it explain the degree of coupling that the NRC desires (see our general comments and comments on the definition of fully coupled models). The need for a fully coupled model cannot be simply presumed by the authors.

NRC should at least admit that a fully coupled model is not necessary to resolve all design problems. We recommend that the approach presented in this section expand upon the more sensible approach described in Appendix C, paragraph 4.

10. Page 8, Section 3.1, <u>Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)</u>

The proposed approach suggests eight steps that "can be used to demonstrate the acceptability of the underground facility design."

Steps two and four should be reversed. Step two would use existing models to show compliance with 10 CFR 60.133(i), and step four would develop design goals/criteria for the underground facility. Even if the existing models were adequate, they cannot be used to show compliance until after design goals and criteria are developed. Later, the STP says the same, "The purpose of developing design goals/criteria... is ... to contribute to the assurance that the design of the underground facility has the likelihood of meeting these performance objectives." (pages 14-15).

11. Page 8, Section 3.1, <u>Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)</u>

Step No. 3 needs to be clarified since it is not apparent if "defensible models" used in Step No. 3 are in fact those "existing models" that will show compliance with 10 CFR 60.133(i) as illustrated in Step #2A, Figure 1.

12. Page 9, Section 3.1, <u>Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)</u>

In step 8, the incorporation of predicted results in the pre- and post-closure performance assessment models appears to contradict other NRC guidance. NRC has consistently advised DOE to perform preliminary and iterative performance assessments using available models. DOE might be able to perform preliminary performance assessments using the models examined in Step 2 or developed in Step 5. The NRC's performance assessment staff might think DOE remiss were it not to use these available models. NRC should consider revising the STP in consultation with their performance assessment staff. DOE would appreciate a clarification of guidance on this point as it may apply to other modeling and performance assessment effects.

13. Page 10, Section 3.2, Development of Detailed Predictive Models

The STP states, "To the extent practical, DOE should develop models ... based on a mechanistic understanding of fully coupled T-M-H-C behavior."

As commented earlier, NRC has not clearly explained what constitutes a fully coupled model, what these models will accomplish in terms of meeting NRC regulations, or what advantage these models have over simple uncoupled models. In short, NRC has not provided any compelling reason to develop fully coupled models.

Also, this type of fully coupled mechanistic model may be impossible to validate in the classical sense of the term. NRC's performance assessment staff has stated that classical model validation cannot be accomplished for a repository. Consultation with NRC's performance assessment staff should be considered in revising the STP, concerning the listing of scenarios and use or formulation of strategies on how DOE could make a demonstration with reasonable assurance.

14. Page 10, Section 3.3, Alternative Predictive Models

This section or the glossary in Appendix A should clarify or provide a precise meaning of "the synergistic effects of T-M-H-C interactions". This phrase is also found on page 16, Section 4.2, first paragraph, last sentence.

15. Page 10, Section 3.3, Alternative Predictive Models

The suggested action in (a) should be clarified. Models cannot affect performance objectives in any way. They can affect one's ability to demonstrate compliance or the receptivity of a reviewer to the information presented.

16. Page 10, Section 4.0, DISCUSSION

The STP repeatedly states that a repository's design must comply with the 10 CFR 60 performance objectives. Here it states, "Also, this methodology [for demonstrating compliance with 10 CFR 60.133(i)] takes into account the performance objective of 10 CFR.111, 60.112, and 60.113, all of which must be satisfied by any design." (emphasis added)

Two of the six performance objectives, a repository's overall performance (10 CFR 60.112) and groundwater travel time (10 CFR 60.113(a)(2)) are more oriented towards natural barriers that cannot be designed. Moreover, according to 10 CFR 60.133(i), "the underground facility shall be designed so that the performance objectives will be met....". Thus the STP should state that the design of the underground facility should not preclude compliance with the performance objectives; rather that the design must satisfy the performance objectives.

17. Page 11, Section 4.1, Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)

The first paragraph states that "a decision will be made if the thermal loads have significant impacts on the performance of the geologic repository." Later, the STP states that this would be an early "programmatic" decision.

Since fully coupled models do not exist (and probably never will), early programmatic decisions must be based on the results of simplified models. DOE recommends that the NRC staff explicitly connect early decisions with simplified models.

18. Page 11, Section 4.1, Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)

These are six performance objectives, not three as stated in the second paragraph, second sentence.

19. Page 11, Section 4.1, Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)

That performance assessment take place as stated in the STP only after all design goals/criteria have been met is inconsistent with the advice given to DOE by NRC. Performance assessment only at the end of the process would be too late particularly if goals and criteria can be met, but performance objectives may not be met. The STP should be clarified on this point.

20. Page 12, Section 4.1, <u>Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)</u>

The second paragraph states, "As illustrated in Figure No. 1, the process may be terminated at different decision points, depending on the state of the knowledge and complexity of the information needs."

Other than the first step, Figure 1 does not indicate decision points at which the process may be terminated. Either add these decision points or do not say that they are present.

21. Page 13, Section 4.1, <u>Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)</u>

At Step No. 3, the first paragraph, last sentence states, "This understanding would include an assessment of the level of phenomenological coupling that may be necessary to reasonably characterize the phenomena and predict the responses."

NRC should define "phenomenological coupling" and specify the degree of coupling desired. For example, does the staff want only direct couplings or both direct and crossed couplings? As commented earlier, the staff has not established a need for such a detailed assessment particularly when the total number of direct and crossed couplings are so numerous. If the staff can justify an assessment of phenomenological coupling, the assessment should be limited to direct couplings.

22. Page 16, Section 4.1, <u>Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)</u>

At Step No. 6, the STP cites NUREG/CR-5428 (Brandshaug, 1989) as an example of "heat-transfer predictions". This citation conflicts with previous text where the STP expects an understanding of "fully coupled effects of thermally induced phenomena" (page seven). Brandshaug's model only represents the one-way T-M coupling. We recommend that NRC reconcile the conflict by acknowledging that valuable insight can be gained by using simplified models.

23. Page 17, Section 4.1, <u>Example of an Acceptable Approach for Demonstrating Compliance with 10 CFR 60.133(i)</u>

At Step No. 9, the second sentence states that final step is reached "when the design goals/criteria as well as the performance objectives have been satisfied ... [then] ... it can be concluded that 10 CFR 60.133(i) requirements have been complied with."

This step falsely implies that compliance with the performance objectives (60.111, 60.112, and 60.113) is a prerequisite for the demonstration of compliance with 60.133(i). As we read 10 CFR 60.133(i), the sequence should be: (1) design an underground facility and (2) meet the performance objectives.

24. Page 18, Section 4.2, <u>Development of Detailed Predictive Models</u>

The second paragraph, last sentence, states, "Thus, predictive models capable of analyzing canister-scale, room-scale, repository-scale, and regional scale problems are required to ensure that appropriate phenomenological detail will be included in the analyses."

We do not believe that this is possible. Predictive models, at their best, can discern the engineered from the natural barriers, but they could never analyze canister scale, room scale, repository scale, and regional scale with phenomenological detail. Instead, bounding analyses can insure that the repository will meet the performance objectives. It should also be noted that the system performance objectives at 10 CFR 60.113 were crafted to accommodate the uncertainties that may arise from the lack of mechanistic understanding of the phenomenological couplings (see our general comments).

25. Page 19, Section 4.2, <u>Development of Detailed Predictive Models</u>

The STP states in the first paragraph, second sentence, "The staff also recognizes, on the other hand, that oversimplification in modeling may obscure the understanding of those processes that might have significant impact on design goals/criteria and/or performance."

Please delete this statement. Overly complex models, even more so than simple models, may obscure (through the influence of competing effects) an understanding of one of the coupled processes.

26. Page 19, Section 4.2, <u>Development of Detailed Predictive Models</u>

The last sentence of the second paragraph indicates that "porosity and permeability of the geologic material" should be considered for the chemical model. The sentence should be corrected to reflect the fact that porosity and permeability are hydrologic properties and therefore, should be considered in the hydrologic model. In addition, working the porosity and permeability into a chemical model without also employing the range of grain sizes would prove difficult, since particle surface area per unit volume is a major factor in determining reaction rates.

27. Page 21, Section 4.2, Development of Detailed Predictive Models

The first sentence in the last paragraph states, "Finally all predictive models used for licensing are likely to require a certain degree of verification and validation."

Unless offered only for information, the text on model validation and code verification should be deleted. All model validation issues, whether the model is coupled or uncoupled, should be confined to NUREG-0856, or a separate STP. If the NRC staff keeps the text, please use the terms "verification" and "validation" consistently with the way they are defined in Appendix A and NUREG-0856. Models are not verified; rather models are validated and computer codes are verified.

28. Page 25, Figure 1

The logic flow after Step #8B is not closed. Clarification should also be provided as to what drives Step #7A, "modify underground facility design", and how it enters the logic flow for an example of an acceptable methodology for demonstrating compliance with 10 CFR 60.133(i).

29. Page 26, Appendix A, Glossary

Appendix A defines fully coupled model as "a model that incorporates in its formulation the interdependency of the four phenomena (thermal, mechanical, hydrological, chemical)." (emphasis added)

The interdependency of the phenomena can be incorporated in the formulation at many different levels. Individual codes representing each phenomenon can be incorporated under a system code in which the output of one code provides the input to the other code(s) in an iterative manner until the problem is solved. Alternatively, a model can be constructed with all equations formulated with the interdependencies built in and solved simultaneously. Whether such a detailed formulation is possible with the current scientific understanding of the phenomena and their interdependency or whether the equations can be solved considering the non-linearities in the equations is beside the issue. What is really meant by the definition is not at all clear.

Most natural phenomena occur through many competing interactive processes. Any change in one process, be it thermal, mechanical, hydrological, or chemical, influences the other processes, which in turn affect the original process by either enhancing it or counteracting it. The degree of interaction among the processes, i.e. degree of coupling, can be strong or weak. From a thermodynamical point of view, the coupling can also be classified as primary or secondary depending on the flux and the gradient relationship. The secondary couplings are generally weak. Under certain conditions, however, they could be several orders of magnitude higher than the effects from primary coupling. For example, the Soret effect (mass flux due to thermal gradient) in a clay backfill could easily exceed any water influx due to hydraulic gradient (Jamet, 1990). This is why for some processes the secondary effects cannot be ignored and a fully coupled model that includes weak couplings may be needed.

The secondary effects, sometimes call Onsager's coupled processes (Carnahan, 1987), are very complicated as shown below with a few examples of such couplings in a fluid medium (de Marsily, 1986).

FORCE / FLUX	TEMPERATURE GRADIENT	POTENTIAL GRADIENT		ELECTRIC FIELD
		Pressure	Concentration	
Heat	FOURIER's law	Thermal osmosis	Dufour effect	Electrothermal effect
Mass	Soret effect	Reverse osmosis	FICK's law	Electrophoresis
Current	Seebeck effect	Electrochemical effects		OHM's law
Percolation	Thermoosmosis	DARCY's law	Chemical osmosis	Electroosmosis

Tableau I. A few examples of possible couplings in a fluid medium (after de Marsily 1986)

A fully coupled model generally means a model that includes both the primary and secondary couplings. These are debates in the scientific community about whether such models are needed or even technically feasible within practical limits of current state of knowledge and whether a numerical code implementing a fully coupled model can be run efficiently on currently available computer hardware.

In addition, even if we ignore the secondary effects, 11 distinct combinations of processes can be considered by combining the T, M, H and C processes. There can be six two-process, four three-process, and one four-process combinations (Tsang, 1987). Any of these combinations could be modeled fully uncoupled, sequentially coupled, one-way coupled or two-way (feedback) coupled. In other words, they can be fully coupled with only two, three, or with all four processes as they are needed. A fully coupled model does not necessarily have to include all four processes unless the need for such a fully coupled model is established.

It also appears that this STP uses the word "model" to represent both the conceptual model and numerical codes. In this sense, it is not clear whether the term "fully coupled model" is also intended to mean fully coupled codes, whose meaning could be controversial.

The definition of fully coupled model is unconventional and ambiguous. It needs to be defined with more details. Also, NRC staff should demonstrate the feasibility of their STP by giving an example of a fully coupled model. Aside from this debate of technical feasibility, it is not clear in this STP (text and the definition in Appendix A) what degree of coupling NRC expects when they request a fully coupled model.

References

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