シビアアクシデント評価に関する
調査研究報告書

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一般社団法人　日本原子力学会
「シビアアクシデント評価」研究専門委員会

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（敬称略，順不同）

１．緒言

1.1　背景

今般の福島第一原子力発電所におけるシビアアクシデントの事象進展を再現するためには，解析コードによるシミュレーションが必要である。既存のシビアアクシデントの事象進展を時系列に沿って再現できる解析コードとしては，MAAP，MELCOR，SAMPSON，THALES 等が挙げられる。これらは，炉心及び圧力容器の損傷の時刻，水素及び放射性物質の放出と言った，シビアアクシデントに伴う諸現象を模擬できる。解析コードは，事故時の複合現象のうち支配的な物理モデルを数値化するとともに，ある条件を仮定して計算するものであり，解析結果はプラント情報として得られた原子炉水位，原子炉圧力，格納容器圧力，放射線線量率等の測定データにより検証できる。ただし，解析コードによる事故の再現には，ある程度の不確かさが含まれることに留意する必要がある。そのため，政府事故調報告書 II.1(3)節に記述されているように，事象進展を十分に再現できないなどの解析上の課題を解決できるように研究を進め，より信頼性の高い解析コードとすることが強く望まれる。

1.2　シビアアクシデント研究の現状

これまで数十年にわたり，多くのシビアアクシデント研究が実施され，その研究成果がまとめられている[1-1][1-2]。シビアアクシデントの諸現象には，ジルコニウム－水反応，溶融炉心の再配置，蒸気爆発，燃料－冷却材相互作用，直接格納容器加熱，溶融炉心－コンクリート相互作用，水素爆発，放射性生成物（FP）エアロゾル挙動といった熱流動の要素が多い。これらの現象解明のための実験が日米欧を中心に多く実施され，得られた実験的知見を踏まえ，日米欧で上述の様な解析コードが開発されてきた。我が国で使用されている解析コードは，米国で開発された MAAP と MELCOR のほか，日本原子力研究開発機構で開発された THALES とエネルギー総合工学研究所で開発された SAMPSON がある。また、圧力容器破損防止のため，炉容器内保持（IVR）といった，シビアアクシデントマネジメントも考えられている。

実験及び解析研究を踏まえて，日本原子力学会では，炉心溶融から環境への放射性物質の放出する事象シーケンスの頻度とソースタームを確率論的に評価するレベル２PSA（確率論的安全評価）標準を策定した[1-3]。ソースタームとは，環境に放出される放射性物質の種類，性状，放出量，放出時期，放出期間，放出エネルギーで定義される。つまり，このソースタームを適切に評価できれば，福島第一原子力発電所の事故時に発電所敷地外に放出された放射性物質量を定量的に評価できると言える。しかしながら，シビアアクシデント後期では不確かさが大きく，未解明の現象も少なくない。

1.3　目的

現在，福島第一原子力発電所事故の事象進展を解明するため，各機関でシミュレーションが行われている。同時に，解析コードの限界も理解されつつあり，解析コードの改良に着手する必要がある。そこで，解析コードの効果的な改良に必要な，改良の優先付けなどを行うため，日本原子力学会熱流動部会では平成 23 年 12 月に「シビアアクシデント評価」研究専門委員会（平成 23 年 12 月～平成 26 年 11 月）を発足した。本委員会では，PIRT サブワーキンググループ（PIRT-SWG）と SAMPSON サブワーキンググループ（SAMPSON-SWG）を設けて効率的に議論を重ねた。PIRT-SWG では，事象進展解析とソースターム評価についてシミュレーションの課題を摘出するため，関連知見の調査を行い，シビアアクシデント時の様々な現象を抽出し，重要項目を選定することを目的とした。SAMPSON-SWG では，我が国で開発された機構論的シミュレーションコード SAMPSON をエネルギー総合工学研究所より貸与いただき，福島第一原子力発電所事故の事象進展解析のための，シミュレーションに対する課題を摘出することを目的とした。本報告書は，PIRT-SWG 及び SAMPSON-SWG の調査研究をまとめたものである。

1.4　参考文献

[1-1]　成合，杉山，ほか「シビアアクシデントに関する熱流動研究の最近の動向」日本原子力学会誌 39 巻 9 号 739-752 頁（1997).

[1-2]　I. Kataoka, "Review of Thermal-Hydraulic Researches in Severe Accidents in Light Water Reactors," J. Nucl. Sci. Technol., Vol.50, No.1, pp.1-14 (2013).

[1-3]　日本原子力学会「日本原子力学会標準　原子力発電所の出力運転状態を対象とした確率論的安全評価に関する実施基準（レベル２PSA 編）：2008」AESJ-SC-P009:2008 (2009).

２．PIRT-SWG

2.1　事象進展解析の課題の抽出（熱水力 PIRT）

福島第一原子力発電所事故の事象進展を解明するためには，シビアアクシデント解析コードによる炉心の溶融及び移行挙動，並びにソースターム評価を行う必要がある。また，燃料デブリの取り出しを含む中長期的な廃止措置に取り組むためには，炉心溶融物の存在位置及び分布を推定することが不可欠である。そこで，事象進展解明及び炉内状況把握のための解析コードの予測精度を高めることを目的として，事象進展解析に係る課題を抽出した。課題の抽出にあたっては，３号機を検討対象とし，１号機及び２号機の特有のシナリオについては，３号機シナリオの枠組みの中で適宜補足することとした。

課題の抽出には，PIRT (Phenomena Identification Ranking Table)という手法を用いた。PIRT とは，設計評価項目と流動上の各基本単位で発生する現象を表形式で組み合わせ，評価結果への影響の大きさ等の観点で専門家によりランク付けすることで，発生現象の重要度を考慮して課題を抽出できる表作成の手法及び表の作成結果である[2-1]。欧州では，PWR のシビアアクシデントを主な対象として，多くのシビアアクシデント研究者によって PIRT を実施し，1000 程度の現象を同定し，106 個の重要かつ知見不足の現象を抽出した[2-2]。今回の PIRT においては，BWR を対象として，海水の注入などの福島第一原子力発電所事故特有の現象も取り入れる必要がある。

３号機では，地震発生／原子炉スクラム，RCIC 起動，津波襲来／全電源喪失，RCIC 停止，（代替格納容器スプレー），HPCI 起動，HPCI 停止，原子炉減圧操作，外部注水，炉心露出，（格納容器ベント），炉心損傷による崩落，下部ヘッドへの炉心溶融物移行，原子炉容器損傷，格納容器への炉心溶融物移行，水素爆発といったシナリオが想定される。本 PIRT では，これらのシナリオを５つの時間フェーズに分割し，原子炉スクラムから燃料の溶融開始までを第１フェーズ，炉心領域からの移行開始までを第２フェーズ，原子炉容器破損までを第３フェーズ，格納容器破損までを第４フェーズ，水素爆発までを第５フェーズとした。図 2-1 に事象進展に対するフェーズを示す。

プラントシステムは，原子炉容器内・格納容器内・原子炉建屋内の３つに大別した。さらに，原子炉容器内では，炉心，シュラウドヘッド，スタンドパイプとセパレーター，ドライヤー，上部ヘッド，主蒸気ライン，上部ダウンカマー，下部ダウンカマー，下部ヘッド，再循環ループの 10 個の物理領域（サブシステム・機器）に分割した。格納容器内では，ペデスタルキャビティ，ドライウェル，ドライウェルヘッド，ベントライン／ウェットウェルダウンカマー，ウェットウェルの５個に分割した。原子炉建屋内では，アイソレーションコンデンサー，原子炉建屋の部屋，非常用ガス処理系，オペレーションフロア，ブローアウトパネル，使用済み燃料プール，設備プールの７個に分割した。

同定された現象の重要度レベルを決めるためには主要な指標が必要となる。PIRT で，この指標を FoM (Figure of Merit)と呼び，各時間フェーズにおいて選定する必要がある。FoM

は，第 1 フェーズでは被覆管最高温度と燃料最高エンタルピ，第２フェーズでは炉心平均温度，第３フェーズでは原子炉容器壁最高温度と下部ヘッド内コリウム最高温度，第４フェーズでは格納容器最高圧力及び温度，第５フェーズではガス（水素，酸素，水蒸気）濃度と設定した。

現象の同定には，現在利用可能な情報及び知識レベルでブレーンストーミングを行うこととした。同研究専門委員会に係るメンバーは熱流動及びシビアアクシデント解析の専門家ではあるが，燃料については核燃料部会の専門家の協力も得た。毎週２回程度の集中議論を行い，FoM に影響を与える事象について詳細度には必ずしもこだわらず，考え得るものを抽出する方針とした。その結果，原子炉容器内では 677 件，格納容器内では 358 件，原子炉建屋内では 124 件の計 1159 件が抽出された。

次に，同定された現象についてランク付けを行うため，各時間フェーズで FoM に影響を与える重要度を定義した。High (H)は FoM に大きく影響，Medium (M)は FoM に中程度に影響，Low (L)は FoM にほとんど影響しない，Not Applicable (N/A)は FoM に無関係とすることとした。

併せて，現状の知識レベル（State of Knowledge：SoK）も３分類に設定した。Known (K)は，現象がよく理解され，実験データや解析モデルにおける不確かさが小さい。Partially known (P)は，現象は一般的に理解されているが，実験データが限られ解析モデルにおける不確かさが中程度であり，更なる研究が必要である。Unknown (U)は，現象がよく理解されておらず，実験データがほとんどなく解析モデルにおける不確かさが大きく，解析は仮定に大きく依存するものであり，現象を理解するためには研究が必須である。

ランク付けは，専門家による議論を通じて行われた（詳細は付録 A 参照）。その結果，表 2-1 に示すような重要度レベル及び知識レベルのランキングが明示された（詳細は表 2-5 参照）。同定された現象 1159 件から，重要度が高く（H），知識レベルが十分でない（P 又は U）現象を抽出すると，208 件と集約された。さらに再整理した上で，大項目に整理すると，表 2-2 に示すように 88 件に集約された。全体的には，炉心から離れるに従って，知識レベルが K に対する P と U の比率が高くなり，知識が十分でなくなる傾向がある。現象の重要度については，事象進展を左右するシビアアクシデント特有の熱流動的現象に加えて，計装配管等の破損など燃料やガスの移行経路となる部位の挙動が重要であることが示された。再臨界は起こりにくいと考えられるが，万一発生した場合には影響が大きいことから重要度が高いと示された。また，コリウム内の混合物質の性状や物性値も挙げられている。福島第一発電所事故特有の海水の影響も選定されている。これらの整理の中から，特に重要と考えられる事象について以下に列挙する。

燃料と構造物間の輻射伝熱，炉心部コリウム移行挙動，計装管溶融などの挙動，主蒸気管等の FP 沈着による発熱，コリウム凝固と再溶融，デブリベッド特性・挙動，溶融金属酸化反応，溶融プール特性，コリウム・下部ヘッド間ギャップ

冷却，再臨界，下部ヘッド・制御棒案内管などの損傷過程，下部ヘッドからのコリウム流出挙動，海水影響，ペデスタル部コリウム移行，ペデスタル壁の酸化，MCCI，ベデスタル部サンプ内コリウム挙動，ドライウェル部からの漏えい，DCH，漏えいパスにおけるＦＰ沈着，ベローズの損傷と漏えい，ウェットウェル部からの漏えい，格納容器破損箇所からの水素漏えい，原子炉建屋内水素拡散混合挙動

上記の重要現象のランキングの精度を更に高めるため、シビアアクシデント解析コードMAAP 及びSAMPSON を用いた感度解析を実施し、ランキングの改訂も実施した。

まず、PIRT（表 2-5）から重要度が H と M の現象を抽出し、それらと MAAP コードの入力パラメータを関連付けた。結果的に、107 個の現象が関連付けられた。感度解析を行うに当たり、各パラメータの不確かさ幅を設定する必要がある。そこで、Yamaguchi et al [2-3]を参照して、以下を設定した。

圧損係数：±30%

熱伝達係数：±10%

崩壊熱：±10%

その他：±10%

これを参照したうえで、シビアアクシデントの専門家として本委員会において議論し、感度解析に用いる MAAP の入力パラメータの不確かさを設定した。

当初の重要現象抽出のための PIRT では、３号機を対象としていたが、その後の調査で３号機は当初のシナリオで想定していた注水量とは異なる可能性があることから、感度解析では２号機の事故進展を対象に感度解析を実施した。

なお、2 号機については、昨年度の事故進展解析で適用した原子炉減圧後の外部注水流量では圧力容器の破損には至らないため、そのままでは PIRT の事故シナリオのフェーズに沿った検討ができなかった。そのため、外部注水量を 30%減少させ、RPV 破損が発生する条件をノミナルケースとし、そこから感度解析の対象となる MAAP の入力パラメータを変化させた。感度解析結果を整理する際、通常、感度を Figure of Merit(FoM)で整理すべきである。しかし、例えば、第１フェーズの FoM は被覆管最高温度であるが、事故の進展にともない全てのケースで被覆管温度は最終的に溶融温度に達するため、FoM だけで直接的に感度を評価することが難しい。一方、被覆管温度の上昇が早ければ、炉心溶融までの時間は短く、第１フェーズの継続時間は短くなるように、各フェーズの FoM の変化はそのフェーズの継続時間に大きく影響する。そこで、下記のように各フェーズの継続時間の差を比較し、各ケースのパラメータの感度を比較した。

第１フェーズ：炉心露出開始から炉心ノード（燃料）温度が 2499K を超える時刻(s)までの経過時間

第２フェーズ：炉心燃料温度が 2499K を超えた時点から下部プレナムへのリロケーショ

ン開始までの経過時間

第３フェーズ：下部プレナムへのリロケーション開始時点から RPV 破損までの経過時間で感度を評価

各フェーズの継続時間に対する MAAP 入力パラメータの感度を、現象のランキングと同様に High(H)、Medium(M)、Low(L)の３段階に区分し、表 2-7 にまとめた。それぞれのランキングの選定基準は、本項の冒頭で定義した各フェーズの継続時間の差が、ノミナルケースに対し 10%以上の差があるものを High、5～10%の差があるものを Medium、それ以下を Low とした。全体として、第１フェーズは感度解析の対象としたパラメータのほとんどがノミナルケースと差がない Low となり、第２、第３フェーズは逆に多くのパラメータが High となる結果となった。このことから、第１フェーズは、被覆管温度上昇への細かな現象の寄与は少ないこと、逆に第２フェーズ以降は、各入力パラメータの事故進展におよぼす感度は大きいだけでなく、第２フェーズの結果がその後の第３フェーズの事故進展にも大きく影響することが示唆された。

本感度解析を基に、本委員会で協議した結果、表 2-8 のようにランキングを改訂した。

変更対象現象： 25 現象

変更箇所： 43 箇所

ランキングダウン： 13 箇所

ランキングアップ： 30 箇所

ランキングがダウンした現象の大半は、第 1 フェーズで見られた。これは、第 1 フェーズにおける圧力の変化や水－金属反応の FoM の影 響が当初考えていたよりも小さくなったためである。一方、ランキングがアップした現象は、 全て、第 2、第 3 フェーズで見られた。これは、炉心内で定義した現象の影響は、第 1 フェ ーズに主に影響すると当初考えていたが、第 2、第 3 フェーズに対しても大きく影響すること が判明したためである。

福島第一事故の事象進展を評価するために，現象として重要なものが抽出されている。これらについては，シミュレーションコードによってモデル化されていない現象もあり，これらの影響評価を今後実施し，また必要に応じてモデル化を進める必要がある。従って，本 PIRT の結果を踏まえて，解析コードの高度化のために研究計画を具体化する必要があると考える。

2.2 ソースターム評価の課題の抽出（ソースターム PIRT）

福島第一原子力発電所事故のソースターム評価には，大気拡散からのソースターム推定方法（SPEEDI コードを用いた逆推定）と事象進展解析からのソースターム推定方法（MELCOR コード等を用いた順推定）の異なる方法がある。両者を組み合わせてソースターム評価の精度を向上させる努力を進めているところである。ここでは，上述の事象進展解析コード

のソースターム評価の予測精度を高めることを目的として，ソースターム評価に係る課題を抽出した。

前節と同様に，課題の抽出にはPIRT手法を用いた。ただし，事象進展解析と異なり，ソースタームPIRTではFoMが環境へのソースターム放出量となる。そのため，抽出される現象，ランキングの重要度レベル及び知識レベルを整理する必要がある。

ソースターム評価は，環境への放出の観点から事象晩期に起こる現象の方が重要であることから，前節の第３フェーズまでをひとまとめにした。よって，時間フェーズは３分割にし，原子炉スクラムから原子炉容器破損までの早期，原子炉容器破損から格納容器破損までの中期，格納容器破損以降（格納容器破損後、2～3 週間程度）の後期と設定した。プラントシステムの分割は，基本的には前節と同様だが，ソースターム評価に必要なものに限定される。専門家の協力を得て，前節と同様のブレーンストーミングを行い，現象を同定した結果，68件が抽出された。

重要度レベルと知識レベルのランク付けを行うため，EURSAFE[2-2]と同様に，専門家による投票を行い，整理した。ある閾値を用いてランク付けを行った後，そのランキングについて議論を行い,表2-3に示すようなランキング結果が明示された(詳細は表2-6参照)。

本PIRTにおいてランキングがHighとなった現象を重要事象として表2-4に整理した。これらは,福島第一原子力発電所事故における環境へのソースターム放出量予測という観点で重要と判断された現象である。早期フェーズでは，圧力容器内での現象が多く抽出され，特に溶融燃料からのFP等の放出(2108)が高い得点を示した。中期以降のフェーズでは，圧力容器の外での挙動が多く抽出されており，特にMCCIやヨウ素化学に関する事象が重要事象として数多く挙げられる傾向が見られた。また，同表で挙げられた事象のうち現状の知識レベル（SoK）がP，又はUについては，解析コードによる事故進展解析技術の高度化といった観点で優先度が高い項目と考えらえる。

本PIRTの結果を踏まえて,解析コードの高度化のための研究計画を具体化する必要があると考える。

2.3　まとめ

福島第一原子力発電所でおきたシビアアクシデント現象の把握，さらには事故で放出されたソースタームを評価するためには，解析コードによるシミュレーションが欠かせない。そのシミュレーションの評価精度を向上するため，事象進展及びソースターム評価の 2 つの観点からPIRTを実施し，課題の抽出を行った。今後，本結果を踏まえて，実験も含めて解析コードの高度化のための研究計画が具体化されるべきである。

なお，本PIRTも定期的に見直し，より充実していくことが必要である。

2.4　参考文献

[2-1]　G.E. Wilson and B.E. Bouyack, "The role of the PIRT process in experiments,

code development and code applications associated with reactor safety analysis," Nucl. Eng. Des., Vol.186, pp.23-37 (1998).
[2-2] D. Magallon, A. Mailliat, et al., "European expert network for the reduction of uncertainties in severe accident safety issues (EURSAFE)," Nucl. Eng. Des., Vol.235, pp.209-346 (2005).
[2-3] Yamaguchi, et al., "Stochastic safety analysis of natural circulation decay heat removal in liquid metal reactor," Proceedings of ICAPP 2007.

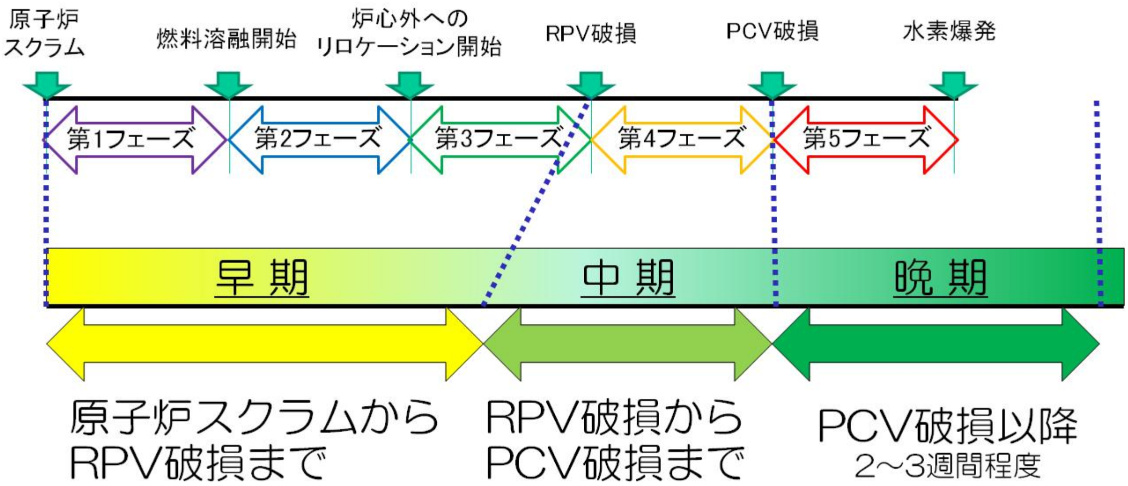

図 2-1　時間フェーズの設定（上段：熱水力 PIRT，下段：ソースターム PIRT）

表 2-1　熱水力 PIRT で同定された現象，重要度レベル，知識レベル

ｼｽﾃﾑ	物理領域（サブシステム・機器）	同定された現象	重要度レベル 第 1 ﾌｪｰｽﾞ H	第 1 ﾌｪｰｽﾞ M	第 1 ﾌｪｰｽﾞ L	第 2 ﾌｪｰｽﾞ H	第 2 ﾌｪｰｽﾞ M	第 2 ﾌｪｰｽﾞ L	第 3 ﾌｪｰｽﾞ H	第 3 ﾌｪｰｽﾞ M	第 3 ﾌｪｰｽﾞ L	第 4 ﾌｪｰｽﾞ H	第 4 ﾌｪｰｽﾞ M	第 4 ﾌｪｰｽﾞ L	第 5 ﾌｪｰｽﾞ H	第 5 ﾌｪｰｽﾞ M	第 5 ﾌｪｰｽﾞ L	知識レベル K	知識レベル P	知識レベル U	H & P or U	項目整理
原子炉内	炉心	178	16	39	36	52	69	48	47	42	87	5	12	161	4	38	132	67	102	9	54	12
	シュラウドヘッド	32	0	1	26	0	1	31	0	1	31	0	3	29	0	6	26	17	12	3	0	0
	スタンドパイプ/セパレーター	32	0	0	29	0	4	28	0	4	28	4	3	25	7	2	23	16	14	2	2	1
	ドライヤー	24	0	0	24	0	4	20	0	4	20	4	1	19	6	3	15	11	6	7	2	1
	上部ヘッド	24	0	2	22	1	6	17	1	6	17	4	6	14	3	7	14	11	9	4	1	1
	主蒸気ライン	32	0	7	22	5	8	18	5	8	18	3	7	21	5	7	0	0	5	2	1	1
	上部ダウンカマー	31	1	3	26	0	5	26	0	5	26	2	12	17	1	12	18	20	6	5	0	0
	下部ダウンカマー	123	2	6	38	2	7	37	42	49	31	0	23	100	1	9	113	28	82	13	0	9
	下部ヘッド	164	0	3	26	1	1	32	78	41	19	21	72	70	14	52	97	25	123	15	0	18
	再循環ループ	37	0	0	29	0	2	29	2	4	31	0	3	34	2	8	27	17	13	7	0	0
	小計	677	19	61	278	61	107	286	175	164	308	43	142	490	43	144	465	212	372	67	60	43
格納容器内	ペデスタルキャビティ	140	0	0	40	0	0	40	0	0	40	69	35	36	54	37	49	24	97	19	67	13
	ドライウェル	105	0	0	50	0	0	50	0	0	50	46	31	28	39	30	36	16	74	15	45	11
	ドライウェルヘッド	33	0	1	28	1	1	30	1	1	30	14	5	14	17	2	14	14	17	2	4	4
	ベントライン／ウェットウェルダウンカマー	40	0	0	36	0	0	36	0	0	36	7	7	26	5	5	30	10	23	7	6	5
	ウェットウェル	40	0	0	33	0	0	34	0	0	34	9	9	22	12	7	21	12	22	6	3	2
	小計	358	0	1	187	1	1	190	1	1	190	145	87	126	127	81	150	76	233	49	125	35
原子炉建屋内	アイソレーションコンデンサー	16	0	9	4	3	2	8	2	2	12	0	2	9	0	4	9	7	9	0	2	1
	原子炉建屋の部屋	65	0	0	10	0	0	10	0	0	10	0	0	11	17	35	13	5	60	0	17	7
	非常用ガス処理系	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	0	0
	オペレーションフロア	30	0	0	9	0	0	9	0	0	9	0	0	9	4	11	15	0	30	0	3	2
	ブローアウトパネル	4	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	3	1	0	1	1
	使用済み燃料プール	6	0	0	4	0	0	4	0	0	4	0	0	4	0	2	4	0	6	0	0	0
	設備プール	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
	小計	124	0	9	27	3	2	31	2	2	35	0	2	33	23	56	42	16	108	0	23	10
合計		1159	19	71	492	65	110	507	178	167	533	188	231	649	193	281	657	304	713	116	208	88

注）重要度レベルでは H：High, M：Medium, L：Low。知識レベルでは K：Known, P：Partially known, U:Unknown。

表 2-2　熱水力 PIRT で重要度が高く知識レベルが十分でない現象の整理(1/2)

No.	RPV or PCV	Subsystem Component	Phenomena	1st Phase FoM: Fuel Rod Enthalpy	2nd Phase FoM: Enthalpy or Avr.Temp. for Core Region	3rd Phase FoM: RPV wall or Corium Maximum Temp.	4th Phase FoM: Maximum Press. and Temp. in PCV	5th Phase FoM: Concent. of Hydrogen, Oxygen and Steam	SOK
1	RPV	Core	Zr-Water Reaction	H	H	M	L	H	P
2			Heat transfer between core materials	N/A	H	H	H	L	P
3			Radiation heat transfer between corium and structures	N/A	H	H	L	L	P
4			Melting of control rod	N/A	H	M	L	L	P
5			Physical properties of core materials	N/A	H	H	M	M	P
6			Corium relocation	N/A	H	H	M	M	P
7			Molten pool behavior	N/A	H	H	L	L	P
8			Oxidation reaction between corium and water	N/A	L	H	L	M	U
9			Solidification of corium	N/A	H	H	H	M	P
10			Melting of corium (particle and crust)	N/A	H	H	L	L	P
11			Re-criticality	N/A	H	H	L	L	P
12			Instrumentation tube related behavior	N/A	M	H	M	H	P
13		Standpipe & Separator	FP deposition/accumulation	L	M	M	H	H	P
14		Driyer	FP deposition/accumulation	L	M	M	H	H	P
15		Upper Head	FP deposition/accumulation	L	M	M	H	H	P
16		Main Steam Line	FP deposition/accumulation	L	H	H	M	H	P
17		Lower down comer	FP accumulation at leakage path	M	H	H	H	H	U
18			Heat transfer between core materials	N/A	N/A	H	M	L	P
19			Corium relocation	N/A	N/A	H	M	M	U
20			Fuel-coolant interaction (FCI)	N/A	N/A	H	M	M	P
21			Solidification of corium	N/A	N/A	H	L	L	U
22			Melting of corium (particle and crust)	N/A	N/A	H	L	L	P
23			Physical properties of core materials	N/A	N/A	H	L	L	P
24			Debris bed properties and behavior	N/A	N/A	H	L	L	P
25		Lower head	Heat transfer between core materials/structures	N/A	N/A	H	M	M	U
26			Debris bed properties and behavior	N/A	N/A	H	M	L	P
27			Oxidation reaction between structures/molten metal	N/A	L	M	L	H	P
28			Corium relocation	N/A	N/A	H	M	M	P
29			Molten pool behavior	N/A	N/A	H	M	L	P
30			Fuel-coolant interaction (FCI)	N/A	N/A	H	M	M	P
31			Solidification of corium	N/A	N/A	H	M	L	P
32			Physical properties of core materials	N/A	N/A	H	M	M	U
33			Melting of corium (particle and crust)	N/A	N/A	H	L	L	P
34			Re-criticality	N/A	N/A	H	M	L	P
35			Formation of gap between corium and lower head	N/A	N/A	H	M	L	P
36			Crack formation in lower head	N/A	N/A	H	M	M	P
37			Mechanical/Chemical damage of lower head	N/A	N/A	H	H	M	P
38			Material relocation through control rod guide tubes	N/A	N/A	H	H	H	P
39			Material relocation through SRM/IRM/TIP/ICM	N/A	N/A	H	H	H	P
40			Radiation heat transfer between corium and structures	N/A	N/A	H	L	H	P
41			Melting of lower head material	N/A	N/A	H	H	H	P
42			Sea salt effect	N/A	N/A	H	H	H	U

表2-2　熱水力PIRTで重要度が高く知識レベルが十分でない現象の整理(2/2)

43	PCV	Pedestal Cavity	Heat transfer between core materials/structures	L	L	L	H	H	P
44			Debris bed properties and behavior	N/A	N/A	N/A	H	L	P
45			Corium relocation	N/A	N/A	N/A	H	H	U
46			Molten corium concrete interaction (MCCI)	N/A	N/A	N/A	H	H	U
47			Heat transfer between core materials	N/A	N/A	N/A	H	H	P
48			Re-criticality	N/A	N/A	N/A	H	L	P
49			Oxidation reaction of pedestal wall	L	L	L	M	H	P
50			Fuel-coolant interaction (FCI)	N/A	N/A	N/A	H	H	P
51			Direct Containment Heating (DCH)	N/A	N/A	N/A	H	H	P
52			Pedestal water level change	L	L	L	H	M	P
53			Melting of structures in pedestal internal	N/A	N/A	N/A	H	H	U
54			Corium flow into sump pit	N/A	N/A	N/A	H	H	P
55		Drywell	Deposition situation of corium on pedestal floor	N/A	N/A	N/A	H	M	P
56			Corium leak into connecting piping inside sump	N/A	N/A	N/A	H	H	P
57			Leakage through containment vessel penetration	L	L	L	H	H	U
58			Heat transfer between core materials/structures	L	L	L	H	H	P
59			Drywell water level change	L	L	L	H	M	P
60			Molten corium concrete interaction (MCCI)	N/A	N/A	N/A	H	H	U
61			Direct Containment Heating (DCH)	N/A	N/A	N/A	H	H	P
62			Crust properties and formation/remelting behavior	N/A	N/A	N/A	H	H	P
63			Re-criticality	N/A	N/A	N/A	H	L	P
64			Oxidation reaction of drywell structures	L	L	L	M	H	P
65			Melting of structures in drywell internal	N/A	N/A	N/A	H	H	U
66			Heat release from drywell wall	L	L	L	H	H	P
67		Drywell Head	Mechanical damage of drywell head	L	L	L	H	H	P
68			Pressure loss of bulk head plate in head	L	L	L	M	H	P
69			FP accumulation at leakage path	M	H	H	H	H	U
70			Direct Containment Heating (DCH)	N/A	N/A	N/A	H	H	P
71		Drywell vent line and downcomer to Wetwell	Mechanical damage of pipe line	L	L	L	H	H	P
72			Direct Containment Heating (DCH)	N/A	N/A	N/A	H	H	P
73			Change of failure crack area on bellows	L	L	L	H	H	P
74			Leakage through bellows	L	L	L	H	H	P
75			Water level change in Drywell/Wetwell ventilation line	L	L	L	H	M	U
76		Wetwell	Mechanical damage of wetwell	L	L	L	H	H	P
77			Leakage from wetwell	N/A	N/A	N/A	H	H	P
78		Isolation Condenser	Leakage from wetwell	L	H	H	N/A	M	P
79	R/B	R/B Compartments	Gas/water leak	N/A	N/A	N/A	N/A	H	P
80			PCV ventilation piping sheet degradation	N/A	N/A	N/A	N/A	H	P
81			Gas reflux flow through PCV ventilation line and stack	N/A	N/A	N/A	N/A	H	P
82			Gas reflux flow through PCV	N/A	N/A	N/A	N/A	H	P
83			Mixing and accumulation	N/A	N/A	N/A	N/A	H	P
84			Hydrogen flame and combustion	N/A	N/A	N/A	N/A	H	P
85			Gas mixing and composition fraction change	N/A	N/A	N/A	N/A	H	P
86		Operation floor	Gas mixing and composition fraction change	N/A	N/A	N/A	N/A	H	P
87			Hydrogen flame and combustion	N/A	N/A	N/A	N/A	H	P
88		Blowout Panel	Opening of the blowout panel	N/A	N/A	N/A	N/A	H	P

表 2-3　ソースターム PIRT で同定された現象，重要度レベル，知識レベル

システム	物理領域（ソースターム放出）又は特徴	同定された現象	重要度レベル									知識レベル			H & P or U
			初期			中期			後期						
			H	M	L	H	M	L	H	M	L	K	P	U	
原子炉内	炉心（炉容器内での放出）	14	4	9	1	1	7	6	0	3	11	3	4	7	4
	原子炉容器・配管（炉容器内での移行）	10	1	9	0	1	9	0	0	6	4	9	1	0	0
	計装配管等（炉容器から格納容器への移行）	3	2	0	1	3	0	0	3	0	0	0	3	0	3
	小計	27	7	18	2	5	16	6	3	9	15	12	8	7	7
格納容器内	ペデスタルキャビティ（格納容器内での放出）	2	0	0	2	1	1	0	1	1	0	1	1	0	1
	ドライウェル／ウェットウェル（格納容器内でのエアロゾル挙動）	16	1	6	9	2	14	0	3	11	1	12	4	0	2
	トップヘッドフランジ等（格納容器から建屋への移行）	5	0	0	5	3	0	2	4	0	1	0	4	1	4
	小計	23	1	6	16	6	15	2	8	12	2	13	9	1	7
原子炉建屋内	原子炉建屋（建屋内でのエアロゾル挙動）	2	0	0	2	0	0	2	1	1	0	1	0	1	0
＊	ヨウ素化学反応	13	0	5	7	1	11	1	13	0	0	0	11	2	13
＊	ヨウ素化学形態	3	0	1	2	0	2	1	3	0	0	1	1	1	2
合計		68	8	30	29	12	44	12	28	22	17	27	30	13	29

注）重要度レベルでは H：High，M：Medium，L：Low。知識レベルでは K：Known，P：Partially known，U:Unknown。

ヨウ素化学は格納容器及び原子炉建屋で見られるため，＊で表記。

表 2-4　ソースターム PIRT のスクリーニング結果（1/2）

番号	現　象	時間フェーズ			SoK
		早期	中期	後期	
1. In-vessel Release					
2106	Pellet form change and radionuclides release at the time of the clad rupture	High			P
2107	Radionuclides release after pellet is exposed to the atmosphere in the core by clad melting	High			U
2108	Radionuclides release from molten fuel	High	High		U
2111	Influence on iodine/cesium chemical form and hydrogen production from molten/re-solidified fuel due to the B4C control rod existence	High			U
2. Gas/Aerosol Behaviour in Vessel, Loop, and Steam line					
2201	Condensation/Re-vaporization/Adsorption	High	High		K
3. Transport in RPV and PCV					
2301	Leakage via instruments, penetration, etc	High	High	High	P
2302	Leakage via gasket	High	High	High	P
2303	Leakage by RPV damage		High	High	P
4. Ex-vessel Release					
2401	MCCI (Concrete erosion)		High	High	P
5. Aerosol Behaviour in Containment					
2501	Scrubbing by steam flow from SRV to S/C	High			K
2502	Scrubbing with the vent from D/W to S/C		High	High	P
2503	Scrubbing due to water injection to the pedestal floor			High	P
2507	Condensation / Re-vaporization / Adsorption		High		K
2513	Deposition by gravitational settling			High	K
6. Transfer out of Containment					
2601	Leakage via instruments, penetrations, gasket, etc		High	High	P
2602	Wetwell vent		High	High	P
2603	Drywell vent		High	High	P
2605	Migration of radioactive material by the injection water into the reactor			High	U
7. Aerosol Behaviour in Reactor Building					
2701	Aerosol Behaviour in Reactor Building			High	K

表 2-4　ソースターム PIRT のスクリーニング結果 (2/2)

番号	現　象	時間フェーズ			SoK
		早期	中期	後期	
8. Iodine chemistry					
2801	Generation of acidic substances by radiolysis			High	P
2802	Hydrolysis			High	P
2803	Re-volatilization of iodine by acidification pH decrease			High	P
2804	Iodine chemical reaction in water pool			High	P
2805	Decomposition reaction of iodine in the atmosphere			High	P
2806	Transfer between gas phase and water pool			High	P
2807	Recombination reaction of iodine in the atmosphere			High	P
2808	Wall deposition of iodine in the atmosphere			High	P
2809	Wall adsorption and desorption of iodine by chemical adsorption process			High	P
2810	Effect of impurities in the water pool			High	P
2811	Iodine chemistry under high water temperature conditions			High	P
2812	Effects of seawater			High	U
2813	Iodine release from R/B contaminated water		High	High	U
9. Chemical form (Iodine, Cesium)					
2901	Re-evaporation of I2 by the decomposition of CsI			High	K
2902	Effects of seawater			High	U
2903	A generation ratio for the inorganic iodine of the organic iodine			High	P

表 2-5　熱水力 PIRT

	RPV or PCV	Subsystem/ Component	Phenomenon (Ranking scale: Importance: **H**igh, **M**edium, **L**ow, **N/A** Sok(state of knowledge): **K**nown, **P**artially known, **U**nknown	1st phase	2nd phase	3rd phase	4th phase	5th phase	SoK
				Fuel Heat Up	Fuel Melting	Relocation from the Core	PCV Deposition	Hydrogen Leak and Explosion	
				FoM: Fuel Rod Enthalpy	FoM: Enthalpy or Average Temperature for Core Region	FoM: Maximum Temperature in RPV wall or Corium Maximum Temperature	FoM: Maximum Pressure and Temperature in PCV	FoM: Concentration of Hydrogen, Oxygen and Steam	
1	RPV	Core	Core Water Level Change	H	H	M	M	M	K
2			Core Flowrate Change	H	H	M	M	L	K
3			Core Coolant Temperature Change	H	L	L	L	L	K
4			Core Pressure Change	H	H	H	H	M	K
5			Boiling due to Depressurization	H	L	L	L	L	K
6			Gap Conductance between Fuel Pellets and Cladding	H	L	L	L	L	K
7			Gas (Condensable/Incondensable) Temperature Change in Channel Region	M	L	L	M	M	K
8			Temperature Change in Fuel Cladding	H	H	L	L	M	K
9			Temperature Change in Fuel Pellets	H	H	L	L	M	K
10			Temperature Change in Control Rods	L	M	L	L		P
11			Decay Heat in Intact Fuel Assemblies	H	M	L	L	L	K
12			Gamma Ray Heat Generation in Core Internals (Except Fuel Rods)	L	L	L	L	L	K
13			Temperature Change in Gaps between Fuel Pellets and Cladding	M	L	L	L	M	K
14			Temperature Change in Channel Boxes	M	H	L	L	M	P
15			Temperature Change in Tie Plates	L	L	L	L	L	K
16			Temperature Change in Spacers	L	L	L	L	L	K
17			Heat Transfer between Water and Fuel Cladding	H	H	L	L	L	K
18			Heat Transfer between Water and Channel Boxes	M	M	L	L	L	K
19			Heat Transfer between Water and Control Rods	L	M	L	L		K
20			Heat Transfer between Water and Tie Plates	L	L	L	L	L	K
21			Heat Transfer between Water and Spacers	M	L	L	L	L	K
22			Heat Transfer between Fuel Cladding and Spacers	L	L	L	L	L	K
23			Heat Transfer between Fuel Cladding and Gas	H	H	L	L	M	K
24			Heat Transfer between Fuel Pellets and Gas	M	L	L	L	L	K
25			Heat Transfer between Channel Boxes and Gas	L	L	L	L	M	K
26			Heat Transfer between Control Rods and Gas	L	M	L	L		K
27			Heat Transfer between Tie Plates and Gas	L	L	L	L	L	K
28			Heat Transfer between Spacers and Gas	L	L	L	L	L	K
29			Hydrogen Absorption in Fuel Cladding	M	M	L	L	M	K
30			Fuel Pellets Composition (Including MOX Fuels and Gd2O3)	M	M	L	L	M	K
31			Fuel Rod Growth (Cladding Irradiation Growth)	M	L	L	L	L	K
32			Pressure Change in Gap between Fuel Pellets and Cladding	M	M	L	L	L	K
33			Gas Composition Change in Gap between Fuel Pellets and Cladding	M	L	L	L	L	K
34			Balooning of Fuel Cladding	M	L	L	L	L	P
35			Contraction of Fuel Cladding Outer Diameter（Creep Down）	M	M	L	L	L	K
36			Fuel Cladding Rupture	L	L	L	L	L	K
37			Changes in Bonding Status of Fuel Pellts to Cladding	L	L	L	L	L	P
38			Pellet Cracks, Grains and Relocation in Cladding	M	L	L	L	L	P
39			Water Flow into Gap between Fuel Pellets and Cladding	N/A	N/A	N/A	L	M	P
40			Steam Flow into Gap between Fuel Pellets and Cladding	M	M	L	L	M	P
41			Zr-Water Reaction Facilitation by Water Flow into Gap between Fuel Pellets and Cladding	N/A	N/A	N/A	L	H	P
42			Core Axial Power Distribution Change	H	H	L	L	M	K
43			Core Radial Power Distribution Change	H	H	L	L	M	K
44			Fuel Axial Exposure(Burn-up) Distribution	M	H	L	L	M	K

45			Fuel Radial Exposure(Burn-up) Distribution	M	H	L	L	M	K
46			Pressure Loss Change for Core Flow Paths	M	M	L	L	L	K
47			Changes in Flowrate Distribution between Fuel Channels and Bypasses	M	M	L	L	L	K
48			Changes in Flowrate Distribution in each Fuel Channel	M	M	L	L	L	K
49			Changes in Pressure Loss at Core Inlet	M	L	L	L	L	K
50			Pressure Loss Increase by Fuel Cladding Swelling	M	L	L	L	L	K
51			Change in 2-Phase Flow Regime Status in Fuel Channels	M	M	L	L	L	K
52			Change in 2-Phase Flow Regime Status in Bypass Regions	M	L	L	L	L	K
53			Gas Natural Circulation above Water Level	H	H	H	L	M	K
54			CCFL at Upper Tie Plate	M	M	L	L	L	K
55			CCFL at Bypass Region	M	M	L	L	L	K
56			CCFL at Core Inlet	M	M	L	L	L	K
57			Changes in Gas Composition in Core Region	M	M	L	L	M	P
58			Changes in Gas Spatial Distbution in Core Region	M	M	L	L	M	K
59			Changes in Gas Mixture Properties in Core Region	M	M	L	L	M	K
60			Changes in the Amount of Residual Burnable Poisons	L	L	L	L	L	K
61			Changes in Properties of Fuel Materials	M	M	L	L	L	K
62			Changes in Properties of Core Internals	L	M	M	L	L	K
63			Zr-Water Reaction Including Oxidation and Hydrogen Production	H	H	M	L	H	P
64			SUS-Water Reaction Including Oxidation and Hydrogen Production	M	M	L	L	H	K
65			Reaction between Water and Other Substances (e.g. B4C), Including Oxidation and Hydrogen Production	M	M	L	L	M	P
66			Heat Transfer between Water(Liquid Phase) and Corium	N/A	H	H	M	L	P
67			Heat Transfer between Gaseous Phase and Corium	N/A	H	H	H	L	P
68			Heat Transfer between Fuel Cladding and Corium	N/A	H	H	L	L	P
69			Heat Transfer between control rods and Corium	N/A	H	H	L	L	P
70			Heat Transfer between Channel Boxes and Corium	N/A	H	H	L	L	P
71			Heat Transfer between Core Shroud and Corium	N/A	H	H	L	L	P
72			Heat Transfer between Water Rods (or Channels) and Corium	N/A	M	M	L	L	P
73			Heat Transfer between Water(Liquid Phase) and Particulate Corium	N/A	H	H	M	L	P
74			Heat Transfer between Gaseous Phase and Particulate Corium	N/A	H	H	H	L	P
75			Heat Transfer between Fuel Cladding and Particulate Corium	N/A	M	M	L	L	P
76			Heat Transfer between control rods and Particulate Corium	N/A	M	M	L	L	P
77			Heat Transfer between Channel Boxes and Particulate Corium	N/A	M	M	L	L	P
78			Heat Transfer between Core Shroud and Particulate Corium	N/A	L	M	L	L	P
79			Heat Transfer between Water Rods (or Channels) and Particulate Corium	N/A	L	L	L	L	P
80			Heat Transfer between Water(Liquid Phase) and Crust	N/A	H	H	M	L	P
81			Heat Transfer between Gaseous Phase and Crust	N/A	H	H	H	L	P
82			Heat Transfer between Fuel Cladding and Crust	N/A	M	H	L	L	P
83			Heat Transfer between control rods and Crust	N/A	M	H	L	L	P
84			Heat Transfer between Channel Boxes and Crust	N/A	M	H	L	L	P
85			Heat Transfer between Core Shroud and Crust	N/A	M	H	L	L	P
86			Heat Transfer between Water Rods (or Water Channels) and Crust	N/A	M	M	L	L	P
87			Heat Transfer between Crusts and Corium	N/A	H	H	L	L	P
88			Heat Transfer between Core Support Plate and Corium	N/A	H	H	L	L	P
89			Heat Transfer between Core Support Plate and Crusts	N/A	H	H	L	L	P
90			Heat Transfer between Core Fuel Support Coupling and Corium	N/A	H	H	L	L	P
91			Radiation Heat Transfer among Fuel Rods	H	H	L	L	L	K
92			Radiation Heat Transfer between Channel Boxes and Fuel Rods	L	M	L	L	L	K
93			Radiation Heat Transfer between Water Rods (or Water Channels) and Fuel Rods	L	M	L	L	L	K
94			Radiation Heat Transfer among Channel Boxes	M	M	L	L	L	K
95			Radiation Heat Transfer between Channel Boxes and Core Shroud	M	M	L	L	L	K
96			Radiation Heat Transfer between control rods and Core Shroud	L	M	L	L	L	K
97			Radiation Heat Transfer between control rods and Channel Boxes	L	M	L	L	L	K

98			Radiation Heat Transfer between Corium and Shroud	N/A	H	H	L	L	P
99			Radiation Heat Transfer between Crusts and Shroud	N/A	M	M	L	L	P
100			Radiation Heat Transfer between Particulate Corium and Shroud	N/A	M	M	L	L	P
101			Radiation Heat Transfer between Corium and Core Support Plate	N/A	H	H	L	L	P
102			Radiation Heat Transfer between Crusts and Core Support Plate	N/A	M	M	L	L	P
103			Radiation Heat Transfer between Particulate Corium and Core Support Plate	N/A	L	L	L	L	P
104			Fuel Pellet Expansion（Thermal Expansion, Gas Swelling, Solid Swelling）	M	M	L	L	L	K
105			FP Absorption into Fuel Pellet	L	L	L	L	L	P
106			FP Release from Pellet to Gap between Fuel Pellets and Cladding (Gap Release)	M	M	L	L	M	P
107			FP Release from Damaged Fuel Rods to Channel Region	M	M	L	L	M	P
108			Melting of Fuel Cladding	N/A	H	M	L	L	K
109			Melting of Fuel Pellet	N/A	H	M	L	L	K
110			Melting of control rod	N/A	H	M	L	L	P
111			Melting of Channel Box	N/A	H	M	L	L	P
112			Melting of Spacers	N/A	M	L	L	L	P
113			Melting of Tie Plates	N/A	M	L	L	L	P
114			Phase changing condition change for core materials (including eutectic)	N/A	H	H	M		P
115			Fuel Rod Collapse and Moving to the Lower Region	N/A	H	H	L	L	P
116			Channel Blockage by Collapsed Fuel Rods	N/A	H	M	L	L	P
117			Melted Fuel 'Candling'	N/A	H	M	L	L	P
118			Channel and Bypass Blockage by Melted Fuel	N/A	H	M	L	L	P
119			Corium Temperature Change	N/A	H	H	L	L	P
120			Formation of Molten Pool	N/A	H	H	L	L	P
121			Natural Circulation in Molten Pool	N/A	H	H	L	L	P
122			Molten Core Flow out of Crust Crack	N/A	H	H	L	L	P
123			Corium Transverse Flow above Blocked Flowpaths	N/A	H	H	L	L	P
124			Corium Spatial Distribution	N/A	L	H	L	L	P
125			Vaporization inside Corium (including FP release)	N/A	M	M	L	L	P
126			Decay Heat Generation from Corium	N/A	H	H	L	L	K
127			Corium-Water Reaction (Including Oxidation and Hydrogen Production)	N/A	L	H	L	M	U
128			Changes in Corium Properties by Mixed Composition	N/A	H	H	L	L	P
129			Crust generation by solidification of corium	N/A	H	H	L	L	P
130			Corium relolcation type through breached core support plate	N/A	N/A	H	M	M	P
131			Change in Ablated Area for Core Support Plate	N/A	N/A	H	L	L	P
132			Changes in Particle Corium (Debris) Composition	N/A	L	L	L	L	P
133			Changes in Particle Corium Shape and Size	N/A	L	L	L	L	P
134			Particulate Corium (Debris) Relocation	N/A	L	M	L	L	P
135			Particle Corium Uneven Distribution	N/A	L	L	L	L	P
136			Crust Formation on Fuel Cladding	N/A	M	M	L	M	P
137			Void Generation inside Crust	N/A	M	M	L	L	P
138			Water Flow around Crust	N/A	M	M	L	L	P
139			Gaseous Flow around Crust	N/A	M	M	L	L	P
140			Formation of Crust Crack	N/A	M	M	L	L	P
141			Crust Temperature Change	N/A	M	M	L	L	P
142			Changes in Crust Properties by Mixed Composition	N/A	M	M	L	L	P
143			Crust-Water Reaction (Including Oxidation and Hydrogen Production)	N/A	M	M	L	M	U
144			Water Flow into Crust	N/A	M	M	L	M	P
145			Crust remelting due to change in the heat transfer status to corium or water	N/A	H	H	L	L	P
146			Particulate corium remelting due to change in the heat transfer status	N/A	H	H	L	L	P
147			Decay Heat Generation from Crust	N/A	M	H	L	L	P
148			Molten Core Re-Criticality	N/A	H	H	L	L	P
149			Molten Core Reflooding by Injection Restart	N/A	H	M	M	L	K

150		FP deposition on core internals	L	L	M	L	M	P
151		FP re-vaporization	L	L	M	L	M	P
152		Decay heat generation from FP	L	L	M	L	M	P
153		FP reaction including iodine chemistry	L	L	L	L	L	P
154		Adsorption and release of gaseous FP	L	L	L	L	L	P
155		Corium Jet through Breached Core Support Plate	N/A	N/A	H	M	M	P
156		Corium Flow into control rod guide tubes through Breached Fuel Support Coupling	N/A	N/A	H	L	L	P
157		Corium Flow to the Downcomer through Breached Core Shroud	N/A	N/A	H	L	L	P
158		Corium Flow out of the Core Inlet Orifice	N/A	N/A	H	L	L	P
159		Corium Solidifcation inside Fuel Support Coupling	N/A	N/A	H	L	L	P
160		Instrumentation Tube Break	N/A	M	H	M	M	P
161		Corium Flow into Instrumentation Tube	N/A	M	H	L	M	P
162		Water Flow into Instrumentation Tube	N/A	M	M	L	M	P
163		Corium Solidifcation inside Instrumentation Tube	N/A	M	M	H	M	P
164		Gas Leak Flow into Instrumentation Tube	N/A	M	M	L	H	P
165		Water Radiolysis	L	L	L	L	L	K
166		Seasalt intake to corium	N/A	M	M	M	M	U
167		Seasalt impact for corium thermodynamic properties	N/A	M	M	L	L	U
168		Seasalt impact for FP reaction and composition	L	L	L	L	L	P
169		Corrosion of Core Internals by Seasalt (including Marine Lives)	L	L	L	L	L	U
170		Impact of Seasalt Deposition on Heat Transfer	M	M	M	L	L	U
171		Channel (Bypass) Flowpath Blockage by Seasalt Deposition	L	M	L	L	L	U
172		Seasalt Dissolution by Reflooding	L	M	L	L	L	P
173		Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
174		Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
175		Corrosion of Core Internals by Boron	L	L	L	L	L	U
176		Impact of Boron Deposition on Heat Transfer	L	L	M	L	L	P
177		Channel (Bypass) Flowpath Blockage by Boron Deposition	L	M	L	L	L	P
178		Boron Dissolution by Reflooding	L	L	L	L	L	P
179	Shroud head	Radiation Heat Transfer between Intact Fuel Rods and Shroud Head	M	L	L	L	L	K
180		Radiation Heat Transfer between Corium and Shroud Head	N/A	L	L	L	M	K
181		Radiation Heat Transfer between Crust and Shroud Head	N/A	L	L	L	L	K
182		Radiation Heat Transfer between Shroud Sidewall and Shroud Head	L	L	L	L	L	K
183		Radiation Heat Transfer between Particulate Corium and Shroud Head	N/A	L	L	L	L	P
184		Heat Transfer between Gas and Shroud Head	L	L	L	M	M	K
185		Shroud Head Break or Deformation by Thermal Stress	L	L	L	L	L	K
186		Shroud Head Oxidation with Steam (Including Reaction Heat and Hydrogen Production)	L	L	L	L	M	K
187		Gamma Ray Heat Generation in Shroud Head	L	L	L	L	L	K
188		Temperature Change in Shroud Head Structure	L	L	L	L	L	K
189		Droplet Spray	N/A	L	L	L	L	K
190		Droplet Deposition on Shroud Head Structure	N/A	L	L	L	L	K
191		Condensation Heat Transfer on Shroud Head	L	L	L	L	L	K
192		Pressure Change in Shroud Head	L	M	M	L	M	K
193		Gas Flow in Shroud Head	L	L	L	L	L	K
194		Gas Composition Change in Shroud Head	L	L	L	M	M	K
195		Gas Temperature Change in Shroud Head	L	L	L	M	M	K
196		FP deposition on shroud head	L	L	L	L	L	P
197		FP re-vaporization	L	L	L	L	L	P
198		Decay heat generation from FP	L	L	L	L	L	K
199		FP Leakage from Flange between Shroud Sidewall and Head	L	L	L	L	L	P
200		FP reaction including iodine chemistry	L	L	L	L	L	P
201		Gas Leakage from Flange between Shroud Sidewall and Head	L	L	L	L	L	P
202		Corrosion of Shroud Head by Seasalt (Including Marine Lives)	L	L	L	L	L	U

203			Influence for heat transfer by salt deposition	L	L	L	L	L	U
204			Spray Nozzle Blockage by Seasalt Deposition	L	L	L	L	L	P
205			Re-solution of salt by reflooding	L	L	L	L	L	P
206			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
207			Corrosion of Shroud Head by Boron	L	L	L	L	L	U
208			Influence for heat transfer by boron deposition	L	L	L	L	L	P
209			Spray Nozzle Blockage by Boron Deposition	L	L	L	L	L	P
210			Re-solution of boron by reflooding	L	L	L	L	L	P
211		Standpipe & Separator	Radiation Heat Transfer between Intact Fuel Rods and Standpipe/Separator	L	L	L	L	L	K
212			Radiation Heat Transfer between Corium and Standpipe/Separator	N/A	L	L	L	L	K
213			Radiation Heat Transfer between Crust and Standpipe/Separator	N/A	L	L	L	L	K
214			Radiation Heat Transfer between Intact Control Rod and Standpipe/Separator	L	L	L	L	L	K
215			Radiation Heat Transfer between Shroud Structure and Standpipe/Separator	L	L	L	L	L	K
216			Radiation Heat Transfer between Particulate Corium and Standpipe(Separator)	N/A	L	L	L	L	P
217			Heat Transfer between Gas and Standpipe/Separator	L	L	L	M	M	K
218			Standpipe/Separator Temperature Change	L	L	L	L	H	K
219			Gamma Heat Generation in Standpipe/Separator	L	L	L	L	L	K
220			Condensation Heat Transfer on Standpipe/Separator	L	L	L	L	L	K
221			Pressure Change in Standpipe/Separator	L	M	M	M	M	K
222			Gas Temperature Change in Standpipe/Separator	L	L	L	H	H	K
223			Gas Flow in Standpipe/Separator	L	L	L	L	L	K
224			Gas Composition Change in Standpipe/Separator	L	L	L	L	H	K
225			Standpipe/Separator Break or Deformation by Themal Stress	L	L	L	L	L	K
226			Standpipe/Separator Oxidation with Steam (Including Reaction Heat and Hydrogen Production)	L	L	L	M	H	K
227			FP deposition on standpipe/separator	L	M	M	H	H	P
228			FP re-vaporization	L	M	M	H	H	P
229			Decay heat generation from FP	L	M	M	H	H	K
230			FP reaction including iodine chemistry	L	L	L	L	L	P
231			Corrosion of Standpipe/Separator by Seasalt (Including Marine Lives)	L	L	L	L	L	U
232			Influence for heat transfer by salt deposition	L	L	L	L	L	P
233			Pick-off Ring Flowpath Blockage by Seasalt Deposition	L	L	L	L	L	P
234			Separator Inlet Flowpath Blockage by Seasalt Deposition	L	L	L	L	L	P
235			Re-solution of salt by reflooding	L	L	L	L	L	P
236			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
237			Corrosion of Standpipe/Separator by Boron	L	L	L	L	L	U
238			Influence for heat transfer by boron deposition	L	L	L	L	L	P
239			Pick-off Ring Flowpath Blockage by Boron Deposition	L	L	L	L	L	P
240			Separator Inlet Flowpath Blockage by Boron Deposition	L	L	L	L	L	P
241			Re-solution of boron by reflooding	L	L	L	L	L	P
242			Standpipe/Separator Tilt by Shroud Head Deformation	L	L	L	L	L	P
243		Dryer	Dryer Temperature Change	L	L	L	L	H	K
244			Gamma Heat Generation in Dryer	L	L	L	L	L	K
245			Heat Transfer between Gas and Dryer	L	L	L	L	M	K
246			Condensation Heat Transfer on Dryer	L	L	L	L	L	K
247			Pressure Change in Dryer	L	M	M	M	M	K
248			Gas Flow in Dryer	L	L	L	L	L	K
249			Gas Temperature Change in Dryer	L	L	L	H	M	K
250			Gas Composition Change in Dryer	L	L	L	L	H	K
251			Dryer Break or Deformation by Thermal Stress	L	L	L	L	L	K
252			Dryer Oxidation with steam (Including Reaction Heat and Hydrogen Production)	L	L	L	L	H	K
253			FP deposition on dryer	L	M	M	H	H	P
254			FP re-vaporization	L	M	M	H	H	P

255			Decay heat generation from FP	L	M	M	H	H	K
256			FP reaction including iodine chemistry	L	L	L	L	L	P
257			Corrosion of Dryer by Seasalt (Including Marine Lives)	L	L	L	L	L	U
258			Influence for heat transfer by salt deposition	L	L	L	L	L	U
259			Dryer Flowpath Blockage by Seasalt Deposition	L	L	L	L	L	U
260			Re-solution of salt by reflooding	L	L	L	L	L	U
261			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
262			Corrosion of Dryer by Boron	L	L	L	L	L	U
263			Impact of Boron Deposition on Heat Transfer	L	L	L	L	L	U
264			Dryer Flowpath Blockage by Boron Deposition	L	L	L	L	L	U
265			Re-solution of boron by reflooding	L	L	L	L	L	P
266			Dryer Structure Tilt	L	L	L	L	L	P
267		Upper Head	Heat Transfer between Gas and Upper Head Wall	L	L	L	H	M	K
268			Gamma Heat Generation in Upper Head	L	L	L	L	L	K
269			Upper Head Temperature Change	L	L	L	M	M	K
270			Radiation Heat Transfer from Upper Head to Drywell Head	M	M	M	H	L	K
271			Condensation Heat Transfer on Upper Head	L	L	L	L	L	K
272			Pressure Change in Steam Dome	L	M	M	H	H	K
273			Gas Flow in Steam Dome	L	L	L	L	L	K
274			Gas Temperature Change in Steam Dome	L	L	L	H	M	K
275			Gas Composition Change in Steam Dome	L	L	L	L	H	K
276			Upper Head Oxidation with Steam (Including Reactin Heat and Hydrogen Production)	L	L	L	L	M	K
277			FP deposition on upper head	L	M	M	M	M	P
278			FP re-vaporization	L	M	M	M	M	P
279			Decay heat generation from FP	L	M	M	M	M	K
280			FP reaction including iodine chemistry	L	L	L	L	L	P
281			Gas Leakage from RPV flange to Drywell Head	L	H	H	M	H	P
282			Corrosion of Upper Head by Seasalt (Including Marine Lives)	L	L	L	L	L	U
283			Influence for heat transfer by salt deposition	L	L	L	L	L	U
284			Re-solution of salt by droplet	L	L	L	L	L	P
285			Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
286			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
287			Corrosion of Upper Head by Boron	L	L	L	L	L	P
288			Influence for heat transfer by boron deposition	L	L	L	L	L	U
289			Re-solution of boron by reflooding	L	L	L	L	L	P
290			Degradation or Falling of Lagging Material	M	M	M	M	L	P
291		Main Steam Line	Main Steam Line Creep Rupture	N/A	M	M	L	L	K
292			Break Flow from Main Steam Line Break	N/A	M	M	L	L	K
293			Gas Flow in Main Steam Line	L	L	L	L	L	K
294			Pressure Change in Main Steam Line	L	M	M	H	H	K
295			Gas Temperature Change in Main Steam Line	L	M	M	H	M	K
296			Gas Composition Change in Main Steam Line	L	L	L	L	H	K
297			Main Steam Line Temperature Change	L	M	M	L	L	K
298			Heat Transfer between Gas and Main Steam Line	L	L	L	M	L	K
299			Heat Transfer between water and Main Steam Line	L	L	L	L	L	K
300			Condensation Heat Transfer on Main Steam Line	L	L	L	L	L	K
301			Heat Transfer to Drywell through Lagging Material	L	L	L	L	L	K
302			Safety Relief Valve Opening Characteristics	M	H	H	L	H	K
303			Leakage from Safety Relief Valve to Drywell	M	H	H	L	H	K
304			Pressure Loss at Safety Relief Valve	M	H	H	L	M	K
305			Safety Relief Valve Temperature Change	L	L	L	L	L	K
306			Heat Transfer between Gas and Safety Relief Valve Blowdown Piping	L	L	L	L	L	K
307			Safety Relief Valve Blowdown Piping Break	L	L	L	L	L	K

308			Safety Relief Valve Blowdown Piping Break Flow	L	L	L	L	L	K
309			MSIV Closure	M	M	M	M	M	K
310			Pressure Wave by MSIV Closure	L	N/A	N/A	N/A	N/A	K
311			Gas Leakage from MSIV	M	M	M	M	M	K
312			FP deposition on main steam line	L	L	L	M	M	K
313			FP re-vaporization	L	L	L	M	M	K
314			Decay heat generation from FP	M	H	H	M	M	K
315			FP accumulation at leakage path	M	H	H	H	H	U
316			Radiation heat transfer to drywell	L	L	L	L	L	K
317			Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
318			Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
319			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
320			FP reaction including iodine chemistry	L	L	L	L	L	P
321			Failure of RPV nozzle welding by thermal stress	N/A	M	M	M	L	P
322			Degradation or Falling of Lagging Material	L	L	L	L	L	P
323		Upper down comer	Heat Transfer between Gas and Upper Downcomer Wall	L	L	L	M	M	K
324			Gamma Heat Generation in Upper Downcomer Wall	L	L	L	L	L	K
325			Upper Downcomer Wall (and Feedwater Sparger) Temperature Change	L	L	L	L	M	K
326			Condensation Heat Transfer on Upper Downcomer Wall (and Feedwater Sparger)	L	L	L	L	L	K
327			Pressure Change in Upper Downcomer	L	M	M	H	M	K
328			Change in water level in upper down comer	H	L	L	L	L	K
329			Gas Flow in Upper Downcomer	L	L	L	L	L	K
330			Gas Temperature Change in Upper Downcomer	L	L	L	H	M	K
331			Gas Composition Change in Upper Downcomer	L	L	L	L	H	K
332			Upper Downcomer Wall (and Feedwater Sparger) Break or Deformation by Thermal Stress	L	L	L	L	L	K
333			Upper Downcomer Wall (and Feedwater Sparger) Oxidation with Steam (Including Reaction Heat and Hydrogen Production)	L	L	L	L	M	K
334			FP deposition on upper down comer	L	L	L	M	M	P
335			FP re-vaporization	L	L	L	M	M	P
336			Decay heat generation from FP	L	L	L	M	M	K
337			FP reaction including iodine chemistry	L	L	L	L	L	P
338			Radiation heat transfer to drywell	M	M	M	M	L	K
339			Corrosion of Upper Head by Seasalt (Including Marine Lives)	L	L	L	L	L	U
340			Influence for heat transfer by salt deposition	L	L	L	L	L	U
341			Re-solution of salt by reflooding	L	L	L	L	L	K
342			Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
343			Corrosion of Upper Head by Boron	L	L	L	L	L	U
344			Influence for heat transfer by boron deposition	L	L	L	L	L	U
345			Re-solution of boron by reflooding	L	L	L	L	L	K
346			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
347			Gas Flow to Main Steam Line	L	L	L	M	M	K
348			FP Flow to Main Steam Line	L	L	L	M	M	K
349			Gas Flow to Feedwater Line	L	L	L	M	M	K
350			FP Flow to Feedwater Line	L	L	L	M	M	K
351			Heat Transfer to Drywell through Lagging Material	M	M	M	M	L	K
352			Failure of RPV nozzle welding by thermal stress	N/A	M	M	M	L	P
353			Degradation or Falling of Lagging Material	M	M	M	M	L	P
354		Lower D/C	Heat transfer between water and shroud wall	L	H	H	L	L	K
355			Heat transfer between water and jet pump	L	L	L	L	L	K
356			Heat transfer between water and pump deck	L	L	L	L	L	K
357			Heat transfer between water and RPV wall	L	L	M	L	L	K
358			Heat transfer between gas and shroud wall	L	L	L	M	L	K
359			Heat transfer between gas and jet pump	L	L	L	L	L	K

360	Heat transfer between gas and pump deck	L	L	L	L	L	K
361	Heat transfer between gas and RPV wall	L	L	L	M	L	K
362	Heat transfer between water and corium	N/A	N/A	H	L	L	P
363	Heat transfer between gas and corium	N/A	N/A	M	M	L	P
364	Heat transfer between corium and shroud wall	N/A	N/A	H	L	L	P
365	Heat transfer between corium and jet pump	N/A	N/A	M	L	L	P
366	Heat transfer between corium and pump deck	N/A	N/A	M	L	L	P
367	Heat transfer between corium and RPV wall	N/A	N/A	H	L	L	P
368	Heat transfer between water and crust	N/A	N/A	M	L	L	P
369	Heat transfer between gas and crust	N/A	N/A	M	L	L	P
370	Heat transfer between corium and crust	N/A	N/A	H	L	L	P
371	Heat transfer between crust and shroud wall	N/A	N/A	H	L	L	P
372	Heat transfer between crust and jet pump	N/A	N/A	M	L	L	P
373	Heat transfer between crust and pump deck	N/A	N/A	M	L	L	P
374	Heat transfer between crust and RPV wall	N/A	N/A	H	L	L	P
375	Heat transfer between water and particulate corium	N/A	N/A	H	L	L	P
376	Heat transfer between gas and particulate corium	N/A	N/A	H	M	L	P
377	Heat transfer between particulate corium and shroud wall	N/A	N/A	H	L	L	P
378	Heat transfer between particulate corium and jet pump	N/A	N/A	M	L	L	P
379	Heat transfer between particulate corium and pump deck	N/A	N/A	M	L	L	P
380	Heat transfer between particulate corium and RPV wall	N/A	N/A	H	L	L	P
381	Heat Transfer to Drywell through Lagging Material	M	M	M	M	L	K
382	Radiation heat transfer between corium and shroud wall	N/A	N/A	M	L	L	P
383	Radiation heat transfer between corium and jet pump	N/A	N/A	M	L	L	P
384	Radiation heat transfer between corium and pump deck	N/A	N/A	M	L	L	P
385	Radiation heat transfer between corium and RPV wall	N/A	N/A	M	L	L	P
386	Radiation heat transfer between particulate corium and shroud wall	N/A	N/A	M	L	L	P
387	Radiation heat transfer between particulate corium and jet pump	N/A	N/A	M	L	L	P
388	Radiation heat transfer between particulate corium and pump deck	N/A	N/A	M	L	L	P
389	Radiation heat transfer between particulate corium and RPV wall	N/A	N/A	M	L	L	P
390	Radiation heat transfer between crust and shroud wall	N/A	N/A	M	L	L	P
391	Radiation heat transfer between crust and jet pump	N/A	N/A	L	L	L	P
392	Radiation heat transfer between crust and pump deck	N/A	N/A	M	L	L	P
393	Radiation heat transfer between crust and RPV wall	N/A	N/A	M	L	L	P
394	Radiation heat transfer to drywell	M	M	M	M	L	K
395	Heat generation by gamma ray in Lower D/C structure	L	L	M	L	L	K
396	Failure of shroud wall by thermal stress	L	L	M	L	L	P
397	Failure of RPV nozzle welding by thermal stress	N/A	N/A	M	M	L	P
398	CCFL in suction part in jet pump	L	L	L	L	L	K
399	Change in water level in Lower D/C	H	H	M	L	L	K
400	Change in pressure in Lower D/C	L	M	M	M	L	K
401	Change of flow regime in Lower D/C	L	L	L	L	L	K
402	Decompression boiling	H	L	M	L	L	K
403	Change in water temperature in Lower D/C	M	L	M	L	L	K
404	Change in gas temperature in lower down comer	L	L	M	L	L	K
405	Change in gas composition in Lower D/C	L	L	L	L	H	K
406	Change in temperature in shroud wall	M	M	H	L	L	K
407	Change in temperature in jet pumps	L	L	H	L	L	K
408	Change in temperature in pump deck	L	L	H	L	L	K
409	Change in temperature in RPV sidewall	M	M	H	M	L	K
410	Corium relocation type through breached core shroud to lower plenum	N/A	N/A	H	M	M	P
411	Corium spreading in Lower D/C	N/A	N/A	H	L	L	U
412	Ablation of outer wall surface of shroud by corium	N/A	N/A	H	L	L	P

413		Change in area of failire opening in shroud	N/A	N/A	H	M	L	K
414		Flow of water and gas through failure opening in shroud	N/A	N/A	M	M	L	K
415		Corium submerged in water by water injection	N/A	N/A	H	L	L	K
416		FCI pre-mixing by contact between corium and water pool	N/A	N/A	H	M	L	P
417		FCI triggering by vapor film collapse	N/A	N/A	H	M	M	P
418		Atomization of corium in water pool and rapid steam generation (FCI)	N/A	N/A	H	M	M	P
419		Pressure wave by FCI	N/A	N/A	H	M	L	P
420		Temperature increas of water and gas by FCI	N/A	N/A	H	M	L	P
421		Failure of RPV lower head by FCI	N/A	N/A	H	M	L	P
422		Scattering of corium, particulate corium and crust in Lower D/C by FCI	N/A	N/A	H	M	L	P
423		Impact for FCI by seawater	N/A	N/A	L	L	L	U
424		Change in corium temperature	N/A	N/A	H	L	L	P
425		Blockage of failure opening in Lower D/C by freezing of corium	N/A	N/A	H	L	L	U
426		Change in physical property by material mixing in corium	N/A	N/A	H	L	L	P
427		Oxidation reaction between corium and water (steam) (including hydrogen generation and reaction heat)	N/A	N/A	M	L	M	U
428		Oxidation reaction between shroud and steam (including hydrogen generation and reaction heat)	L	M	M	L	M	P
429		Oxidation reaction between jetpump and steam (including hydrogen generation and reaction heat)	L	L	L	L	L	P
430		Oxidation reaction between pump deck and steam (including hydrogen generation and reaction heat)	L	L	L	L	L	P
431		Oxidation reaction between RPV sidewall and steam (including hydrogen generation and reaction heat)	L	L	L	L	M	P
432		Crust generation by solidification of corium	N/A	N/A	H	L	L	P
433		Crust remelting due to change in the heat transfer status to corium or water	N/A	N/A	M	L	L	P
434		Particulate corium remelting due to change in the heat transfer status	N/A	N/A	M	L	L	P
435		Corium spreading in circumferential direction in Lower D/C	N/A	N/A	M	L	L	P
436		Decay heat in corium	N/A	N/A	H	L	L	P
437		Relocation of corium by failure of pump deck	N/A	N/A	M	L	L	P
438		Relocation of corium by failure of jet pump	N/A	N/A	M	L	L	P
439		Particulation of corium by contact with water	N/A	N/A	H	L	L	P
440		Change in physical property of particulate corium	N/A	N/A	H	L	L	P
441		Change in size and shape of particulate corium	N/A	N/A	M	L	L	P
442		Entrainmentof of particulate corium from corium falling into water	N/A	N/A	H	L	L	P
443		Aggregation and bed formation of particulate corium	N/A	N/A	H	L	L	P
444		Change in temperature of particulate corium	N/A	N/A	H	L	L	P
445		Decay heat in particulate corium	N/A	N/A	H	L	L	P
446		Change in temperature of crust	N/A	N/A	H	L	L	P
447		Bubble formation in crust	N/A	N/A	M	L	L	P
448		Water inflow into crust through crack on surface of crust	N/A	N/A	M	L	L	P
449		Decay heat in crust	N/A	N/A	H	L	L	P
450		Change in physical property by material mixing in crust	N/A	N/A	M	L	L	P
451		Oxidation reaction between crust and water (steam) (including hydrogen generation and reaction heat)	N/A	N/A	M	L	L	U
452		Flow path blockage in Lower D/C (including jet pump) by crust	N/A	N/A	H	L	L	P
453		Recriticality	N/A	N/A	M	L	L	P
454		Flow of corium (including particulate corium) out of RPV side wall	N/A	N/A	N/A	M	L	P
455		Flow of corium (including particulate corium) into recirculation loop piping	N/A	N/A	M	L	L	P
456		Radiation decomposition of water	L	L	L	L	L	K
457		FP deposition on Lower D/C	L	L	L	L	L	P
458		FP re-vaporization	L	L	L	L	L	P
459		Decay heat generation from FP	L	L	L	L	L	P
460		FP release from corium surface	N/A	N/A	M	M	M	U
461		FP reaction including iodine chemistry	L	L	L	L	L	P
462		Adsorption and release of gaseous FP	L	L	L	L	L	P
463		Thermal failure of pump deck by radiation heat transfer from lower head	N/A	N/A	H	L	M	K
464		Corrosion of structure in Lower D/C by salt content of seawater (including marine lives)	L	L	L	L	L	U
465		Seasalt intake to corium	N/A	N/A	M	M	M	U

466			Influence for heat transfer by salt deposition	L	L	L	L	L	U
467			Flow path blockage in jet pump by salt deposition	L	L	L	L	L	U
468			Re-solution of salt by reflooding	L	L	L	L	L	P
469			Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
470			Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
471			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
472			Corrosion of structure in Lower D/C by boron	L	L	L	L	L	U
473			Influence for heat transfer by boron deposition	L	L	L	L	L	P
474			Flow path blockage in jet pump by boron deposition	L	L	L	L	L	U
475			Re-solution of boron by reflooding	L	L	L	L	L	P
476			Degradation or Falling of Lagging Material	M	M	M	M	L	P
477		Lower head	Heat transfer between water and lower head including crack	L	L	H	M	L	K
478			Heat transfer between water and penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes)	L	L	H	M	L	K
479			Heat transfer between gas and lower head including crack	N/A	L	H	L	L	K
480			Heat transfer between gas and penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes)	N/A	L	M	L	L	K
481			Heat transfer between corium and water (including CHF)	N/A	N/A	H	M	L	P
482			Heat transfer between corium and gas	N/A	N/A	H	M	M	P
483			Heat transfer between corium and penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes)	N/A	N/A	H	M	L	P
484			Heat transfer between corium and lower head	N/A	N/A	H	M	L	P
485			Heat transfer between particulate corium and water	N/A	N/A	H	L	L	P
486			Heat transfer between particulate corium and gas	N/A	N/A	H	M	M	U
487			Heat transfer between particulate corium and penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes)	N/A	N/A	H	L	L	U
488			Heat transfer between particulate corium and lower head	N/A	N/A	H	L	L	P
489			Heat transfer between particulate corium and light metal layer	N/A	N/A	H	L	L	U
490			Heat transfer between crust and water (including CHF, inner crack and gap)	N/A	N/A	H	L	L	P
491			Heat transfer between crust and gas	N/A	N/A	M	L	L	P
492			Heat transfer between corium and crust	N/A	N/A	H	M	L	P
493			Heat transfer between crust and penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes)	N/A	N/A	H	M	L	P
494			Heat transfer between crust and lower head	N/A	N/A	H	M	L	P
495			Heat transfer between crust and light metal layer	N/A	N/A	M	L	L	P
496			Heat transfer between light metal layer and water (including CHF)	N/A	N/A	M	L	L	P
497			Heat transfer between light metal layer and gas	N/A	N/A	L	L	L	P
498			Heat transfer between light metal layer and penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes)	N/A	N/A	M	L	L	P
499			Heat transfer between light metal layer and lower head	N/A	N/A	M	M	L	P
500			Heat transfer between heavy metal layer in corium pool and lower head	N/A	N/A	L	L	L	P
501			Heat transfer between heavy metal layer in corium pool and penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes)	N/A	N/A	L	L	L	P
502			Heat transfer between heavy metal layer in corium pool and metal-oxide layer in corium	N/A	N/A	L	L	L	P
503			Radiation heat transfer between particulate corium and core	N/A	N/A	M	L	M	K
504			Radiation heat transfer between light metal layer and core	N/A	N/A	M	L	M	K
505			Radiation heat transfer between corium and lower head	N/A	N/A	H	L	L	K
506			Particulate Corium Bed Porosity	N/A	N/A	H	M	L	P
507			Change in temperature of penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes	L	L	H	L	H	K
508			Change in temperature of RPV lower head	L	L	H	M	M	K
509			Deformation of RPV lower head by thermal stress	L	L	H	M	L	K
510			Failure of RPV nozzle welding by thermal stress	N/A	N/A	M	M	L	P
511			Oxidation reaction between penetration tubes (control rod guide tubes, drain lines, and instrumetation tubes) and steam (including hydrogen generation and reaction heat)	N/A	L	M	L	H	P
512			Oxidation reaction between lower head and steam (including hydrogen generation and reaction heat)	N/A	L	M	L	M	P
513			Change in pressure in lower plenum	L	L	H	H	M	K
514			Change in water temperature in lower plenum	L	L	M	L	L	K
515			Change in gas temperature in lower plenum	L	L	M	M	M	K

516			Change in gas composition in lower plenum	L	L	L	L	H	K
517			Decompression boiling	M	L	M	L	M	K
518			Change in temperature inside corium	N/A	N/A	H	M	L	P
519			Non-uniform corium spreading in lower head	N/A	N/A	H	M	L	P
520			Evaporation of materials from inside corium (including FP)	N/A	N/A	M	L	L	P
521			Corium jet into water pool	N/A	N/A	H	M	M	P
522			Formation of corium pool	N/A	N/A	H	M	L	P
523			Stratification of corium pool	N/A	N/A	H	M	L	P
524			Atomization of corium by contanct with water (jet breakup)	N/A	N/A	H	M	L	P
525			Change in temperature in light metal layer	N/A	N/A	H	M	L	P
526			Change in temperature in heavy metal layer	N/A	N/A	H	M	L	P
527			Change in composition of particulate corium	N/A	N/A	H	M	L	P
528			Change in size and shape of particulate corium	N/A	N/A	H	L	L	P
529			Crust generation by solidification of corium	N/A	N/A	H	L	L	P
530			Accumulation and bed formation of particulate corium	N/A	N/A	H	L	L	P
531			Non-uniform spreading of particulate corium bed	N/A	N/A	H	M	L	P
532			Change in temperature of particulate corium bed	N/A	N/A	H	M	L	P
533			Decay heat in particulate corium	N/A	N/A	H	M	L	P
534			Oxidation reaction between light metal layer and water (steam) (including hydrogen generation and reaction heat)	N/A	N/A	M	L	H	P
535			FCI pre-mixing by contact between corium and water pool	N/A	N/A	H	L	L	P
536			FCI triggering by vapor film collapse	N/A	N/A	H	M	M	P
537			Particulation of corium in water pool and rapid steam generation (FCI)	N/A	N/A	H	M	M	P
538			Pressure wave by FCI	N/A	N/A	H	M	M	P
539			Temperature increas by FCI	N/A	N/A	H	M	M	P
540			Failure of RPV lower head by FCI	N/A	N/A	H	M	M	P
541			Scattering of corium and material in lower plenum by FCI	N/A	N/A	H	M	M	P
542			Impact for FCI by seawater	N/A	N/A	L	L	L	U
543			Mixing state and physical property of corium	N/A	N/A	H	M	L	P
544			Oxidation reaction between corium and water (steam) (including hydrogen generation and reaction heat)	N/A	N/A	M	L	M	U
545			Natural convection in corium pool	N/A	N/A	H	L	L	P
546			Decay heat of corium	N/A	N/A	H	L	L	P
547			Solidification of corium	N/A	N/A	H	M	L	P
548			Flow of water in lower plenum	L	L	H	L	L	K
549			Reflooding of molten material in lower plenum by water injection	N/A	N/A	H	M	M	K
550			Flow of gas in lower plenum	L	L	M	L	L	K
551			Change in an amount of purge water in CRD guide tube	M	L	H	L	L	K
552			Change in water level in lower plenum	M	M	H	L	M	K
553			Radiation decomposition of water	L	L	L	L	L	K
554			Bubble formation in crust	N/A	N/A	M	L	L	P
555			Water inflow into crust through crack on surface of crust	N/A	N/A	M	M	L	P
556			Oxidation reaction between crust and water (steam) (including hydrogen generation and reaction heat)	N/A	N/A	M	L	M	U
557			Change in physical property by material mixing in crust	N/A	N/A	H	M	M	U
558			Change in temperature of crust	N/A	N/A	H	M	M	P
559			Decay heat in crust	N/A	N/A	H	L	L	P
560			Recriticality	N/A	N/A	H	M	L	P
561			Gap formation between corium and lower head	N/A	N/A	H	M	L	P
562			Inflow of coolant into gap between corium and lower head	N/A	N/A	H	M	M	P
563			Crack formation on lower head	N/A	N/A	H	L	L	P
564			Inflow of coolant into crack on lower head	N/A	N/A	H	L	L	P
565			Corrosion of lower head by corium jet	N/A	N/A	H	M	M	P
566			Erosion of lower head by corium pool	N/A	N/A	H	M	M	P
567			Flow of corium out of lower head bottom section by lower head failure	N/A	N/A	N/A	H	L	P
568			Crust remelting due to change in the heat transfer status to corium or water	N/A	N/A	H	L	L	P

569			Particulate corium remelting due to change in the heat transfer status	N/A	N/A	H	L	L	P
570			Change in area of failire opening in lower head bottom section	N/A	N/A	N/A	H	L	P
571			Formation of flow path by ablation between control rod guide tubes and lower plenum	N/A	N/A	H	M	M	P
572			Formation of flow path by jet impingemnet to control rod guide tubes	N/A	N/A	H	M	M	P
573			Flow of corium through failed control rod guide tubes from/to lower plenum	N/A	N/A	H	M	L	P
574			Flow of water through failed control rod guide tubes from/to lower plenum	N/A	N/A	H	M	L	P
575			Flow of gas through failed control rod guide tubes from/to lower plenum	N/A	N/A	H	H	M	P
576			Purge water steaming in control rod guide tubes due to corium inflow	N/A	N/A	M	M	M	P
577			Formation of flow path to pedestal by ablation of control rod guide tube internals	N/A	N/A	N/A	H	H	P
578			Changes in breached area in control rod guide tubes to pedestal (including blockage)	N/A	N/A	N/A	M	M	P
579			Ejection of control rod guide tubes	N/A	N/A	N/A	H	H	P
580			Flow of corium out of control rod guide tubes into pedestal	N/A	N/A	N/A	H	L	P
581			Flow of water out of control rod guide tubes into pedestal	N/A	N/A	N/A	H	H	P
582			Flow of gas out of control rod guide tubes into pedestal	N/A	N/A	N/A	H	H	P
583			Formation of flow path between SRM/IRM tubes and lower plenum	N/A	N/A	M	M	M	P
584			Formation of flow path by jet impingemnet to SRM/IRM tubes	N/A	N/A	M	M	M	P
585			Flow of corium through failed SRM/IRM tubes from/to lower plenum	N/A	N/A	M	M	L	P
586			Flow of water through failed SRM/IRM tubes from/to lower plenum	N/A	N/A	M	M	L	P
587			Flow of gas through failed SRM/IRM tubes from/to lower plenum	N/A	N/A	M	H	M	P
588			Ejection of SRM/IRM tubes	N/A	N/A	N/A	H	M	P
589			Flow of corium out of SRM/IRM tubes into pedestal	N/A	N/A	N/A	M	L	P
590			Flow of water out of SRM/IRM tubes into pedestal	N/A	N/A	N/A	M	M	P
591			Flow of gas out of SRM/IRM tubes into pedestal	N/A	N/A	N/A	H	M	P
592			Formation of flow path between TIP/ICM tubes and lower plenum	N/A	N/A	H	H	H	P
593			Formation of flow path by jet impingemnet to TIP/ICM tubes	N/A	N/A	M	M	M	P
594			Flow of corium through failed TIP/ICM tubes from/to lower plenum	N/A	N/A	M	M	L	P
595			Flow of water through failed TIP/ICM tubes from/to lower plenum	N/A	N/A	M	M	L	P
596			Flow of gas through failed TIP/ICM tubes from/to lower plenum	N/A	N/A	M	H	M	P
597			Formation of flow path to Pedestal by ablation of TIP/ICM tube internals	N/A	N/A	N/A	H	H	P
599			Ejection of TIP/ICM tubes	N/A	N/A	N/A	H	M	P
600			Flow of corium out of TIP/ICM tubes into pedestal	N/A	N/A	N/A	M	L	P
601			Flow of water out of TIP/ICM tubes into pedestal	N/A	N/A	N/A	M	M	P
602			Flow of gas out of TIP/ICM tubes into pedestal	N/A	N/A	N/A	H	M	P
603			Flow of gas out of TIP tubes into PCV	N/A	N/A	N/A	H	H	P
604			Formation of flow path to Pedestal by ablation of RPV drain lines	N/A	N/A	N/A	M	M	P
605			Changes in breached area in RPV drain lines to pedstal (including blockage)	N/A	N/A	N/A	M	M	P
606			Flow of corium out of RPV drain lines into pedestal	N/A	N/A	N/A	M	M	P
607			Flow of water out of RPV drain lines into pedestal	N/A	N/A	N/A	M	M	P
608			Flow of gas out of RPV drain lines into pedestal	N/A	N/A	N/A	M	M	P
609			Deformation of lower head	N/A	N/A	H	L	L	P
610			Corium Focusing Effect on Lower Head Sidewall	N/A	N/A	L	L	L	P
611			Change in area of failire opening in lower head side section	N/A	N/A	N/A	M	M	P
612			Flow of corium out of lower head side section by lower head failure	N/A	N/A	N/A	H	L	P
613			Failure of shroud support leg	N/A	N/A	M	L	L	P
614			Change in flow resistence in shroud support leg	N/A	N/A	L	L	L	K
615			FP deposition on lower head	L	L	L	L	L	P
616			FP re-vaporization	L	L	L	L	L	K
617			Decay heat generation from FP	L	L	M	L	L	K
618			FP release from corium surface	N/A	N/A	M	M	M	U
619			FP reaction including iodine chemistry	L	L	L	L	L	P
620			Adsorption and release of gaseous FP	L	L	L	L	L	P
621			Buckling of Control Rod Guide Tubes	N/A	H	L	L	M	K

622		Radiation heat transfer between corium and pump deck bottom surface	N/A	N/A	H	L	H	P
623		Corrosion of structure in lower plenum by salt content of seawater (including marine lives)	L	L	L	L	L	U
624		Melting point change for lower head materials	N/A	N/A	H	M	M	P
625		Eutectic (Corium and lower head materials)	N/A	N/A	H	M	M	P
626		Melting of lower head penetration lines	N/A	N/A	H	H	H	P
627		Melting of lower head wall	N/A	N/A	H	M	M	P
628		Melting of jet pump	N/A	N/A	M	L	L	P
629		Melting of pump deck	N/A	N/A	M	L	L	P
630		Melting of shroud	N/A	N/A	M	L	L	P
631		Influence for heat transfer by salt deposition	L	L	M	L	L	U
632		Seasalt intake to corium	N/A	N/A	H	H	H	U
633		Seasalt impact for corium thermodynamic properties	N/A	N/A	H	L	L	U
634		Re-solution of salt by reflooding	L	L	M	L	L	P
635		Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
636		Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
637		Seasalt impact for FP reaction and composition	L	L	L	L	L	P
638		Corrosion of structure in lower plenum by boron	L	L	L	L	L	U
639		Influence for heat transfer by boron deposition	L	L	M	L	L	U
640		Re-solution of boron by reflooding	L	L	M	L	L	P
641	Recirculation Loop	Heat transfer between recirculation loop piping and water	L	L	L	L	L	K
642		Heat transfer between recirculation loop piping and gas	L	L	L	L	L	K
643		Heat Transfer to Drywell through Lagging Material	L	L	L	L	L	K
644		Radiation heat transfer to drywell	L	L	L	L	L	K
645		Change in temperature of recirculation loop piping	L	L	L	L	M	K
646		Change in pressure in recirculation loop piping	L	L	L	L	M	K
647		Change in water level in recirculation loop piping	L	L	L	L	M	K
648		Change in water temperature in recirculation loop piping	L	L	L	L	M	K
649		Change in flow of water and/or steam in in recirculation loop piping (including flow regime)	L	L	L	L	L	K
650		Change in gas temperature in recirculation loop piping	L	L	L	L	M	K
651		Change in gas composition in recirculation loop piping	L	L	L	L	H	K
652		Change in flow of corium in recirculation loop piping	N/A	N/A	L	L	L	P
653		Oxidation reaction between recirculation loop piping and steam (including hydrogen generation and reaction heat)	L	L	L	L	M	P
654		Leakage of gas from breached gasket or PLR pump seal	N/A	M	H	M	H	K
655		Leakage of water from breached gasket or PLR pump seal	N/A	M	H	M	M	K
656		Water Radiolysis	L	L	L	L	L	K
657		Bubble formation in crust	N/A	N/A	L	L	L	P
658		Flow path blockage in recirculation loop piping by solidification of corium	N/A	N/A	L	L	L	U
659		Corrosion of structure in recirculation loop piping by salt content of seawater (including marine lives)	L	L	L	L	L	U
660		Influence for heat transfer by salt deposition	L	L	M	L	L	U
661		Seasalt intake to corium	N/A	N/A	L	L	L	U
662		Re-solution of salt by reflooding	L	L	L	L	L	P
663		Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
664		Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
665		Seasalt impact for FP reaction and composition	L	L	L	L	L	P
666		Corrosion of structure in recirculation loop piping by boron	L	L	L	L	L	U
667		Influence for heat transfer by boron deposition	L	L	L	L	L	P
668		Re-solution of boron by reflooding	L	L	L	L	L	P
669		FP deposition on recirculation loop	L	L	L	L	L	P
670		FP re-vaporization	L	L	L	L	L	K
671		Decay heat generation from FP	L	L	L	L	L	K
672		Leakage of FP from recirculation loop piping	L	L	M	L	L	K
673		FP release from corium surface	N/A	N/A	M	M	M	U

674			FP reaction including iodine chemistry	L	L	L	L	L	P
675			Adsorption and release of gaseous FP	L	L	L	L	L	P
676			Melting of recirculation piping	N/A	N/A	M	L	L	P
677			Degradation or Falling of Lagging Material	L	L	L	L	L	P
678	PCV	Pedestal/Cavity	Liquid film flow of corium at outer surface of penetration pipes (control rod guide tube, drain line, instrumentation tube) sticking out from RPV bottom(<-- Liquid film flow of corium at protrusion surface of penetration pipes (control rod guide tube, drain line, instrumentation tube))	N/A	N/A	N/A	M	L	P
679			Thermal conduction of penetration pipes (control rod guide tube, drain line, instrumentation tube) sticking out from RPV bottom (<-- Thermal conduction on protrusion surface of penetration pipes (control rod guide tube, drain line, instrumentation tube))	L	L	L	M	L	P
680			Heat transfer between corium and outer surface of penetration pipes (control rod guide tube, drain line, instrumentation tube) sticking out from RPV bottom (<-- Heat transfer between corium and outer surface of protrusion on penetration pipes (control rod guide tube, drain line, instrumentation tube))	N/A	N/A	N/A	M	L	P
681			Heat transfer between corium and water (including CHF)	N/A	N/A	N/A	H	H	P
682			Heat transfer between corium and gas	N/A	N/A	N/A	H	H	P
683			Heat transfer between crust and water (including CHF)	N/A	N/A	N/A	H	H	P
684			Heat transfer between crust and gas	N/A	N/A	N/A	H	H	P
685			Heat transfer between crust and corium (including heat transfer enhancement at gas generation due to MCCI)	N/A	N/A	N/A	H	H	P
686			Heat transfer between corium particle and water	N/A	N/A	N/A	H	H	P
687			Heat transfer between corium particle and gas	N/A	N/A	N/A	H	H	P
688			Heat transfer between corium particle and pedestal floor/wall	N/A	N/A	N/A	H	H	P
689			Heat transfer between pedestal floor/wall and corium	N/A	N/A	N/A	H	H	P
690			Heat transfer between pedestal floor/wall and crust	N/A	N/A	N/A	H	H	P
691			Heat transfer between pedestal floor/wall and water	L	L	L	H	H	P
692			Heat transfer between pedestal floor/wall and gas	L	L	L	M	L	P
693			Heat transfer from lower head to gas in pedestal region	L	L	L	M	L	P
694			Heat transfer from protrusion of penetration pipes (control rod guide tube, drain line, instrumentation tube) to water (leak flow)	N/A	N/A	N/A	M	L	K
695			Heat transfer from protrusion of penetration pipes (control rod guide tube, drain line, instrumentation tube) to gas	L	L	L	M	L	K
696			Radiation between lower head and pedestal floor/wall	L	L	L	M	L	K
697			Radiation between lower head and pedestal internal structure	L	L	L	M	L	K
698			Radiation between corium and pedestal wall	N/A	N/A	N/A	M	M	K
699			Radiation between corium and RPV wall	N/A	N/A	N/A	M	M	K
700			Radiation between corium and pedestal internal structure	N/A	N/A	N/A	M	M	K
701			Radiation between crust and pedestal wall	N/A	N/A	N/A	M	M	K
702			Radiation between crust and RPV wall	N/A	N/A	N/A	M	M	K
703			Radiation between crust and pedestal internal structure	N/A	N/A	N/A	M	M	K
704			Radiation between corium particle and pedestal wall	N/A	N/A	N/A	M	M	K
705			Radiation between corium particle and RPV wall	N/A	N/A	N/A	M	M	K
706			Radiation between corium particle and pedestal internal structure	N/A	N/A	N/A	L	L	K
707			Particulate Corium Bed Porosity	N/A	N/A	N/A	H	L	P
708			Pedestal deformation/failure due to thermal stress	N/A	N/A	N/A	L	L	P
709			Pedestal wall heatup due to corium adhesion to pedestal wall	N/A	N/A	N/A	H	H	P
710			Pressure change in pedestal	L	L	L	H	M	K
711			Gas temperature change in pedestal	L	L	L	H	M	K
712			Water temperature change in pedestal	L	L	L	H	L	K
713			Thermal conduction / Temperature change of corium	N/A	N/A	N/A	H	H	P
714			Thermal conduction / Temperature change of crust	N/A	N/A	N/A	H	H	P
715			Thermal conduction / Temperature change of pedestal floor/wall	L	L	L	H	H	K
716			Gas flow in pedestal internal space	L	L	L	H	M	K
717			Local gas flow and turbulence	L	L	L	L	L	P
718			Water flow on pedestal floor	L	L	L	H	L	K
719			Ejection conditions (corium, mixture state of water/steam) of corium jet	N/A	N/A	N/A	H	H	P
720			Oxidation of grating due to collision of corium jet with grating and oxidation	N/A	N/A	N/A	L	H	U
721			Splash of corium towards pedestal floor by collision of	N/A	N/A	N/A	L	H	P

	corium with grating						
722	Gas composition change in pedestal	L	L	L	M	H	K
723	Erosion of pedestal floor / wall	N/A	N/A	N/A	H	H	P
724	Physical properties of concrete ingredients (C, Si, etc.)	N/A	N/A	N/A	H	H	P
725	Mass transfer of concrete ingredients into corium	N/A	N/A	N/A	H	H	P
726	Water evaporation from concrete by concrete heating	N/A	N/A	N/A	H	H	P
727	Gas generation (H2, CO, CO2, etc.) from concrete-corium interaction (reaction?)	N/A	N/A	N/A	H	H	P
728	Aerosol generation from concrete-corium interaction (reaction?)	N/A	N/A	N/A	H	H	P
729	Heat generation from chemical reaction between corium and concrete ingredients	N/A	N/A	N/A	H	H	P
730	Corium flow / spread in pedestal	N/A	N/A	N/A	H	M	P
731	Corium flow into drywel by spread in pedestal (Mark-I)	N/A	N/A	N/A	H	H	P
732	Corium entrainment in pedestal by sparging gas	N/A	N/A	N/A	H	H	P
733	Generation of corium particle due to breakup at jet drop	N/A	N/A	N/A	H	H	P
734	Corium ejection from crack in the crust (includion generation of corium particle)	N/A	N/A	N/A	H	H	P
735	Outflow of corium particle with water flow	N/A	N/A	N/A	L	H	P
736	Composition of corium particle	N/A	N/A	N/A	M	M	P
737	Size / configuration of corium particle	N/A	N/A	N/A	M	M	P
738	Aggregation / debris bed formation of corium particle	N/A	N/A	N/A	M	M	P
739	Generation / attenuation of decay heat from corium particle	N/A	N/A	N/A	H	H	P
740	Temperature change of corium particle bed	N/A	N/A	N/A	H	H	P
741	Corium solidification	N/A	N/A	N/A	H	M	P
742	Generation / attenuation of decay heat from corium	N/A	N/A	N/A	H	H	P
743	Oxidation reaction (including generation of hydrogen and reaction heat) between corium ingredients and water (steam)	N/A	N/A	N/A	H	H	U
744	Mixture state (fuel, structure, concrete, etc.) and physical properties of corium ingredients	N/A	N/A	N/A	H	H	P
745	Corium stratification	N/A	N/A	N/A	H	M	P
746	Remixing of corium stratification associated with corium flow and internal gas generation	N/A	N/A	N/A	H	M	P
747	Change in corium deposit conditions on the pedestal floor	N/A	N/A	N/A	H	L	P
748	Crust segregation and waftage	N/A	N/A	N/A	H	M	P
749	Crust generation on the surface of penetration pipes sticking out of RPV lower head	N/A	N/A	N/A	H	L	U
750	Crust remelting due to change in the heat transfer status to corium or water	N/A	N/A	N/A	H	H	P
751	Particulate corium remelting due to change in the heat transfer status	N/A	N/A	N/A	H	H	P
752	Water flow into crust	N/A	N/A	N/A	H	M	P
753	Bubble formation in crust	N/A	N/A	N/A	M	M	P
754	Crack generation in crust	N/A	N/A	N/A	H	M	P
755	Generation / attenuation of decay heat from crust	N/A	N/A	N/A	H	H	K
756	Oxidation reaction (including generation of hydrogen and reaction heat) between crust ingredients and water (steam)	N/A	N/A	N/A	M	H	U
757	Mixture state (fuel, structure, concrete, etc.) and physical properties of crust	N/A	N/A	N/A	H	H	P
758	Recriticality	N/A	N/A	N/A	H	L	P
759	Oxidation (including generation of hydrogen and reaction heat) of pedestal wall by steam	L	L	L	M	H	P
760	Radiation decomposition of water	L	L	L	L	L	K
761	FCI's premixing due to corium contact to water pool	N/A	N/A	N/A	M	M	P
762	FCI triggering by vapor film collapse	N/A	N/A	N/A	H	M	P
763	Corium atomization and rapid steam generation (FCI) in water pool	N/A	N/A	N/A	H	H	P
764	Pressure wave due to FCI	N/A	N/A	N/A	H	M	P
765	Temperature increas of water and gas by FCI	N/A	N/A	N/A	H	M	P
766	Pedestal failure due to FCI	N/A	N/A	N/A	H	H	P
767	Dispersion of corium and pedestal internal material due to FCI	N/A	N/A	N/A	H	H	P
768	Impact for FCI by seawater	N/A	N/A	N/A	L	L	U
769	Droplet behavior in the pedestal free space	L	L	L	L	L	P
770	Condensation heat transfer on the pedestal wall and internal surfaces	L	L	L	L	L	P
771	Interaction between gas and water film flow on the pedestal wall and internal surfaces	L	L	L	L	L	P
772	FP particle transport by gas in the pedestal	L	L	L	L	L	P

773			FP particle agglomeration/fragmentation in the pedestal	L	L	L	L	L	P
774			FP particle deposition on the pedestal wall and internal surfaces	L	L	L	L	L	P
775			FP transport by water flow on the pedestal wall and internal surfaces	L	L	L	L	L	P
776			FP re-entrainment	L	L	L	L	L	P
777			FP deposition on pedestal wall	L	L	L	M	M	P
778			FP re-vaporization	L	L	L	M	M	K
779			Decay heat generation from FP	L	L	L	M	M	K
780			FP release from corium surface	N/A	N/A	N/A	M	M	U
781			FP reaction including iodine chemistry	L	L	L	L	L	P
782			Adsorption and release of gaseous FP	L	L	L	L	L	P
783			Direct Containment Heating (DCH)	N/A	N/A	N/A	H	H	P
784			Pedestal water level change	L	L	L	H	M	P
785			Thermal stratification	L	L	L	L	L	P
786			Collision of corium with penetration tube support beams and oxidation	N/A	N/A	N/A	M	M	U
787			Collision of corium with CRD purge lines and oxidation	N/A	N/A	N/A	M	M	U
788			Collision of corium with other structures in the pedestal and oxidation	N/A	N/A	N/A	M	M	U
789			Melting point change for penetration pipings sticking out of RPV lower head	N/A	N/A	N/A	M	M	U
790			Eutectic (Corium and metal in pedestal internals)	N/A	N/A	N/A	H	H	U
791			Melting of penetration pipes sticking out of RPV lower head	N/A	N/A	N/A	H	H	P
792			Melting of gratings	N/A	N/A	N/A	L	L	P
793			Melting of penetration tube support beams	N/A	N/A	N/A	L	L	P
794			Melting of CRD purge lines	N/A	N/A	N/A	L	L	P
795			Melting of other structures in the pedestal	N/A	N/A	N/A	H	H	U
796			Seasalt intake to corium	N/A	N/A	N/A	L	L	U
797			Seasalt impact for corium thermodynamic properties	N/A	N/A	N/A	L	L	U
798			Corrosion of pedestal internals by seasalt (including marine lives)	L	L	L	L	L	U
799			Salt effects on heat transfer	L	L	L	L	L	U
800			Salt remelting from flood	L	L	L	L	L	U
801			Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
802			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
803			Boron corrosion of pedestal internal structure	L	L	L	L	L	U
804			Boron effects on heat transfer	L	L	L	L	L	U
805			Boron remelting from flood	L	L	L	L	L	P
806			FP aerosol absorption in water pool at upper surface of corium	N/A	N/A	N/A	L	L	P
807			FP release from water pool at upper surface of corium	N/A	N/A	N/A	M	L	P
808			Corium flow into sump pit (drainage pit) and reaction	N/A	N/A	N/A	H	H	P
809			Heat transfer between sump floor/wall and corium	N/A	N/A	N/A	H	H	P
810			Heat transfer between sump floor/wall and crust	N/A	N/A	N/A	H	H	P
811			Heat transfer between sump floor/wall and corium particle	N/A	N/A	N/A	H	H	P
812			Heat transfer between sump cover and corium	N/A	N/A	N/A	L	L	P
813			Heat transfer between sump cover and crust	N/A	N/A	N/A	L	L	P
814			Heat transfer between sump cover and corium particle	N/A	N/A	N/A	L	L	P
815			Heat capacity of structure inside sump	N/A	N/A	N/A	M	M	P
816			Deposition situation of corium on pedestal floor	N/A	N/A	N/A	H	M	P
817			Corium leak into connecting piping inside sump	N/A	N/A	N/A	H	H	P
818		Drywell	Attack on containment vessel shell (interaction between metal and corium)	N/A	N/A	N/A	H	H	U
819			Containment vessel penetration seal degradation (Seal degradation at containment vessel penetration)	L	L	L	H	H	P
820			Water leak from deteriorated part of containment vessel penetration	L	L	L	H	M	P
821			Gas leak from deteriorated part of containment vessel penetration	L	L	L	H	H	P
822			Deformation / failure of drywell internal equipment due to thermal stress	L	L	L	L	L	P
823			Deformation / failure of drywell wall by thermal stress	L	L	L	H	H	P
824			Heat transfer between corium and water (including CHF)	N/A	N/A	N/A	H	H	P

825	Heat transfer between corium and gas	N/A	N/A	N/A	H	H	P
826	Heat transfer between crust and water (including CHF)	N/A	N/A	N/A	H	H	P
827	Heat transfer between crust and gas	N/A	N/A	N/A	H	H	P
828	Heat transfer between crust and corium	N/A	N/A	N/A	H	H	P
829	Heat transfer between corium particle and water	N/A	N/A	N/A	H	H	P
830	Heat transfer between corium particle and gas	N/A	N/A	N/A	H	H	P
831	Heat transfer between corium particle and drywell floor/wall	N/A	N/A	N/A	H	H	P
832	Heat transfer between drywell floor/wall and corium	N/A	N/A	N/A	H	H	P
833	Heat transfer between drywell floor/wall and crust	N/A	N/A	N/A	H	H	P
834	Heat transfer between drywell floor/wall and water	L	L	L	H	H	P
835	Heat transfer between drywell floor/wall and gas	L	L	L	M	L	P
836	Heat transfer from drywell internal structure (lagging material, biological shield wall) to water	L	L	L	M	L	P
837	Heat transfer from drywell internal structure (lagging material, biological shield wall) to gas	L	L	L	M	L	P
838	Radiation between corium and drywell wall	N/A	N/A	N/A	M	M	K
839	Radiation between corium and drywell internal structure	N/A	N/A	N/A	M	M	K
840	Radiation between crust and drywell wall	N/A	N/A	N/A	M	M	K
841	Radiation between crust and drywell internal structure	N/A	N/A	N/A	M	M	K
842	Radiation between corium particle and drywell wall	N/A	N/A	N/A	M	M	K
843	Radiation between corium particle and drywell internal structure	N/A	N/A	N/A	M	M	K
844	Particulate Corium Bed Porosity	N/A	N/A	N/A	M	L	P
845	Gas stratification in drywell	L	L	L	H	H	K
846	Jet/plume gas interaction and entrainment effects	L	L	L	L	L	P
847	Pressure change in drywell	L	L	L	H	H	K
848	Gas temperature change in drywell	L	L	L	H	H	K
849	Gas composition change in drywell	L	L	L	M	H	K
850	Thermal conduction / temperature change of corium	N/A	N/A	N/A	M	H	P
851	Thermal conduction / temperature change of crust	N/A	N/A	N/A	M	H	P
852	Thermal conduction / temperature change of drywell floor/wall	L	L	L	M	H	K
853	Thermal conduction / temperature change of drywell internal structure	L	L	L	M	L	K
854	Water temperature change in drywell	L	L	L	M	L	K
855	Gas flow in drywell	L	L	L	H	H	K
856	Local gas flow and turbulence	L	L	L	L	L	P
857	Water flow in drywell	L	L	L	H	M	K
858	Drywell water level change	L	L	L	H	M	P
859	Thermal stratification	L	L	L	L	L	P
860	Erosion of drywell floor (concrete)	N/A	N/A	N/A	H	H	P
861	Physical properties of concrete ingredients (C, Si, etc.)	N/A	N/A	N/A	H	H	P
862	Transition of concrete ingredients into corium	N/A	N/A	N/A	H	H	P
863	Water evaporation from concrete by concrete heating	N/A	N/A	N/A	H	H	P
864	Gas generation (H2, CO, CO2, etc.) from concrete-corium interaction (reaction?)	N/A	N/A	N/A	H	H	P
865	Aerosol generation from concrete-corium interaction (reaction?)	N/A	N/A	N/A	H	H	P
866	Heat generation from chemical reaction between corium and concrete ingredients	N/A	N/A	N/A	H	H	P
867	Reaction (including generation of hydrogen and reaction heat) between corium ingredients and water (steam)	N/A	N/A	N/A	H	H	U
868	Corium flow / spread in drywell	N/A	N/A	N/A	H	L	P
869	Outflow of corium particle with water flow	N/A	N/A	N/A	H	L	P
870	Composition of corium particle	N/A	N/A	N/A	M	M	P
871	Size / configuration of corium particle	N/A	N/A	N/A	L	M	P
872	Aggregation / debris bed formation of corium particle	N/A	N/A	N/A	L	M	P
873	Generation / attenuation of decay heat from corium particle	N/A	N/A	N/A	H	M	P
874	Temperature change of corium particle bed	N/A	N/A	N/A	M	M	P
875	Corium solidification	N/A	N/A	N/A	H	M	P
876	Generation / attenuation of decay heat from corium	N/A	N/A	N/A	M	M	P
877	Mixture state (fuel, structure, concrete, etc.) and physical properties of corium ingredients	N/A	N/A	N/A	H	H	P

878			Corium stratification	N/A	N/A	N/A	M	M	P
879			Direct Containment Heating (DCH)	N/A	N/A	N/A	H	H	P
880			Water flow into crust	N/A	N/A	N/A	H	M	P
881			Bubble formation in crust	N/A	N/A	N/A	M	M	P
882			Crack formation in crust	N/A	N/A	N/A	M	M	P
883			Crust composition	N/A	N/A	N/A	H	M	P
884			Generation / attenuation of decay heat from crust	N/A	N/A	N/A	H	M	P
885			Crust remelting due to change in the heat transfer status to corium or water	N/A	N/A	N/A	H	H	P
886			Particulate corium remelting due to change in the heat transfer status	N/A	N/A	N/A	H	H	P
887			Oxidation reaction (including generation of hydrogen and reaction heat) between crust ingredients and water (steam)	N/A	N/A	N/A	M	M	U
888			Mixture state (fuel, structure, concrete, etc.) and physical properties of crust	N/A	N/A	N/A	M	M	P
889			Recriticality	N/A	N/A	N/A	H	L	P
890			Oxidation (including generation of hydrogen and reaction heat) of drywell wall by steam	L	L	L	M	H	P
891			Oxidation (including generation of hydrogen and reaction heat) of drywell internal structure by steam	L	L	L	L	H	P
892			Radiation decomposition of water	L	L	L	L	L	K
893			FP aerosolization	L	L	L	M	M	P
894			FP deposition on drywell wall	L	L	L	M	M	P
895			FP re-vaporization	L	L	L	M	M	P
896			Decay heat generation from FP	L	L	L	M	M	P
897			FP removal from drywell internal space by spray	N/A	N/A	N/A	M	M	U
898			FP particle transport by gas in the drywell	L	L	L	L	L	P
899			FP particle agglomeration/fragmentation in the drywell	L	L	L	L	L	P
900			FP particle deposition on the drywell wall and internal surfaces	L	L	L	L	L	P
901			FP transport by water flow on the drywell wall and internal surfaces	L	L	L	L	L	P
902			FP re-entrainment	L	L	L	L	L	P
903			FP release from corium surface	N/A	N/A	N/A	M	M	U
904			FP reaction including iodine chemistry	L	L	L	L	L	P
905			Adsorption and release of gaseous FP	L	L	L	L	L	P
906			Eutectic (Corium and metal in pedestal internals)	N/A	N/A	N/A	H	H	U
907			Droplet behavior in the drywell free space	L	L	L	L	L	P
908			Condensatiion heat transfer on the drywell wall	L	L	L	H	L	P
909			Interaction between gas and water film flow on the drywell wall and internal surfaces	L	L	L	L	L	P
910			Seasalt intake to corium	N/A	N/A	N/A	L	L	U
911			Seasalt impact for corium thermodynamic properties	N/A	N/A	N/A	L	L	U
912			Corrosion of drywell internals by seasalt (including marine lives)	L	L	L	L	L	U
913			Salt effects on heat transfer	L	L	L	L	L	U
914			Salt remelting from flood	L	L	L	L	L	U
915			Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
916			Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
917			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
918			Boron corrosion of drywell internal structure	L	L	L	L	L	U
919			Boron effects on heat transfer	L	L	L	L	L	U
920			Boron remelting from flood	L	L	L	L	L	U
921			Heat release from drywell wall	L	L	L	H	L	P
922			Steam condensation by PCV spray	L	L	L	H	H	P
923		Drywell Head	Heat transfer between D/W head inner wall and gas	L	L	L	H	H	K
924			Heat transfer between D/W head inner wall and water	L	L	L	H	M	K
925			Gas stratification in D/W head internal space	L	L	L	H	H	K
926			Gas composition in D/W head internal space	L	L	L	M	H	K
927			Steam condensation in D/W head	L	L	L	H	H	K
928			Gas flow in D/W head	L	L	L	H	H	K
929			Pressure change in D/W head internal space	L	L	L	H	H	K
930			Temperature change in D/W head internal space	L	L	L	H	H	K

931			Thermal conduction / Temperature change of D/W head	L	L	L	H	H	K
932			Deformation / failure of drywell head by thermal stress	L	L	L	H	H	P
933			Seal failure of D/W head flange	L	L	L	H	H	K
934			Gas flow from D/W head flange	L	L	L	H	H	K
935			Pressure loss of bulk head plate in head (including air duct)	L	L	L	M	H	P
936			Gas flow through air conditioner duct	L	L	L	M	M	P
937			Local gas flow and turbulence	L	L	L	L	L	P
938			Jet/plume gas interaction and entrainment effects	L	L	L	L	L	P
939			Droplet behavior in the drywell head free space	L	L	L	L	L	P
940			Condensatiion heat transfer on the drywell head wall	L	L	L	L	L	P
941			Interaction between gas and water film flow on the drywell head wall	L	L	L	L	L	P
942			FP attachment	N/A	M	M	H	H	K
943			FP reevaporation	N/A	L	L	M	H	K
944			Generation / attenuation of FP decay heat	N/A	L	L	M	H	K
945			FP particle transport by gas in the drywell head	L	L	L	L	L	P
946			FP particle agglomeration/fragmentation in the drywell head	L	L	L	L	L	P
947			FP particle deposition on the drywell head wall	L	L	L	L	L	P
948			FP transport by water flow on the drywell head wall	L	L	L	L	L	P
949			FP re-entrainment	L	L	L	L	L	P
950			FP accumulation at leakage path	M	H	H	H	H	U
951			FP reaction including iodine chemistry	L	L	L	L	L	P
952			Thermal stratification	L	L	L	L	L	P
953			Direct Containment Heating (DCH)	N/A	N/A	N/A	H	H	P
954			Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
955			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
956		Drywell vent line and downcomer to Wetwell	Deformation / failure of pipe line due to thermal stress	L	L	L	H	H	P
957			Flow resistance	L	L	L	M	L	K
958			Heat transfer between vent pipe and water	L	L	L	L	L	K
959			Heat transfer between vent pipe and gas	L	L	L	L	L	K
960			Pressure change in vent line	L	L	L	M	M	K
961			Gas temperature change in vent line	L	L	L	H	L	K
962			Water temperature change in vent line	L	L	L	L	L	K
963			Temperature change of vent pipe	L	L	L	L	L	K
964			Gas flow in vent line	L	L	L	M	L	K
965			Local gas flow and turbulence	L	L	L	L	L	P
966			Water flow in vent line	L	L	L	L	L	K
967			Gas composition change in vent line	L	L	L	M	H	K
968			Corium particle entrainment by gas / water	N/A	N/A	N/A	L	L	P
969			Heat transfer between entrainment corium particle and vent pipe	N/A	N/A	N/A	L	L	P
970			Heat transfer between entrainment corium particle and water	N/A	N/A	N/A	L	L	P
971			Droplet behavior in the drywell vent line free space	L	L	L	L	L	P
972			Condensation heat transfer on the drywell vent line inner surface	L	L	L	L	L	P
973			FP particle transport by gas in the drywell vent line and downcomer	L	L	L	L	L	P
974			FP particle agglomeration/fragmentation in the drywell vent line	L	L	L	L	L	P
975			FP particle deposition on the drywell vent line	L	L	L	L	L	P
976			FP deposition on vent line	L	L	L	M	M	P
977			FP re-vaporization	L	L	L	M	M	P
978			Decay heat generation from FP	L	L	L	M	M	P
979			FP transport by water flow on the drywell vent line and downcomer	L	L	L	L	L	P
980			FP re-entrainment	L	L	L	L	L	P
981			FP reaction including iodine chemistry	L	L	L	L	L	P
982			Local water flow in the drywell vent line and downcomer	L	L	L	L	L	P
983			Direct Containment Heating (DCH)	N/A	N/A	N/A	H	H	P

984			Change of failure crack area on bellows	L	L	L	H	H	P
985			Water leak from failure crack on bellows	L	L	L	H	L	P
986			Gas leak from failure crack on bellows	L	L	L	H	H	P
987			Corrosion of piping by seasalt (including marine lives)	L	L	L	L	L	U
988			Water level change in Drywell/Wetwell vantilation line	L	L	L	H	M	U
989			Salt effects on heat transfer	L	L	L	L	L	U
990			Salt remelting from flood	L	L	L	L	L	U
991			Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
992			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
993			Boron corrosion of vent pipe	L	L	L	L	L	U
994			Boron effects on heat transfer	L	L	L	L	L	U
995			Boron remelting from flood	L	L	L	L	L	U
996		Wetwell	Deformation / failure of Wetwell by thermal stress	L	L	L	H	H	P
997			Pressure change in wetwell	L	L	L	H	H	K
998			Water flow in wetwell	L	L	L	M	M	K
999			Temperature change in wetwell structure	L	L	L	M	H	K
1000			Gas composition change in wetwell	L	L	L	M	H	K
1001			Corium particle entrainment by gas / water	N/A	N/A	N/A	M	M	P
1002			Corium particle waftage	N/A	N/A	N/A	M	M	P
1003			Corium particle deposition / accumulation	N/A	N/A	N/A	M	M	P
1004			Heat transfer between pool water in wetwell and corium particle	N/A	N/A	N/A	M	M	P
1005			Gas ejection	L	L	L	L	H	K
1006			Steam condensation (with/without non-condensable gases)	L	L	L	H	H	K
1007			Temperature stratification (three-dimensional temperature distribution)	L	L	L	H	H	K
1008			Stratification of gas composition	L	L	L	L	H	K
1009			Dynamic load on wetwell wall (with/without non-condensable gases)	L	L	L	M	L	K
1010			Scrubbing	N/A	L	L	M	M	P
1011			Gas flow at vacuum breaker valve	L	L	L	H	H	K
1012			Local gas flow and turbulence	L	L	L	L	L	P
1013			Water level change	L	L	L	H	H	K
1014			Droplet behavior in the wetwell above water level	L	L	L	L	L	P
1015			Condensation heat transfer on the wetwell wall above water level	L	L	L	L	L	P
1016			Interaction between gas and water film flow on the wetwell wall above water level	L	L	L	L	L	P
1017			FP particle transport by gas in the wetwell	L	L	L	L	L	P
1018			FP particle agglomeration/fragmentation in the wetwell	L	L	L	L	L	P
1019			FP particle deposition on the wetwell wall above water level	L	L	L	L	L	P
1020			FP transport by water flow on the wetwell wall above water wall	L	L	L	L	L	P
1021			FP re-entrainment	L	L	L	L	L	P
1022			FP reaction including iodine chemistry	L	L	L	L	L	P
1023			Corrosion of wetwell by seasalt (including marine lives)	L	L	L	L	L	U
1024			Adsorption and release of gaseous FP	L	L	L	L	L	P
1025			Salt remelting from flood	L	L	L	L	L	U
1026			Influence on Heat Transfer by Seasalt Concentration Change	L	L	L	L	L	P
1027			Influence for heat transfer between wetwell and torus room by seawater	L	L	L	L	L	U
1028			Influence on Instrumentation and Measurements by Seasalt Concentration Change	L	L	L	L	L	U
1029			Seasalt impact for FP reaction and composition	L	L	L	L	L	P
1030			Boron corrosion of wetwell wall	L	L	L	L	L	U
1031			Boron effects on heat transfer	L	L	L	L	L	P
1032			Boron remelting from flood	L	L	L	L	L	U
1033			Heat release from wetwell wall to torus room	L	L	L	H	M	K
1034			Gas leak from wetwell (vacuum breaker)	N/A	N/A	N/A	H	H	P
1035			Water leak from wetwell (vacuum breaker)	N/A	N/A	N/A	H	H	P
1036	Reactor	Isolation	Heat transfer between steam and inner wall of IC heat transfer tube	M	L	L	L	L	K

1037	building	Condenser	Heat transfer between condensate and inner wall of IC heat transfer tube	L	L	L	L	L	K
1038			Heat transfer between pool water and outer wall of IC heat transfer tube	M	L	L	L	L	K
1039			Heat transfer between air and IC heat transfer tube in case of low pool water level	M	L	L	L	L	P
1040			Fouling factor of heat transfer tube (inner/outer surface)	M	L	L	L	L	K
1041			Degradation of condensation heat transfer coefficient due to non-condensable gas (Hydrogen, Noble gas)	L	H	L	L	L	K
1042			Volatile FP attachment into IC heat transfer tube	N/A	N/A	L	L	L	P
1043			Volatile FP reevaporation from IC heat transfer tube	N/A	N/A	L	L	L	P
1044			Heat generation of volatile FP attached inside IC heat transfer tube	N/A	N/A	L	L	L	P
1045			Pressure change(pressure loss) along IC system	M	L	L	N/A	N/A	P
1046			Pressure of IC heat transfer tube	M	L	L	N/A	N/A	K
1047			Water level in IC tank (shell side)	M	L	L	N/A	N/A	K
1048			Gas leak inside PCV boundary	M	M	M	M	M	P
1049			Water leak inside PCV boundary	M	M	M	M	M	P
1050			Gas leak outside PCV boundary	L	H	H	N/A	M	P
1051			Water leak outside PCV boundary	L	H	H	N/A	M	P
1052		R/B Compartments	Heat transfer between gas/water and walls in R/B compartments	L	L	L	L	M	P
1053			Heat transfer between gas/water and pipes in R/B compartments	L	L	L	L	M	P
1054			Heat transfer between gas/water and equipment in R/B compartments	L	L	L	L	M	P
1055			Gas/water flow between neighboring compartments	L	L	L	L	M	P
1056			Gas/water leak through the hatch on top of the wetwell to the torus room	N/A	N/A	N/A	N/A	M	P
1057			Gas/water leak through the bellows hole to torus room	N/A	N/A	N/A	N/A	M	P
1058			PCV ventilation piping sheet degradation by halogen compound chemical reaction	N/A	N/A	N/A	N/A	H	P
1059			Gas leak from valves on steam piping systems (MSIV, RCIC etc) to R/B compartments	N/A	N/A	N/A	N/A	M	P
1060			Gas leak from flanges in steam piping systems (MS, RCIC etc) to R/B compartments	N/A	N/A	N/A	N/A	M	P
1061			Gas/water leak from valves on RPV injection lines (FW, CS, HPCI, LPCI etc) to R/B compartments	N/A	N/A	N/A	N/A	M	P
1062			Gas/water leak from flanges in RPV injection lines (FW, CS, HPCI, LPCI etc) to R/B compartments	N/A	N/A	N/A	N/A	M	P
1063			Gas/water leak from valves on PCV cooling system piping (sprays and local cooling) to R/B compartments	N/A	N/A	N/A	N/A	M	P
1064			Gas/water leak from flanges in PCV cooling system piping (sprays and local cooling) to R/B compartments	N/A	N/A	N/A	N/A	M	P
1065			Gas leak from valves on gas system piping (inert gas injection, FCS etc) to R/B compartments	N/A	N/A	N/A	N/A	M	P
1066			Gas leak from flanges in gas system piping (inert gas injection, FCS etc) to R/B compartments	N/A	N/A	N/A	N/A	M	P
1067			Gas/water leak from valves on pedestal sump piping to R/B compartments	N/A	N/A	N/A	N/A	H	P
1068			Gas/water leak from flanges in pedestal sump piping to R/B compartments	N/A	N/A	N/A	N/A	H	P
1069			Gas/water leak from valves on CRD system piping to R/B compartments	N/A	N/A	N/A	N/A	M	P
1070			Gas/water leak from flanges in CRD system piping to R/B compartments	N/A	N/A	N/A	N/A	M	P
1071			Gas/water leak from valves on instrumentation lines to R/B compartments	N/A	N/A	N/A	N/A	H	P
1072			Gas/water leak from flanges in instrumentation lines to R/B compartments	N/A	N/A	N/A	N/A	H	P
1073			Gas/water leak from valves on PCV other utility system piping to R/B compartments	N/A	N/A	N/A	N/A	M	P
1074			Gas/water leak from flanges in PCV other utility system piping to R/B compartments	N/A	N/A	N/A	N/A	M	P
1075			Gas/water leak through PCV piping penetration	N/A	N/A	N/A	N/A	M	P
1076			Gas/water leak from seal of electric cable penetration	N/A	N/A	N/A	N/A	H	P
1077			Gas/water leak through PCV equipment/personnel hatch	N/A	N/A	N/A	N/A	H	P
1078			Rupture disk break in PCV ventilation line	N/A	N/A	N/A	N/A	M	K
1079			Gas/water leak through PCV ventilation lines	N/A	N/A	N/A	N/A	M	P
1080			Gas/water flow through PCV ventilation line to environment	N/A	N/A	N/A	N/A	M	P
1081			Pressure change in R/B compartments	L	L	L	L	M	P
1082			Pressure change in R/B piping and air stack	L	L	L	L	M	P
1083			Successful operation of PCV ventilation	N/A	N/A	N/A	L	M	K
1084			Gas reflux flow through PCV ventilation line and stack to another unit	N/A	N/A	N/A	N/A	H	P
1085			Gas reflux flow through PCV ventilation line to SGTS line	N/A	N/A	N/A	N/A	H	P
1086			Gas reflux flow through PCV ventilation line to R/B ventilation ducts	N/A	N/A	N/A	N/A	H	P
1087			Chimney effect at the elevator	L	L	L	L	M	K
1088			Chimney effect at the stairways	L	L	L	L	M	K
1089			Chimney effect at R/B air conditioner/ventilation ducts	L	L	L	L	M	K

1090		Filtration characteristics such as efficiency and pressure loss at SGTS system	N/A	N/A	N/A	N/A	L	P
1091		Gas mixing and composition fraction change in R/B compartments	N/A	N/A	N/A	N/A	H	P
1092		Gas composition stratification in R/B compartments	N/A	N/A	N/A	N/A	M	P
1093		Hydrogen accumulation at locally elevated piping (e.g. inverted U-shaped piping)	N/A	N/A	N/A	N/A	H	P
1094		Thermal stratification at R/B compartments	N/A	N/A	N/A	N/A	M	P
1095		Gas mixture thermodynimic properties change in R/B compartments	N/A	N/A	N/A	N/A	L	P
1096		Changes in gas mixing and concentration for each composition in pipings	N/A	N/A	N/A	N/A	H	P
1097		Gas mixture thermodynimic properties change in ventilation lines	N/A	N/A	N/A	N/A	L	P
1098		Oxidation of metal component in R/B compartments with steam (including hydrogen generation and reaction heat)	N/A	N/A	N/A	N/A	H	P
1099		Steam condensation in R/B compartment structures	N/A	N/A	N/A	N/A	L	P
1100		Ignition event for hydrogen combustion	N/A	N/A	N/A	N/A	M	P
1101		Catalytic effect by metal components in R/B compartments	N/A	N/A	N/A	N/A	M	P
1102		Hydrogen flame propagation regime	N/A	N/A	N/A	N/A	H	P
1103		Hydrogen combustion transition to detonation	N/A	N/A	N/A	N/A	H	P
1104		Pressure load to the structures in R/B	N/A	N/A	N/A	N/A	H	P
1105		Local gas flow and turbulence in the R/B compartments	L	L	L	L	M	P
1106		Droplet behavior in R/B compartment free space	N/A	N/A	N/A	N/A	M	P
1107		Interaction between gas and water film flow on R/B compartment walls	N/A	N/A	N/A	N/A	M	P
1108		FP particle transport by gas flow in R/B compartments	N/A	N/A	N/A	N/A	L	P
1109		FP deposition on R/B compartment structures	N/A	N/A	N/A	N/A	L	P
1110		FP re-entrainment from R/B compartment structures	N/A	N/A	N/A	N/A	L	P
1111		FP re-vaporization from R/B compartment structures	N/A	N/A	N/A	N/A	L	P
1112		FP particle agglomeration/fragmentation in R/B compartments	N/A	N/A	N/A	N/A	L	P
1113		FP transport by water flow on R/B compartment structures	N/A	N/A	N/A	N/A	L	P
1114		Seasalt impact for FP reaction and composition	N/A	N/A	N/A	N/A	L	P
1115		FP accumulation at leakage paths	N/A	N/A	N/A	N/A	L	P
1116		FP reaction including iodine chemistry	N/A	N/A	N/A	N/A	L	P
1117	SGTS	Gas leak through SGTS line valves or seals to R/B compartments	N/A	N/A	N/A	N/A	M	P
1118		Ventilation ratio by SGTS	N/A	N/A	N/A	N/A	M	K
1119	Operation Floor	Heat transfer between gas/water and walls in the operation floor	L	L	L	L	M	P
1120		Heat transfer between gas/water and pipes in the operation floor	L	L	L	L	M	P
1121		Heat transfer between gas/water and equipment in the operation floor	L	L	L	L	M	P
1122		Pressure change in the operation floor	L	L	L	L	M	P
1123		Gas inflow from the stairways	L	L	L	L	M	P
1124		Gas inflow from the elevator	L	L	L	L	M	P
1125		Gas inflow from operation floor air conditioner/ventilation ducts	L	L	L	L	M	P
1126		Gas inflow from the drywell head flange	N/A	N/A	N/A	N/A	H	P
1127		Gas mixing and composition fraction change in the operation floor	N/A	N/A	N/A	N/A	H	P
1128		Gas composition stratification in the operation floor	N/A	N/A	N/A	N/A	M	P
1129		Gas flow in the operation floor	L	L	L	L	M	P
1130		Oxidation of metal component in the operation floor with steam (including hydrogen generation and reaction heat)	N/A	N/A	N/A	N/A	L	P
1131		Steam condensation on the operation floor structures	N/A	N/A	N/A	N/A	L	P
1132		Local gas flow and turbulence in the operation floor	L	L	L	L	L	P
1133		Droplet behavior in operation floor free space	N/A	N/A	N/A	N/A	L	P
1134		Interaction between gas and water film flow on the operation floor or walls	N/A	N/A	N/A	N/A	L	P
1135		FP particle transport by gas flow in the operation floor	N/A	N/A	N/A	N/A	L	P
1136		FP deposition on the operation floor structures	N/A	N/A	N/A	N/A	L	P
1137		FP re-entrainment from operation floor structures	N/A	N/A	N/A	N/A	L	P
1138		FP re-vaporization from operation floor structures	N/A	N/A	N/A	N/A	L	P
1139		FP particle agglomeration/fragmentation in the operation floor	N/A	N/A	N/A	N/A	L	P
1140		FP trasnport by water flow on the operation floor	N/A	N/A	N/A	N/A	L	P
1141		Seasalt impact for FP reaction and composition	N/A	N/A	N/A	N/A	L	P

1142		FP accumulation at leakage paths	N/A	N/A	N/A	N/A	L	P
1143		FP reaction including iodine chemistry	N/A	N/A	N/A	N/A	L	P
1144		Absorption and release of gaseous FP from the spent fuel pool	N/A	N/A	N/A	N/A	L	P
1145		Ignition event for hydrogen combustion	N/A	N/A	N/A	N/A	M	P
1146		Catalytic effect by metal components in the operation floor	N/A	N/A	N/A	N/A	M	P
1147		Hydrogen flame propagation regime	N/A	N/A	N/A	N/A	H	P
1148		Hydrogen combustion transition to detonation	N/A	N/A	N/A	N/A	H	P
1149	Blowout Panel	Opening of the blow-out panel	N/A	N/A	N/A	N/A	H	P
1150		Design pressure of the blowout panel	N/A	N/A	N/A	N/A	M	K
1151		Opening area of the blowout panel	N/A	N/A	N/A	N/A	H	K
1152		Installation location of blowout panel	N/A	N/A	N/A	N/A	M	K
1153	Spent Fuel Pool	Heat transfer between gas/water and the spent fuel pool	L	L	L	L	M	P
1154		Steam condensation on the spent fuel pool interface	N/A	N/A	N/A	N/A	L	P
1155		Decay heat from spent fuel in the pool	L	L	L	L	L	P
1156		Spent fuel pool water radiolysis	L	L	L	L	L	P
1157		Temperature change in the spent fuel pool	L	L	L	L	L	P
1158		Metal - water reaction of spent fuel and pool water (hydrogen generation)	N/A	N/A	N/A	N/A	M	P
1159	Equipment Pool	Steam condensation at pool surface	N/A	N/A	N/A	N/A	L	P

表 2-6　ソースターム PIRT

No.	System	Subsystem /Component	Major phenomenon	Phenomenon / Related phenomena, other specific features	Early phase Heat up/ Melting/ Relocation	Middle phase PCV Deposition	Late phase Release to environment	SoK
			1. In-vessel Release					
2101	RPV	Core	(1) Radionuclides (FPs and actinides) behaviour before cladding damage	**Radionuclides generating** Related parameters - Irradiation history - Neutron spectrum *Radionuclides generating rate has relatively large error due to estimation error of the cooling state of the fuel assembly.* *There is area to develop the measurement of radionuclides inventory.*	Middle (2.115)	Low (1.115)	Low (1.192)	P
2102	RPV	Core		**FP gas release** Related parameters - Pellet microstructure - Burnup - Irradiation history (Temperature history) - Pellet characteristics - Atmosphere in the fuel rod - Fuel Temperature - Gas partial pressure, Gas equilibrium partial pressure, the molar density of fuel, and the fuel volume - Pressure *Additional FP gas release is small at the temperature in recovering the clad irradiation defect, because the temperature gradient in the pellet is low at the accident. Thus, the internal pressure of fuel rod will affect the timing of the cladding damage.* *The knowledge of the FP gas release was obtained during steady state condition, but the knowledge about influence of the release due to the crushing pellets is not enough.* *FP release is different from new fuel and spent fuel.* *Less knowledge about FP release from high burnup fuel and MOX fuel*	Middle (2.115)	Low (1.038)	Low (1.038)	P
2103	RPV	Core		**FP movement before the clad damage** Related parameters See also 2102 *The amount of FP that move to the gap before the accident affect the release of at clad rupture. This is similar to the FP gas release.* *The knowledge about volatile FP's behavior during steady-state operation is relatively abundant.* *When fuel center temperature is high during normal operation, the release ratio of Cs exceed 20%.*	Middle (2.154)	Low (0.846)	Low (0.846)	K
2104	RPV	Core		**Pellet-clad bonding** Related parameters - Irradiation history - Pellet/Clad characteristic (binding force) *The existence of the bonding layer that is mainly composed (U,Zr)O2 affects the liquidus line of clad.* *The knowledge about a bonding generating condition is summarized.* *There is little knowledge about bonding of the MOX. But the bonding does not occure in the case of Fukushima to be little loaded the MOX fuel.*	Middle (2.038)	Low (0.846)	Low (0.846)	K
2105	RPV	Core		**Pellet-clad contact** *The fuel melting behavior is affected by the pellet-clad contacting.* *Lowering of the fuel liquidus-solidus line by eutectic reaction between fuel and clad*	Middle (2.038)	Low (0.846)	Low (0.846)	K
2106	RPV	Core	(2) Radionuclides behavior from clad damage to clad	**Pellet form change and radionuclides release at the time of the clad rupture**	High (Engineering Judgement)	Low (Engineering Judgement)	Low (Engineering Judgement)	P

			melting	Related parameters - The characteristic of the clad creeping - Temperature history during the accident - Internal pressure of fuel rod - the state of fuel and radionuclides before the clad rupture - Temperature history - Atmosphere See also 2102 *The phenomenon of the crushing pellets, with the weakened binding force of the pellets at high burnup, is known when the pellet temperature is higher than the temperature experienced during irradiation. It may crush finely for the high burnup organization (Rim organization and Pu spot).* *When a pellet crushes, a lot of radionuclides are released and affect the radionuclides diffusion. However, it is not clear the behavior before clad rupture.* *Crushing pellets due to the rapid decrease of pellet stress with the clad rupture affects the later behaviour (the increasing of radionuclides release, the radiocuclides movement inside and outside fuel).* *The clad rupture causes the release of radionuclides accumulated in the gap, the foam change with clad crushing, and the additional release by the pellet oxidation with the steam.* *The axial distrubution of the oxygen potential in fuel rod changes. (The clad is embrittled by hydrogen away from the the ruptured position.)*				
2107	RPV	Core	(3) Radionuclides behavior in the state that the pellet shape stability was kept after clad melting	**Radionuclides release after pellet is exposed to the atmosphere in the core by clad melting** Related parameters - Atmosphere (existence of the steam) - Atmosphere (existence of hydrogen produced by the reaction of steam and clad) - Atmosphere (internal leakage of the nitrogen/air by the instrumentation pipe damage) - Specific surface of fuel (including surface depletion) - fuel temperature - Ambient pressure *During the state of the pellet dropping (not melting) due to clad melting, the release is mostly due to the thermal effect (diffusion or evaporation) and the chemical reaction.* *When UO2 is oxidized with steam, the FP in the crystal lattice of U becomes easy to move. The release behaviour is different the oxidized fuel from reduced fuel.* *There is a possibility that the volatility will increase significantly in the high oxygen potential (air infiltration conditions) in specific FP (especially Ru).* *The radionuclide release of the elements (I,Te,Cs,Sr,Ba,Pu,Ru) that have been observed in the Fukushima accident.*	High (2.417)	Middle (1.962)	Low (1.423)	U
2108	RPV	Core	(4) Radionuclides behavior after the fuel melting	**Radionuclides release from molten fuel** Related parameters - Temperature - Composition - Atmosphere *Radionuclides release and evaporation by melting* *Radionuclides release rate is increased when fuel is liquefied.*	High (2.615)	High (2.462)	Middle (1.692)	U
2109	RPV	Core, Lower plenum		**Radionuclides release from re-solidification fuel** Related parameters - Temperature - Composition - surface area - Nuclear fission	Middle (1.750)	Middle (2.077)	Middle (1.692)	U

				Radionuclides release from the corium solidified above the water surface in a situation which no water is splashed in. *Radionuclides release by re-heating after solidified molten debris has not been assumed so far.*				
2110	RPV	Core		**Radionuclides release during the reflood** Related parameters - Cooling rate - FP dissolution to a coolant *FP release due to cracking / grain refining of fuel by the reflood* *The CORA experiment in Germany provides the result that FP release promotes during reflood.* *Less knowledge about the FP release during reflooding.*	Middle (1.808)	Middle (1.885)	Low (1.654)	U
2111	RPV	Core	(5) Other behaviors and factors which affect the radionuclides release	**Influence on iodine/cesium chemical form and hydrogen production from molten/re-solidified fuel due to the B4C control rod existence** *Influence on behavior of (3) and (4)* *Mixing process of fuel and B4C affects the source term. This clarification is important.* *The formation of organic iodine increases in B4C control rod.* *Less knowledge about the chemical contribution of iodine, cesium, and tellurium, etc. which are included in the control rod and the other constituents.*	High (2.423)	Middle (2.192)	Middle (1.692)	U
2112	RPV	Core		**Influence of the MOX (Pu concentration)** *It should be considered about composition of Pu concentration, non-uniformity of Pu spots, and chemistry in the fuel rod as an influence on the behaviour of (1) to (4).* *If oxygen potential is high, FP is oxidized, and a release rate changes by chemical form (vapor pressure) changing.* *The oxygen potential in MOX fuel is higher than UO2 fuel.*	Middle (2.231)	Middle (1.769)	Low (1.385)	P
2113	RPV	Core, Lower plenum		**Radionuclides release due to the re-criticality** Related parameters - Debris shape - Composition - Coolant ratio *Radionuclides generating and release when partial or extensive re-criticality occurred* *It is necessary to make it clear about the re-criticality during the accident.* *Influence on behaviour of (2) to (4)*	Low (1.500)	Middle (1.731)	Low (1.423)	U
2114	RPV	Core		**Change of the amout of heat generation in the fuel (Decay heat) by the radionuclides release** *Due to each stage of the radionuclides release and the changes of the heat source at each place, there is influence of the temperature evaluation that is important to the release behaviour.* *Influence on behaviour of (2) to (4). If there is a transition in the fuel rod at (1), there is also influence on behaviour.*	Middle (2.077)	Middle (1.885)	Low (1.654)	U
2201	RPV	Vessel, Loop, Steam line	2. Gas/Aerosol Behaviour in Vessel, Loop, and Steam line	**Condensation / Re-vaporization / Adsorption** Related parameters - Vapor partial pressure difference between FP and aerosol surface - Water injection via CS - Mass transfer coefficient, Sherwood number - Amount of FP saturated vapor - FP vapor concentration - Vaporization rate (Condensation rate) of FP vapor in the condensation plane - Diffusion coefficient of the vapor - Diffusion coefficient of the FP gas - Temperature - Vaporization of deposited chemical species - Condensation on the wall surface	High (2.583)	High (2.654)	Middle (2.231)	K
2202	RPV	Vessel, Loop, Steam line		**Re-suspension** Related parameters - Velocity	Middle (2.136)	Middle (2.200)	Low (1.500)	K
2203	RPV	Vessel,		**Agglomeration**	Middle	Middle	Low	K

		Loop, Steam line		Related phenomena －Thermal agglomeration with Brownian motion －Kinetic agglomeration by the velocity difference －Turbulent agglomeration Related parameters －Temperature caused by decay heat, steam leakage, water injection, and radiation to PCV －Difference of the particle diameter －Difference of the particle velocity	(1.909)	(2.000)	(1.455)	
2204	RPV	Vessel, Loop, Steam line		**Deposition by diffused migration** Related phenomena －Stefan flow －Interdiffusion －Brownian motion Related parameters －Bulk flow of mixtured gas (Non-condensable gas and water vapor) －Concentration gradient of the gas mixture －Mass flux of the steam condensation －Temperature caused by decay heat, steam leakage, water injection, and radiation to PCV	Middle (2.091)	Middle (2.000)	Low (1.625)	K
2205	RPV	Vessel, Loop, Steam line		**Diffused deposition by convection** Related phenomena －Fluid state (turbulent/laminar flow) －Noncondensable gas generation (high temperature) －Steam generation due to FCI －Chemical reacton between gas －Hydrogen Combustion －Recriticality	Middle (2.091)	Middle (2.273)	Middle (1.792)	K
2206	RPV	Vessel, Loop, Steam line		**Deposition by thermophoresis** Related parameters －Temperature gradient between gas and wall －Thermophoretic coefficient	Middle (2.000)	Middle (2.091)	Low (1.625)	K
2207	RPV	Vessel, Loop, Steam line		**Deposition by gravitational settling** Related parameters －Density of the aerosol particles －Particles diameter －Cm(Cunningham) correction factor －Spatial volume －Deposition area	Middle (2.273)	Middle (2.182)	Middle (1.909)	K
2208	RPV	Vessel, Loop, Steam line		**Inertial deposition** Related parameters －Gas velocity －Stokes number	Middle (2.273)	Middle (2.091)	Middle (1.708)	K
2209	RPV	Vessel, Loop, Steam line		**Aerosol growth by hygroscopicity**	Middle (2.125)	Middle (1.875)	Middle (1.727)	K
2210	RPV	Lower Plenum		**Scrubbing** Related phenomena －Water injection into the lower plenum retaining debris *There are knowledge in general under the lower temeperature during steady state condition.*	Middle (2.208)	Middle (2.273)	Middle (1.958)	P
2301	RPV	－	3. Transport in RPV and PCV	**Leakage via instruments, penetration, etc** Leak potential －In-Core instrument (SRM/IRM,TIP) －Instrumentation pipe －Pump seal Related phenomena －Inertial deposition －Re-suspension by the turbulence diffusion Related parameters －Temperature －Liquidus-solidus line of the instrumentation tube －Leakage area －Pressure	High (Engineering Judgement)	High (Engineering Judgement)	High (Engineering Judgement)	P
2302	RPV	－		**Leakage via gasket** Leak potential	High (Engineering	High (Engineering	High (Engineering	P

				– RPV flange – MSL gasket – MSIV Related phenomena See also 2301 Related parameters – Liquidus–solidus line of the RPV wall – Liquidus–solidus line of the CRD guide tube See also 2301	Judgement)	Judgement)	Judgement)	
2303	RPV	Lower Head		**Leakage by RPV damage** Related parameters – Liquidus–solidus line of the RPV wall – Liquidus–solidus line of the CRD guide tube See also 2301	Low (1.400)	High (2.455)	High (2.364)	P
2401	PCV	Pedestal	4. Ex–vessel Release	**MCCI (Concrete erosion)** Related phenomena – Concrete erosion – State of the debris layer – Crusting – Heat transfer on the boundary layer of debris – Heat transfer in the gap of concrete debris – Heat transfer between the water and the debris – Spreading on the floor – Chemical reaction with the corium – Generation of non–condensable gas (CO and H2) by oxidizing the metal by CO2 and H2O generated by decomposed concrete – Scrubbing and crust generation when there is a pool on the molten pool Related parameters – Heat flux to the concrete, Concrete density, and Enthalpy of eroded concrete – Sensible heat of the concrete, Energy by chemical reaction, and Heat generation by melting the oxides – Components of the concrete – Debris density distribution – Temperature distribution in the crust, Solidification temperature of the debris – Gas film, Slag film – Chemical reaction between the debris and the concrete floor – Convection and temperature distribution in the debris – Debris properties – Vaporization – Steam release from the hydroxide – CO2 release from carbonate	Low (0.182)	High (2.875)	High (2.731)	P
2402	PCV	Pedestal		**Re–entrainment of aerosols by PCV depressurization** *Major technical knowledge related to the migraion of aerosol behavior in the PCV is generally sufficient.*	Low (0.333)	Middle (2.125)	Middle (1.833)	K
2501	PCV	S/C	5. Aerosol Behaviour in Containment	**Scrubbing by steam flow from SRV to S/C** Related phenomena – Inertial impaction – Condensation – Gravity settling – Aerosol collection in the bubbles – Brownian diffusion Related parameters – Bubble rise velocity – Bubble density – Bubble diameter – Velocity at the discharge outlet – Vapor mass flux – Steam ratio in carrier gas – Career gas viscosity – Carrier gas pressure – S/C water temperature – S/C water level – Diffusion coefficient of the particles	High (Engineering Judgement)	Middle (Engineering Judgement)	N/A (Engineering Judgement)	K

				− Total pressure of S/C − Steam pressure of S/C − Quencher diameter − Cm(Cunningham) correction factor				
2502	PCV	S/C		**Scrubbing with the vent from D/W to S/C** Related parameters − vapor flow − S/C water level − S/C water temperature	Low (1.542)	High (2.625)	High (2.375)	P
2503	PCV	Pedestal		**Scrubbing due to water injection to the pedestal floor**	Low (0.583)	Middle (2.292)	High (2.333)	P
2504	PCV	D/W, S/C		**Traping due to steam condensation by spray** Related phenomena − Diffused migration − Stefan flow Related parameters − Steam condensation rate − Molecular weight of steam and gas − Mol fraction of steam and gas − Mol concentration of bulk gas − Particle deposition velocity − Droplet surface area − Spatial volume	Low (1.273)	Middle (2.167)	Middle (2.208)	K
2505	PCV	D/W, S/C		**Trapping due to collision with droplets by spray** Related phenomena − Interruption − Inertial collision − Brownian diffusion Related parameters − Aerosol particle radius − Spray droplet radius − Reynolds number of droplet − Spray volumetric flow − Spray drop height − Spatial volume − Stokes number − Peclet number	Low (1.273)	Middle (1.818)	Middle (1.875)	K
2506	PCV	D/W		**Steam condensation by drywel cooler** Related parameters − Steam condensation rate − Bulk gas density − Gas phase volume *Aerosol deposition model to tubes have been constructed.* *But there are a large amount of uncertainty.*	Low (1.455)	Middle (2.083)	Middle (2.000)	P
2507	PCV	D/W		**Condensation / Re-vaporization / Adsorption** See also 2201	Middle (1.818)	High (2.455)	Middle (2.208)	K
2508	PCV	D/W		**Re-suspension** See also 2202	Low (1.455)	Middle (2.125)	Middle (2.083)	K
2509	PCV	D/W		**Agglomeration** See also 2203	Middle (1.700)	Middle (2.100)	Middle (2.000)	K
2510	PCV	D/W		**Deposition by diffused migration** See also 2204	Low (1.500)	Middle (1.864)	Middle (1.727)	K
2511	PCV	D/W		**Diffused deposition by convection** See also 2205	Middle (2.000)	Middle (2.300)	Middle (2.091)	K
2512	PCV	D/W		**Deposition by thermophoresis** See also 2206	Middle (1.700)	Middle (1.955)	Middle (1.818)	K
2513	PCV	D/W		**Deposition by gravitational settling** See also	Middle (1.792)	Middle (2.273)	High (Engineering Judgement)	K

				2207				
2514	PCV	D/W		**Inertial deposition** See also 2208	Low (1.545)	Middle (1.909)	Middle (1.875)	K
2515	PCV	D/W		**Aerosol growth by hygroscopicity** See also 2209	Middle (1.792)	Middle (1.875)	Middle (1.727)	K
2516	PCV	D/W		**DCH** Related parameters － Pressure	Low (1.300)	Middle (1.792)	Low (1.500)	P
2601	PCV	－	6. Transfer out of Containment	**Leakage via instruments, penetrations, gasket, etc** Leak potential － Top head flange － TIP(Traversing Incore Probe) penetration － CRD (Control Rod Drive) hatch － S/C manhole － Equipment hatch － Electric penetration － Bellows (vent, penetration) － Vacuum breaker (1F1 only) Related phenomena － Inertial deposition － Re-suspension by the turbulence diffusion － Decay heat － MCCI － Radiation from RPV Related parameters － Vapor temperature － Liquidus-solidus line of the organic seal material － Leakage area － PCV pressure	Low (Engineering Judgement)	High (Engineering Judgement)	High (Engineering Judgement)	P
2602	PCV	S/C		**Wetwell vent** Related phenomena － Inertial depositoin － Scrubbing － Scrubbing at the rapid de-pressurization － Scrubbing at the depressurized boiling － Scrubbing at the time when a large amount of hot gas containing the FP vapor was flowing	Low (1.000)	High (2.455)	High (2.545)	P
2603	PCV	D/W		**Drywell vent** Related phenomena － Inertial depositoin	Low (1.000)	High (2.636)	High (2.909)	P
2604	PCV	－		**Filtered Containment Venting Systems (FCVS)**	Low (0.955)	Low (1.455)	Low (1.636)	P
2605	RPV, PCV	－		**Migration of radioactive material by the injection water into the reactor**	Low (0.800)	Low (1.364)	High (2.364)	U
2701	R/B	－	7. Aerosol Behaviour in Reactor Building	**Aerosol Behaviour in Reactor Building** Related phenomena － Condensation / Re-vaporization / Adsorption － Re-suspension － Agglomeration － Deposition by diffused migration － Diffused deposition by convection － Deposition by thermophoresis － Deposition by gravitational settling － Inertial deposition － Aerosol growth by hygroscopicity See also 2201 – 2209	Low (Engineering Judgement)	Low (Engineering Judgement)	High (Engineering Judgement)	K
2702	R/B	－		**Aerosol deposition on the narrow part (clearance of the shield plugs, etc)**	Low (1.292)	Low (1.625)	Middle (2.292)	U
2801	PCV	D/W, S/C	8. Iodine chemistry	**Generation of acidic substances by radiolysis** Related phenomena － Production of nitric acid from the nitrogen by radiolysis － Production of hydrochloric acid from the cable coating material of the electric wire by radiolysis Related parameters	Low (1.409)	Middle (2.182)	High (Engineering Judgement)	P

				- Nitrogen mass in the atmosphere - Dose rate in the atmosphere - Cable insulator mass - Dose rate of the cable insulator				
2802	PCV	S/C		**Hydrolysis**	Low (1.409)	Middle (2.300)	High (Engineering Judgement)	P
2803	PCV	S/C		**Re-volatilization of iodine by acidification pH decrease** Related parameters - Hydrogen-ion concentration - Ionic activity - Ionic strength	Middle (1.708)	Middle (Engineering Judgement)	High (2.545)	P
2804	PCV	S/C		**Iodine chemical reaction in water pool** Related parameters - The molarity of the active chemical species - Gas pressure in the atmospheree - Water density - Molarity of the iodine species - Reaction rate constant (Forward/Reverse) - Source by radiolysis	Middle (1.708)	Middle (Engineering Judgement)	High (2.545)	P
2805	PCV	D/W, S/C		**Decomposition reaction of iodine in the atmosphere** Related phenomena - Thermal decomposition reaction - Radiolysis reaction Related parameters - Hydrogen concentration - Ozone concentration - Ambient temperature - Dose rate atmosphere - Oxygen concentration - Water vapor concentration	Low (1.542)	Middle (2.125)	High (2.417)	P
2806	PCV	S/C		**Transfer between gas phase and water pool** Mass transfer coefficient between atmosphere and water pool Surface area of water pool Atmospheree volume Molarity in the atmospheree and water pool	Middle (2.091)	Middle (Engineering Judgement)	High (2.833)	P
2807	PCV	D/W, S/C		**Recombination reaction of iodine in the atmosphere** Related parameters - Molarity of I and I2 - Ambient temperature - Partial pressure of I and I2 - Equilibrium constant	Low (1.500)	Middle (2.125)	High (2.333)	P
2808	PCV	D/W, S/C		**Wall deposition of iodine in the atmosphere** Related parameters - I2 concentration in the atmosphere - the amount of I2 deposition per unit area - Adsorption rate - Desorption rate	Low (1.625)	Middle (Engineering Judgement)	High (2.545)	P
2809	PCV	D/W, S/C		**Wall adsorption and desorption of iodine by chemical adsorption process** Related phenomena - Adsorption/Desorption in the atmosphere (Chemical adsorption to the paint with CH3I and I2) - Adsorption/Desorption in the water pool (Chemical adsorption to the paint with I-, I2, and CH3I)	Middle (1.792)	Middle (Engineering Judgement)	High (2.545)	P
2810	PCV	-		**Effect of impurities in the water pool**	Low (1.000)	Middle (1.682)	High (2.400)	P
2811	PCV	-		**Iodine chemistry under high water temperature conditions**	Middle (1.818)	Middle (2.208)	High (2.545)	P
2812	PCV	-		**Effects of seawater**	Low (1.100)	Low (1.591)	High (2.400)	U
2813	PCV	-		**Iodine release from R/B contaminated water**	N/A (Engineering	High (Engineering	High (Engineering	U

					Judgement)	Judgement)	Judgement)	
			9. Chemical form (Iodine, Cesium)	*There are still large uncertainties about the chemical form of iodine.* *Large amounts of gaseous cesium that can not be explained by conventional knowledge was observed in Fukushima accident.*				
2901	RPV	Core, Lower Plenum		**Re-evaporation of I2 by the decomposition of CsI** Related phenomena – Decomposition of CsI with boric acid – I2 generation due to the oxidation of CsI by an air atmosphere	Middle (1.667)	Middle (2.208)	High (Engineering Judgement)	K
2902	PCV	–		**Effects of seawater**	Low (1.100)	Low (1.591)	High (2.400)	U
2903	RPV, PCV	–		**A generation ratio for the inorganic iodine of the organic iodine**	Low (1.500)	Middle (2.167)	High (2.375)	P

表 2-7　感度解析を実施した各パラメータの感度

パラメータ	1st	2nd	3rd
支持板破損時のコリウム流路面積	-	-	H
SR 弁流路面積	L	M	H
コリウムないし燃料棒の輻射率	L	H	H
RPV 破損時のひずみ	-	-	L
RPV から格納容器内への輻射率	L	H	H
ジェットエントレインメントのモデル係数	-	-	H
燃料棒崩壊ノードにおける流路閉塞のポロシティのクライテリア	-	H	H
溶融ノードにおける流路閉塞ポロシティ閾値	-	H	H
粒子状デブリのポロシティ	-	-	L
炉内構造物壁面からの輻射率	L	H	H
燃料崩壊時の水力直径、面積の減少割合	-	H	H
被覆管外面積の補正係数	M	H	H
計装管破損時の排出係数	L	H	H
ドリフトフラックス分布係数	L	H	H
粒子状デブリの発生粒径の補正係数	-	-	H
ギャップ熱伝達係数補正	-	-	M
炉心の初期崩壊熱割合	H	H	H
平板 CHF の補正係数	-	-	M
キャンドリングの粘性係数補正パラメータ	L	H	H
ドリフトフラックスモデルのボイド率算出モデルパラ メータ	L	H	H
Xe のギャップ内存在率	L	H	L
制御棒からバイパス流への熱伝達係数(W/m2C)	L	H	H
燃料と被覆管の熱伝達（冠水時）	L	H	H
燃料と被覆管の熱伝達（露出時）	L	H	H
コリウムからプールへの膜沸騰熱伝達係数	L	H	H
被覆管膨れ計算のオプション	M	M	H
溶融プールの計算オプション	L	H	M
溶融炉心横方向リロケーションのオプション	L	H	H
SR 弁の開閉差圧	L	H	H
SR 弁開設定圧	L	H	H
被覆管破裂温度	L	M	H
鉄の liquidus	-	-	H
鉄ー酸化物の liquidus	-	-	H
鉄の solidus	-	-	H
鉄ー酸化物の solidus	-	-	H
崩壊炉心領域のポロシティ	-	H	H
エントレインメント時のボイド率	-	-	H
コリウムジェット時の水接触初期径	-	-	H
下部ヘッド—コリウムギャップ幅	-	-	H
粒子状デブリと周辺構造物との熱ギャップ	-	-	H
配管付着クラストの最大厚さ	-	-	L
下部クラストの最大厚さ	-	-	H
下部クラストの最小厚さ	-	-	M
上部クラストの最大厚さ	-	-	H

表 2-8　PIRT の改訂(In-vessel)

No.	Region	Phenomena	Importance		
			1st	2nd	3rd
4	Core	Core pressure change	H-->L	H	H
6		Gap conductance between fuel pellets and cladding	H-->L	L-->H	L-->H
10		Temperature change in control rods	L	M	L
11		Decay heat in Intact fuel assemblies	H	M-->H	L-->H
13		Temperature change in gaps between fuel pellets and	M-->L	L-->H	L-->H
19		Heat transfer between water and control rods	L	M-->H	L-->H
33		Gas composition change in gap between fuel pellets and	M-->L	L-->H	L
34		Balooning of fuel cladding	M	L-->M	L-->H
46		Pressure loss change for core flow paths	M-->L	M-->H	L-->H
50		Pressure loss increase by fuel cladding balooning	M	L-->M	L
51		Change in 2-phase flow regime status in fuel channels	M-->L	M-->H	L-->H
63		Zr-Water reaction including oxidation and hydrogen	H-->M	H	M-->H
66		Heat transfer between water(liquid phase) and corium	N/A	H	H
73		Heat transfer between water (liquid phase) and particulate	N/A	H	H
74		Heat transfer between gaseous phase and particulate	N/A	H	H
75		Heat transfer between fuel cladding and particulate corium	N/A	M	M
76		Heat transfer between control rods and particulate corium	N/A	M	M
77		Heat transfer between channel boxes and particulate	N/A	M	M
80		Heat transfer between water(liquid phase) and crust	N/A	H	H
81		Heat transfer between gaseous phase and crust	N/A	H	H
91		Radiation heat transfer among fuel rods	H	H	L
92		Radiation heat transfer between channel boxes and fuel	M	M	L
93		Radiation heat transfer between water rods (or water	L	M	L
94		Radiation heat transfer among channel boxes	M	M	L
95		Radiation heat transfer between channel boxes and core	M	M	L
96		Radiation heat transfer between control rods and core	L	M	L
97		Radiation heat transfer between control rods and channel	H	M	L
98		Radiation heat transfer between corium and shroud	N/A	H	H
99	Core	Radiation heat transfer between crusts and shroud	N/A	M-->H	M-->H
100		Radiation heat transfer between particulate corium and	N/A	M-->H	M-->H
101		Radiation heat transfer between corium and core support	N/A	H	H
102		Radiation heat transfer between crusts and core support	N/A	M-->H	M-->H
115		Fuel rod collapse and moving to the lower region	N/A	H-->M	H
116		Channel blockage by collapsed fuel rods	N/A	H	M-->H
117		Melted fuel 'candling'	N/A	H	M-->H
118		Channel and bypass blockage by melted fuel	N/A	H	M
126		Decay heat generation from corium	N/A	H	H
131		Change in ablated area for core support plate	N/A	N/A	H
155		Corium jet through breached core support plate	N/A	N/A	H
164		Gas leak flow into instrumentation tube	N/A	M-->H	M-->H
179	Shroud head	Radiation heat transfer between intact fuel rods and shroud	M	L	L
192		Pressure change in shroud head	L	M	M
221	Standpipe & Separator	Pressure change in standpipe/separator	L	M	M
229		Decay heat generation from FP	L	M	M
247	Dryer	Pressure Change in Dryer	L	M	M
255		Decay heat generation from FP	L	M	M
270	Upper head	Radiation Heat Transfer from Upper Head to Drywell Head	M	M	M
279		Decay heat generation from FP	L	M	M
294	Main Steam Line	Pressure change in main steam line	L	M-->H	M-->H
302		Safety relief valve opening characteristics	M-->L	H	H
303		Leakage from safety relief valve to drywell	M-->L	H	H
304		Pressure loss at safety relief valve	M-->L	H	H
314		Decay heat generation from FP	M	H	H

327	Upper down comer	Pressure change in upper downcomer	L	M	M
475	Lower head	Heat transfer between water and lower head including	L	L	H
476		Heat transfer between water and penetration tubes	L	L	H
477		Heat transfer between gas and lower head including crack	N/A	L	H
478		Heat transfer between gas and penetration tubes (control	N/A	L	M
479		Heat transfer between corium and water (including CHF)	N/A	N/A	H
480		Heat transfer between corium and gas	N/A	N/A	H
482		Heat transfer between corium and lower head	N/A	N/A	H
483		Heat transfer between particulate corium and water	N/A	N/A	H
484		Heat transfer between particulate corium and gas	N/A	N/A	H
485		Heat transfer between particulate corium and penetration	N/A	N/A	H
486		Heat transfer between particulate corium and lower head	N/A	N/A	H
487		Heat transfer between particulate corium and light metal	N/A	N/A	H
488		Heat transfer between crust and water (including CHF, inner	N/A	N/A	H
489		Heat transfer between crust and gas	N/A	N/A	M
492		Heat transfer between crust and lower head	N/A	N/A	H
493		Heat transfer between crust and light metal layer	N/A	N/A	M
494		Heat transfer between light metal layer and water (including	N/A	N/A	M
497		Heat transfer between light metal layer and lower head	N/A	N/A	M
501		Radiation heat transfer between particulate corium and	N/A	N/A	M-->H
503		Radiation heat transfer between corium and lower head	N/A	N/A	H
504		Particulate Corium Bed Porosity	N/A	N/A	H-->M
505		Change in temperature of penetration tubes (control	L	L	H
506		Change in temperature of RPV lower head	L	L	H
508		Failure of RPV nozzle welding by thermal stress	N/A	N/A	M
511	Lower head	Change in pressure in lower plenum	L	L	H
512		Change in water temperature in lower plenum	L	L	M
513		Change in gas temperature in lower plenum	L	L	M
516		Change in temperature inside corium	N/A	N/A	H
519		Corium jet into water pool	N/A	N/A	H
520		Formation of corium pool	N/A	N/A	H
521		Stratification of corium pool	N/A	N/A	H
522		Atomization of corium by contanct with water (jet breakup)	N/A	N/A	H
523		Change in temperature in light metal layer	N/A	N/A	M
524		Change in temperature in heavy metal layer	N/A	N/A	M
525		Change in composition of particulate corium	N/A	N/A	H
526		Change in size and shape of particulate corium	N/A	N/A	H
527		Crust generation by solidification of corium	N/A	N/A	H
528		Accumulation and bed formation of particulate corium	N/A	N/A	H
530		Change in temperature of particulate corium bed	N/A	N/A	H
541		Change in physical property by material mixing in corium	N/A	N/A	H
545		Solidification of corium	N/A	N/A	H
555		Change in physical property by material mixing in crust	N/A	N/A	H
556		Change in temperature of crust	N/A	N/A	H
559		Gap formation between corium and lower head	N/A	N/A	H
566		Crust remelting due to change in the heat transfer status to	N/A	N/A	H
567		Particulate corium remelting due to change in the heat	N/A	N/A	H
606		Lower head creep deformation	N/A	N/A	H-->L
621		Melting point change for lower head materials	N/A	N/A	H
623		Melting of lower head penetration lines	N/A	N/A	H
624		Melting of lower head wall	N/A	N/A	H

３．SAMPSON-SWG

3.1　はじめに

SAMPSON-SWG では，我が国で開発されたシビアアクシデント解析コード SAMPSON を(財)エネルギー総合工学研究所（以下，エネ総工研）より貸与いただき，福島第一原子力発電所 1～3 号機の事故進展やシビアアクシデントに関する既往実験等の解析を通じて,SAMPSON コードの課題を摘出することを目的とした。

3.2　SAMPSON コードの開発経緯と概要

SAMPSON-SWG における検討状況を述べる前に，1993 年度より 10 年計画でコードが開発された経緯とコードの概要をまとめておく。詳しくは文献[3-1][3-2]を参照されたい。

原子力プラントにおいてシビアアクシデントを想定した場合，通常運転時から事故の終息に至る間に，熱流動挙動や化学挙動に加えて核分裂生成物の挙動等が複雑に錯綜し，かつ相互に影響し合いながら現れるため，事故時の一連の挙動を試験のみによって解明するのは極めて困難である。したがって，試験では，事故時の特定の局面に着目し，その断面における詳細な現象の解明を目指しているものがほとんどである。そのため，事故時におけるプラントの全体的な挙動の把握は解析コードに頼らざるを得ない。

主なシビアアクシデント解析コードのうち，MAAP, MELCOR, THALES などのいわゆる Lumped-Parameter コードは，主として経験式を採用し，大規模試験に基づいて経験定数やチューニング・パラメータを決定するという方法をとっている。計算負荷が小さいことが最大の特長であり，シビアアクシデント対策の有効性評価，レベル 2 PRA のソースターム解析などを感度解析も含めて系統的に実施することが可能である。

これに対して，詳細解析のためのメカニスティックコードといわれるものとして，米国原子力規制委員会(USNRC)は，原子炉容器内の事象を対象とした RELAP/SCDAP や格納容器内の事象のみを対象とした CONTAIN 等を開発した。しかし，これらのメカニスティックコードにおいても，現象そのものの複雑さから，あるいは現象の理解が不十分なために，一部簡略化したモデル（例えば，RELAP5/SCDAP では溶融炉心の移動挙動，CONTAIN では水素の燃焼挙動等で)を採用している。また，水蒸気爆発現象については，これらのコードではモデル化されていない。さらに，原子炉容器内の事象から格納容器内事象に至る一連の事象を一貫して解析できるメカニスティックコードは，SAMPSON 以前には存在していなかったと言われている[3-1]。

このような状況の下，当時の㈶原子力発電技術機構(NUPEC)では通商産業省(当時)の委託を受け，我が国で実用化されている軽水型原子力発電プラントを対象として，通常運転時からシビアアクシデントに至る一連の事象を解析できるソフトウェアを整備し，計算機シミュレーションによって事故時の安全裕度を実証することを目的とした事業を 1993 年度よ

り 10 年計画で発足させた。整備するソフトウェアは，軽水炉の安全裕度を評価できるものとするため，できるだけ物理現象を精緻に記述した機構論的モデルで構築することとし，かつ運用・保守の効率を考慮してモジュール構成としている。このような特徴を考慮し，整備するソフトウェアそのものを IMPACT(Integrated Modular Plant Analysis and Computing Technology)と称した。“IMPACT”は，コード開発のプロジェクト名にも使われた。

SAMPSON (Severe Accident analysis code with Mechanistic, Parallelized Simulations Oriented towards Nuclear fields)は，軽水炉発電プラントの通常運転時から原子炉容器内事象を経て格納容器内事象に至る間の一連の現象を対象として，事故の一貫解析を可能とするために開発されたものであり，IMPACT プロジェクトで開発されたコードの中心と位置づけられている。現在はエネ総工研が所有し保守されている。なお，USNRC のコードを等価無償交換する取り決めが 1997 年 6 月に締結されている。

SAMPSON は，11 個の解析モジュールと，事象進展に応じて解析モジュール群の実行制御を行う解析制御モジュールとで構成されている。また 2 つのオフラインモジュールとして，水素混合解析モジュール（hyna）と水素燃焼挙動解析モジュール（ddoc)がある。解析モジュールのうち，原子炉容器内熱水力解析モジュールには USNRC の RELAP5 を，格納容器内熱水力解析モジュールには USNRC の CONTAIN を利用し，1 次系内 FP 挙動解析モジュールおよび格納容器内 FP 挙動解析モジュールは，一括して NUPEC で開発された冷却系内 FP 輸送解析コード MACRES を改良して利用している。解析制御モジュール(ACM)は，事故シナリオに応じた 11 種類の解析モジュールの動的な配置，実行制御，通信制御およびタイムステップ制御を行う。

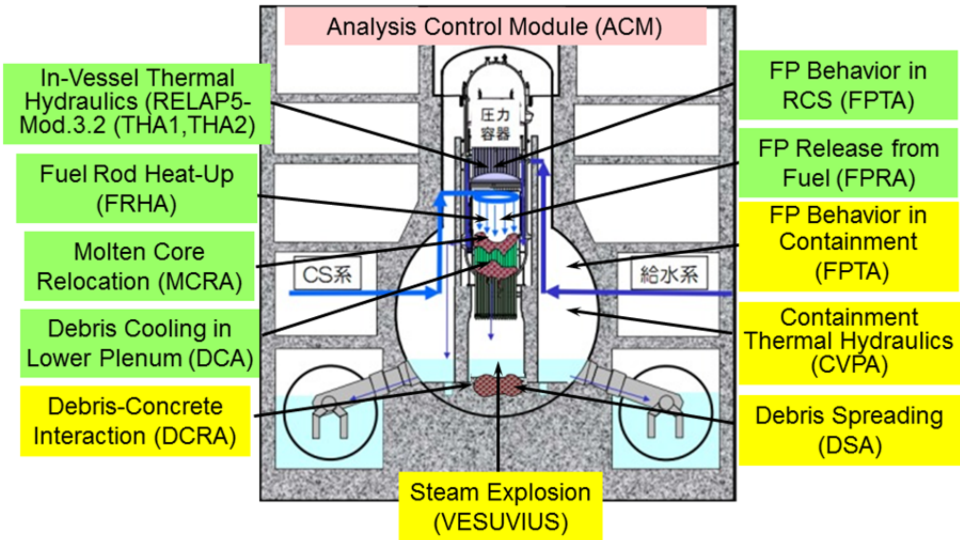

図 3-1　SAMPSON のモジュール

3.3 SAMPSON-SWG の活動概要

本研究専門委員会の設立直後の 2011 年 11 月に SAMPSON-SWG が立ち上がり，これまで，6 回開催した。まず，IMPACT プロジェクトに参画していた大坂大学・片岡教授から「SAMPSON の開発と物理モデルについて」と題した包括的な講義，および当時既に SAMPSON ユーザであった㈱テプコシステムズから「SAMPSON の調査報告・インストール経験について」というユーザ視点の発表を頂いた。開発元であるエネ総工研から委員に対するコード，入力，マニュアルの配布は 2011 年 12 月より開始し，これまでに３度の修正バージョーンの配布があった。なお，本研究専門委員会で配布される SAMPSON の入力データは，公開情報に基づく「福島第一原子力発電所 1 または 2,3 号機相当」のものであり，エネ総工研が国からの委託で進めている解析や OECD/NEA の BSAF（Benchmark Study of the Accident at the Fukushima Daiichi Nuclear Power Station）で用いられている入力データとは厳密には一致しない。

SAMPSON コードが配布された機関は，東京大学，大阪大学，電気通信大学，早稲田大学，北海道大学，東京工業大学，福井大学，日本原子力研究開発機構，原子力安全基盤機構，電力中央研究所，東京電力，テプコシステムズ，東芝，日立製作所，日立 GE ニュークリア・エナジー，三菱重工，三菱総研（順不同）である。ユーザ機関による検討状況は，定期的に開かれる SAMPSON-SWG の会合で紹介され，開発元のエネ総工研を加えた活発な議論が交わされてきた。

3.4 SAMPSON コードに関する検討状況

ここでは，本専門委員会発足後に各ユーザが発表した公開文献を基に，SAMPSON コードに関する検討状況を簡単に紹介する。これらの公開文献は，付録 B を参照されたい。

3.4.1 In-vessel モデルの検討と福島第一原子力発電所事故の初期過程の解析

開発元のエネ総工研からは，福島第一原子力発電所事故を踏まえた SAMPSON コードの改良計画[3-3]のほか，福島第一原子力発電所 1,2,3 号機の事故進展解析結果[3-4～25]が多数公開されている。

1 号機では，地震発生から約 5 時間後に約 7[MPa]の炉圧が計測され，約 9 時間後に設計圧力を大幅に超えるドライウェル圧力が計測され，12 時間後には炉圧が約 0.9MPa に減圧していることが計測されている。これらの事実は，遅くとも地震発生の約 9 時間後には原子炉冷却系の圧力バウンダリが破損してドライウェルへの直接リークが生じていたことを強く示唆している。原子炉圧力容器（RPV）の下部ヘッド破損が唯一のリークパスだと仮定した初期の解析では，地震発生から約 14 時間後の RPV 下部ヘッド破損までは炉圧の低下やドライウェル圧力の上昇が生じない結果となった[3-4]。東京電力が MAAP を用いて解析した結果も，地震発生後約 15 時間での RPV 下部ヘッド破損というものであった[3-26]。そこで，東京電力のその後の解析でも採用されたものと同様に，エネ総工研では，逃し安全弁（SRV）

のガスケットからのリークと，炉内まで延びている線源領域検出器（Source Range Monitor: SRM）/中間領域検出器（Intermediate Range Monitor: IRM)のガイドチューブの損傷を仮定した解析を実施し，計測データの傾向をある程度再現する結果が得られている[3-12,15,16,19,20,22,25]。また，現状では炉心構造物の約 67%が溶融し，約 572kg の水素が RPV 内で発生したものと評価されている[3-25]。

2 号機では，原子炉格納容器からの除熱が喪失した状況で原子炉隔離時冷却系（RCIC）が長時間稼働していたことから，サプレッションプール水温上昇による蒸気凝縮能力の低下が起こり，結果としてドライウェル圧力が徐々に上昇したものと考えられている。SAMPSON による当初の解析では，このドライウェル圧力の上昇を実測値より過大評価していた[3-6]。その後の解析では，津波によりトーラス室が浸水し，地震発生から約 56 時間でトーラス室体積の 30%まで海水で満たされたと仮定すると，約 70 時間までのドライウェル圧力の解析結果が実測値をよく再現することが示された[3-23]。また，2 号機では RCIC 制御用の直流電源が喪失したため，炉内の水位をレベル 2 と 8 の間に保つように RCIC が起動／停止を繰り返すことができなくなり，RCIC の稼働中は炉内水位がレベル 8 を超えていたと考えられている。エネ総工研では，RCIC の駆動タービンに二相流が流れこんだ際の効果を新たにモデル化することで，事故初期段階の炉圧の測定値が概ね再現されている[3-13,17,19,20,23,25]。また，現状では炉心構造物の約 38%が溶融し，約 930kg の水素が RPV 内で発生したものと評価されている[3-25]。

3 号機では，運転員による高圧注水系（HPCI）の部分負荷運転に伴う炉圧の一時的な低下が観測されており，それを再現するための部分負荷運転モデルがエネ総工研で提案されている[3-11,18,19,20,25]。また，サプレッションプールの温度成層化による蒸気の不完全凝縮やサプレッションプールスプレイのモデルを追加することで，ドライウェル圧力の測定値が概ね再現されている[3-15,18]。また，代替注水により実際に炉心に入った水量が RPV 下部ヘッド破損の有無に大きな影響を及ぼすことが示唆されている[3-24]。また，現状では炉心構造物の約 40%が溶融し，約 880kg の水素が RPV 内で発生したものと評価されている[3-25]。

初期過程に関連するモデル改良の検討と 1 号機の事象進展解析は，東京大学でも実施されている[3-27〜35]。RPV の減圧に関するものとして，SRM ガイド管や主蒸気配管のクリープ破損モデルが検討されている。炉内の伝熱流動現象に関するものとして，燃料被覆管のクリープ破損，被覆管内面やチャンネルボックス，制御棒シース，制御棒被覆管の酸化モデル，酸化反応が水蒸気を消費することによる下流域への影響，輻射伝熱による炉内温度分布の平坦化，金属の酸化による熱伝導率の低下，B_4C とステンレスの相互作用による液化温度の低下などが検討されている。

今後は，RPV 内外のデブリ分布の推定や，コア-コンクリート反応（MCCI）の状況，原子炉格納容器の破損モードやタイミングなどの評価とそれに必要なモデル開発・改良などが重要課題として挙げられる。エネ総工研は、下部プレナムへのデブリ流出モデルの改良を

検討している[3-36～38]。2 号機については，RCIC タービンからの排気がサプレッションプールの一箇所に流れ続けたことによるプール水の温度成層化の検討が課題として挙げられており、東京大学では縮小実験による検討を行っている[3-39]。

3.4.2　Ex-vessel モデルの検討

福島第一原子力発電所事故の解析としては，前節で紹介したように，現状は In-vessel について主に検討されている。Ex-vessel の諸現象は，In-vessel に比べて更に不確かさが大きくなると考えられており，前述のとおり，デブリ分布の推定や，コア-コンクリート反応（MCCI）の状況，原子炉格納容器の破損モードやタイミングなどが重要課題として挙げられる。SAMPSON-SWG においては，Ex-vessel での不確かさ低減を目的としたモデル検討や既往実験との比較，必要に応じて新たな小規模実験などが実施されている。

今後，福島第一原子力発電所 1～3 号機の廃炉作業を進める上で，格納容器内におけるデブリの分布状況に関する情報が必要であるが，これは，RPV からの溶融燃料の漏洩状況の影響を受けると考えられる。例えば，液噴流の微粒化が顕著な場合には，液噴流はより広範囲に分散するとともに，周囲気体との熱交換により固化が促進されたと考えられる。気体中に噴出する液体噴流の流動特性は，流体力学分野における基本的な興味の対象の 1 つであるが，特に噴出孔の口径が 1mm を超える場合，噴流の広がり特性や微粒化特性に関する知見は，きわめて限られた状況にある。電気通信大学では，液体噴流の流動特性に特に強い影響をもつ因子として，噴出口の形状と背圧が液体噴流の広がり特性及び微粒化特性に及ぼす影響について，実験的な検討がなされている[3-40～43]。並行して，デブリの落下断面積や最小流動厚さにより，ペデスタル床面上におけるデブリの広がり状況がどのように変化するのか，SAMPSON コードのデブリ広がり挙動モジュール（DSA）を用いて数値実験的に検討されている[3-41,42]。

炉心溶融物（コリウム）の格納容器床における広がり挙動は MCCI の初期条件であるのみならず，BWR マーク I 格納容器のライナー健全性とも関係する重要テーマである。早稲田大学では，この挙動を非圧縮性連続体の相変化や大変形を経験式によらず機構論的に解析できる粒子法（MPS 法）計算コードを用いて種々の条件で解析し，SAMPSON コードの当該モデルの検証が行われている[3-45～49]。これまでに，既往の FARO/26S，ECOKATS-VI 及び Theofanous 水実験が MPS コードでよく再現されている。この MPS コードとの比較を通じて，SAMPSON の DSA モジュールにおける高さ方向の計算格子の設定方法が検討されている。

また，㈱日立製作所においても，DSA モジュールによるデブリ拡がり予測精度向上を目的とする解析モデルの高度化が検討されている[3-50,52]。さらに、MCCI 解析モデルについても㈱日立製作所と京都大学で検討が行われており、化学反応モデル、上部クラストの熱伝達モデルの高度化が検討されている[3-53～56]。

3.5 まとめ

シビアアクシデントの事象進展評価における大きな不確かさを低減し，福島第一原子力発電所でおきたシビアアクシデント現象（特にデブリの分布状況）の推定や今後のアクシデントマネジメント策などの評価・改良に資するために，SAMPSON コードとその課題について調査・検討した。今後も様々なモデル改良や検証を継続していくことが必要である。

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４．結言

福島第一原子力発電所でおきたシビアアクシデント現象の把握、さらには事故で放出されたソースタームを評価するためには、解析コードによるシミュレーションが欠かせない。そのシミュレーションの評価精度を向上するため、事象進展及びソースターム評価の 2 つの観点から PIRT を実施し、課題の抽出を行った。また、シビアアクシデントの事象進展評価における大きな不確定性を低減し、福島第一原子力発電所でおきたシビアアクシデント現象（特にデブリの分布状況）の推定や今後のアクシデントマネジメント策などの評価・改良に資するために、SAMPSON コードとその課題について調査・検討した。

今後、本 PIRT 結果を踏まえて、実験も含めて解析コードの高度化のための研究計画が具体化されるべきである。さらに、本 PIRT も定期的に見直し、より充実していく事が必要である。SAMPSON コードについては、今後も様々なモデル改良や検証を継続していくことが必要である。