NUREG-0050

資料 11-2

# RECOMMENDATIONS RELATED TO BROWNS FERRY FIRE　ブラウンズフェリー火災に関する提言

# 1.0 SUMMARY AND RECOMMENDATIONS　概要と提言

## 1.1 introduction　導入

On March 22, 1975, a fire was experienced at the Browns Ferry Nuclear Plant near Decatur, Alabama.
1975 年 3 月 22 日、Alabama 州の Decatur 近くにあるブラウンズフェリー原子力発電所で火災を経験した。

The Special Review Group was established by the Executive Director for Operations of the Nuclear Regulatory Commission (NRC) soon after the fire to identify the lessons learned from this event and to make recommendations for the future in the light of these lessons.
特別検討グループは火災事故の後、直ちに原子力規制委員会（NRC）の運営に関する常任理事によって設立され、火災事故から学ぶべき教訓を把握し、これらの教訓から将来への提言を作成した。

Unless further developments indicate a need to reconvene the Review Group, its task is considered complete with the publication of this report.
更なる進展が検討グループに必要とされない限り、火災事故の課題に対する議論はこの報告書により完結するものとみなす。

The Review Group's recommendations cover a variety of subjects.
検討グループの提言は多様な主題を網羅している。

The responsibility for implementation of the various recommendations belongs to the Nuclear Regulatory Commission generally, and to appropriate offices within the NRC specifically.
様々な提言の実施に関する責任は全般的に原子力規制委員会、特に NRC 内の関連部門に帰属している。

Although recommendations are offered on a variety of specific items where improvements could be useful, the Review Group does not believe that action is needed in every plant in response to each of these comments.
たとえ提言では特定機器の多様性について、実用可能な是正が述べられていたとしても、検討グループはこれらの見解をすべてのプラントへ適用する必要があるとは考えていない。

The overall objective of the recommendations is to achieve an acceptable degree of

protection from fires.
それらの提言の総合的な目的は火災防護の許容度合を達成することである。

A balanced approach must be used in the application of the recommendations to specific facilities, with due consideration for the details of the design and construction of each specific plant.
均衡のとれたアプローチは、それぞれ特定プラントの建設及び設計の詳細に関する考慮のために、特定施設に対する提言の適用へ利用されなければならない。

The Review Group has not duplicated the investigation into the incident conducted by the Office of Inspection and Enforcement or the safety review conducted by the Office of Nuclear Reactor Regulation, both reported elsewhere.
検討グループは調査是正部門または原子炉規制部門のそれぞれ行われた事故の調査を繰り返していない。

However, these reports, as well as input from the Tennessee Valley Authority and other sources, were used by the Review Group in its evaluation.
しかしながら、これらのレポート並びに Tennessee Valley Authority 等からの情報は検討グループによって事故の評価に使用された。

The Group's recommendations are necessarily based on today's knowledge and understanding.
検討グループの提言は必然的に今日の知見と知識に基づくものである。

The Browns Ferry Construction Permit was issued in 1966, and its issuance based on the state of knowledge at that time.
ブラウンズフェリー原子力発電所の建設許諾は 1966 年に発行され、それは当時の知識に基づいたものであった。

Similarly, the Operating License review in 1970-72 was based on the technology of that period.
同様に、1970～1972 年の運転認可の審査もその時期の技術に基づいたものであった。

Many things that are now deemed evident as a result of the incident and its analysis were not evident previously.
事故とその分析の結果として、明白であると考えられる多くのことは、以前では明白でな

かったものである。

The recommendations of the Review Group reflect the increase in knowledge and understanding during recent years.

検討グループの提言は近年までの知見と知識をより強固に反映しているものである。

### 1.2 Sequence of Events in the Fire　火災時における事象の経過

The Browns Ferry plant consists of three boiling water reactors, each designed to produce 1067 megawatts of electrical power.

ブラウンズフェリー発電所はそれぞれ1067MWの電力を生成するよう設計された３機の沸騰水型原子炉から構成されている。

Units 1 and 2 were both operating at the time of the fire.

１号機と２号機は火災時に両方とも運転中であった。

Unit 3 is still under construction.

また、３号機は建設中であった。

Units 1 and 2 share a common control room with a cable spreading room located beneath the control room.

１号機と２号機は共通の制御室と制御室の真下に位置するケーブル処理室を共有している。

Cables carrying electrical signals between the control room and various pieces of equipment in the plant pass through the cable spreading room.

制御室とプラント内にある設備の様々な部分の間で電気信号を運んでいるケーブルはケーブル処理室を通過している。

The immediate cause of the fire was the ignition of polyurethane foam which was being used to seal air leaks in cable penetrations between the Unit 1 reactor building and a cable spreading room located beneath the control room of Units 1 and 2.

火災の直接原因としては、１号機と２号機の制御室の真下にあるケーブル処理室と１号機の原子炉建屋の間にあるケーブル貫通孔の空気漏洩シールとして使われていたポリウレタンフォームへの着火が挙げられる。

The material ignited when a candle flame, which was being used to test the penetration for leakage, was drawn into the foam by air flow through the leaking penetration.

ウレタンフォームは漏えい孔を通過する空気の流れにより、ろうそくの炎（貫通孔の漏え

い試験によく使われていた）がフォームに引き寄せられたことで着火した。

Following ignition of the polyurethane foam, the fire propagated through the penetration in the wall between the cable spreading room and the Unit 1 reactor building.
ポリウレタンフォームの着火に続き、１号機の原子炉建屋とケーブル処理室の間にある壁内の貫通孔を通過して火災が伝播した。

In the cable spreading room, the extent of burning was limited and the fire was controlled by a combination of the installed carbon dioxide extinguishing system and manual fire fighting efforts.
ケーブル処理室内では、燃焼の拡大は制限され、火災は設置されていた $CO_2$ 消火設備と手動消火努力の組み合わせにより、鎮圧された。

Damage to the cables in this area was limited to about 5 feet next to the penetration where the fire started.
ケーブル処理室内にあったケーブルへの被害は、火災が出火した貫通孔からおよそ５フィート（1.524m）に限られていた。

The major damage occurred in the Unit 1 reactor building adjacent to the cable spreading room, in an area roughly 40 feet by 20 feet, where there is a high concentration of electrical cables.
火災による大きな損傷は、およそ幅 40 フィート（12.192m）、長さ２０フィート（6.096m）の範囲内でケーブル処理室へ隣接する１号機の原子炉建屋内で発生した。

About 1600 cables were damaged.
およそ 1600 本のケーブルが損傷した。

There was very little other equipment in the fire area, and the only damage, other than that to cables, trays, and conduits, was the melting of a soldered joint on an air line and some spalling of concrete.
火災の区域内にはごくわずかの機器しかなく、ケーブルやトレイ、コンジットへの損傷以外の唯一の損傷は、コンクリートの剥離と空気パイプのはんだ継手されていたジョイントの溶融であった。

The electrical cables, after insulation had been burned off, shorted together and

grounded to their supporting trays or to the conduits, with the result that control power was lost for much of the installed equipment such as valves, pumps, and blowers.
電気ケーブルは絶縁体が燃え尽きて短絡し、支持トレイやコンジットに落ちたことで、ベンやポンプ、ブロワ―のような設置されていた機器の大半に対する制御力を失う結果となった。

Sufficient equipment remained operational throughout the event to shut down the reactors and maintain the reactor cores in a cooled and safe condition, even though all of the emergency core cooling systems for Unit 1 were rendered inoperable, and portions of the Unit 2 systems were likewise affected.
たとえ１号機の緊急炉心冷却設備のすべてが運転不能になったとしても、原子炉の冷却と安全状態の維持および原子炉を停止するための十分な機器は、火災を通しても運転可能なままであった。また２号機の機器の一部が同様の影響を受けた。

No release of radioactive material above the levels associated with normal plant operation resulted from the event.
火災事象の結果として通常運転時に関わる程度以上に放射性物質の放出はなかった。

In addition to the cable damage, the burning insulation created a dense soot which was deposited throughout the Unit 1 reactor building and in same small areas in the Unit 2 reactor building.
ケーブルの損傷に加えて、燃えている絶縁体が２号機の原子炉建屋内にあるいくつかの小さな区域と１号機の原子炉建屋中に堆積した濃い煙を発生させた。

The estimated 4,000 pounds of polyvinyl chloride insulated cable which burned also released an estimated 1400 pounds of chloride to the reactor building.
また、燃えたケーブルに使われていた推定 4000 ポンド（1816 ㎏）のポリ塩化ビニルは推定 1400 ポンド（635.6 ㎏）の塩化物を原子炉建屋内へ放出した。

Following cleaning, all exposed surfaces of piping, conduit, and other equipment were examined for evidence of damage.
清掃するにつれて、パイプやコンジット、そのほかの機器など、すべての暴露された表面の被害形跡が確認された。

Piping surfaces where soot or other deposits were noted were examined by dye penetrant procedures.

ススまたは他の堆積物が示されているパイプの表面は染料浸透剤により確認された。

With the exception of small (3 and 4 inch diameter) uninsulated carbon steel piping, one run of aluminum piping, heating and ventilation ducts, and copper instrument lines in or near the fire zone, no evidence of significant chloride corrosion was found.
原子炉内や近くの火災区域にある、絶縁されていない小さな径の塩素鋼配管とアルミニウム配管の１系統、空調ダクト、銅製機器配線を除いて、重要な塩素腐食の形跡は見つからなかった。

Where such evidence was found, the material affected will be replaced.
そのような形跡が見つかった場所では、火災の影響を受けた材料は交換される予定である。

For some stainless steel instrument lines, an accelerated inspection program has been established to determine if effects of chloride may later appear.
ステンレス鋼製機器配線については、経年による塩化物の影響が現れるかどうか、判断するために促進的な点検プログラムが設立された。

### 1.3 How Safe was the Public?　公衆はどのくらい安全であったか？

The Review Group has studied the considerable evidence now available on the Browns Ferry fire and has considered the possibility that the consequences of the event could have been more severe, even though in fact they were rather easily forestalled.
検討グループはブラウンズフェリーの火災で今日に適用できる重要な証拠を調査し、たとえ実際には簡単に先回りして妨げられるとしても、その事象がより過酷な結果となる可能性を考慮した。

It is certainly true that, in principle, degraded conditions that did not occur could have occurred.
原則として、起こらなかった崩壊状態が十分に起こりえたことは確かな事実である。

Some core cooling systems were, or became, unavailable to cool the core; others were, or became, available and some of these were used to cool the core.
いくつかの炉心冷却設備は、炉心を冷却するために利用できなかったが、ほかの設備は利用でき、残りの炉心冷却設備も用いて炉心の冷却が行われた。

Much attention was drawn to the unavailability of Emergency Core Cooling Systems.
ほとんどの注意は緊急炉心冷却設備が利用不可能となったことにひかれた。

While it is certainly true that the availability of these systems would have been comforting, they were not required during the Browns Ferry fire.
これらの設備が利用可能であることが、人々を元気づけたことは確かな事実であると同時に、それらはブラウンズフェリーの火災の間に必要とされなかった。

In the absence of a loss of coolant accident, systems other than those designated as emergency core cooling systems are capable of maintaining an adequate supply of water to the core.
冷却材喪失事故が起こっていない場合、緊急炉心冷却設備として指定されている設備以外の設備は、炉心への十分な給水を維持する能力を有している。

This was indeed the case during the fire at Browns Ferry.
これはブラウンズフェリーの火災時には確かにそうであった。

One way of looking at public safety during this event is to inventory the subsystems that were available at various times during the course of the fire and to assess their redundancy, and to consider what actions were potentially available to increase the redundancy.
この事故中における公衆の安全性について調べる１つの方法には、火災の進行中に様々な時点で利用できた補助設備の目録を作ること、及びそれら設備の冗長性を評価し、どんな行動がそれらの冗長性を高めるために潜在的に利用できたのか、よく考えることである。

This is considered in Section 4.1.1.
このことについては、第 4 章の 1.1 節で考慮されている。

Such an inventory shows that there was a great deal of redundant equipment available or potentially available during most of the incident.
そのような目録は、冗長性を有する機器の大部分が事故のほとんどの期間で利用可能、または潜在的に利用可能であったことを示している。

Two periods of limited redundancy were:
冗長性の制限された 2 つの期間は以下の通りである、

1. The period (about one-half hour) before Unit 1 was depressurized at 1:30 p.m. During this period, the operating high pressure pumps had insufficient capacity to

inject additional water to make up for steam loss, but could have been augmented in several ways.

午後 1 時 30 分に 1 号機が減圧された以前の期間（およそ 1 時間半）では、稼働中の高圧ポンプは蒸気喪失を補うためにさらなる水を注水する時において不十分な能力であったが、いくつかの方法で能力を増加することができた。

Alternatively, the system could have been depressurized to allow utilization of redundant low pressure pumps, and this was done.

代わりとして、その系統は冗長性のある低圧ポンプの利用を可能にするために減圧させることが可能であり、実際にそれが行われた。

2. The period (about four hours) during which remote manual control of the Unit 1 relief valves, and thus the capability to depressurize the reactor, was lost.

1 号機の安全弁の遠隔手動制御やこのように原子炉を減圧するための能力が失われた期間（およそ 4 時間）

During this period, only high-pressure pumping could be effective; there remained available three control-rod drive pumps, any one of which could keep the core covered and cooled, provided that a steam drain valve was opened (this was done some hours later) or a bypass valve opened.

この期間では高圧ポンプのみが効果的であった。どれもが炉心を網羅しており、炉心の冷却を維持することができた 3 系統の制御棒駆動ポンプは、圧力逃がし弁、つまりバイパス弁が開かれれば（これは数時間後に行われた）利用可能のままであった。

In addition, two standby liquid control system pumps were also available, which together could keep the core covered with the steam drain valve open, and either of which, added to any one control-rod drive pump, could keep the core covered even without a drain or bypass valve being opened.

加えて、２つのホウ酸水注入系ポンプも利用可能であり、それらは蒸気排出弁の開放により炉心を覆い、維持することが可能であった。そして排出、言い換えるとバイパス弁の開放なしで炉心を覆い、維持することができたどれでも 1 つの制御棒駆動ポンプが利用可能なものに追加された。（→要はホウ酸注入系ポンプと制御棒駆動ポンプが同様に機能できる状態であったことを言いたいだけ？）

Other actions were available which could have been taken to augment high pressure capability or to restore low pressure capability.

高圧注水能力を増幅することができ、低圧注水能力を復旧することができたため、他の行動は実行可能であった。

Actually, the remote manual control of the relief valves was restored and the added redundancy of the three available condensate booster pumps made the other options academic.
実際、安全弁の遠隔手動制御は復旧し、その３つの利用可能な復水ブースターポンプに関して追加された冗長性はその他のオプションをアカデミックにした。

These other options are discussed in Section 4.1.1.
これらの他のオプションは 4 章の 1.1 節で議論されている。

A probabilistic assessment of public safety or risk in quantitative terms is given in the Reactor Safety Study (1).
公衆安全の確率論的評価、つまりリスクの定量的な表現は原子炉安全研究（１）で与えられる。

As the result of a calculation based on the Browns Ferry fire, the study concludes that the potential for a significant release of radioactivity from such a fire is about 20% of that calculated from all other causes analyzed.
ブラウンズフェリーの火災に基づく計算の結果として、その研究では火災から放射線の重大な放出に至る可能性は、すべての他の原因の中でおよそ 20%を占めていると結論づけている。

This indicates that predicted potential accident risks from all causes were not greatly affected by consideration of the Browns Ferry fire.
これはあらゆる原因から予測された潜在的な事故のリスクが、ブラウンズフェリー火災の考慮によって大いに影響を受けるわけではないことを示している。

This is one of the reasons that urgent-action in regard to reducing risks due to potential fires is not required.
これは潜在的な火災のために、リスクを減らすことに関する切迫したアクションが必要とされない理由の１つである。

The study also points out that "rather straightforward measures, such as may already exist at other nuclear plants, can improve fire prevention and fire-fighting capability

and can significantly reduce the likelihood of a potential core melt accident that might result from a large fire.
その研究はまた、むしろもう既に他の原子力発電所にあるかもしれない直接的な方法は火災予防および消火性能を改善することができ、大規模な火災から発生するかもしれない潜在的な炉心溶融事故の可能性をかなり減らすことができると指摘している。

The Review Group agrees.
検討グループは賛同している。

Fires occur rather frequently; however, fires involving equipment unavailability comparable to the Browns Ferry fire are quite infrequent (see Section 3.3).
火災はむしろ頻繁に発生している、しかしながら、ブラウンズフェリー火災ほど機器の利用不能を伴う火災はごく稀である（3 章の 3 節を参照）。

The Review Group believes that steps already taken since March 1975 (see Section 3.3.2) have reduced this frequency significantly.
1975 年 3 月（3 章 3.2 節を参照）からすでに取り組まれている行程がこの頻度を十分に減らしている、と検討グループは考えている。

### 1.4 Perspective　相関関係、見解

The Browns Ferry fire and its aftermath have revealed some significant inadequacies in design and procedures related to fires at that plant.
ブラウンズフェリーの火災とその影響は、そのプラントで火災に関連した対策、及び設計におけるいくつかの重大な不備を明らかにした。

In addition to the direct fire damage, there were several kinds of failures.
その直接的な火災損傷に加えて、数種類の誤作動や失敗があった。

Some equipment did not function correctly, and, in hindsight, some people's actions were incorrect or at least not as effective as they should have been.
いくつかの機器は正しく機能せず、後日検証では何人かの行動が不正確であり、言い換えると少なくとも彼らがそうしなければならなかったほど効果的ではなかった。

The fire, although limited principally to a 20×40 interior space in the plant, caused extensive damage to electric power and control systems, impeded the functioning of normal and standby cooling systems, degraded the capability to monitor the status of

the plant, and caused both units to be out of service for many months.
主に発電所内の 20 フィート×40 フィートの範囲に制限されたとはいえ、その火災は電源や制御設備へ広大な被害を引き起こし、通常及び待機冷却設備が機能することを妨げ、発電所の状態を把握するモニターの能力を喪失させ、1 号機と 2 号機の長期的な営業停止を引き起こした。

The history of previous small fires that had occurred at this plant, the apparent ease with which the fire started and cable insulation burned, and the many hours that the fire burned all indicate weaknesses in fire prevention and fire fighting.
ブラウンズフェリー発電所で発生した以前の小規模火災の記録と、その火災が長時間であったこと、及びケーブルの絶縁体が燃えて火災が発生したという明白な容易さは、火災予防と消火活動の脆弱さをすべて示している。

The inoperability of redundant equipment for core and plant cool-down shows that the present separation and isolation requirements should be reexamined. Deficiencies in quality assurance programs were also revealed.
炉心と発電所の冷却機能のための冗長性のある機器の作動不能は、今日の機器の独立性及び分離性が再検査されなければならないことを示している。

There is another way of looking at the lessons of the Browns Ferry fire.
また、ブラウンズフェリー火災の教訓には、もう一つの見方が存在する。

The outcome with regard to the protection of public health and safety was successful.
公衆衛生及び安全の防護に関する結果は成功していた。

In spite of the damage to the plant as a result of the fire, and the inoperable safety equipment, the reactors were shut down and cooled down successfully.
作動できない安全機器、及び火災の結果としての発電所への損傷をものともせずに、その原子炉は安全停止及び冷却に成功した。

No one on site was seriously injured.
発電所敷地内で重傷を負った作業員がいなかった。

No radioactivity above normal operating amounts was released; thus there was no radiological impact on the public as a result of the fire.
通常運転時の総放出量以上の放射線の放出がなかった、したがって火災の結果として、公

衆への放射線の影響はなかった。

The nuclear fuel was not affected by the fire and the damage to the plant is being repaired.
核燃料は火災により影響を受けず、発電所の損傷は修繕されている。

Based on its evaluation of the incident, the Review Group believes that even if a fire such as the one at Browns Ferry occurred in another existing plant, the most probable outcome would not involve adverse effects on the public health and safety.
事故の評価に基づいて、検討グループはたとえブラウンズフェリーで起こったような火災が他の既存する発電所で起こったとしても、最もありそうな結果が公衆衛生と安全へ対する悪影響を与えないだろうと考えている。

The question naturally arises: How can a serious fire that involved inoperability of so many important systems result in no adverse effect on the public health and safety?
それほど多くの重要な設備が巻き込まれた深刻な火災をどのようにして公衆衛生、及び安全へ悪影響を及ぼさないようにしたのか、という質問は当然のように起こる。

The answer is to be found in the defense-in-depth used to provide safety in nuclear power plants today.
その回答は今日の原子力発電所における安全性を備える深層防護の中で理解される。

It provides for achieving the required high degree of safety assurance by echelons of safety features.
深層防護は安全確保の要求された高い度合を達成するために、安全機能の段階によって備えられている。

The defense-in-depth afforded in this way does not depend on the achievement of perfection in any single system or component, but the overall safety is high.
このように備えられる深層防護は、どんな設備や機器の完全な機能達成にも依存しないが、全体的な安全は高度である。

The lessons of Browns Ferry show that defense against fires had gaps, and yet the outcome of the fire shows that the overall defense-in-depth was adequate to protect the public safety.
ブラウンズフェリーの教訓は火災に対する防護に隙間があることを示したが、その火災の

結果としては全体的な深層防護が公衆の安全を保護するのに十分だったことを示している。

The Review Group suggests that this principle be applied in defense against fires.
検討グループはこの原則が火災に対する防護で適用されるように提案している。

This defense in-depth principle would be aimed at achieving safety through an adequate balance in:
この深層防護の原則は、以下について十分なバランスを通して安全を成し遂げることを目的とする、

1. Preventing fires from getting started.
火災の出火を妨げること。

2. Detecting and extinguishing quickly such fires as do get started and limiting their damage.
出火及びそれらの被害を制限するように、そのような火災を素早く検知し、消火すること。

3. Designing the plant to minimize the effect of fires on essential functions. No one of these echelons can be perfect or complete. Strengthening any one can compensate in some measure for deficiencies in the others.
重要な機能に対する火災の影響を最小限とするよう発電所を設計すること。これらの段階のすべてが完璧、つまり完全ではありないこと。どれかを補強することがある程度においては他の不足へ対しての補償となり得ること。

### 1.5 General Conclusions　全般的な結論

Based on its review of the events transpiring before, during and after the Browns Ferry fire, the Review-Group concludes that the probability of disruptive fires of the magnitude of the Browns Ferry event is small, and that there is no need to restrict operation of nuclear power plants for public safety.
ブラウンズフェリー火災の以前、最中、以後に起こっている出来事の検討に基づき、検討グループはブラウンズフェリー事故の規模の破壊的な火災が発生する可能性は小さく、公衆安全のために原子力発電所の運転を制限する必要がないと結論づけている。

However, it is clear that much can and should be done to reduce even further the likelihood of disabling fires and to improve assurance of rapid extinguishment of fires that occur.

しかしながら、発生する火災の早期消火の確実性を改善すること、および安全機能を無効にする火災の発生率をさらにたくさん減らすことが可能であり、なされなければならないのは明らかである。

Consideration should be given also to features that would increase further the ability of nuclear facilities to withstand large fires without loss of important functions should such fires occur.
提言は、そのような火災の発生で重要な機能が喪失することなく、大規模火災を耐えるために、原子力施設の能力をさらに高めるための機能について課されなければならない。

The Review Group believes that improvements, especially in the areas of fire prevention and fire control, can and should be made in most existing facilities.
その検討グループは、特に火災予防および火災制御の範囲においては、ほとんどの既存施設で改善が可能であり、されなければならないと考えている。

The Office of Nuclear Reactor Regulation in its evaluation of individual plants must weigh all of the factors involved in fire prevention, detection, extinguishing, and system design to assure that an acceptable balancing of these factors is achieved.
個々の発電所へ対するその評価において、原子炉規制課はこれらの要因の許容バランスが成し遂げられることを確かめるために、システム設計、火災消火、火災検知、火災予防を含む全要因に注目しなければならない。

For each plant, the actual measures to be taken will depend on the plant design and the nature of whatever improvement may be needed.
各発電所に対して、とられるべき実際の処置は必要とされるかもしれない改善の種類、及び発電所の設計に依存するであろう。

The various alternatives available in each case should be evaluated consistent with these factors.
それぞれの場合で利用可能である様々な選択肢は、これらの要因と一貫して評価されなければならない。

### 1.6 Principal Recommendations 主な提言

In the following subsections, the Review Group's principal recommendations are summarized.
以下のサブセクションでは、検討グループの主な提言がまとめられている。

For further information regarding a recommendation, the reader is referred to the place in the body of this report where the recommendation and its basis are discussed in detail.
提言に関するより詳細な情報については、提言及び基本が詳細に議論されている本報告書の本文中にあるその箇所が参照されている。

As indicated in the discussions of several specific topics in this report, there is presently a notable lack of definitive criteria, codes, or standards related to fire prevention or fire protection in nuclear power plants.
この報告書内のいくつかの特定の話題に関する議論で示されているように、今日の火災予防、言い換えると原子力発電所の火災防護に関連している決定的な基準、法規、要件の明らかな不足は存在している。

Likewise, the existing criteria covering separation of redundant control circuits and power cables need revision.
同様に、電線及び冗長性のある制御回路の分離に係る既存要件は修正を必要とする。

The review group recommends that development or revision of the needed standards and criteria receive a high priority.
検討グループは必要とされる基準や高い優先度を受ける要件の開発または修正を勧めている。

The group also recommends that the regulatory guidance regarding the proper balancing of the three factors identified as defense-in-depth principles for fires in Section 1.4 of this report be augmented.
またこの報告書の１章４節で、火災に対する深層防護の原則として認識されている、３つの要素の適切なバランスをとることに関して規制ガイドを強化するよう勧めている。

The reader should be reminded that not every recommendation applies to every nuclear power plant.
読者は全原子力発電所へ対してすべての提言が当てはまるわけではないことを思い出さなければならない。

For each plant, a comprehensive evaluation should be conducted using the perspective in Section 1.4 and the echelons of safety discussed therein.

各発電所に対して、包括的な評価は１章の４節とその中で議論された安全の段階における考え方を用いて行われなければならない。

The design of that plant, together with its operating and emergency procedures, should be reviewed to determine whether changes are needed to achieve adequate defense in depth for fires at that facility.
その発電所の設計、その発電所の運転時及び緊急時の両法の処置は、その施設における火災のための十分な深層防護を成し遂げるために変更が必要であるかどうか、判断するために審査されなければならない。

Each echelon of safety should be sufficiently effective; the overall safety and the balance among the echelons should also be considered.
安全の各段階は十分に効果的でなければならない、すなわち全体的な安全性とその段階間におけるバランスが考慮されなければならない。

The Review Group's recommendations can therefore be regarded to some extent as representing alternatives to the designer or evaluator.
したがって検討グループの提言は、設計者または評価者へ対して代案を示している、とある程度は考えられることができる。

Other alternatives besides those recommended by the Review Group may be equally acceptable.
検討グループによって推奨されるそれらのほかにも、他の代案が等しく許容できる場合がある。

From among the various alternatives, those appropriate and sufficient should be chosen for a given plant.
様々な代案の中からそれらの適切で十分なものが、所定の発電所のために選ばれなければならない。

For different plants, it will quite likely be found that different choices are appropriate and sufficient.
異なる発電所について、異なる選択肢が適切で十分であることはすぐに理解されるだろう。

### 1.6.1 Fire Prevention　火災予防

The first line of defense with regard to fires is an effective fire prevention program. The

Review Group's recommendations for fire prevention are discussed in detail in Sections 3.3 and 3.4.
火災に関する防護の第一段階は効果的な火災予防計画である。火災予防に関する検討グループの提言は3章の3節、3章の4節で詳細に議論されている。

An undesirable combination of a highly combustible material (not included in the design) and an unnecessary ignition source (the candle's use as a leak detector) represent the specific cause of the Browns Ferry fire.
（設計に含まれていない）燃えやすい材料、及び不必要な着火源（漏えい検知器としてのろうそくの使用）の望ましくない組み合わせがブラウンズフェリー火災の具体的な原因であると提示されている。

Once the fire was started, other combustible materials, primarily cable insulation and penetration sealant, enabled the fire to spread.
火災が出火してすぐに、他の可燃性材料、特にケーブルの絶縁体と貫通密閉材が炎の延焼を容易にした。

The ease with which the fire was started and the rapid ignition of these other materials indicates a deficiency in the fire prevention provisions for Browns Ferry.
火災の発生、および他の材料が迅速に着火したような容易さは、ブラウンズフェリーにおける火災予防対策に関する欠陥を示している。

Information obtained from licensees and from special inspections performed at other reactor sites by the NRC indicate that similar types of deficiencies also exist to some degree at other facilities.
運転許諾者、及びNRCにより他の原子炉で実行された特別点検から得られた情報は、他の施設でもある程度の類似した種類の欠損が存在していることを示している。

None of the facilities, however, was found to have the combination of highly combustible flexible foam, unfinished penetrations, and incomplete work control procedures which existed at Browns Ferry.
しかしながら、ブラウンズフェリーで存在した不完全な作業制御手順、未完成の貫通孔、燃えやすい柔軟なフォームの組み合わせがあったことは、施設の誰もが気づかなかった。

Several facilities had open penetrations between the cable spreading room and the

control room or between the cable spreading room and other plant areas.
いくつかの施設はケーブル処理室と他の設備区域の間、またはケーブル処理室と制御室の間に開いている貫通孔が存在した。

Since some facilities had no reference to fire stops or penetration seals in their Safety Analysis Reports, and since the NRC had placed no emphasis in these areas, actual conditions vary widely.
いくつかの施設はそれらの安全分析報告で防火仕切り、つまり貫通孔シールへ対する言及がなく、NRC はこれらの分野について重視しなかったので、実際の状況は広範囲に異なっている。

NRC and licensee programs are underway to upgrade those plants that need it.
NRC 及び運転許諾者の計画はそれらの発電所をグレードアップするために進行中である。

The Review Group recommends that greater attention be given to fire prevention measures generally in nuclear plants, and that they should be reviewed and upgraded as appropriate in this respect.
一般に原子力発電所でより大きな注意が火災予防対策へ対して払われ、それらがこの点において適切であるようにグレードアップし、見直されなければならないことを検討グループは提言している。

Consideration should be given to limiting the amount and nature of combustible material used in nuclear plants, to use of flame retardant coatings for combustible material where appropriate, and to the use of measures to control potential ignition sources such as open flames or welding equipment.
提言は、原子力発電所に用いられる可燃性材料の性質と量を制限すること、必要に応じて可燃性材料へ難燃性コーティングを施すこと、裸火または溶接設備のような潜在的な着火源を管理する処置を用いることを課されなければならない。

In implementing this recommendation, guidance in the form of standards or Regulatory Guides is needed and should be developed.
この提言を実行する際には、基準形式の指針、つまり規制指針が必要とされ、整備されなければならない。

Such guidance must strike a reasonable balance among the factors involved.
そのような指針は関係する要因の間で理にかなったバランスを保たなければならない。

For example, if the fire zone approach (section 4 of this report) is used, the flammability of materials may not have the same degree of importance as in other designs; if small amounts of combustible material are present in a given area, the need for fire retardant coatings is reduced.
たとえば火災区域のアプローチ（第 4 章）が適用される場合、他の設計では材料の引火性が同程度の重要度でないかもしれない、すなわち可燃性材料の少量が所定の範囲に存在するならば、難燃性コーティングの必要性は減少する。

Standard qualification tests should be developed to assure that acceptable materials and configurations are used for items such as cable insulation and penetration seals.
標準能力試験はケーブルと貫通シール材のようなアイテムに関して、許容できる材料と配置が用いられることを保証するために、発達されなければならない。

Some research will be needed to develop improved tests to characterize the flammability and the nature of the products of combustion of potentially flammable materials.
潜在的な可燃性材料の燃焼生成物の特徴とその引火性を特徴づけるために、試験を改善するためには、いくつかの研究が必要となる。

The flexible polyurethane foam that caught fire in Browns Ferry was not part of the original design, but was being used to stuff into holes to stop leaks.
ブラウンズフェリーで出火した柔軟なポリウレタンフォームは最初の設計通りではなく、漏えい止めとして孔の中に詰めていた。

Recent tests have shown that seals containing this material are highly flammable.
最近の試験は、この材料を含んでいるシールが高い燃焼性を有することを示した。

The Review Group recommends that seals 17 containing this material should be removed and replaced where possible; where this is not possible, other measures should be taken as needed to assure safety.
この材料を含んでいるシール 17 は実行上可能な限り取り除かれ、交換されなければならない、またそれが不可能である場合は安全性を保障するために必要とされる他の対策を取らなければならない、と検討グループは推奨している。

Other types of polyurethane foam, including that used in the original Browns Ferry design, are less flammable; the potential improvement in safety from their replacement

should be balanced against the potential hazard of disturbing a large number of cables and seals.
最初のブラウンズフェリーの設計で使われていた他の種類のポリウレタンはより低い燃焼性であった、それらの交換からの安全に関する潜在的な改良は多数のケーブルとシールを妨げるような潜在的なハザードに対してバランスを取らなければならない。

### 1.6.2 Fire Fighting　消火活動

It must be anticipated that fires will occasionally be initiated in spite of fire prevention measures.
火災予防対策をものともせずに、場合によっては火災が発生することを予想して対策を講じなければならない。

Any fire that does get started should be detected, confined in extent, and extinguished promptly.
出火するどのような火災であっても検知され、範囲を制限され、すぐに消火されなければならない。

Discussion of the Review Group's recommendations in this area is given in Section 3.5.
この領域における検討グループの議論は 3 章の 5 節で提供される。

There was smoke in the Browns Ferry spreading room, but the smoke detectors did not alarm, possibly because the normal flow of air from the spreading room to the reactor building drew the smoke of the fire away from the installed detector in the spreading room.
ブラウンズフェリーの処理室内には煙が存在したが、煙感知器は警報されなかった、おそらく処理室から原子炉建屋への空気の通常流れが処理室内に設置された検知器から火の煙を引き離したためである。

The smoke also penetrated the control room (through the unsealed cable entryways) but the fire detectors installed in the control room were of the ionization type which did not detect the products of combustion generated by the cable fire and did not alarm.
また、煙は（密閉されていないケーブル通路を通じて）制御室へ侵入したが、制御室に設置された火災感知器はケーブル火災によって生成される燃焼生成物を検知しないイオン式であったために警報されなかった。

There was a great deal of smoke in the reactor building in the vicinity of the fire, but

detectors had not been installed in that area.
火災の近隣である原子炉建屋内には莫大な量の煙が存在したが、その区域には検知器が設置されていなかった。

Detectors should be designed to detect the products of combustion of the combustible materials actually or potentially present in an area and should be properly located.
検知器はある区域内に実際または潜在的に存在する可燃性材料の燃焼生成物を検知するよう設計され、確実に設置されなければならない。

The fire in the Browns Ferry cable spreading room was controlled and extinguished without the use of water.
ブラウンズフェリーのケーブル処理室の火災は、水を使用することなく、制御および消火された。

By contrast, the fire in the reactor building was fought unsuccessfully for several hours with portable carbon dioxide and dry chemical extinguishers; however, once water was used, it was put out in a few minutes.
対照的に原子炉建屋の火災は、不成功に終わった可搬式二酸化炭素消火器と乾燥式化学消火器によって数時間対応されたが、1 度水が使われると数分の間に消火された。

During the long period of burning, there were progressive increases in the unavailability of equipment important to safety.
火災の長い期間の間、安全上重要な機器の利用不可能な状態に段階的な増加があった。

It is obvious that the longer a fire burns, the more damage it will do.
火災がより長く続くと、よりたくさんの被害が生じることは明らかである。

The Browns Ferry fire shows that prompt extinguishing of a fire is, in most circumstances, also the way to limit the consequences of a fire on public safety.
ブラウンズフェリーの火災は大部分の状況下で、火災の迅速な消火が公衆安全上の火災の影響を制限する方法であることを示している。

Fire experts consulted by the Review Group and the experience at Browns Ferry suggest that if initial attempts to put out a cable fire without the use of water are unsuccessful, water will be needed.
検討グループにより意見を求められた火災の専門家、及びブラウンズフェリーにおける経

験は、ケーブル火災を消すための水を使用しない初動対応が失敗した場合、水の使用が必要であることを示唆している。

Many people have been taught, "Don't use water on electrical fires.
大多数の人々は「電気火災において水を使うな！」と教育されている。

The Group is concerned that widespread opinion and practice emphasize the reasons for not using water as compared to those for its prompt use.
検討グループは、広範囲にわたる見解と経験が水をすぐに使用すること、と比較して水を使わないことに関する理由を強調することを懸念している。

Procedures and fire training should give the use of water appropriate emphasis In the light of the foregoing considerations.
手順と火災訓練は前述の考慮点に照らして、水の使用の適切な強調を与えなければならない。

The Review Group recommends that serious consideration be given to installing or upgrading fixed water sprinkler systems, and to making them automatic.
検討グループは、熱心な考慮が固定式スプリンクラー設備の設置または更新、及びそれらの自動化することが与えられることを推奨している。

This is especially important in areas containing a high density of cables or other flammable materials, where there is a combination of flammable materials and redundant safety equipment or where safety equipment is located and where access for fire fighting would be difficult.
これは高密度のケーブル、または他の燃えやすい材料を含んでいる区域、燃えやすい材料と冗長性のある安全機器の組み合わせがある区域、安全機器が設置されている区域、消火活動のための接近が困難な区域で特に重要である。

Adequate fire hoses should also be provided, and access for manual fire fighting should be considered in the design and in procedures.
手動消火活動のための接近経路は設計及び手順において考慮されなければならず、適切な消火栓もまた設置されなければならない。

Capability for the control of ventilation systems to deal with fire and smoke should be provided, but such provisions must be compatible with requirements for the

containment of radioactivity.
火災と煙を対処するための換気設備の制御に関する能力は提供されなければならないが、そのような設備は放射能の閉じ込めに関する要件と両立しなければならない。

These provisions and requirements may not be mutually compatible and in some cases may be in direct conflict with each other.
これらの設備と要件は相互に両立できない場合、及び互いに衝突する場合がある。

For example, operating ventilating blowers to remove smoke may fan the fire; the same action may also result in a release of radioactivity, either directly by transport of radioactive particles with the smoke or by decreasing the effectiveness of filters whose purpose it is to aid in containing the radioactivity.
たとえば、煙を取り除くために換気ブロワ―を稼働することはその火災をたきつける場合がある、すなわちその行為が直接的に放射線を閉じ込めることを目的としたフィルタの効果を減少すること、煙とともに放射性粒子の輸送することの両方で放射線の漏えいを引き起こすかもしれない。

It is obvious that some compromise will be necessary and that flexibility of operation may be needed, depending on the nature of any event that may occur.
起こるかもしれないあらゆる事象の特徴に依存して、いくらかの妥協と動作の柔軟性が必要であることは明らかである。

The pros and cons of each provision and requirement should be considered in the development of detailed guidance.
各設備と要件のメリット・デメリットは詳細な指針の発展の中で議論されなければならない。

The control room should be protected as well, both from radioactivity and from smoke or toxic gases.
制御室は放射線と煙、言い換えると有毒ガスから、同様に防護されなければならない。

Adequate breathing apparatus and recharging equipment should be available for operators, fire fighters, and damage control crews which may be working simultaneously during a prolonged incident.
適切な酸素補給装置と充電機器は、長引く事故の間、同時に作業するかもしれない被害抑制作業員、消防士、運転員のために利用可能でなければならない。

In addition to adequate equipment design, successful fire fighting requires testing and maintenance of the equipment and training and practice as teams under realistic conditions for the onsite and offsite personnel who must fight the fire.
適切な機器の設計に加え、広く適応した消火活動には、火災を対応しなければならない施設内外の人員に関して、現実的な条件下のチームとして習慣づけること、訓練すること、その機器の維持と検査が必要である。

Onsite and offsite equipment should be compatible.
施設内外の機器は両立されなければならない。

Emergency plans should recognize the need for fire fighting concurrent with other activities.
緊急計画は他の活動と同時に消火活動の必要性を認知しなければならない。

They should provide for division of available personnel into preassigned, trained teams responsible for the various activities needed, with proper utilization of offsite firefighters.
緊急計画は施設外の消防隊の適切な動員とともに、必要とされる様々な行動に対して理性的思考のできるよう訓練され、前もって選定されたチームのうち、動員可能な人員の分配に関して提供しなければならない。

### 1.6.3 Provisions to Maintain Important Functions in Spite of a Fire　火災時においても重要な機能を維持するべき設備

The public safety importance of a fire in a nuclear power plant arises from its potential consequences to the reactor core and the public.
原子力発電所における火災の公衆安全重要性は、炉心や公衆に対する火災の潜在的な影響から生じる。

During the course of the Browns Ferry fire, numerous systems became unavailable as a result of the cable damage.
ブラウンズフェリー火災の事態の間、極めて多数の設備はケーブル損傷の結果として利用不能となった。

By a combination of alternative switching, manual manipulation of valves, remote controls, and temporary wiring, the operating staff kept enough equipment operating to

shut down and cool down the reactor cores.
代替物への切り替え、弁の手動操作、遠隔制御（リモコン）、臨時配線などの組み合わせにより、運転スタッフは安全停止と炉心を冷却するために動作する十分な機器を確保した。

Redundancy was available at all times in case additional outages had occurred.
さらなる機能不全が起こった場合には、冗長性はいつでも利用可能であった。
Redundancy is introduced into system design so that one or more unavailable components or sub-systems will not make the system function unavailable.
１つ以上の利用できない機器、または補助設備がそのシステムの機能を利用できなくしないように、冗長性はシステム設計の中で導入されている。

The effectiveness of redundancy depends on the independence of the redundant equipment.
冗長性の効果は、冗長性のある機器の独立性に依存する。

The Browns Ferry fire induced failures of sane of the redundant devices that were provided, thus negating the redundancy and failing the system.
ブラウンズフェリー火災は、備えられていた冗長性のある装置の健全な損傷を引き起こした、したがってその冗長性は駄目になり、その仕組みを果たさなかった。

It is now known that the independence was negated by two errors:
今日ではその独立性が２つの過失によって無効となったことが知られている、

(1) wires connecting indicator lamps in the control room to control circuits for redundant safety equipment were not separated from each other; the fire damaged some of these wires in such a way as to cause unavailability of the redundant equipment, and
冗長性のある安全機器のための制御回路に対して、制御室内にある表示ランプを接続していた配線が互いに分離されていなかった、すなわち、火災がその冗長性のある機器の利用不能を引き起こすようにこれらの配線の一部へ損害を与えた。

(2) wires of redundant subsystems were routed in the same area in the mistaken belief (embodied in design criteria) that putting one set of such wires in electrical conduit (a lightweight pipe) would protect it. In the fire, the conduit got too hot and the wires in it short-circuited.
冗長性のある補助設備の配線は、電線管（軽量パイプ）の中にそのような配線の１まとま

りを設置することが配線を防護する、というような間違った考え（設計要件の中に含まれていた）で同じ区域に配線された。火災では、その導管は過熱され、その中にある配線は短絡した。

This caused concurrent unavailability of the redundant safety equipment, part of which was fed from failed electrical circuits in the burning trays, and the other part, fed from the failed wires in the conduit.
これは燃えているトレイの中にあった電気回路から送電されていた一部と電線管内の損傷した配線から送電されていた冗長性のある安全機器の利用不能を同時に引き起こした。

The Review Group has concluded that existing separation and isolation criteria need improvement.
既存の分離性と独立性の要件は改善の必要がある、と検討グループは結論づけた。

A suitable combination of electrical isolation, physical distance, barriers, resistance to combustion, and sprinkler systems should be applied to maintain adequately effective independence of redundant safety equipment, and therefore the availability of safety functions, in spite of postulated fires.
電気的な隔離、物理的な距離、障壁、燃焼に対する耐性、及びスプリンクラー設備の適切な組合せは、想定火災にもかかわらず、冗長性のある安全機器の十分に効果的な独立性、および安全機能の有効性を維持するために適用されなければならない、

Detailed discussions of the independence of redundant subsystems, separation criteria, and other systems considerations are given in Chapter 4.
冗長性のある補助設備の独立性、分離要件、他の設備の考慮点は 4 章で提供される。

The Review Group notes that while some methods of improving separation are practicable only on new designs, others are feasible and practical on existing plants.
検討グループは分離を改善するためのいくつかの方法が新規のプラントへのみ実行可能であることに対して、他のものは既存のプラントへ実行可能であり、実用的であることを指摘している。

Examples of the latter type are addition of barriers, fire-retardant coatings, and sprinkler systems, which contribute to improvement of fire fighting as well as to maintenance of important functions in spite of postulated fires.
後者の実例としては、想定火災にもかかわらず、重要な機能の維持だけではなく消火活動

の改善へ関与するスプリンクラー設備、難燃性コーティング、障壁の追加が挙げられる。

#### 1.6.4 Quality Assurance　品質保証

Quality assurance (QA) programs are intended to catch errors in design, construction, and operation, and to rectify such errors; QA is an essential component of defense-in-depth.
品質保証計画は運転、建設、設計における過失を把握するとともに、そのような過失を修正することを目的としている、すなわち品質保証は深層防護に必要不可欠な要素である。

Many aspects of the Browns Ferry fire can be considered as lapses in QA.
ブラウンズフェリー火災の多くの面は、品質保証におけるちょっとした過失として考えられることができる。

Examples are unfinished fire stops, inadequate separation of cables containing indicator lamp circuits, testing operations with a candle, use of highly flammable material to plug leaks in fire stops, and failure to pay attention to earlier small candle-induced fires.
実例としては、未完成の火災止め、表示ランプ回路を含んだケーブルの不十分な分離、ろうそくによる試験作業、火災止めにおける漏れの栓をするための高引火性材料の使用、火災を引き起こした初期の小さなろうそくへ対する注意の欠如が挙げられる。

The Review Group believes that the causes, course, and consequences of the Browns Ferry fire are evidence of substantial inadequacies in the Browns Ferry QA program.
検討グループは、ブラウンズフェリー火災の原因、過程、結果がブラウンズフェリー発電所の品質保証計画の中に実在する不備の証拠である、と考えている。

A revised QA program has been adopted by TVA; the Group has not evaluated the details of the new program.
修正された品質保証計画は TVA によって採用されている、すなわち検討グループは新規の計画の詳細については評価していない。

It should be evaluated in the light of experience.
それは経験と照らし合わせて評価されなければならない。

The Review Group notes that NRC (and formerly AEC) licensing review and inspection also failed to uncover these lapses in QA.

検討グループは、NRC（および前 AEC）の認可審査と点検が品質保証におけるこれらの不備を網羅していなかったことも指摘している。

The extensive QA requirements of the NRC are applied to systems and components designated as important to reactor and public safety.
NRC の広範囲な品質保証要件は、原子炉と公衆安全に対して重要であると示されている機器と設備へ適用されている。

Before the Browns Ferry fire, this did not include such items as fire protection systems or sealing of penetrations in walls, floors, and other barriers aside from radioactivity containment structures.
ブラウンズフェリー火災の以前は、これは放射線格納構造物を除いた他障壁、火災防護設備、言い換えると床や壁内にある貫通孔のシーリングのような項目を含まなかった。

The QA requirements of the NRC are being revised consistent with increased attention to fire protection in all NRC licensing, standards, and inspection activities.
その NRC の品質保証要件は、全ての NRC の認可（ライセンス）、標準、点検活動において火災防護へ対するさらなる配慮に基づき、修正されている。

The QA programs of all nuclear power plant licensees should be reviewed.
全ての原子力発電所の運転許諾者の有する品質保証計画は再吟味されなければならない。

QA programs in some operating plants that are known not to conform to current standards should be upgraded promptly.
現行の標準に対して従っていないことが知られている、いくつかの運転プラントにおける品質保証計画は、ただちに更新されなければならない。

The NRC review of licensee QA programs should be correspondingly upgraded, in particular to include explicitly fire protection, fire fighting, and provision to maintain important functions in spite of a fire.
運転許諾者の品質保証計画に対する NRC の審査は、特に火災をものともせずに、重要な機能を維持するための規定、消火活動、火災防護を含む項目に相応して更新されなければならない。

Detailed discussion of QA is given in Sections 5.1 and 5.2, for TVA actions, and Section 6.3.2, for NRC action.

品質保証の詳細な議論は、TVA の行動に関する 5 章 1 節と 5 章 2 説、及び NRC の行動に関する 6 章の 3.2 節で提供される。

### 1.6.5 Response of Other Governmental Agencies　他政府機関の反応

If the Browns Ferry fire had developed into a situation where action by other governmental 17 agencies would have been required to protect people located offsite, effective action would have depended on effective communication between TVA personnel and the cognizant Federal, State, and local governmental agencies; see the discussion in Chapter 7.
もしもブラウンズフェリー火災が、他 17 の政府機関による行動が施設外にいる人々を防護するために必要とされた状況に発展したならば、効果的な行動は TVA の人員と認識力のある連邦、州、および地方の政府機関の間における効果的なコミュニケーションに依存したであろう。

In accordance with emergency plans, TVA personnel notified radiation control supervisors of the States of Alabama and Tennessee and maintained communication with them until the fire was out.
緊急事態計画に従い、TVA の人員は Alabama と Tenessee 州の放射線制御管理者に通報して、火災が鎮火するまでそれらとコミュニケーションを維持した。

These States attempted to notify additional agencies as indicated in their radiological emergency plans, even though a radiological emergency did not exist.
これらの州はたとえ放射線緊急事態が存在しなかったとしても、それらの放射線緊急事態計画で示されるようにさらなる政府機関へ通報しようとした。

These attempts at notification revealed that elements of the Alabama plan had weaknesses.
通報におけるこれらの試みは Alabama の計画の一部に欠点があることを明らかにした。

More frequent exercises and drills to check the response of governmental emergency organizations are needed in order to maintain an effective response posture of these organizations.
政府緊急組織の反応を確認するためのより頻繁な演習と訓練がこれらの組織の効果的な反応体勢を維持するために必要である。

The Review Group has not studied the question whether drills involving the general

public should be instituted and has no recommendation on this subject.
検討グループは一般大衆を含めた訓練が設定されなければならないかどうかについては検討していないため、この議題については何も推奨していない。

#### 1.6.6 Recommendations for the NRC　NRC に対する提言

The NRC must also consider the Browns Ferry lessons for improving its policies, procedures, and criteria.
NRC は NRC の方針、手続き、基準を改善するためにブラウンズフェリーの教訓を考慮しなければならない。

The NRC is responsible for assuring the health and safety of the public and the safe operation of Browns Ferry and all other reactors.
NRC は公衆安全と健康、及びブラウンズフェリーとその他の原子炉の安全運転を保証することに対して責任がある。

NRC provides this assurance of public safety through the establishment of safety standards, evaluation of the safety of plants, and inspection and enforcement programs.
NRC は点検とその実施計画、発電所の安全性評価、安全基準の設立を通して、この保証を提供する。

The licensee, TVA, has the responsibility for the safe design, construction, and operation of its plant within the framework of the NRC regulatory program.
運転許諾者である TVA は NRC の規制プログラムの範囲内で、その発電所の運転および建設、安全設計に対して責任がある。

If the NRC were to become too closely involved in the licensee's operations, this might have an adverse effect on the licensee's view of his safety responsibilities.
もしも NRC が運転許諾者の作業に伴い、あまりにも密接な関係となった場合、これは NRC の安全責任に対する運転許諾者の見解に悪い影響があるかもしれない。

In other words, it is the licensee's responsibility to operate the reactor safely, and it is NRC's responsibility to assure that he does so.
言い換えると、安全に原子炉を運転することは運転許諾者の責任であり、運転許諾者がそうすることを保証することが NRC の責任である。

The Review Group's evaluation of the events associated with the fire indicates that

improvements are needed in NRC licensing, standards development, and inspection programs.
火災に関連した事象へ対する検討グループの評価は、NRC の認可（ライセンス）、標準の開発、点検計画について改善が必要であることを示している。

NRC actions and related Review Group recommendations are discussed in Chapter 6.
NRC の行動と関連した検討グループの提言は 6 章で議論されている。

The Review Group recommends that ongoing efforts to upgrade NRC programs in fire prevention and control and related QA be expanded as needed, and as recommended elsewhere in this report, and coordinated to form a more coherent regulatory program in this area.
検討グループは、火災予防と火災制御、そして関連した品質保証において、NRC の計画をアップグレードするために進行中である努力は必要とされるように、そしてこの報告書内の他の部分で推奨されているように拡大され、この分野におけるより筋の通った規制計画を作るために整合させることを勧めている。

During the incident, troubles were experienced with communications among TVA, NRC, and other organizations.
事故の間、TVA と NRC、そして他の組織間で通信上のトラブルが経験された。

The Review Group believes that some communications problems are inevitable but that improved communications facilities are feasible and should be provided.
いくつかの通信問題は不可避であるが、その改善された通信施設は実現可能であり、そして提供されなければならない、と検討グループは考えている。

A systems study on communication needs is at least as important as purchase of new equipment; both should be undertaken.
通信の必要性に関するシステム研究は少なくとも新しい機器の購入と同じぐらいは重要である、すなわち両方が着手されなければならない。

After the fire occurred and the initial evaluation indicated that public safety had been maintained, the division of responsibility within NRC between the Office of Inspection and Enforcement (IE) and the Office of Nuclear Reactor Regulations (NRR) resulted in an unnecessary delay of several weeks in accomplishing a detailed technical evaluation by NRC of the safety of the plant in the post-fire configuration.

火災の発生と公衆安全は維持されていたことが示された最初の報告書の後、調査是正と原子炉規制の部門間の NRC 内における責任の分担が、火災発生後におけるプラントの安全性について、NRC による詳細な技術評価を成し遂げるために、結果として数週間の不必要な遅れを起こした。

While the Review Group finds no evidence that there was any immediate hazard during this period of time, certain aspects of the plant status were improved following the detailed technical evaluation performed in May 1975, by NRR.
検討グループはこの期間の間にどれほどの直接的な危険があったという証拠はわからなかったが、発電所の状態のある面については原子炉規制部門によって 1975 年 5 月に行われた詳細な技術評価に基づき、改善された。

Specifically, the minimum crew size was increased to provide for required manual valving operations, and added cooling system redundancy for critical components such as the diesel generators was provided.
具体的には、最小限の職員数規模が必要とされる手動弁作業のために増員され、ディーゼル発電機のような重要な機器のためにさらなる冷却系統の冗長性が提供された。

The Review Group recommends that the procedures followed by NRR and IE in evaluating the safety of the Browns Ferry plant be revised to ensure that detailed safety review of such an occurrence will be more timely in the future.
ブラウンズフェリー発電所の安全性を評価する中で、原子炉規制部門と点検是正部門によって支持されている方法が、そのような将来的にはより適時なものとなり得る出来事について、詳細な安全審査を確実とするために修正されるよう推奨している。

The Review Group has consulted with cognizant NRC management during its review, and is aware that programs to implement recommendations contained in this report are being developed in several areas.
検討グループはその審査の間、認識力のある NRC 経営陣と協議して、この報告書に含まれる提言を実行するための計画がいくつかの分野では作成されていることを認識している。

# 2.0 INTRODUCTION　序論

## 2.1 Objective and Plan of this Report　この報告書の目的と構想

### 2.1.1 Objective　目的

In this evaluation of the Browns Ferry fire incident, the Special Review Group has reviewed the design and design criteria of the equipment involved, and the actions of persons and organizations before, during, and after the incident.

The objective, as stated in the Group's Charter(2)*was:

"... to review the circumstances of the incident and to evaluate its origins and consequences from both technical and procedural viewpoints.

"The Group's review is not intended to duplicate, or substitute for, the necessary investigations by the licensee and the staff of NRC I&E Region II.

Rather, the Group is charged with marshalling the facts from these investigations and evaluating them to derive appropriate proposed improvements in NRC policies, procedures, and technical requirements."

In accordance with this charter, the Review Group has tried to distill from the available information those lessons that should be learned for the future.

Some of these lessons apply to operating groups, others to designers, standards developers, State and local authorities, and the NRC.

### 2.1.2 Plan of this Report この報告書の構想

The summary of this report is presented in Chapter 1, including the major recommendations.

Following the introduction of Chapter 2, Chapter 3 deals with the fire, including fire prevention and fire fighting, and also materials combustibility considerations.

Chapter 4 includes systems considerations.

It covers the availability and non-availability of plant subsystems during the event, and considers criteria for the separation of redundant subsystems, including their associated electrical cables.

Chapters 5, 6, and 7 deal with people's actions and procedures for such actions, for TVA, NRC, and other government bodies, respectively.

## 2.2 Sources of Information　情報の提供源

The Review Group did not attempt to du~plicate other fact-finding investigations into the incident.

Rather, these were used as sources of information for our evaluation, as discussed in the following paragraphs.

This information was supplemented as needed from other sources.

Where information from published sources is essential to understanding the Review Group's conclusions and recommendations, it has been briefly summarized.

Otherwise, the report relies heavily on referencing this material.

The licensee, Tennessee Valley Authority, is conducting an extensive engineering and administrative program related to the incident.

The TVA Recovery Plan (3) includes the report of the TVA Preliminary Investigating Conmmittee, investigations into chemical, structural, and electrical damage, and a program to restore the plant to operation. The Group has obtained much useful information from the Recovery Plan (a much-revised and expanded document now approaching 1000 pages) and from detailed supporting information (4) furnished by the licensee.

With the issuance of its Investigation Report (5), the NRC Office of Inspection and Enforcement completed its investigation of the proximate causes, course, and consequences of the fire.

The conclusions and findings in that report are presented in a detailed reconstruction of the events of the incident, which in turn is based on extensive witness interrogation and technical analysis.

This constituted a principal source of information for the Review Group's evaluation.

As a result of the IE-Region II investigation of the Browns Ferry fire, an enfcircement letter was sent to TVA itemizing infractions, areas of concern, conclusions, and findings of facts as perceived by the investigating team (6).

TVA has replied to the letter (7), taking issue with Reproduced as Appendix A some of the items and agreeing with others.

A reply was sent from the Region II Office (8) acknowledging one error of fact in the enforcement letter and commenting on the TVA response to it.

There are several areas where differences of opinion still exist. Some of the differences involve conflicting statements by different people interviewed by the investigators, some represent differing views as to the interpretation of requirements, and some represent opposing philosophical views.

It is evident from this correspondence and from testimony presented at the JCAE hearing that differing viewpoints will persist with regard to interpretation and philosophy, and that the conflicting statements can never be fully reconciled.

The Review Group has considered these different views, and has also sought expert guidance from outside sources, in reaching the conclusions presented in this report.

In pursuit of its licensing responsibilities, the NRC Office of Nuclear Reactor Regulation (NRR) formed a Task Force to evaluate the safety of the Browns Ferry reactors following the incident and during reconstruction and return to operation. Several reports, technical specification changes, and safety evaluations are available (9).

They summarize referenced technical information supplied by the licensee and evaluate the safety of the reactors in the post-fire configuration and during the proposed restoration or operational phase.

The Review Group has used this material as an important source of information in its study.

The licensee's Restoration Plan is still under development and includes 35 revisions received by the time of writing (3).

Much additional information regarding proposed design features remains to be developed by TVA, along with its analysis of the safety of the plant as restored.

Each step in the restoration program, and each change in plant configuration, must be authorized by the NRC. Each authorization is based on an NRC safety evaluation, which in turn depends primarily on information and analysis furnished by TVA. Future steps not yet authorized will be covered by future NRC safety evaluations.

After the fire, the Nuclear Energy Liability and Property Insurance Association (NEL-PIA) visited the Browns Ferry plant. This investigation report (65) and other documents (20) contain recommendations for Browns Ferry that are also stated to be generally applicable to other plants (20). NRC comments on the NEL-PIA recommendations as they apply to Browns Ferry have already been published (67). The Review Group has considered all of the NEL-PIA reports and recommendations in its evaluation. Discussion by the Review Group of the various subjects treated by NEL-PIA will be found in the appropriate sections of this report.

### 2.3 Scope of Review　精査の範囲

In view of the objective of the Review Group as delineated in Section 2.1, and of the other NRC activities described in Section 2.2., the purview of this report is limited to the lessons to be learned from the Browns Ferry incident. The viewpoint is toward application of these lessons.

Where appropriate, back-fitting of operating plants is considered as well as plants under construction and those not yet designed, but these considerations are general and not specific to any single plant. In particular, while the lessons surely pertain to the Browns Ferry reactors, the application of these lessons to Browns Ferry, as to all specific reactors, is left to the cognizant NRC organizations. The special circumstances of removing and restoring the damaged portions of the Browns Ferry plant, and the safety requirements for these

operations
and the redesign involved, are, as noted in Section 2.2.3, the purview of a special NRR Task
Force.

## 2.4 Note on Changes with the Passage of Time　時間の経過に伴う変化の記録

The Group's review is necessarily based on knowledge and understanding at the time of writing--
1975/76. The reader must, however, understand that safety technology continues to develop as
new knowledge and experience is gained and that safety evaluation is a growing and evolving
art. The Browns Ferry application was originally filed on July 7, 1966, and the construction
permit was issued on May 10, 1967 for Units 1 and 2; July 31, 1968 for Unit 3. The design and
the review were governed by the state of the art at that time. The operating license review
during 1970-72 used the technology of that period, modified as needed to account for the earlier
construction permit approval.

Differences in safety technology and evaluation criteria from then to now are highly significant
to the Group's conclusion. These changes are considered in the separate discussions of each
topic in Chapters 3-7 of this report.

It is a truism that everyone should learn from experience. The quantum of experience represented
in this incident has been analyzed here for this purpose. But it is also true that hindsight
vision is 20/20. Many things are now evident to the Review Group, as a result of the incident
10a
and its analysis, that previously were not evident. This is the increment in knowledge
attributable to the present effort. The discussions in this report of shortcomings in people
and hardware have been included as deemed necessary to learning the lessons. Since

the group
believes these lessons to be useful and significant, their value is believed to outweigh any
chagrin on the part of those who are criticized.

## 2.5 Perspective on Reactor Safety: Defense in Depth　原子炉の安全上における見解：深層防護

The principal goal of the NRC, and the primary concern of the Review Group, is the assurance of
adequate protection of the health and safety of the public, and the maintenance at an acceptably
low value of the risk due to nuclear power technology. This means, principally, the containment
of the radioactive materials, and the prevention of their release in significant quantities.
The provision of multiple barriers for such containment, and the concept of defense-in-depth,
are the means for providing the needed safety assurance.
The echelons of safety embodied in defense-in-depth can be viewed as the following:
1. High quality in the plant, including design, materials, fabrication, installation, andF
operation throughout plant life, with a comprehensive quality assurance program.-
2. Provisison of protective systems to deal with off-normal operations and failures of equipment
that may occur.
3. Provision, in addition, of safety systems to prevent or mitigate severe potential accidents
that are assumed to occur in spite of the means employed to prevent them and the protective
systems provided.
No one of these echelons of safety can be perfect, since humans are fallible and equipment is
breakable. It is their multiplicity, and the depth thus afforded, that provide the required
high degree of safety in spite of the lack of perfection in any given system. The goal is a
suitable balance of the multiple echelons; increased strength, redundancy, performance, or
reliability of one echelon can compensate in some measure for deficiencies in the others.
As applied to fires in nuclear power plants, defense-in-depth can be interpreted as

follows:

1. Preventing fires from getting started.

2. Detecting and extinguishing quickly such fires as do get started and limiting their damage.

3. Designing the plant to minimize the effect of fires on essential functions.

At Browns Ferry, a fire did get started, and burned for several hours in spite of efforts to extinguish it. The damage to electrical cables disabled a substantial amount of core cooling equipment, including all the emergency core cooling system pumping capability for Unit 1. In the absence of a loss-of-coolant accident, this equipment was not needed for its intended function. The reactors were successfully shut down and their cores kept covered with water.

In spite of the plant damage, the burned cables and the inoperable equipment, no radioactivity release greater than normal occurred and the safety of the public was preserved. Thus, the overall defense-in-depth was successful.

Given this success, why write the present report? The answer is that the apparent ease with which the fire started, the hours that elapsed before it was put out, and the unavailability of redundant equipment as a result of the fire all point to some inadequacies in each of the echelons of defense. The Review Group has pointed out the inadequacies and presented reconmmendations for improvement, not all of which need to be applied for each reactor. A suitable combination should be implemented to achieve an adequate balance of fire protection, appropriate to the specific circumstances involved.

The Review Group feels impelled to make one other observation that is perhaps beyond its purview of public safety. The fire at Browns Ferry involved principally cables for Unit 1 functions, yet Unit 2 systems were in some cases affected. As a result of this Unit 1 cable fire, Unit 2 will be out of service for most of a year and the startup of Unit 3 is likely to have been

delayed. Thus, the interconnections and interactions between units designed into this multiunit
generating station resulted in unavailability of two 1100 Mw units that could have been avoided at least in part by a different design approach. The wasted resources and extra power
costs have no direct safety significance, but should be considered by designers and operators.
I

## 3.0 FIRE PREVENTION AND CONTROL　火災予防と火災制御

In this chapter, the Review Group considers all aspects of the fire that can be divorced from plant systems considerations, which are the subject of Chapter 4.
この章では、検討グループは第４章の主題であるシステム上の問題と切り離すことができる火災のすべての面を考慮する。

Following a brief summary of the fire event as it occurred (Section 3.1), the chapter treats fire prevention (Section 3.2), combustibility of materials (Section 3.3), and fire fighting (Sections 3.4 and 3.5).
以下の 3.1 節では、火災発生時の事象の概要について、3.2 節では火災予防について、3.3 節では可燃性材料について、3.4 節と 3.5 節では消火活動について扱う。

### 3.1 Details of the Fire　火災事象の詳細

#### 3.1.1 Sequence of Events 火災事象の経過

A report detailing the sequence of events associated with the fire and with operational actions required to place the Browns Ferry reactors in a safe shutdown condition has been issued by the NRC Office of Inspection and Enforcement (5).

TVA has also prepared a summary of significant operational events (10).

The immediate cause of the fire was the ignition of polyurethane foam which was being used to seal leaks in cable penetrations between the Unit 1 reactor building and the cable spreading room.

A candle flame was being used to detect air leakage at the penetration.

When the candle was brought close to recently installed polyurethane foam, the flame was drawn into the foam by air flow through the penetration which was still leaking.

A pressure differential which is normally maintained between the cable spreading room and the reactor building, created a draft through the leak, thus making possible the leak detection but also fanning the fire once ignition had taken place.

Immediately after the polyurethane foam ignited, the workman who had been using the candle to check for leaks attempted to extinguish the fire using first a flashlight to beat out the flames, and then attempting to smother it with rags.

Efforts were then made to extinguish the fire from within the cable spreading room using portable C02 extinguishers, followed by attempts with portable dry chemical extinguishers.

The fire was fought in this manner for about 15 minutes, after which an evacuation alarm associated with the C02 fire-fighting system sounded in the cable spreading room. The $CO_2$ (Cardox) system was discharged into the cable spreading room about 12:45 to 1:00 p.m.

The fire started at about 12:20 p.m. CDT on March 22, 1975. At 12:35 p.m., the fire was reported to the control room of Unit 1.

This call resulted in initiation of the fire alarm.

Additionally, announcements of the fire were made over the public address system.

By this time, it was determined that the fire had progressed through the cable penetration and was burning on the reactor building side of the wall.

Starting immediately after the fire alarm was sounded, fire fighting efforts were initiated on the reactor building side of the wall, where both C02 and dry chemical extinguishers were used.

Because of the inaccessibility of the burning cables, this effort was sporadic and tedious.

The cable trays are located about 20 to 30 feet above the floor and accessible only by ladder.

The dense smoke and limited availability of breathing apparatus was cited by several individuals as materially hampering fire fighting efforts.

At 1:09 p.m., the Athens, Alabama fire department was called.

At some time between about 1:00 and 1:10 p.m., fire fighting efforts in the reactor building appear to have been greatly reduced, with no organized fire fighting efforts being resumed until about 4:30 p.m.

There was reluctance to use water to fight the fire, but dry chemical and C02 were used intermittently.

At some time between 5:30 and 6:00 p.m., use of water was authorized. At about 7:00 p.m., two men, using the fire hose located near the fire area, directed water on the fire.

Because of difficulty with the breathing apparatus, the water hose nozzle was wedged into a position where it would continue to pour water on the fire and the men left the fire area.

At 7:15 p.m., two men returned and found no evidence of continued burning.

The area was sprayed again, and the fire was declared "out" at 7:45 p.m.

The control room was occupied throughout the event; however, there were minor problems with smoke and C02 entering the control room through unsealed floor penetrations when the C02 system was discharged into the cable spreading room.

### 3.1.2 Extent of Fire Damage　火災損傷の拡大

The fire originated in a cable tray penetration between the cable spreading room and the reactor building. Figure 1 shows the extent of the fire damage.

Cables and raceways were damaged for a distance of about five feet inside the spreading room.

The major damage occurred on the reactor building side of the penetration.

Visible damage was observed in the cables in a double stack of three trays south as far as a fire stop about 28 feet from the penetration and west along the double stack of five trays for a distance of about 38 feet.

Cables in four vertical trays were also damaged downwards for a distance of about 10 feet.

TVA has identified and tabulated 117 conduits, 8 conduit boxes, 26 cable trays and a total of 1611 cables routed in these trays and conduits that are damaged or assumed damage (11).

## Evaluation of Temperatures Reached and Duration　継続時間と到達温度の評価

A program has been developed by TVA for evaluating temperature effects on structures and components.

This program is described in Section VIII of the TVA Browns Ferry Recovery Plan (3).

Temperatures as high as 15000F based on concrete discoloration and melted aluminum were reached in the most intense area of the fire in the reactor building just outside the penetration.

This area was roughly 10' by 8'. A second area just beyond the 1500*F area was estimated to have reached temperatures of about 1200OF based on melted aluminum.

This area included some areas of high cable density and the area above the burned cable trays from the top horizontal tray to an elevation (encompassing all of the evidences of melted aluminum,) within a few feet of the ceiling.

Other zones of lower temperatures were identified. All these areas are depicted in Reference (12).

## Fire Damage to Structures and Equipment　構造物と設備の火災損傷

In the following paragraphs is summiarized the damage to the plant besides the burned cables.

An extensive TVA investigation program was undertaken to identify all damage. Plans have been made to replace or repair all damaged material and equipment.

Trays and Conduits. トレイとコンジットの火災損傷

Damage to trays and conduits includes some corrosion caused by the corrostvmes phrecreated by the burnint cable jackets and insulation.

Some aluminum conduit located above the burning trays was melted by the intense heat, and some cracking was noted in some of the steel conduits.

Damage to Piping Systems.　配管系の損傷

The only direct damage of pipe was the melting of a soldered Joint in an air supply line which passed through the fire area.

This air line supplied control air to valves in the Unit 1 Reactor Water Cleanup Demineralizer System, and the line from the refueling floor to the Standby Gas Treatment System.

Structural Damage.　構造的な損傷

There is no evidence of significant structural damage except to trays, tray supports, conduits, conduit supports, and perhaps some piping supports in the fire area.

Smoke and Soot; Chlorides.　煙とスス：塩化化合物

Extensive deposition of soot occurred on all equipment located in the reactor building below the refueling floor.

It appears that no permanent damage resulted, but extensive cleaning requiring disassembly of many instruments and other equipment was required.

Following cleaning of all exposed surfaces of piping, conduit, ard other equipment, examination for evidence of damage was conducted.

Piping surfaces where soot or other deposits were noted were examined by dye penetrant procedures.

With the exception of small (3 and 4 inch diameter) uninsulated carbon steel piping, one run of aluminum piping, heating and ventilation ducts, and copper instrument lines in or near the fire zone, no evidence of significant chloride corrosion was found.

In the cases mentioned, the material affected will be replaced. In the case of some stainless steel instrument lines, an accelerated inspection program has been established to determine if delayed effects of chloride may later appear.

Water. There has been no evidence of any damage resulting from water used in fighting the fire.

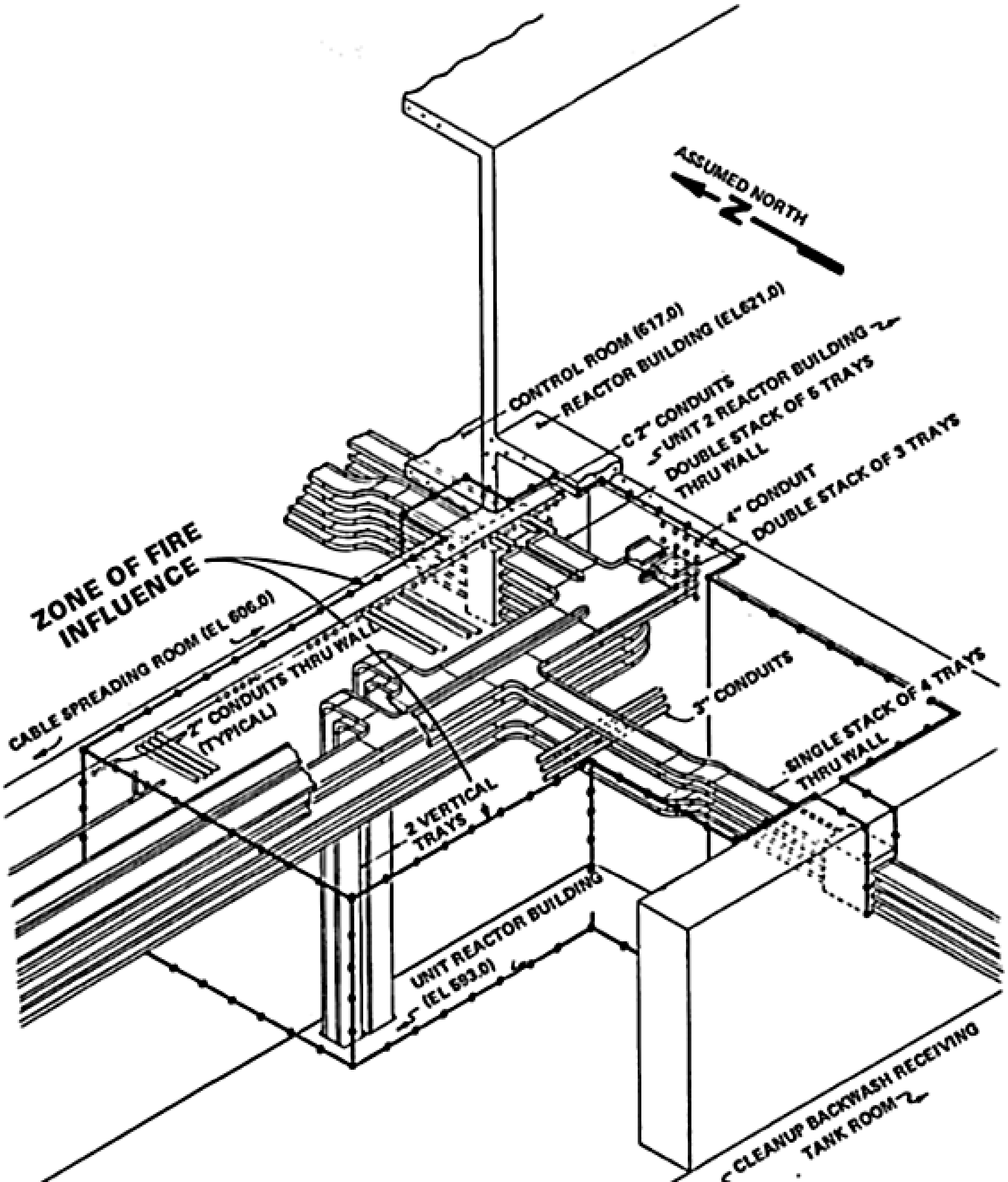

FIGURE 1 AREA OF FIRE

Damage Due to Electrical Shorts, Overloads, etc. 過熱、電気短絡による損傷

Except for cables, conduits, cable trays, and cable ladders, there is no evidence of significant equipment damage to electrical equipment.

Randomly selected panels in several systems have been closely inspected. Nothing abnormal has been found that would indicate overheating, arcing, or flashovers.

It has been noted that several fuses had been replaced in various panels, based on the number of old fuses found lying in the bottom of the panels.

It is not known how many such replacements were made before, during, or immediately following the fire.

In the clean-up work and retesting completed to "[date, no electrical components have failed or been found to be damaged in such a~way as to indicate shorting or arcing had occurred.

Some items, such as molded-case circuit breakers, for which cleaning costs would be excessive, are being replaced.

Complete inspection and testing during pre-operational testing will be the final arbiter.

Based on the inspections and testing completed thus far, gross or extensive damage to electrical equipment is not believed to be a problem.

### 3.2 Criteria for Fire Prevention and Control　火災予防と制御に関する要件

Criterion 3 of the General Design Criteria for Nuclear Power Plants (Appendix A to 10 CFR 50) F reads as follows:

"<u>Fire protection.</u> Structures, systems and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the containment and control room. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components."

This criterion implements the defense-in-depth concept used in the design of nuclear power plants and discussed in Section 2.5. In general, a methodology that can be used in applying this concept to fires is described as follows:

Prevention

During the design, steps are taken to minimize the use of combustible material where it is practical to do so, and to protect it where it is used.

During operation, the use of combustible materials and ignition sources is controlled by procedures.

Control

In spite of these steps to minimize the probability of a fire, it is assumed that a fire can happen, and means are provided to detect, control and extinguish a fire.

This is done by providing installed fire detection systems and fire extinguishing systems of appropriate capacity and capability in areas of high concentration of combustible materials, difficult access, or where fire damage could have a significant safety impact.

Fire barriers are provided to limit the spread of a fire.

A backup capability is provided in areas of high fire risk and in the plant in general to limit the extent of a fire and extinguish it if other measures fail by use of manual fire-fighting equipment consisting of hoses, connectors, nozzles and air breathing equipment by properly trained fire fighting personnel.

Limiting Consequences

Provisions are made to limit the consequences of such a fire by providing isolation in the form of barriers or suitable separation between redundant systems and components provided to carry out each safety function.

This separation is enhanced if the plant is divided into suitable fire zones since redundant safety equipment can then be placed in separate zones.

Provisions are also made to facilitate fire fighting and limit the consequences of a fire by suitable design of the ventilation systems so that the spread of the fire and products of combustion to other areas of the plant is prevented.

Presently there is no regulatory guide or industry standard available to provide detailed guidance in how to meet the requirements of General Design Criterion 3.

An industry standard, ANSI N18.10, was published for trial use and comment in September 1973, but the guidance given is so general that it is of limited use to the designer.

Notwithstanding its limitations, it does require an analysis of potential fire and explosion hazards in order to provide a basis for the design of fire protection systems.

<u>The International Guidelines for the Fire Protection of Nuclear Power Plants</u> (13) provides a step-by--step approach to assessing the fire risk in a nuclear power plant n describes protective measures to be taken as a part of the fire protection of these plants.

It provides the best guidance available to datei~iO this important area. -

The NRC staff in April 1975 issued Section 9.5.1 of the Standard Review Plan (14).

This provides for the review and evaluation of the fire potential (to be described in the applicant's SAR) and an analysis of the amounts of combustibles located onsite and the effects of [the hazards on safety-related equipment located nearby.

The Review Group concludes that more comprehensive regulatory guidance which provides fire protection design criteria to implement the requirements of General Design Criterion 3 is needed.

A body of standards should be developed which will present acceptable design methodology to be used in fulfilling specific requirements of prevention, detection, and extinguishing of fires at nuclear power plants.

### 3.3 Fire Prevention　火災予防

Fire prevention is discussed In Section 2.5 as one of the three echelons of safety important to defense-in-depth. The initiation of the Browns Ferry fire shows lapses in fire prevention.

The combination of the open flame on the candle and the highly flammable flexible foam used in the seal repairs had caused many small fires prior to the large fire which finally occurred.

Failure to take corrective action as a result of the smaller fires reveals a disregard of fire dangers and points to the need for a stronger fire prevention program.

Fire prevention begins with design and must be carried through during all phases of construction and operation. References (15-16) give a history of fires in U.S. and some foreign nuclear power plants. A substantial fraction (14 out of 46 in the U.S.) were associated with construction or major maintenance.

The Browns Ferry fire was also partly of this class. Including Browns Ferry, the 32 non-construction fires in the U.S. so far in operating reactors gives an incidence rate of the order of one fire per 10 reactor years.

Their consequences ranged from trivial to serious. Based on this history, a nuclear power plant can on the average be expected to experience about three fires during its lifetime.

Most of these fires will not-be very serious* based on past experience.

Fire prevention efforts are aimed at decreasing these rates.

They cannot be reduced to zero.

### 3.3.1 Fire Prevention in Design　設計時における火災予防

Each design should include measures to avoid potential problems with areas containing a high density of combustible material.

There should be a methodical investigation of how to limit L the amount of combustible material in areas containing safety-related equipment.

Good practice would dictate a system for maintaining an inventory of combustible material included in the design in order to:

a. limit such material to applications where they are necessary

b. provide the bases for establishing fire zones

C. guide in the development of fire protection design requirements.

The design of Browns Ferry Incorporated provisions for sealing the openings between major structural divisions such as the reactor building, the cable spreading room and the control room.

However, in the case of the Browns Ferry fire, one such seal between the cable spreading room and the reactor building was not only ineffective in limiting the spread of the fire but was the primary cause of the fire.

The lack of other seals, such as those between the cable spreading room and the control room, impeded plant operation during the fire.

There does not appear to have been an adequate understanding of the magnitude of the potential hazard from the use of the flexible polyurethane in the cable seals.

From combustibility testr data developed after the Browns Ferry fire by the Marshall Space Flight Center using the types L of polyurethane material found in the Browns Ferry seal (17), it is apparent that the specified Flamemastic coating would have generally reduced the hazard associated with the highly flammable flexible foam.

*Based on the fa-c-t tIat one fire of the Browns Ferry severity has occurred in several hundred reactor-years to date the incidence rate of such fires is estimated at between 10-S and 10-2 per reactor year.

It does not appear that the combustibility of the densely packed cables in the reactor building adjacent to the cable spreading room was understood adequately by TVA or NRC, since cables serving redundant safety equipment were permitted by the design in this area, without fireretardant coatings or sprinkler protection, and without adequate separation in the absence of other protective measures.

In reviewing the overall effort for fire prevention during design the Review Group concludes that more attention must be paid to this area.

An assessment of the amount of combustible material in each safety-related area should be accomplished.

An appropriate combination of the following measures should be taken where needed:

a. Limitation or replacement of combustible material

b. use of fire retardant coating

C. suitable barriers and seals to reduce the exposure of remaining combustible material.

For future plants, an additional alternative is available: establishment of fire zones basedr upon the amount of combustible material present and selection of a suitable design basis fire, arranged so that adequate isolation can be provided for redundant safety-related systems and equipment.

### 3.3.2 Operating Considerations in Fire Prevention　火災予防上の運転時における要件

Fire prevention during operation is a collection of actions by people to make the chance of a fire being started low.

By contrast to the preceding discussion of design considerations, the plant design is here taken to be fixed.

A fire requires a combustible material, oxygen, and an ignition source. A power plant has pipes containing water or steam that are hot enough to ignite some hydrocarbons.

Indeed, References (15-16) include a number of fires involving oil in nuclear power plants. In other plant areas,*there would normally be no ignition sources.

But experience indicates that the occasional cigarette butt or electrical spark or welding torch can be present.

The measures available for fire protection are therefore to minimize the combustibles under the operator's control, to recognize the combustibles he can't control (like cable insulation), and to maintain strict control of ignition sources.

These measures should be embodied in written procedures.

A fire prevention program can be looked on as a part of the plant operating quality assurance program.

The fire prevention procedures involve inspections (for stray combustibles), permits and precautions (for welding) and prohibitions (smoking in fire hazardous areas).

They generally involve written information (inspection reports, welding permits) that can be audited.

Especially important is the control and limitation of open flames (for example, during welding) and the taking of adequate precautions when their use is essential.

A principal lesson of Browns Ferry is the failure of fire prevention. The candle flame was an obvious ignition source.

The foam actually used is highly combustible, far more so than the material specified in the design.

The small fires actually experienced did not induce a fire preventive response.

Following the Browns Ferry fire, the NRC sent out Bulletins to licensees (18) pointing out some of these facts and calling for a re-evaluation of their fire prevention procedures.
Almost all licensees in replying cited systems of work permits and management review that should prevent such obvious lapses.

The Review Group, however, retains a certain skepticism. It is the experience of the group's members, and that of the experts the group has talked to, borne out by the tone of many of the licensee's replies to the Bulletin, that only a continuing attention by the operating staff can achieve a satisfactory degree of fire prevention, and that many such staffs remain complacent about fire prevention in their plants.

This complacency has until recently been mirrored by the absence of fire-related matters in the NRC licensing and inspection programs.

That has now been partially remedied. The Review Group believes thatL better regulatory guidance and greater NRC inspection attention should be directed toward fire prevention and control in general, with particular attention to fire prevention.

This will require development of suitable regulatory guides and also allotment of review and inspection resources for this purpose.

### 3.4 Criteria for Combustibility of Materials　材料の燃焼性に関する要件

Most fire prevention programs deal with solvents, oils, oily rags and waste, wooden structures, and electric sparks.

The Browns Ferry fire, on the other hand, involved cable insulation and the seals installed around cables at wall and floor penetrations to control air movement and act as fire stops.

The following sections deal with the combustibility of these two categories of materials.

For neither application are there adequate criteria for the selection of materials or standardized test methods.

The Review Group's recommnendation must therefore be for more development work on materials and testing methods and development of selection criteria rather than for present adoption of a particular standardized and tested material.

The Review Group believes that materials less combustible than those that burned at Browns Ferry can and should be developed and qualified using improved standardized tests for application in future plants, and that means are available and should be used in existing plants to decrease the combustibility of present materials found to need protection.

#### 3.4.1 Cable Insulation Criteria　ケーブルの絶縁体に対する要件

The Browns Ferry FSAR contains no criteria which specifically address the combustibility of theF insulated cables. The statement is made, however, that the cables were selected to minimize excessive deterioration due to temperature, humidity, and radiation during the design life of the plant.

There were 16 basic combinations of cable construction materials involved in the fire.

A list of the cable materials is given in Table 1.

TABLE 1.
CABLE MATERIALS
Insulation Materials Jacketing Materials
Polyethylene Nylon
Cross-linked polyethylene Polyvinyl-chloride
High density polyethylene High density polyethylene
Nylon backed rubber tape Polyvinyl
Irradiated blend of polyolef ins Aluminum foil
and polyethylene Chl orosul fated polyethylene
Fiberglass reinforced silicone
tape
Neoprene
Cross-linked polyethylene

TVA cable specifications for polyethylene insulated and cross-linked polyethylene insulated wire and cable require number 8 AWG and larger sizes to pass the vertical flame test found in IPCEA* S-19-81 Section 6.19.6 and number 9 AWG and smaller sizes to pass the horizontal flame test found in Section 6.13.2 of the same document.

No flame testing was required for nylon Jacketed single conductor or multi-conductor cables. The vertical and horizontal flame tests in IPCEA S-19-81 are single cable flame tests.

At the time of the approval of the Browns Ferry design there were no specific regulatory requirements concerning the flame retardant properties of electric cables. No consensus existed as to what test should be used and exactly what could be inferred from the test results.

Cable flame tests found in the various standards at the time were single cable tests.

Predictions of the spread of fires in cable trays based on the results of the single cable flame tests were not available.

The NRC requirements for flame retardancy of cables have been changed since the Browns Ferry safety reviews by the NRC. Regulatory Guide 1.75 (66) endorses IEEE Standard 384-1974, "IEEE Trial Use Standard Criteria for Separation of Class IE Equipment and Circuits." IEEE 384-1974 requires that flame retardant cable be used as a prerequisite to the applicability of the cable separation criteria specified in the standard.

"Flame retardant" is defined in the standard as "capable of preventing the propagation of a fire beyond the area of influence of the energy source that initiated the fire," but IEEE 384-1974 contains no further guidance for the selection or testing of flame retardant cable. This is given in IEEE Standard 383-1974, "IEEE Standard for Type Test for Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations," which is presently used in NRC construction permit evaluations and is under consideration for endorsement in a future Regulatory Guide.

IEEE 383-1974 specifies a method for testing of a vertical tray containing a number of cables to determine their relative ability to resist fire. Unfortunately, the flame test of IEEE 383-1974 does not simulate the normal cable tray installations very well.

The test arrangement calls for several lengths of cable to be arranged in a single layer in the bottom of a cable tray with approximately 1/2 cable diameter spacing between the cables.

By contrast, typical cable trays in plants contain several layers of cables with no space deliberately left between individual cables.

Although NRC criteriatpresently require cables to be "flame retardant" (but not yet specifying even the IEEE-383 test and some flame tests are now available, the effect of a fire ignited in a typical cable tray configuration with flame retardant cable is still not well-known.

Prior to the Browns Ferry fire, NRC had signed a contract with Sandia Laboratories to perform experiments in which cables in typical cable tray configurations are ignited, but results of this work are not yet available.

Since the Browns Ferry fire, fire experts have expressed reservations similar to those discussed above about the adequacy of the cable configuration in the IEEE 383 cable combustibility test (19, 20).

They have also recommended that higher energy ignition sources than that specified in IEEE 383 be used In performing flame tests.

A Nuclear Energy Liability and Property Insurance Association (NELPIA) sponsored cable testing program is being conducted at Underwriters' Laboratory to determine the relative performance of cables when subjected to the IEEE 383 vertical flame tests, but using 20,000, 210,000, and 400,000 Btu per hour gas burners to investigate the effect of varying the energy of the ignition source (20). Various control cable constructions will be tested vertically and horizontally in multi-tiered groups of trays to determine the effects of the ignition source intensity and cable geometry on flame propagation and circuit integrity.

Reference (65) contains a recommendation that mineral insulated metal sheathed cable or equivalent fire resistant cable should be used in one of the safety divisions.

(For a discussion of "safety divisions," see Section 4.3.3.1.) The objective of the recommendation appears to be to provide one safety division capable of surviving a fire that envelopes all safety divisions and destroys all other safety divisions.

Although this approach may have merit in particular situations, the Review Group questions its utility and believes it is not needed as a universal requirement.

There are other ways of accomplishing the objective of adequate divisional isolation. (See Sections 4.3.4.4 and 4.3.4.5).

Consideration of cable (and perhaps coating) materials is involved in all three components of defense in depth. Proper selection of cable materials can reduce the probability that a fire will start.

Cable installations of good flame retardancy characteristics will limit the spreading of a fire and thus aid in the control of a fire. Good flame retardancy in conjunction with adequate separation and isolation of redundant safety divisions is important in maintaining avialability of safety functions in the event a fire occurs.

The Sandia and NELPIA-UL programs are efforts to fill the gap In present knowledge.

The NRC staff should follow these programs closely and encourage their prompt completion.

If the results of these programs indicate that additional investigation is required, such investigation should also proceed in a timely manner.

If the results of these programs indicate that significant improvement in safety can be achieved by changes in existing plants, such changes should be implemented if needed.

Improved criteria for flame retardancy of cables with or without flame retardant coatings should also result from these investigations.

L An associated problem at Browns Ferry was the corrosive and toxic gases and dense smoke given off by burning cable materials.

The Review Group recommends that investigations into flammability include study of the airborne products of heating and combustion, and that these be considered in selecting cable insulation materials.

It is not possible at the present time to forsee whether new cable insulating materials should be developed.

Certainly materials less flammable than those now commonly used are available; they have drawbacks in cost, electrical and mechanical characteristics, availability, and other properties and have not been widely used.

Decisions regarding their adoption should be based on assessment of the defense-in-depth components at each plant.

It should also be pointed out that fire retardant coating materials are available for use with existing cable materials.

They can be applied to areas in operating plants that might be deemed to need additional fire resistance, without the necessity for disturbing the present cables or trays.

Tests of these coating materials by their manufacturers, reactor vendors and others, the results of which are now being collected and evaluated by the NRC, indicate that proper application of these materials can provide considerable fire protection.

The Review Group believes that Judicious use of such coatings in areas of high cable density or high fire vulnerability has the potential for significantly reducing the risk from extensive cable fires in operating and future reactors'.

It recommends that research and testing be conducted as needed to evaluate where and how such coatings can be used to decrease the cable fire hazard.

### 3.4.2 Criteria for Fire Stops and Seals　防火仕切りと漏洩防止装置に関する要件

The Browns Ferry FSAR provided design criteria for fire stops and seals.

It states that any openings in the floors for vertical cable trays carrying redundant cables of cable Divisions I or II are to be sealed and the cables coated with a fire retardant material (Flamemastic 71A* or equal). Likewise, openings in walls for horizontal cable trays between buildings (reactor and control) are sealed.

Although the regulatory staff was concerned with fire prevention techniques, there were no regulatory requirements concerning fire stops per se at the time of approval of the Browns Ferry design.

General Design Criterion 3, however, staEtes that noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in the containment and the control room.

The design of the cable penetration where the fire started called for a 1/2-inch thick steel plate bulkhead, slightly smaller than the dimensions of the penetration, in the center of an opening in a concrete wall.

Openings were cut in the bulkhead plate and steel sleeves welded into the openings.

The trays stop short of the opening and only the cables extend through the wall penetration.

The sleeves were to be filled with polyurethane foam after the cables were installed to limit air leakage.

The design called for pourable polyurethane foam to be applied over and around the installed cables.

Upon hardening of the pourable polyurethane foam, sprayable polyurethane was to be used to finish filling the sleeve.

The pourable foam was specified because it more completely fills the voids between the cables. A fire retardant coating, Flamemastic, was then to be applied 1/8 to 1/4-inch thick over the foam and the cables on both sides of the bulkhead for a distance of 12 inches.

TVA reported (21) on testing of a typical fire stop penetration in June 1973, and concluded from the results that this fire stop design would provide a good barrier.

The report further stated that the Flamemastic manufacturer recommendation that the cables should be coated for 6 to 8 feet on both sides of the penetration was not valid; the one foot distance used in the test was stated to be sufficient.

It is important to note the ways in which the seal that caught fire differed from the seal as designed and tested.

A principal difference was the use of the flexible foam for stuffing into leaks.

While sealing the penetrations, a dam was required in some cases to prevent the liquid foam from flowing out of the sleeves.

One solution for this problem was the use of a flexible, resilient polyurethane foam (quite different in properties from the "polyurethane" discussed in the preceding paragraph), cut to size for insertion into the sleeve openings to form a dam.

Although it goes by the same "polyurethane" name as the pour and spray foam "polyurethane," its properties are different. In particular, it is far more easily set afire and burns in a different way. (See just below and Reference (17)).

It is not known whether a piece of the flexible material was used for a dam on the seal tested in 1973. It is known that the seal that caught fire had a hole through it (2 by 4 inches in cross-section) and that a piece of the flexible foam had been stuffed into that hole.

Moreover, that piece of flexible foam had, of course, no fire retardant coating.

Another difference may have been in the fire retardant coating.

The Review Group has been unable to find out whether the seal being repaired, that is, the one that caught fire, was originally coated with Flamemastic. Some seals at Browns Ferry were not coated in accordance with the design (21a).

A third difference was that the seal that was tested did not have a pressure differential across it, which would have induced drafts through any leaks.

Such a pressure differential at Browns Ferry, in accordance with the design of their containment, contributed to both the initiation and the spread of the fire.

Following the fire, the NRC had an independent set of tests performed on the materials found in the cable penetration area.

The following excerpt presents some findings from those tests (17):

*The Flamemaster Corporation, 11120 Sherman Way, Sun Valley, California 91352
20 "Experimental tests clearly verified the ease of ignition of the foam rubber stuffing by the candle. (In fact, actual contact with the flame is not required.)

The resulting very rapid, almost flash, burning combined with release of burning droplets constitutes not only an intense local source of ignition but also a means of propagation of fire over a much larger area, leading easily to a general conflagration with other local combustible materials, especially in an air draft as acutally occurred.

"Initial cursory tests on materials collected in the cable spreader room confirmed that [ readily combustible materials were in the vicinity: rags, pour foam, and cable ties. "Interpretation of the ASTM test results must be done with caution. These are intended to be relative tests only and are done in a draft-free environment in a strictly empirical test procedure. "For example, the manufacturer's claim that the "instafoam" is "self-extinguishing" was experimentally substantiated by testing in accordance with the referenced ASTM specification (D-1962). However, the data on both the spray and pour foam samples show that the materials do very barely meet the requirements to be rated as "self-extinguishing" by F this test.

Specifically, the requirement is that in this horizontal test no specimens burn ast a 5-inch gauge mark from the ignited end. Inspection of the data shows burn lengths of 5", 3", and 5" for the pour foam and 5", 4-1/2, and 5" for the spray foam.

One could infer from these data that the 5-inch limit may have been derived from these type materials, and thus the test was designed to accept such materials.

The same inference could be drawn from the ASTM vertical burning test (D-3014) in which a 10-inch long specimen is specified.

The data show burn lengths of 8 to 10 inches. "However, the lead paragraph of both ASTM specifications states:

'This method should not be used solely to establish relative burning characteristics and should not be considered or used as a fire hazard classification' and further therein, 'Correlation with flammability under use conditions is not implied.

"Clearly, both materials are readily ignited, support combustion, and exposed surfaces would contribute significantly to a general conflagration.

"The data do show that the polyurethane foam rubber burns much faster than the pour or spray foams, and releases burning droplets.

Further, these samples of pour foam burn considerably faster than the spray foam.

In addition, coating exposed surfaces with Flamemastic was extremely beneficial.

In fact, coated pour and spray foam samples did not burn under the test conditions."

It can be concluded from the results of the two independent tests that Flamemastic 71A provides considerable fire protection when utilized properly.

However, more recently, TVA informed NRC (22) that tests on a seal of the original design including the Flamemastic coating gave unsatisfactory results.

In one such test (Test 1.2.3 - External Flame Test) an explosion occurred in the cold side of the test building.

The explosion apparently resulted from the ignition of flammable gases by flame passing through the cable tray seal.

Additionally, there was some damage to cables on the cold side of the seal up to approximately four feet from the seal.

These cables were somewhat charred and showed evidence that cable jackets melted.

These tests were considerably more severe than the 1973 TVA tests, and used a much hotter ignition source than the candle that started the actual fire. Nevertheless, TVA has subsequently decided (57) to remove such polyurethane foam seals as is practicable and to replace them with a material found by testing to be more fire-resistant.

The Browns Ferry fire experience indicates that the materials of construction for fire stops requires close examination.

This is true in spite of the fact that the 1973 TVA tests indicate that a properly made fire stop of the Browns Ferry design (with Flamemastic and without flexible foam) would probably not have initiated the fire (21) from the candle. The tests also indicate that even if a fire had started, a fire stop made in accordance with the original design may well have prevented its spread outside of the room where it started.

Inspections of all operating nuclear generating stations (23) revealed a number of deficiencies associated with fire stops at a number of plants, although many plants had no deficiencies or only trivial ones. Some of the deficiencies found were:

1. Required fire stops had never been installed.

2. Fire stops had been opened to install additional cables and had not been repaired.

3. Fire stops had been Improperly constructed.

4. Fire stops had been repaired with improper materials (including flammable ones).

5. Fire stops contained combustible materials left from construction (such as foam dams and pull ropes).

6. Fire stops had deteriorated (crumbling concrete or shrunken and cracked coatings).

These deficiencies are being repaired. The experience is another manifestation of the need for improved attention to fire prevention and control by both licensees and the NRC.

There are suitable materials available (24-28) that are less flammable than the type of polyurethane in which Browns Ferry fire started. Tests run by one utility (24) were stated to show that the polyurethane tested in their case would not burn, but blackened and charred without significant degradation.

This is additional indication that different types of "polyurethane" have different flammability properties.

Unfortunately, the flammability characteristics of the materials have not been compared by common tests.
The claims for some of the materials come F from promotional literature.

The Review Group recommends that a standard qualification test be developed to resolve the problem of the uncertainties of flammability of fire stop materials and designs and to assure acceptable performance of fire stops.

Qualification tests of the separate materials of construction are needed as well as tests of the assembled fire stop, to give a measure of the performance of fire stops with deteriorated or faulty fire retardant coating.

It would be preferable to have the qualification testing performed by a qualified testing laboratory. This would not only eliminate any potential conflict of interest but would also permit the testing organization to develop a high level of competency in fire testing and qualification.

The Review Group understands that Underwriters' Laboratory and Factory Mutual Insurance Company are currently listing and approving devices and construction configurations for wall openings (20).

The possibility of providing fire stops at specified intervals in long cable trays has been suggested (65).

Such fire stops have the potential for further limiting the spread of a cable tray fire and may offer a significant improvement in safety in certain installations.

A suggestion has been made that unapproved foam plastic seals be removed from existing plants and that they be replaced with suitable items (65).

Although this suggestion has merit, the Review Group does not believe that this should be a blanket recommendation.

Because there is a potential for damaging safety related cables in the removal of fire stops and seals, the Review Group believes that this should be considered on a case-by-case basis with the ease and safety of removal considered along with the potential improvement in safety achievable with the replacement of seal material.

Realistically, not all of the old materials will be removed and not all the void space will be filled with new material.

Use of a flame-retardant coating could help to offset the inability to remove and replace existing flammable seal material. The improvement would, to a degree, be a function of the original seal design.

Although tests of some fire stops containing "polyurethane" show apparently acceptable results, tests of fire stops that contain material such as the flexible polyurethane foam used as dams and plugs at Browns Ferry show that they are extremely flammable.

Fire stops which contain or are believed to contain these types of highly combustible material should be replaced or demonstrated to be acceptable on some other basis.

Cable penetrations are not the only places where fire seals and stops may be appropriate.

It is important that the habitability of the control room be protected in the event of a fire.

It is important, therefore, that all openings in the control room be sealed to prevent the entry of smoke or other substances that might cause evacuation to be necessary.

Consideration should be given to the addition of stops and seals in existing plants where they can significantly reduce the probability of the spread of fire, smoke, and toxic or corrosive gases.

## 3.5 Fire Fighting　消火活動

The detection, control, and extinguishing of fires that get started (in spite of. fire prevention
programs) involve both equipment and people. In the following sections are discussed the
Browns Ferry lessons related to fire fighting.
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### 3.5.1 Fire Detection and Alarms Systems　火災の感知および警報系

A fire must be detected before it can be fought. At Browns Ferry, the workman with the candle
detected the fire immediately. The installed smoke detectors did not alarm, so there are fire

detection lessons that have become evident.
Browns Ferry had smoke detectors in 7 areas including the cable spreading room and rate-of-rise
temperature detectors in other areas.[
The fire started in the cable spreading room; yet the fire detectors in the cable spreading
room were not effective in signaling the start of the fire. It is the opinion of TVA that because of the air pressure differential between the cable spreading room and the reactor
building, the flow of air drew the smoke from the fire in the cable spreading room away from
the detectors. That there was smoke in the cable spreading room is demonstrated by its later
displacement into the control room through the unsealed penetrations in the floor by the $CO_2$ of
the Cardox System when it was actuated.
The fire detectors installed in the control room did not alarm either. These detectors were ofF
the ionization type, and did not detect the products of combustion from the burning cable
insulation.
There was a great deal of smoke in the reactor building in the vicinity of the fire, but detectors had not been installed in that area.
NELPIA and other fire prevention engineers are of the opinion that the effectiveness of a
detector is stongly dependent on its location and the type used for a particular product of
combustion. During the design of a fire detection system, assurance should be provided, including testing if needed, of the compatibility of the detector at a particular location with
the products of combustion that would result from a fire in the materials occupying the area
where the detector is to be installed, and such adjacent areas as are appropriate.
Little regulatory guidance is available regarding fire detectors. The available draft standard
(ANSI-NI8.lO) provides little guidance. The National Fire Protection Association

Standard on
Automatic Fire Detectors (NFPA No. 72E-1974) provides some information on the location,
maintenance and testing of detectors, but the guidance is incomplete. The Review Group believes
that more and better guidance should be provided preferably by a suitable standard based on
experiments with existing cables and detectors. The standard should be augmented when improved
materials become available.
It is the recommnendation of the Review Group that the fire detection systems for all plants be
reviewed to assure that suitable detectors are Installed at the proper locations. This review
should include verification of the effectiveness of the installed detectors for fires in the
materials present. The detection systems at operating plants should be upgraded as necessary
based upon this review.
Another lesson learned as a result of the Browns Ferry fire is that there may be areas within
other plants which contain significant amounts of combustible material where a detection system
is not provided. At Browns Ferry, the areas within the reactor building where a high density
of cables existed did not contain fire detection systems because these cables were not considered
to be a fire hazard. Horizontal cable tray configurations were assumed to be self
extinguishing and vertical tray runs of cabling were considered to present an acceptable hazard
based on the assumed vertical fire propagating properties of these cables.

### 3.5.2 Design of Fire Extinguishing Systems　火災消火系の設計

The objective of fire extinguishing systems is to provide automatic fire protection for areas
or equipment where it is needed and to provide adequate manually actuated fixed and portable
fire extinguishing systems for the entire plant.

The Browns Ferry FSAR describes three fire extinguishing systems:

1. A high pressure water system which supplies water for fixed water spray or fog systems for
selected equipment and to fire hoses and hydrants throughout the turbine building, reactor
building, service building, radioactive waste building, office building, and yard.

Automatic fog systems are provided for the following:

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a. Main turbine oil tanks,,

b. Reactor feed pump turbine oil tanks

c. Turbine head ends

d. Hydrogen seal oil units

e. HPCI pump turbine oil tanks

Automatic spray systems are provided in the service building for the carpenter shop, oxygen-acetylene storage room and oil storage room.

2. Low pressure carbon dioxide with manual initiation is provided in the following areas:

a. Cable spreading rooms

b. Auxiliary instrument rooms

c. Computer rooms

Carbon dioxide from this system, with automatic control, is supplied to the four diesel generator rooms, the lube oil purification room of the turbine building, and the paint shop.

3. Fire Extinguishing Portable Equipment

Portable extinguishers to be used on Type A, B, and C fires (as defined by NFPA Standard
10-1967) are installed at various locations throughout the plant. The predominant type is
a dry-chemical type filled with potassium bi-carbonate and a gas propellant.

Neither the FSAR nor the SER for Browns Ferry covers the basis for the selection of the types
of fire extinguishing systems and the locations where these systems are installed, or considers
the type and amount of combustible material present in each area.

At Browns Ferry, areas containing a high density of electrical cables did not have installed

water sprinkler systems. This of course included the fire area in the reactor building. Fire
hoses and nozzles connected to hydrants were, however, available in the vicinity of the fire.

Although the fire in the cable spreading room was controlled and extinguished without the use
of water, the fire in the reactor building burned on for several hours in spite of numerous
attempts to put it out with portable COI and dry chemical extinguishers. However, once water
was used, it was put out in a few minutes.

The use of water to fight the fire was recommnended by the Athens, Alabama, fire chief early
during the fire (32). The plant superintendent's decision to use water was taken late and
reluctantly, after consultation with TVA management. Although TVA and Browns Ferry written
procedures do not forbid use of water to fight fires in electrical cables, TVA has defended the
long delay in deciding to use it.

Replies by licensees to the NRC Bulletin (18) have revealed a widespread reluctance to use
water on a fire in electrical cables. Much fire control training includes a prohibition of
"lusing water on electrical fires."

TVA maintains (29) that the plant superintendent made a conscious and correct decision not to
use water because of the possibility of shorting circuits and thus inducing further degradation
of the plants to a condition that would have been more difficult to control. TVA stated their
strong opinion that reactor safety concerns should take precedence over extinguishing a local
fire, and that only after a stable plant condition had been reached should water have been
used.

The Review Group agrees in principle that reactor safety comes first, but does not agree that this principle mitigates against the use of water on cable fires. The sequence of events in Browns Ferry shows that the fire caused successive failures, as detailed in Refarence (5). The initial series of failures occurred in the first half hour, up to about 1:00 p.m. At 1:15 p.m., more equipment became unavailable. As late as about 6:00 p.m., remote manual control of the relief valves was lost as a result of the progression of the fire (56), greatly reducing the available redundancy.

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Moreover, if the fire had been quickly extinguished and the smoke cleared, the efforts to restore equipment and make temporary repairs would probably have been successful more quickly.

For example, the effort to manually align the RHR system valves was thwarted by the smoke from the fire. Therefore, promptly extinguishing the fire, which the Review Group believes could have been accomplished by the earlier use of water, would not only have prevented the failure of equipment, but would have aided in the prompt restoration of the equipment which had been disabled.

Of less merit, in the Group's opinion, is the TVA argument (30) that personnel safety considerations also mitigated against the use of water. A special nozzle for use on "electrical fires" was available and was finally used to put out the fire without hurting anyone (31). Whatever personnel danger was present earlier was not likely to be significantly less at 7:00 p.m.

Clearly there is a balancing of pros and cons to be made in cases like this. The Group's concern is that widespread opinion and practice emphasize the reasons for not using water as compared to those in favor of prompt water use. The Group certainly does not intend that water shall be used immediately on all fires, and acknowledges the reasons against using water.

Nevertheless, the Group wishes to emphasize the need for quickly putting out all fires, especial- r
ly in situations where the unexpected is occurring. For this reason, in view of the Browns
Ferry experience, fire procedures and fire training should include these considerations in the
balancing of alternatives that all hazard control operations inevitably involve.

It has already been noted (32) that the Athens fire chief was of the same opinion as the Review
Group. The group has discussed this question with a variety of fire experts, who all favor the
early use of water in most circumstances. The experience at Browns Ferry, as well as expert
opinion, suggests that if initial attempts to put out a cable fire with non-water means are unsuccessful,
water will be needed.

Fire fighting--by all methods--was impeded by the inaccessibility of the fire site. For areas
of high cable density--or high density of any flammable material--fixed extinguishing systems
should be installed, especially where access is difficult. Assessment of access should consider
firefighting conditions including vision impairment (smoke, lights out) and the need for wearing
breathing apparatus. Consideration should be given to making such a system automatic, which is
preferred if feasible, especially where access is difficult. The amount of water to be handled
can be minimized by judicious placement of sprinkler heads and using directional sprays where
appropriate.

TVA has also stated (33) that the limited number of air-breathing sets available forced the
plant staff to make priority decisions to favor valve and control manipulation in the smokefilled
area over firefighting activities, and that this decision accounts for the lack of

firefighting
in the reactor buildin5 between 1:10 p.m. and 4:30 p.m. (58). The Review Group accepts this explanation, but believes it has only limited relevance to the water--no water question.

The Group also points out that this difficulty experienced at Browns Ferry is another reason
for automatic initiation of firefighting systems. Putting out the fire would cut off the generation of smoke and allow use of breathing apparatus for other purposes.

In principle, a C02 or Halon gas system could be effective in fighting a fire in a closed space
where oxygen could be excluded. The asphyxiation hazard to personnel is greater with such a
system than with water. Initiation of the C02 system in the Browns Ferry cable spreading room
was properly delayed to ensure personnel safety. This was also the stated reason for leaving
the metal plates installed, preventing local manual actuation of the system (see Section 3.5.5).

NELPIA and a number of fire protection consultants have questioned the ability of carbon dioxide
or dry chemicals to extinguish a deep seated cable fire. They argue that if a means is not provided to remove the heat generated by the fire, the material will re-ignite once the oxygen
is readmitted to the hot combustible material.

Due care must be exercised in the design and installation of water systems. There must be a
drain for the water. Equipment that could be damaged by water should be shielded or relocated
elsewhere away from the fire hazard and the water. It is also good practice to separate redundant
equipment so water applied to put out a fire in one division will not affect the others.

General Design Criterion 3 requires that fire fighting systems be designed to assure that their
rupture or inadvertent operation do not significantly impair the safety capability of structures,
systems and components important to safety. With the increased emphasis on the ose of

installed
water sprinkler systems for the fire protection of electrical cables in nuclear power plants,
this specific requirement of General Design Criterion 3 takes on added significance. The Review Group believes that guidance should be developed for the specification of quality and
design requirements in order to assure that installed water sprinkler systems will have adequate
integrity and reliability during the life of the plant.
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For each plant, the Group recommends a detailed review of fire hazards and the installation or
upgrading of such systems as are needed. This assessment should be in conjunction with the
review of fire prevention measures and flammability recommended in Section 3.3. The Review
Group recommends that serious bonsideration be given to fully automatic directional sprinkler
or spray systems in areas containing high concentrations of combustible materials including
specifically cables used for safety-related equipment, and in areas where access for fire fighting would be difficult.
It is further recommended that the design of all future plants should continue to provide for a
reliable high-pressure water-system including appropriate hoses, nozzles, and hydrants, In all
areas of the plant including those protected by sprinkler or spray systems.

### 3.5.3 Ventilation Systems and Smoke Control　換気系および煙制御

At Browns Ferry, ventilation was lost at 12:45 p.m., shortly after the fire started, and was
not reestablished until 4:00 p.m. Even if venting the smoke through the installed ventilation
system had been planned in the design, it would not have been possible because of the inoperability
of the system. The loss of the ventilation system was brought about because of loss of power to the ventilation system and loss of power to its control subsystem. Control and

power
cables of a ventilation system important to fire control should not be routed through areas the
system must ventilate in the event of a fire.
The Review Group recommends that ventilation systems in all operating plants be reviewed and
upgraded as appropriate to assure their continued functioning if needed during a fire. It is
further recommended that present designs be provided with the capability of isolating fires by
use of cutout valves or dampers.
Capability for the control of ventilation systems to deal with fire and smoke should be provided,
but such provisions must be compatible with requirements for the containment of radioactivity.
These provisions and requirements may not be mutually compatible and in some cases may be in
direct conflict with each other. For example, operating ventilating blowers to remove smoke
may fan the fire; the same action may also result in a release of radioactivity, either directly
by transport of radioactive particles with the smoke or by decreasing the effectiveness of the
filters provided to contain the radioactivity. It is obvious that some compromise will be
necessary and that flexibility of operation may be needed, depending on the nature of any event
that may occur. The pros and cons of each provision and requirement should be considered in
the development of detailed guidance.
At Browns Ferry, there was no attempt made to limit the transport of smoke to other areas of
the plant by closing vent dampers and valves. After actuation of the $CO_2$ system, openings
between the control room and the cable spreading room had to be plugged to stop the entry of
smoke and $CO_2$ into the control room. Some of these openings were in the floor of the

control
room at the points where the cables entered the control room. This appears to violate the
design provision that these cable entryways would be sealed. In the event of a serious fire in
the cable spreading room the control room might have become uninhabitable because of smoke and
toxic fumes. Actuation of the CO2 system in the cable spreading room made the situation worse,
driving the smoke into the control room.

### 3.5.4 Fire Fighting　消火活動

Fire fighting encompasses the ability to extinguish a fire and to prevent re-ignition. The equipment design aspects of fire fighting were discussed in the preceding section; here we
treat the personnel aspects.

One aspect of fire fighting which is important is the access to and egress from a potentially
hazardous area. The emergency plans for all plants should lay out access and escape routes to
cover the event of a fire in 'the reactor building and other critical areas of the plant.

Consideration should be given in the design of future plants to providing access and escape
routes for each fire zone and in particular, areas containing a potential fire hazard.

There are areas within the plant where access for the purpose of fighting fires is especially
important. In particular, the cable tray area and the seals between the reactor compartment
and the cable spreading room were important in the Browns Ferry fire. Access to the seals and
the cable trays was extremely limited. Moreover, the design provision for centering the seals
in the wall between the cable spreading room and the reactor building was not carried out, with
the result that the seal areas were extremely difficult to reach from the cable spreading room.

After the fire had spread to the cables in the trays in the reactor building, fire fighting

efforts were hampered by lack of access to the affected areas (some 30' above the floor) even
though temporary wooden ladders were available in these areas.
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During the Browns Ferry fire certain pieces of onsite fire extinguishing equipment were found
to have threaded connections which were not compatible with equipment used by the Athens Fire
Department. Such a situation could lead to decreased effectiveness of offsite fire fighting
units in a serious fire at a nuclear power plant. The Review Group recommends that all plants
should assure compatibility of fire fighting equipment with offsite fire fighting units which
may be called upon in an emergency.
Another important factor in fighting a fire is the equipment available to support life while
fighting the fire. At Browns Ferry the breathing apparatus capacity was not sufficient to
support all reactor system manipulation, electrical repair, and needed fire fighting activities
(33). The breathing apparatus available at Brown's Ferry had a design capacity of one-half
hour. Even assuming a well-trained operator and good access to the fire area, the 30-minute
capacity of the equipment presently approved for toxic atmospheres causes difficulties for an
operator at the scene fighting the fire (or doing anything else important) without having to
leave to get another fully charged unit.
There are two principal types of breathing apparatus--positive pressure and recirculating type.
To date the Occupational Safety and Health Administration (OSHA approves only the positive
pressure type for toxic atmospheres.
The largest positive pressure standard equipment currently available is rated at 30

minutes. A representative of the Montgomery County, Maryland, Fire Department Training Academy stated that although these units are rated for 30 minutes, fire departments in general recommend limiting use to 20 minutes. If the mask does not fit properly, a considerable fraction of the air is lost, and the service life may be less than 20 minutes.

Recirculation, or closed loop breathing apparatus is available with considerably larger usage life. In one such type, exhaled air, rather than exhausting to atmosphere, is recirculated through a purification canister, then a metered amount of pure oxygen is added to return the air to 20% oxygen. There are three disadvantages to this type apparatus: (1) potential inleakage of toxic fumes; (2) once a canister has been activated it must be discarded, even if not used at all; and (3) the oxygen bottles must be returned to a supplier for recharge. The obvious advantage is longer usage life. A second recirculation type uses the purification canister without oxygen.

Browns Ferry personnel made limited use of the latter type of breathing apparatus, with generally acceptable results. Some individuals experienced difficulty in breathing with these units. This is a fairly common complaint, especially when the user is engaged in heavy physical activity or operating under significant stress.

Los Alamos Scientific Laboratory is doing a considerable amount of work on protective equipment for NRC. This work is directed toward the use of protective equipment in the presence of airborne radioactivity. However, the type of equipment available for use is the same, regardless of the type of atmospheric contaminant.

The method used by TVA to recharge their breathing equipment (cascading method) resulted in excessive charging times and below capacity charges. It is recommended that all operating plants review and upgrade as necessary the breathing equipment available as well as

the capacity
and method of charging of breathing equipment, and that future designs include adequate recharging
equipment.

### 3.5.5 Prevention and Readiness Efforts During Construction and Operation 建設及び運転中における予防と準備努力

The Browns Ferry FSAR specifically states that no special test of the fire protection and detection system is required and that routine visual inspection of the system components,
instrumentation and trouble alarms is adequate to verify system operability. This approach was
demonstrably not adequate to assure the complete availability of the C02 system in the cable
spreading room for this incident. During the early stage of the fire, the operation of this system installed in the cable spreading room was impeded and slightly delayed (59) because
metal plates had been installed over all the local control buttons in order to protect workmen
and prevent release of the C02 during the period of Browns Ferry Unit 3 construction.
An effective licensee inspection program by persons knowledgeable in fire protection and effective
NRC audit of this program would have corrected this situation or, if the inhibition was necessary, everyone would have been informed and alternative procedures developed: A plan
should be developed which provides for the required periodic tests and lists the responsible

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individuals and their responsibilities in connection with adequate testing and inspection of
these systems. The requirements for operability and testing for the fire extinguishing systems--that is, the Limiting Conditions for Operation and the Surveillance Requirements--
should be included in the Technidal Specifications to assure that these necessary systems are

available and in proper working condition.

Fire extinguishing systems must be disabled at times for maintenance on the systems. In certain 1 cases, automatic fire extinguishing systems must be disabled to avoid risk to personnel, working in a confined area, from inadvertent actuation. In such cases, temporary measures must be provided for fire protection in areas covered by the disabled equipment. Such measures should include fire watches equipped with manual extinguishers, appropriate for the area protected, standby personnel at hose stations, capability for manual restoration and/or actuation of the disabled system or other acceptable substitute for the temporarily disabled system. This also holds where fire seals must be breached. They should be restored promptly or, if this is not practical, adequate temporary measures should be taken.

The NRC inspection report of the Browns Ferry fire (5) contains a number of examples where the actions taken by the plant operating staff during the fire are stated not to be indicative of a high state of training of plant personnel in fire fighting operations.

TVA has stated in reply (34) that training in fire fighting techniques was carried out prior to the March 22 fire and that this training was effective. Since 1970, approximately 325 employees have attended the Fire Brigade Leader Training Course and four safety professionals have attended the Texas Firemen's Training School at Texas A & M University.

While the Review Group believes that such basic training is a necessary element in effective preparation for fire fighting, such training alone does not assure smooth operation of fire fighting personnel during a fire. Emergency plans should recognize the need for fire fighting

concurrent with other activities. There must be a clear understanding of the duties of the
onsitepersonnel, with preassigned and trained teams for each needed function. The degree of
dependency upon trained onsite fire fighting personnel must be related to the availability of
support personnel from professional fire fighting units (city or county fire departments,
military fire control units, etc.) or trained personnel in the licensee's organization who are
available for such emergency service. In general, the onsite personnel should have sufficient
training and practice to handle all small fires, and to contain larger fires until the offsite
units arrive. When it is deemed prudent to call in the offsite units, their capabilities
should be used to the greatest extent possible. Periodic drills, involving all onsite and
offsite organizations which may be expected to respond to a fire, should be held to enable the
groups to train as a team, permit the offsite personnel to become familiar with the plant
layout, and to permit evaluation of the effectiveness of communication among all those
involved.
These drills should include operations personnel, those specifically assigned to fire fighting,
any offsite emergency control centers involved in the plan, and all those other organizations
that would normally respond to such emergencies.

## 4.0 SYSTEMS CONSIDERATIONS　システム全体の問題点

4.0　システム全体の問題点

The importance of a fire in a nuclear power station to public safety arises from its potential consequences to the reactor core and the public.

公衆安全へ対する原子力発電所における火災の重要度は、炉心及び公衆へ対する火災の潜在的な重大さに起因している。

This importance, discussed briefly in Sections 2.5 and 3.5.2, is the subject of the present chapter.

2.5 節と 3.5.2 節で簡潔に述べられている重要度は、この章のテーマである。

Systems availability during and after the fire is the subject of Section 4.1.
火災時および火災後のシステム全体の有効性は 4.1 節のテーマである。

The concepts of redundancy and the separation of redundant equipment are treated in Section 4.2.
冗長性及び冗長性のある機器の分離に関する概念は 4.2 節で扱われている。

Section 4.3 treats the application of these concepts to electrical power and control systems, how the Browns Ferry fire in the cables of these systems led to the failures experienced, and the lessons to be learned.
4.3 節は電源系及び制御系に対するこれらの概念の適用について扱っている。また、これらの系統のケーブルにおけるブラウンズフェリー火災がどのような破損を引き起こし、どのような教訓を得たのかについても述べている。

Section 4.4 discusses the related subject of instrumentation needed during an event such as a fire.
4.4 節は火災のような事象において必要とされる機器に関連がある議題について、議論している。

## 4.1 Availability of Systems During the Event　事象中におけるシステム全体の有効性

4.1　事象中におけるシステム全体の有効性

The detailed history of availability of systems as a function of time during and after the fire is given in Reference (35).
火災時及び火災後の時刻歴のようなシステム全体の有効性に関する詳細な記録は、参考文献の（35）に基づき作成されている。

During the course of the fire, numerous instruments and other equipment gave indications of unavailability.
火災の経過中、数値的な機器及びその他の機器は使用不可の表示を出しました。

Restoration to service was accomplished in some cases by alternate switching, and in some cases by installation of temporary cabling, both during and after the fire.

It is very difficult, therefore, to establish with accuracy which equipment was serviceable at what time. It is known that power was lost to all Unit 1 Emergency Core Cooling System (ECCS) equipment, including valve and pump motor controls. Additionally, many instrument, alarm, and indicating circuits were affected by short circuits and grounds when the fire burned the insulation off their cables, creating false and conflicting indications of equipment operation.

Starting about 12:40 p.m.. or about 5 minutes after the first notification about the fire to the control room, alarms began to be received on the Unit I control panel that contains the controls and instrumentation for much of the ECCS. Comparison between the indications (alarms) revealed discrepancies. For example, one panel indicated all the ECCS pumps were operating, whereas another indicated normal reactor parameters with no need for such emergency operation.

Intermittent and apparently spurious alarming continued at a lesser rate. At 12:51 p.m., the recirculating pumps tripped and the operator manually scrammed the reactor, that is, inserted the control rods to shut off the power generation. Control rod position indication was still operating at this time, and all rods were verified to be fully inserted.

The Unit I scram was initiated after many spurious alarms; the reactor power had by this time decreased from 1100 MWe to almost 700 MWe due to a decrease in recirculating pump speed from a cause unknown to the operator. The Unit 2 reactor was scrammed at 1:00 p.m., ten minutes after Unit I was scrammed and after spurious alarms had occurred on Unit 2.

At the time, the operators did not know the extent of the fire and its location was only generally defined. The operators did verify that there was no immediate threat to the safety of

the reactors, but that the fire was affecting the emergency core cooling systems.
The operators did not appear to have any specific conditions in mind which would require the
reactors to be scrammed. In fact, the reactors were scrammed only after the spurious signals
had essentially prevented further operation.
The Review Group recognizes that no hard and fast rules can be laid down in advance covering
all possible contingencies, because of the enormous number of possible combinations of events.
In fact, this is one argument for the need to have highly trained operators. Although scram is
automatically initiated for most of the potentially hazardous conditions foreseen by the
designers, the conditions at Browns Ferry were obviously not anticipated. This will be the
case for many events. The operator has a difficult decision to make under these conditions.
He must have a certain amount of reluctance to initiate a scram or he would scram the reactor
needlessly every time an off-normal signal was indicated. Then again, one of his important
functions is to initiate a scram in situations that have not been anticipated by the designer
and require the operator's thought and action.
All this being the case, the time it took the operators to scram is not unexpected. In fact,
the regulatory staff has generally applied a "rule-of-thumb" to operator actions: The design
does not require operators to respond in less than ten minutes. Automatic controls are required
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if the required response time isiless than ten minutes. The events at Browns Ferry seem to
confirm that operators need a significant amount of time to receiVe information, evaluate its
significance, make a decision, and put the decision into action. The Review Group has

no
recommendation to make in this area. This discussion is included in the report because of
earlier criticism by others of the reactor's operators (62); the Review Group does not join in
this criticism. -7
Normal cooldown was interrupted when the main steam line isolation valves closed on Unit 1 less
than fifteen minutes after scram and on Unit 2 less than ten minutes after scram. Although
isolated from the main condenser, the plants could remain at operating pressure, but zero
power, by using the standby Reactor Core Isolation Cooling System (RCIC) provided for this
situation. Each unit has a steam driven centrifugal pump which injects water into the reactor
to maintain water level. Eleven relief valves are available to control the reactor pressure by
venting steam from the reactor to the suppression pool. The relief valves are self actuating
on high steam pressure, but can also be pneumatically actuated with manual control from the
control room. This RCIC system requires only d-c control power, which is supplied from the
emergency power system. The system can operate several hours by itself before the water in the
suppression pool would get too hot; normally, a pool cooling system dumps the energy and the
RCIC can then cool the reactor indefinitely.
Operation of the RCIC system was initiated on Unit 2, but the system on Unit 1 was disabled by
the fire. The Unit 1 RCIC had started automatically earlier, but was not needed then and was
shutdown. When required later it could not be restarted, because of power failure to the
isolation valve in the RCIC steam line which prevented opening it to admit reactor steam to the

RCIC turbine. However, the RCIC can also be driven by steam from the plant auxiliary boiler.

The system is not normally connected to the boiler and this connection must be accomplished by
inserting a special piece of pipe (spool piece) between the RCIC turbine steam admission line -
and the auxiliary boiler. The piece of pipe had been used for startup tests and was available
to bolt on in an hour or less. With this capability in mind, the operators started the auxiliary
boiler, and it was ready for use by 1:30 p.m. (36). However, the spool piece was not installed, as discussed later.

The High Pressure Coolant Injection System (HPCI) is similar to the RCIC but has a larger steam
turbine driven pump, and is a part of the ECCS. The HPCI systems in Units I and 2 were disabled
by fire damage to control cables.

Both units also have auxiliary systems, which as a necessary part of their normal function can
provide water and thus cooling to the core when the reactor is at any pressure. These systems r
include the Control Rod Drive (CRD) pumps and the Standby Liquid Control (SLC) Pumps. These L
systems can be supplied with electrical power from the diesel generators through the emergency
buses as well as from offsite power.

At 1:30 p.m., forty minutes after scram, an operator stated that he knew that the Unit 1 reactor water level could not be maintained with the CRD pump then operating and that the only
other available pumps could not inject water into the reactor at reactor pressures above 350
psig. After realigning the necessary valves in the feedwater train, and determining that two
of the three condensate pumps and one of the three condensate booster pumps were running, the
four Unit I relief valves that could be manually operated from the control room were

opened and the steam released to lower the reactor pressure. During the blowdown the water level dropped to about 48 inches above the top of the core and then began to rise as the pressure fell below 350 psig, and the condensate booster pump started injecting water into the reactor. Within two hours after scram, conditions in Unit 1 had stabilized with water level maintained with a condensate booster pump and steam vented to the suppression pool through the manually actuated relief valves.

Unit 2 during this period following scram was under control, using the RCIC to maintain water level and venting steam through the relief valves even though manual operation of these valves was lost for nearly an hour. However, one hour after scram (2:10 p.m.), a relief valve apparently stuck open and the reactor pressure began to fall. The operators then decided to continue to depressurize the reactor, with the water level being maintained with a condensate booster pump as in Unit 1.

Although the condition of both reactors was stable at this time (3:00 p.m.), two hours after scram, neither reactor was in the normal long term shutdown cooling mode. The'Unit 1 reactor was venting steam to its suppression pool, which contains over a million gallons of water.

The Unit 2 reactor was venting steam to its main condenser and cooling of its suppression pool

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had been established while the reactor was being blown down (2:30 p.m.). The operators' aim, however, was to establish both reactor and suppression pool normal shutdown cooling on both reactors using the Residual Heat Removal (RHR) systems.

The Unit 1 suppression pool cooling using the RHR system was established twelve hours after
scram (1:30 a.m. March 23) and normal Unit I reactor shutdown cooling using the RHR system was
established 15 hours after scram (4:10 a.m. March 23). -7
The Unit 2 suppression pool cooling using the RHR system was, as noted previously, established
one-half hour (1:30 p.m.) after scram while the reactor was still being blown down. The Unit 2
reactor shutdown cooling using the RHR system was established nine hours after scram (10:45
p.m.).

#### 4.1.1 Redundancy of Reactor Core Cooling Equipment　原子炉冷却設備の冗長性

Reference (35) gives a detailed analysis of cooling capability and redundancy for the Unit 1
reactor core during and after the fire. The periods of significant concern were before the F
reactor was depressurized at 1:30 p.m. and between 6:00 p.m. and 9:50 p.m., when the ability
was lost to open the relief valves to reduce the reactor pressure and utilize the redundant
low-pressure pumps to add reactor water.
The rate of water addition needed decreases as the reactor core decay heat decreases with time.
The decay heat boils the water in the core, and as the steam generated leaves the reactor,
water must be put in to replace it.
Before the Unit I relief valves were opened at 1:30 p.m. to depressurize the reactor, and after
6:00 p.m., when the relief valves could not be opened, the steam generated in the reactor core
caused the reactor pressure to rise slowly. When the pressure was above 350 psi, the condensate
booster pump, although operable, could not pump at such a high pressure and so could not inject
water into the reactor. That left a single CRD pump injecting somewhat more than 100

gpm of
water as the pressure rose.
At high reactor pressure, the automatic makeup is normally provided by the feedwater system
backed up with either the steam driven HPCI or RCIC systems. On Unit 1, neither the HPCI or
RCIC were available following their unneeded operation at the start of the fire.
Besides the CRD pump on Unit 1, other installed sources of high pressure makeup were the CRD
pump on Unit 2, a shared spare CRD pump and standby liquid control (SLC) pumps. The CRD pumps,
while performing their normal functions associated with the control rod drive system, also
provide water to the vessel at high or low pressure. One CRD pump per unit is normally in
operation and the pump for Unit 1 operated continuously throughout the course of the incident.
In addition the SLC pumps are each capable of providing approximately 56 gpm of water at
pressures up to reactor coolant system design pressure. The SLC pumps were not required as a
backup reactivity shutdown system since the control rods functioned normally. An analysis of
the available evidence suggests that there was a period of up to three hours following the
initiation of the fire during which the SLC pumps were not available due to loss of power;
however, the power for at least one pump is known to have been available at 6:00 p.m., and the
other either was easily available or could have been made available, if needed, within 1 hour.
The CRD pump in operation was part of a system for Units 1 and 2 which consisted of three CRD
pumps. One pump normally operates for each unit and the third pump can be used on either unit.
Subsequent examination of the actual piping configuration confirmed that it is also

possible to
align the Unit 2 pump to provide water to Unit 1. Means also exist to increase the output of a
CRD pump by valving in a pump test bypass line which provides an additional flow path. It is
estimated that by opening this single valve it would have been possible to have provided sufficient water, approximately 225 gpm, to maintain the core covered throughout the course of
the incident. No other systems would have been required to provide water to maintain an
adequate inventory of water in the reactor vessel and depressurization would not have been
necessary. This flow (225 gpm) could have been increased to in excess of 300 gpm with an
additional CRD pump.

An additional source of high pressure water mentioned previously as being unavailable due to
fire damage was the Unit 1 RCIC system.

It would have been capable of providing sufficient flow (600 gpm) for makeup water requirements
throughout the entire course of the incident if the decision had been to make it available. It
appears that this system could have been made available within an hour after making this
decision. The source of steam for the RCIC system would have been the auxiliary boiler which
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was used for testing the RCIC prior to plant operation. Two procedures are necessary to provide the st~am path. First. the auxiliary boiler must be put into operation. Full steam
pressure from this source can be obtained in less than one hour. The operators actually put
the auxiliary boiler into operation by 1:30 p.m. (36), and it was available during the time the
relief valves could not be opened. The second procedure is the installation of a piping piece

to make up the flow path from the auxiliary boiler to the RCIC turbine. This could have been[
accomplished in less than one hour. The operation of the RCIC would then have been possible
from the backup control room; however, the system was not actuated. Instead, the action to
restore relief valve operability was accomplished in approximately 3-1/2 hours following which
time the reactor vessel pressure was once again reduced within the capability of the condensate
booster pump to inject water.

There were other courses of action which might have been taken by the operator in the event
that remote-manual operability of the relief valves was lost. No immediate problem existed
since the pressure would have increased up to the setpoints of the relief valves in their
overpressure protection mode with subsequent steam relief to the suppression pool. The CRD
pump was providing a source of makeup water. With the much reduced decay heat, considerable
time was available for other operator action: two hours at 1:30 p.m.; at least 8 hours at 6:00
p.m. The alternative sources of high pressure makeup water were still available if control air
to the relief valves could not be reestablished.

Calculations, however, indicate (35) that after 7:00 p.m. no augmentation of CR0 pump flow was
necessary to maintain the plant in a safe condition. This is due to the availability of a
depressurization and heat removal path via the main steam line drain valves to the condenser.

Both of these valves were inoperable by electrical means as a result of fire damage. The
operators, however, decided to return draining capability to the main steam line and this was
achieved at approximately 7:00 p.m. It is calculated that the quantity of steam being removedfrom
the pressure vessel through the main steam drain line was great enough that the

reactor
pressure would have leveled off at a safe value prior to reaching the relief valve setpoint.
An equilibrium condition would then have been maintained with the reduced reactor pressure
reducing the head on the operating CR0 pump such that the pump would provide sufficient makeup
flow to maintain the core covered throughout the remainder of the incident.

### 4.1.2 Role of Normal Cooling Systems　通常時冷却設備の役割

By contrast to the safety systems provided to cool the reactor core in a postulated accident,
the systems used to cool the reactor in normal operation are not required to meet safety criteria. Components of these systems--CRD pumps, condensate and condensate booster pumps, and
associated valves--were used successfully to cool the reactor during and following the Browns
Ferry fire. Redundant safety systems designed to cool the reactor in the event of failure of
the normal systems became unavailable as a result of the fire. (See Section 4.3.1 for details).
The survival of normal cooling systems when safety systems failed seems to have been the
result of the particular location of the fire rather than differences in their design criteria.
The fact that normal cooling systems kept the reactor cooled and safe during and following the
Browns Ferry fire, leads one to consider whether they should be designated as safety-related
systems. The most obvious question to ask is whether safety criteria should be applied to some
or all of the normal cooling systems. In general, the number of systems and components required to meet safety criteria is deliberately limited in number. It is generally believed
that a safer design results when an intensive safety design effort can thus be concentrated on
these relatively few devices.

The number of systems and components designed to safety criteria would considerably increase if
normal cooling systems were so designed. The flexibility of the designer to design the most
efficient and economical systems for power generation would probably be limited. It is possible
that if normal cooling systems were required to meet safety requirements, designers might have
a tendency to reduce the attention given to the safety systems which back up the normal cooling
systems. Normal cooling systems tend to be large high capacity systems, and the cost of
upgrading their designs to meet safety criteria would, therefore, tend to be large. The Review
Group believes that the increased cost of designing normal cooling systems to safety criteria
would not be balanced by a large increase in safety. The Review Group has, therefore, concluded
that upgrading normal cooling systems to meet safety criteria is not required and is not
necessarily desirable. Any required improvements in safety can be accomplished more effectively
and at less cost inother areas.

The independence of the normal cooling systems from the systems that could cool the reactor in
the event of failure of the normal cooling systems failed should be considered. In particular,
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the safety systems provided to cool the reactor should be located and protected so as not to be
affected by fires (or other events) that could make the normal cooling systems unavailable.

## 4.2 Redundancy and Separation - General Considerations　冗長性と分離性（独立性）-全般的な問題点

Redundancy is a design feature universally employed in systems that perform safety functions in[
nuclear power plants. It is defined as the provision of more than one component or subsystem,

arranged so that the system function is not halted upon the failure of a single component or
subsystem. The multiple devices are said to be redundant devices, and the "single failure
criterion" is used to govern the system design.

The reason for employing redundancy is the need for highly reliable safety functions in the
real world of pumps, valves, and other components known to be subject to failures. Perfect
components are unattainable. Improvements in the reliability of components can be achieved for
a cost, but there is a practical limit on what can be accomplished in this way. Given reasonablyr
reliable components, redundancy is generally far more effective in achieving highly reliable
systems than further efforts toward improvements in component reliability.

The large improvement predicted in system reliability as a consequence of redundancy is,
however, contingent on the independence of any failure affecting the redundant elements. That
is, the benefits of redundancy would be negated for any type of event that would induce concurrent
failures in more than one of the redundant devices. Such events are called "common
mode failures." They can arise in various ways, the most obvious of which are the following:

1. An adverse "environment" affects the redundant devices--fire, flooding with water, high or
low temperatures, earthquake.
2. An auxiliary function or device necessary to operation fails and the failure affects the
redundant devices--electric power, lubrication, cooling.
3. A human action or series of actions affects the redundant devices--adjustment, manipulation
of controls, sabotage.

The Browns Ferry fire induced common-mode failures of redundant core cooling subsystems. The
damage to power and control cables by the fire caused the equipment served by these

cables to
become unavailable for cooling the reactor core. Even during the fire, availability of some
equipment was restored, by switching actions to avoid using the damaged cables and by running
new wires to essential equipment via routes away from the fire.

One design feature which can and did lessen the operational consequences of the common mode
failures in the Browns Ferry electrical system was the capability to operate equipment manually,
principally valves, using handwheels. By contrast, the inability of the operators to open manually the (single, non-redundant) air supply valve after it failed closed contributed to the
long inoperability time of the relief valves. The air supply was made operable and relief valve operation restored by temporarily bypassing the air around the supply valve with some
copper tubing. As a result of this experience, TVA is now providing the capability to open most fluid lines manually, in the case of the air supply for the relief valves by the addition
of a manual valve in parallel with the solenoid operated air supply valve. The Review Group
recommends that in general the capability to manipulate valves manually be a design consideration
in all plants. The operability of this manual capability should be periodically checked to assure that such valves are manually operable and handwheels are not missing.

The Browns Ferry designers did not intend their design to be vulnerable to common mode failures;
the results were unexpected and contributed to the difficulties experienced during the event.

In the following sections, these cotmmon mode failures are examined for the lessons that can be
learned from them.

It should be pointed out that isolation of redundant safety devices and their cables is an ideal, not fully achievable in real life. The goal of isolation and separation requirements is
that an adequate degree of isolation be provided. The control room and the cable

spreading
room have already been identified as areas where isolation is difficult. Others are inside the
containment, in the vicinity of the reactor, and in the main electrical switchyard. The redundant subsystems and their cables are associated with a single reactor, a single containment,
a single turbine-generator, and a single control room. As with other echelons of safety, perfection is neither required nor achievable, and the safety goal is a balanced defense-indepth
rather than perfect isolation and separation.
a 33

TABLE 2

ASSIGNMENT OF DAMAGED CABLES TO REDUNDANT DIVISIONS

| Plant Usage | Number | Safety Classification | Channel or Division* |
|---|---|---|---|
| Common | 20 | Engineered Safeguard - ECCS | I |
| Units I-II-III | 20 | Engineered Safeguard - ECCS | II |
| | 13 | Engineered Safeguard - Diesel A | IA |
| | 33 | Engineered Safeguard - Diesel C | IIC |
| | 5 | Engineered Safeguard - Diesel D | IID |
| | 7 | Load Shedding - Diesel A | A1 |
| | 9 | Load Shedding - Diesel C | B1 |
| | 7 | Support Auxiliaries - Electrical | IE |
| Subtotal | 114 | | |
| Unit 1 | 6 | Engineered Safeguard - ECCS | I |
| | 182 | Engineered Safeguard - ECCS | II |
| | 4 | Load Shedding - Diesel A | A1 |
| | 5 | Load Shedding - Diesel C | B1 |
| | 1 | Load Shedding - Diesel D | B2 |
| | 52 | Neutron Monitoring (also activates RPS) | IA |
| | 52 | Neutron Monitoring " " " | IB |
| | 52 | Neutron Monitoring " " " | IIA |
| | 52 | Neutron Monitoring " " " | IIB |
| | 14 | Primary Containment Isolation | I |
| | 39 | Primary Containment Isolation | II |
| | 2 | Reactor Protection (control rod scram) | IA |
| | 2 | Reactor Protection " " " | IB |
| | 2 | Reactor Protection " " " | IIA |
| | 2 | Reactor Protection " " " | IIB |
| | 3 | Reactor Protection " " " | IIIB |
| | 12 | Supporting Auxiliaries - Electrical | IE |
| Subtotal | 482 | | |
| Unit 2 | 15 | Engineered Safeguard - ECCS | I |
| | 3 | Engineered Safeguard - ECCS | II |
| | 4 | Supporting Auxiliaries - Electrical | IE |
| Subtotal | 22 | | |
| Unit 3 | 4 | Engineered Safeguards - ECCS | I |
| | 3 | Engineered Safeguards - ECCS | II |
| | 3 | Supporting Auxiliaries - Electrical | IE |
| Subtotal | 10 | | |
| TOTAL | 628 | | |

*See Legend (following page) for channel or division definitions.

## TABLE 2 - LEGEND

The following apply to all cables:

| | | |
|---|---|---|
| I | - | Division I engineering safeguard or Primary Containment Isolation cables |
| II | - | Division II engineering safeguard or Primary Containment Isolation cables |
| IA | - | Diesel generator A shutdown logic cables (may be routed in cable tray with Division I cables) |
| IB | - | Diesel generator B shutdown logic (routed in conduit) |
| IE | - | Supporting auxiliaries needed for safe shutdown of plant |
| IIC | - | Diesel generator C shutdown logic (may be routed in cable tray with Division II cables) |
| IID | - | Diesel generator D shutdown logic cables (routed in conduit) |

The following apply to Load Shedding Cables:

| | | |
|---|---|---|
| A1 | - | 480V load shedding logic channel A1: (routed with IA-Diesel A) |
| A2 | - | 480V load shedding logic channel A2: (routed with IB-Diesel B) |
| B1 | - | 480V load shedding logic channel B1: (routed with IIC-Diesel C) |
| B2 | - | 480V load shedding logic channel B2: (Routed with IID-Diesel D) |

The following apply to Reactor Protection and Neutron Monitoring cables:

| | | |
|---|---|---|
| IA | - | RPS logic channel A1 |
| IIA | - | RPS logic channel A2 |
| IB | - | RPS logic channel B1 |
| IIB | - | RPS logic channel B2 |

The following apply to Reactor Protection cables:

| | | |
|---|---|---|
| IIIA | - | RPS manual and back-up scram solenoid channel A |
| IIIB | - | RPS manual and back-up scram solenoid channel B |
| A | - | 120V a-c RPS channels A1, A2, and A3 supply (RPS MG set A) |
| B | - | 120V a-c RPS channels B1, B2, and B3 supply (RPS MG set B) |

### 4.3 Separation of Redundant Electric Circuits　冗長性を有する電気回路の分離

#### 4.3.1 Common Mode Failures Caused by the Fire　火災に起因する共通モード故障

The chronicle of the Browns Ferry fire includes mdny examples of unavailability of redundant
equipment. Evidently the independence provided between redundant subsystems and equipment was
not sufficient to protect against common mode failures. Therefore, although the system function--
cooling the reactor core--was in fact successful (see Section 4.1.1), the multiple unavailabilities
need investigating.

Reference (37) contains a detailed accounting of the cables damaged by the fire. A summnary
listing is given here in Table 2, which is taken from Reference (37).

Separation of redundant subsystems is accomplished by dividing the safety equipment into redundant
divisions. As can be seen from Table 2, on Browns Ferry the engineered safeguards are in
two divisions, the reactor protection instrumentation in four. Power sources are also separated
into divisions. The distribution of power sources and essential equipment (power loads)
is arranged so that no failure of a single divison can interrupt essential functions.

The Browns Ferry design was intended to embody the principles of separated redundant divisions.

Yet Table 2 makes it obvious that the fire damaged cables belonging to both major divisions,
thereby inducing common mode failures. This is borne out by the chronology (35) wherein it is
recorded that redundant subsystems were unavailable. Some of the more notable examples for
Unit 1 are summarized in Table 3. In addition many redundant instruments were inoperative,
including all reactor neutron monitoring.

TABLE 3

UNIT 1 REDUNDANT SUBSYSTEMS NOT AVAILABLE

| System | Number of Subsystems |
|---|---|
| Core Spray | 2 |
| Residual Heat Removal[a] | 2 |
| Relief Valves[a] | 11 (4 restored) |
| High Pressure Coolant Injection[a] | 1 |
| Reactor Core Isolation Cooling[a] | 1 |
| Standby Liquid Control | 2 |

This result is surprising in view of the redundancy and separation that were part of the plant
design basis. TVA has conducted an extensive review of the reasons for these inoperable multiple redundant subsystems (37). The two principal causes of the common-mode failures that
occurred are discussed in the following sections. They are (1) feedback through indicator light connections, and (2) proximity of conduit to cable trays. Following technical discussions
of these two principal causes, a survey of separation criteria is given along with recommendation
for improvement.

### 4.3.2 Common Mode Failures Attributable to Indicator Light Connections 表示ランプの接続に起因する共通モード故障

Equipment status indicators are essential to correct operation. The operator must have available
to him enough information to assess the status of his plant and to supervise its operation.
A complex installation like a Browns Ferry unit--like any nuclear power unit--contains dozens
of systems and hundreds of devices. The arrangement of indicators and controls must facilitate
supervision of the operation by one or two people. The indicators are grouped and arranged to
enhance visual comprehension of the information patterns likely to be important.
Lights are used extensively to indicate the status of equipment. Their small size and easy
recognition when lit commend them to the designer and operator. The Browns Ferry

control
panels, like most panels of their type, are liberally provided with them. One use of such lights is to monitor the status of the plant's electric power system. This is especially important during off-normal operation, and should have been helpful during the fire. Unfortunately,
the damaged cables included the wires leading from the various power distribution panels to the indicator lights that were supposed to tell the operator where he could find power available for important systems. Additional damaged cables connected other indicator
lights to the control cubicles for motor-operated valves.

a For supplying water with the reactor at high pressure, these systems are redundant alternatives;
the relief valves must be coupled with low-pressure pumping.

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It is indeed ironic that provision of indicator lights to aid the operator in doing the correct
thing during an emergency led to unavailability of multiple redundant devices. The light
circuits were thought to be isolated from the power sources and safety circuits by series resistors. These resistors were ineffective because the circuit designers did not consider the
types of short circuits that actually occurred during the fire. When the cable insulation had
burned away, the resulting short-circuits among the wires in the trays fed power backwards from
the lights toward the power and control panels in spite of the series resistors, causing breaker trip coils to remain energized thereby keeping breakers open. Tripping the breakers
removed power from safety equipment and made normal breaker control impossible. This was
discovered during the fire; some power and control circuits were restored by physically disconnecting
the light circuits at the control or power panel, then replacing blown fuses and realigning tripped breakers (5). This operation had in many cases to be carried out in dense
smoke by a craftsman wearing breathing apparatus, while the panel he worked on was

energized by
normal power and by the short circuits.
Because these circuits were not recognized as potential sources of failure of safety equipment,
their cables were not separated into divisions and segregated away from non-safety cables.F
Rather, they were treated as non-safety cables whose routing and tray companions were of no
moment. Therefore, when failures occurred, there was no divisional separation and the equipment
unavailability thus induced was not confined to one division in accordance with the plant
design objectives.
Today there are better criteria for this type of circuit (see Section 4.3.4.2). Circuits of this sort would either (1) be designated as "associated circuits" and be required to meet the
same separation criteria as safety circuits or (2) be isolated adequately from the safety circuits. The Review Group recommnends that where there are interconnections between safety
equipment and nonsafety circuits such as indicator light circuits, the adequacy of the isolation
should be assured.

### 4.3.3 Proximity of Cables of Redundant Divisions　冗長区分におけるケーブル間の近接

#### 4.3.3.1 Trays and Conduit　トレイとコンジット

A nuclear power unit includes many thousands of electrical cables, some with multiple circuits.
Nearly all the control power, and much of the motive power, for the motors and pumps and valves
in the plant are electrical. The 1600 cables damaged by the Browns Ferry fire are in fact a
small fraction of the total. These cables are connecti *ons; the things they interconnect are
located throughout the plant. Therefore, there must be a system of "highways" along which are
routed groups of cables going the same way. In the Browns Ferry plant, as in most, this

function is performed principally by steel cable trays, typically 18 inches wide and a few inches deep.

Separation of redundant equipment requires separation of their associated cables, therefore separation of the trays for these cables. Grouping equipment into divisions naturally results in grouping cable trays into divisions. The Browns Ferry fire started in one of a group of ten trays, all of Division II (see Table 2). In principle, then, in accordance with design criteria, only Division II equipment should have lost availability. This was evidently not the case.

One of the reasons was the presence of Division I cables in the fire zone, in spite of the supposed separation. Upon examination (TVA has reported an extensive study in Reference (37)), it turns out that the damaged Division I cables were in "electrical conduit"--pipes of aluminum or steel also used as "highways" for electrical wires and cables.

TVA in their "Restoration Plan" (37) identified 68 places in the Browns Ferry plant where cables of one division are now deemed to be too close to trays containing cables of a redundant division. The Group has been informed that there may be more such places. TVA has now developed proposed criteria to define "too close," to be considered later in Section 4.3.4.5. They are proposing to ameliorate these 68 situations with suitable combinations, relocation, improved barriers, sprinkler protection, or other means; the details of the corrections are not within the scope of the Review Group, but are to be reviewed in connection with other aspects of Browns Ferry Licensing.

The areas of proximity were designed, reviewed, inspected, and approved that way. Running cables in conduit is considered very good practice. The conduit was provided to solve routing

problems that would otherwise call for too close proximity of divisional trays; the conduit was
to isolate the cables from their redundant counterparts.
This lesson of Browns Ferry is that the conduit in the fire zone did not protect all cables adequately. Improved criteria regarding the use of conduit are needed in the light of this lesson; recommendations are given later in Section 4.3.4.
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#### 4.3.3.2 Non-Divisional Cables　冗長区分でないケーブル

It is worth noting that many cables are not safety-related and therefore belong to no division.
At first thought, it might be believed that the routing of such cables has no safety significance.
This is true only if the non-safety cables never come into proximity with any safety cables. If they do, then the potential for interaction of the non-safety cables with those of a safety division suggests that the same non-safety cables should not come into proximity with
the other safety division(s). This concept is elaborated as "associated circuits" in present- 11
day cable separation criteria, as discussed later in Section 4.3.4.2.

#### 4.3.3.3 Cable Spreading Room　ケーブル集中室

It should also be noted that in present designs of cable spreading rooms--including Browns
Ferry--it has been found necessary to provide less separation of divisional cables than in other parts of the plant. The problem arises in the layout of the control panels for ease in
operator comprehension--an essential--rather than separation of redundant divisions. In
addition, the routing problem in the cable spreading room is severe. Cables from every part of
the control room must be routed in many different directions to their destinations in the rest
of the plant. The result is congestion in most cable spreading rooms, and Browns Ferry is no
exception. In view of the obvious concentration of cables and circuits, and the reduced divisional
separation, cable spreading rooms deserve, and receive, special attention in design and

procedures for fire prevention and fire fighting.
The installed CO system was successful in conjunction with repeated manual applications of dry
chemicals in minimizing the fire damage in the cable spreading room in the Browns Ferry fire.
The control of more than one generating unit from a single control room increases the potential
vulnerability of the cable spreading room, but has advantages in economy and operational coordination.
Criteria for cable spreading rooms need further attention and improvement, in the [
Review Group's opinion. Also needed are some varied design approaches to seek improvement in
divisional (and, when applicable, multi-unit) separation. Improved access for fire-fighting
should also be sought. Criteria for cable spreading rooms are discussed further in Section
4.3.4.4.

### 4.3.4 Physical Separation Criteria for Cables　ケーブルに関する物理的な分離要件

#### 4.3.4.1 Browns Ferry Criteria for Physical Separation and Isolation of Redundant Circuits　冗長性のある回路の隔離と物理的な分離に関するブラウンズフェリーにおける要件

The Browns Ferry design provided redundant safety equipment and circuits to prevent the failure
of any single component or circuit from causing the loss of a safety function. The FSAR states
that the overall objective of the Browns Ferry separation criteria is to preclude loss of
redundant equipment by a single credible event. These criteria are summarized in Table 4,
along with more recent improved criteria.
TVA and NRC have conducted extensive evaluations of cable separation in the as-built Browns
Ferry plant. The results, and the Review Group's review of cable tray and conduit layout
drawings, and inspection of the physical installation, showed general compliance with the

physical separation criteria documented in the FSAR. There were, however, a number of areas in
which the objective of the separation criteria appear to have been compromised.
The Browns Ferry FSAR stated that routing of safety related cable through rooms or spaces where
fire hazards exist were generally avoided. The FSAR further states that in cases where it was
impossible to provide other routing, only one division of redundant cables was permitted in any
such areas. It is clear from the cable tray and conduit routing that TVA did not consider the
reactor building in the vicinity of the fire to be an area where significant fire hazard existed.
The events of the fire show that under the conditions existing at the time a fire hazard did
exist. The potential hazard would have been lower if the seals between rooms had been in their
design condition. The non-fireproofed seal, the highly flammable flexible foam, and the candle
created the hazard and the fire resulted.
The philosophy used by TVA in the design of the Browns Ferry electric system made the actual
assignment of circuits to redundant divisions and the implementation of their physical separation
difficult. It was TVA's philosophy to provide considerable versatility in the design
which resulted in many interconnections between redundant power sources. These interconnections
really pertain to both divisions. A separate and redundant system, with no interconnections
between redundant divisions, would be easily divided into a minimum number of divisions. Each
component or cable would be clearly identifiable as belonging to its division. In laying out
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TABLE 4
COMPARISON OF BROWNS FERRY FSAR

SEPARATION REQUIREMENTS WITH
REGULATORY GUIDE 1.75

1. Requirement for use of flame retardant cable

RG 1.75 - Required

Browns Ferry Criteria - No requirements specified in FSAR. Some cable specifications require IPCEA flame tests.

2. Associated circuits must meet same criteria as safety circuits up to an isolating device F

RG 1.75 - Required

Browns Ferry Criteria - None except minor restrictions on associated circuits.

3. Separation of safety circuits from non-safety circuits

RG 1.75 - Same separation required as between redundant safety divisions.

Browns Ferry Criteria - None

4. Methods of separation

RG 1.75 - Separate Class I structures, distance, barriers
(RG 1.75 states preference for separate Class I structure)

Browns Ferry Criteria - Not discussed

5. Distance separation

5.1 Hazardous Areas (fire, missiles, pipe whip)

RG 1.75 - By ad hoc analysis

Browns Ferry Criteria - Avoid. Where not possible to avoid route only one safety division.

5.2 Non-hazardous areas

RG 1.75 - 3 feet horizontal
5 feet vertical

Browns Ferry Criteria - 3 feet horizontal. Vertical stacking avoided where possible. Where not possible 5 feet vertical separation.* 18 inches permitted where redundant divisions cross.*

*With solid metal bottoms on upper tray and solid metal top on lower tray.

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5.3 Cable spreading room

RG 1.75 - Where feasible redundant cable spreading areas should be
utilized. Otherwise provide 1 foot horizontal, 3 feet
vertical.
Browns Ferry Criteria - 3 feet horizontal and 18 inches vertical. Conduit
where separation cannot be maintained.
5.4 With use of barriers
RG 1.75 - 1 inch horizontal
1 inch vertical
Browns Ferry Criteria - 18 inches vertical
Horizontal not specified
6. Barrier material requirements
RG 1.75 - Mttal (type not specified)
Cable tray covers approved by example.
Browns Ferry Criteria - Steel cable tray covers
7. Barrier configuration
RG 1.75 - 6 inches to 1 foot overlap depending on configuration
but metal covers with no overlap are permitted.
Browns Ferry Criteria - Not discussed
8. Separation within safety divisions
RG 1.75 - No requirements
Browns Ferry Criteria - 4 inch horizontal
9 inches (tray bottom to tray bottom) vertical
9. Conduits F
9.1 Use of conduits
RG 1.75 - Same requirements as for cable trays. Not specified
as to whether they qualify as barriers.
Browns Ferry Criteria - Permitted as barriers in cable spreading
room where adequate spacing cannot be
maintained. Reactor protection and containment
isolation systems in conduits.
9.2 Conduit Materials
RG 1.75 - Not specified
Browns Ferry Criteria - Not specified
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equipment locations and cable routings the designer would need only be concerned with
keeping

one division separated and isolated from the other(s) and with avoiding areas where both divisions are subject to failure from a common cause such as missiles, pipe whip, high energy fluids, flooding, or fires. With interconnected systems, the designer has to decide whether he must keep an interconnection separated from both divisions or only one. If he decides that separation of all interconnections is not required he must perform a careful analysis to determine which interconnections can be routed together and develop an orderly method to assure that the separation and isolation is properly implemented.

The separation criteria for these interconnections were not clearly stated in the Browns Ferry FSAR. It is possible that the large number of interconnections was partially responsible for the fact that conduits for one division were run quite close to cable trays of the other division.

The complexity of the interconnected design was probably responsible for errors being made that resulted in the normal power supply to power distribution panels in one division being electrically connected to the alternate supply to panels in another division. For example, the normal supply to 480 volt shutdown board lB was electrically connected to the alternate supply to 480 volt shutdown board lB. This lack of electrical isolation introduced by interconnections provided to give increased flexibility appears to have decreased system availability in the Browns Ferry fire.

The complexity of the Browns Ferry interconnections probably resulted in errors made in the d-c controls for the 4kV shutdown boards that resulted in a power interruption on 4kV shutdown board D (37). Each 4kV shutdown board is provided with a normal, an alternate, and an emergency

supply of d-c control voltage. The availability of any two of these three control voltage sources was designed to be sufficient. In the actual installation, however, failure of a single d-c cable made the board inoperative. TVA is redesigning the boards so that each is
fully functional with a single d-c supply; alternate supplies are also being provided.
There were violations of the intent of the Browns Ferry separation and isolation criteria in .
the indicator light circuits as discussed previously in Section 4.3.2. It is often desirable to provide connections between safety circuits and non-safety circuits. Examples are connections
from safety circuits to indicator lights and meters in the control room and to the
plant computer to permit the operator to monitor the performance of safety systems. Where this
is done, present NRC criteria require that adequate isolating devices be provided in the safety
equipment so that credible faults in the non-safety monitoring circuits will not affect the safety circuits.
Although the Browns Ferry criteria do not mention conduit except for the cable spreading rooms,
the principles of physical separation and fire barriers were violated in the lack of adequate
separation of conduit containing cables of one division from cable trays of another division,
as discussed in Section 4.3.3.1. The Browns Ferry criteria require an 18 inch separation in
conjunction with steel cable tray covers in congested areas. At least one aluminum conduit
containing Division I cables was run parallel to and only 2 or 3 inches above a cable tray
containing Division II cables. In addition to violating the separation distance criterion, the
aluminum conduit proved to be an inadequate fire barrier. Based on the Review Group's discussions
with fire experts (19), the steel cable tray covers permitted by the criteria also
appear to be inadequate fire barriers.

#### 4.3.4.2 Comparison of Browns Ferry Separation Criteria with Current NRC Separation Criteria　現行している NRC の分離要件とブラ

ウンズフェリーの分離要件の比較

Section 50.55a of Title 10, Code of Federal Regulations, requires that protection systems meet
the requirements set forth in the Institute of Electrical and Electronics Engineers Standard,
"Criteria for Protection Systems for Nuclear Power Generating Stations," (IEEE 279). Section
4.6 of IEEE 279 requires, in part, that the channels that provide signals for the same protective
function be independent and physically separated. General Design Criterion 3, "Fire Protection"
of Appendix A tO 10 CFR Part 50 requires, in part, that the structures, systems, and components
important to safety be designed and located to minimize, consistent with other safety requirements
the probability and effect of fires. General Design Criterion 17 requires, in part, that the
onsite electric power supplies, including the batteries and the onsite electric distribution
system, have sufficient independence to perform their safety functions pssuming a single failure.
General Design Criterion 21 requires, in part, that the independence designed into protection
systems be sufficient to insure that no single failure results in loss of the protection function.
Regulatory Guide 1.75 (66) documents separation requirements that have been found to be acceptable
by the NRC staff. It endorses Institute of Electrical and Electronics Engineers Standard
IEEE 384-1974, but in addition modifies certain requirements of IEEE 384-1974 and provides
additional restrictions.
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Table 4 provides a summary comparison of the Browns Ferry separation criteria as documented in
the FSAR with those of Regulatory Guide 1.75. In most significant areas the Browns Ferry FSAR

criteria compare quite favorably with Regulatory Guide 1.75. The comparison is particularly
favorable when one considers that the criteria documented in Regulatory Guide 1.75 were developed
over the 7 years after the construction permits for Browns Ferry 1 and 2 were issued in 1967.
Regulatory Guide 1.75 requires the use of flame retardant cable as a basis for using the separation
distances specified in the guide. The standard endorsed by the guide defines the term
"flame retardant" as capable of preventing the propagation of a fire beyond the area of influence U
of the energy source that initiated the fire. The standard, however, provides no guidance for
testing to determine whether a specific cable qualifies as being flame retardant. The Browns
Ferry FSAR contains no criteria with regard to the flame retardancy of the cable to be used.
This subject is treated in Section 3.4.1 of this report.
The concept of associated circuits as documented in Regulatory Guide 1.75 is a recent refinement.
Associated circuits are defined as non-safety circuits that share power supplies,
enclosures, or raceways with safety circuits or are not physically separated from safety circuits
by acceptable separation distance or barriers. The guide specifies that associated
circuits meet the same separation requirements as the safety division with which they are
associated, up to and including an isolation device. Beyond the isolation device the associated
circuit is not subject to safety circuit separation requirements. The guide defines an isolation
device as a device which prevents malfunctions in one section of a circuit from causing
unacceptable influences in other sections of the circuits or other circuits. If isolation
devices meeting this definition had been provided at Browns Ferry between circuit breaker
control circuits and cables to control room indicating lights (see Section 4.3.2), the system

unavailability as a result of the fire would probably have been decreased.
Regulatory Guide 1.75 contains provisions for isolating safety cables from non-safety cables in
the same way safety divisions are isolated from each other. The Review Group believes that
this represents a significant improvement over the Browns Ferry criteria. Much of the cable L
insulation that contributed to the extent of the Browns Ferry fire belonged to non-safety
cables. Isolation of that cable from safety cables would tend to reduce the fuel involved in a
safety cable fire. In addition it would tend to eliminate faults in non-safety cables as a
potential source of a fire in safety related cables. Such isolation could be provided in
several ways, such as physical separation, solid barriers, or fire-retardant coatings.
The Browns Ferry FSAR criteria for running cables in hazardous areas--areas subject to fire,
missiles, pipe break, etc.--are more specific than those contained in the Regulatory Guide.
The guide indicates that the routing of cables in such areas are to be justified by analysis.
The Browns Ferry FSAR criteria require these areas to be avoided where possible, and where not
possible only one safety division is to be routed through such an area.
The guide and Browns Ferry FSAR criteria for routing cables in non-hazardous areas and in the
cable spreading room are quite similar although the separation distances permitted by the
Browns Ferry FSAR criteria are somewhat less.
The guide and the Browns Ferry FSAR criteria both permit the use of barriers in areas where the
required physical separation cannot be maintained. The Browns Ferry FSAR criteria are somewhat
more stringent than those of the guide. Neither the guide nor the Browns Ferry FSAR criteria
are very specific with regard to barrier material requirements. Regulatory Guide 1.75 contains
no restrictions with regard to the type of metal permitted as cable tray cover barriers.

The Browns Ferry FSAR criteria permit cable tray covers to be used as barriers. The use of conduit as barriers is vague in both the guide and the Browns Ferry criteria. The guide indicates that the same requirements apply to conduit as apply to cable trays but the use of conduit as barriers is not mentioned. The Browns Ferry FSAR criteria permit conduit in the cable spreading room where adequate spacing cannot be provided. Neither the guide nor the Browns Ferry FSAR criteria provide any restriction with regard to the conduit materials.

Recently, the TVA has proposed (37) modified separation criteria to be used for design modifications deemed to be needed for rebuilding Browns Ferry. The Review Group has not evaluated these criteria, which are evidently still being developed.

Regulatory Guide 1.6, "Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems" describes an acceptable system consisting of redundant, independent power sources and load groups. Restrictions are placed on interconnections between load groups. Although Regulatory Guide 1.6 does not specifically discuss physical separation, it describes a design that is conducive to good physical separation. A system designed in accordance with Regulatory Guide 1.6 would not contain the numerous interconnections contained

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in the Browns Ferry design, and the proper identification and separation of redundant circuits could be more easily achieved.

There was no specific regulatory guidance concerning the sharing of onsite electric systems between units and the electrical interconnections between units at the time of the Browns Ferry safety evaluation. In the Browns Ferry plant, such sharing and interconnections are

more
extensive than in most plants. The staff has more recently issued Regulatory Guide 1.81 to
provide a more orderly approach to minimizing interactions of onsite electric systems. The
regulatory position for new plants contained in Regulatory Guide 1.81 is that each unit should
have separate and independent onsite emergency and shutdown electric systems.

#### 4.3.4.3 Adequacy of Existing NRC Separation Criteria 現行する NRC の分離要件の妥当性

The basis for the present NRC separation criteria described in the previous section is that the
cables are run in a non-hazardous area and the only flammable material considered in the design
is the cable insulation. Although the Browns Ferry fire was started in flammable material
external to the cable insulation, the fire propagation in the cable trays suggests to the
Review Group that the flammability of cable insulation was underestimated in the development ofF
these criteria, which were based on a review of the consequences of past cable tray fires. The -
results of the two cable tray fires that occurred at San Onofre Unit 1 in 1968 and the 1965
fire that occurred during the construction of Peach Bottom Unit 1 were reviewed (24,38). The
results of cable tray fires in non-nuclear units were also considered (39,40). During the
development of the IEEE-384 separation criteria, fire experts of the Nuclear Energy Liability
and Property Insurance Association (NELPIA) were consulted. Other technical experts experienced
in cable manufacture and nuclear power plant design and operation were also consulted at IEEE
working group meetings. Later, the results of construction fires experienced more recently at
nuclear plants were evaluated to determine whether the criteria required modification (41-43).

It was the opinion of the NRC staff that the existing NRC guidance (IEEE-384 modified and expanded) took into account the fire experience to date and the best expert advice available.

The Browns Ferry fire has provided additional information that must be considered in a reevaluation of NRC separation and isolation criteria.

As discussed in Section 3.1.2, TVA evaluated the temperatures reached during the fire and developed a zone of influence (Figure 2) showing the area around a group of cable trays within which cables of another division might be subject to fire damage. Such a zone of influence could be used as a basis for improving the separation and isolation criteria and guidance.

Figure 2 shows that the TVA study did not establish a distance above the fire where it would be safe to run redundant cable. Therefore, criteria based on the Browns Ferry fire data would have to preclude vertical stacking of cable trays of redundant safety divisions or of conduitcontaining redundant safety circuits above trays. A single specified minimum distance for horizontal separation would also not be an adequate requirement, because the width of the zone of influence (Figure 2) varies with the distance above the reference trays.

Another point brought out by the fire concerns the concept of an area that is "non-hazardous" with regard to fire. The existing NRC guidance specifies that the minimum separation distances are permitted only in non-hazardous areas. A non-hazardous area is defined as one in which the only fire threat to safety circuits is the cable insulation. The specified minimum separation distances would not necessarily be adequate if appreciable amounts of flammable materials in addition to the cable insulation were present. The Browns Ferry fire has shown that an

area
intended to be non-hazardous with regard to fires will not necessarily remain non-hazardous for
the life of the plant. Although the Browns Ferry fire seals in their design condition might
not have constituted a significant fire hazard, the hazard was increased by removing the fire
retardant coating to install additional cables. Such a condition could result from deter
ioratlon with time, construction operations, plant modifications, or poor housekeeping.
Deficiencies observed during the inspections of the fire seals of a number of other plants (see
Section 3.4.2) illustrate that improvements in construction and operation quality assurance
programs will be required if areas designed to be non-hazardous are to be maintained nonhazardous.
Another concern with the present NRC separation and isolation criteria involves the definition
of flame retardancy of cable insulation. IEEE 384 requires as a condition for utilizing the
specified minimum separation distances that the cable insulation be flame retardant. The
subject of cable insulation and the difficulties in demonstrating flame retardancy are discussed
in detail in Section 3.4.1.

#### 4.3.4.4 Criteria for the Future　将来的な要件

The Review Group has concluded that the existing MRC separation and isolation criteria require
improvement. The Browns Ferry fire has shown a number of areas in which improvement is needed

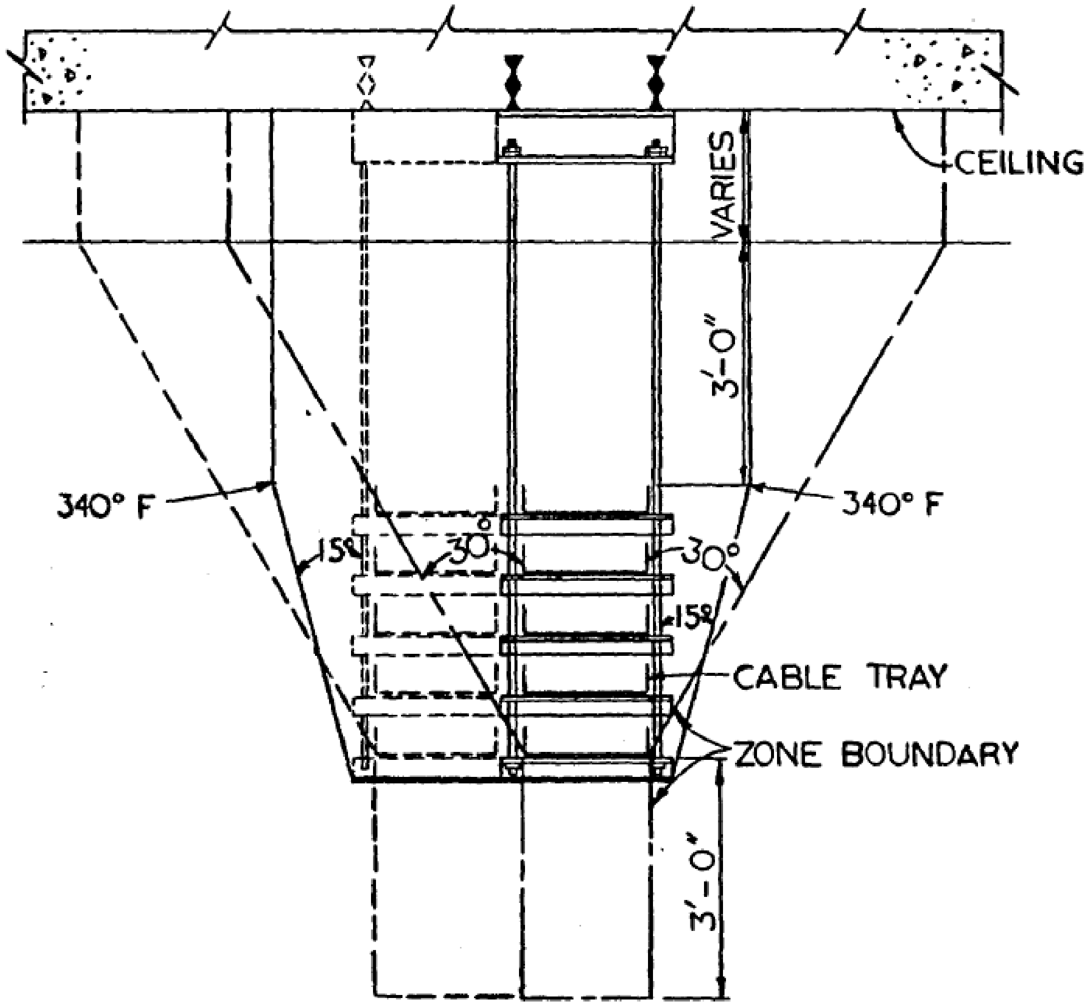


**FIGURE 2 REGION OF INFLUENCE OF FIRE IN CABLE TRAY**

These include the assumptions underlying isolation criteria, the ways in which the requirements
are stated, inclusion of conduit, and the role of fire barriers and fire retardant coatings.
The fact that operating plants and those under construction are in many respects similar in
design to Browns Ferry, indicate that a reevaluation is needed. Either of two possible basic

approaches appears to have the potential for providing the necessary improvement. One would be
to use a suitable region of influence and the other would be to locate the redundant safety
equipment in separate fire zones. A third possibility--the bunkered system--is also perhaps
worth exploring.

In developing improved isolation and separation criteria, NRC and associated organizations
should bear in mind the role of isolation in defense-in-depth, and the impossibility of achieving
complete isolation. Emphasis should be on the establishment of goals and criteria, plus methods
of implementation known to be acceptable. The Review Group views the methods discussed below
as acceptable alternative candidates for implementation. Other acceptable methods will prob
ably be devised.

Practical limitations will narrow the choice of acceptable isolation methods for existing r
plants, whereas for future plants, new and different design approaches are likely to be more
cost-effective in achieving the desired degree of isolation.

For each plant, a suitable combination of electrical isolation, physical distance, barriers, resistance to combustion, and sprinkler systems should be applied to maintain adequately effective
independence of redundant safety equipment in spite of postulated fires. The Review
Group notes that physical separation and physical barriers also offer a measure of protection
against common mode failures from adverse conditions other than fires.

・Region of Influence Approach　影響の区域アプローチ

This approach is to revise the minimum cable separation distance criteria to take into account
a suitable specified "region of influence." To establish this reference region, the validity, conservatism, and applicability of the TVA "zone of influence" should be investigated. A suitable region of influence should be developed and used to evaluate physical

separation and isolation. Where safety-related cables of one division are found to fall within the region of influence of another safety division or where more than one safety division falls within the region of influence of non-safety cable, consideration should be given to cable relocation, installation of fire barriers, or other measures such as provision of fixed automatic directional sprinkler systems. Fire retardant coatings for the cables could also be considered. Where barriers are used they should be shown to provide the necessary insulating qualities. The Browns Ferry fire indicates, and discussions with fire experts reaffirm (19), that uninsulated thin metal such as conduits or sheet metal tray covers are of questionable value as fire barriers.

・Fire Zone Approach　火災区域のアプローチ

The second approach would be to abandon the concepts of "non-hazardous areas" and minimum separation distances. Regulatory Guide 1.75 states, "In general, locating redundant circuits and equipment in separate safety class structures affords a greater degree of assurance that a single event will not affect redundant systems. This method of separation should be used whenever practical and where it does not conflict with other safety objectives." A fire in one division would not affect the redundant division because of the safety class walls and floors separating the divisions. These barriers could also be capable of withstanding fires, explosions, missiles, steam and water jets, and pipe whip. Such a concept could provide protection against other events in addition to fires.

The International Guidelines for the Fire Protection of Nuclear Power Plants (13) recommends

subdivision of nuclear generating stations into fire zones to prevent the spread of fire. The
identification of fire zones, with the requirementthat--equipment, including cables, of no more
than one safety division be located in any fire zone, would provide an orderly and effective
means of providing physical separation. The International Guidelines recommend that an inventory
of combustible material be made for each fire zone and that the appropriate fire resistance
rating be designed into the walls, floors, doors, and penetration seals to prevent the spread
of fire from one fire zone to another.

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There are advantages and disadvantages to the fire zone concept. A disadvantage is that it is
probably impractical to implement it to any great extent in operating plants or those under
construction. For nearly completed designs, even though constructibn has not begun, the cost
of implementing the fire zone concept (see Appendix D) would probably outweigh the advantages.
To be most effective, provision of independent fire zones would have to be a design objective
from the start of the design effort.
Another disadvantage is that independence of fire zones cannot be implemented completely.[
Because the redundant systems are provided for the safety of a single reactor, the concept is
more difficult to implement close to the reactor. This is probably not a serious disadvantage
because most safety related cabling is located outside the containment where fire zones can be
implemented. Inside the containment other techniques such as physical separation, barriers and
minimizing combustible materials can be used.

An advantage of the fire zone concept is that it is not necessary to place reliance on "nonfire hazard areas" and the administrative procedures needed to maintain them. Another advantage of fire zones is that sprinklers can be used without fear of the water disabling redundant safety equipment. The reluctance to use water to put out a fire involving electrical equipment7 has been a recurring theme of the Browns Ferry fire investigation. In present designs the decision of whether to use water and when water must be used is often left to the operator who may have to make the decision under conditions involving considerable stress. The fire zone design approach would make the decision easier by eliminating the consideration of water induced failure of redundant safety equipment. It also simplifies the design of automatic systems using water.

The fire zone concept has the additional advantage that it can strengthen all three levels of the defense-in-depth. It strengthens fire prevention by providing an orderly way to control and minimize combustible materials in important areas of the plant. It strengthens fire fighting in that it limits the spread of fire and permits water to be used without the concernF of disabling redundant safety equipment. It minimizes the effects of a fire by limiting it to a single safety division.

Implicit in the concept of locating redundant circuits in separate fire zones is a requirement for separate cable spreading rooms for redundant divisions. Although it has not been the practice in the nuclear industry to provide separate cable spreading rooms, the Review Group believes that providing separate cable spreading rooms can be a practical approach in

future
plants. The increased cost could be kept relatively small if the concept were adopted at the
initiation of the design. The fact that at least one U.S. architect-engineering group has a design including separate cable spreading rooms that is incorporated into a nuclear power plant
presently under construction (44) is one indication of the practicality of this approach.
Reference (45) also describes a design incorporating separate cable spreading rooms, one above
the control room and one below the control room.
The NELPIA report (65) recommiended that each unit have a separate cable spreading room. This
recoimmendation has the merit that it would tend to avoid a multi-unit outage as the result of a
single fire. Most of the advantages would, therefore, be in areas of power cost and reliability.
It is however, noted that trouble in one or more additional units as a consequence of trouble
in one unit could be of safety concern. Where possible, safety problems and hazards, and safety-related incidents like fires, should be confined to a single unit. The Review Group does not believe that the increment in safety is large enough to make separate cable spreading
rooms a mandatory requirement, even for future plants. For existing plants, changeover to
separate cable spreading rooms is impractical and unnecessary, in view of other alternatives.

・Bunkered System Approach　搭載済み設備のアプローチ

A different approach has been suggested that involves the addition of a system for shutdown
cooling totally separate from other systems. The system would have the following characteristics:
(1) isolation from all other systems in the plant; (2) fully protected against fire,
flooding, missiles, high energy line breaks, etc., in other parts of the plant; (3) selfsufficient
in that it would contain dedicated power and water sources, heat sink, and fluid and
electrical systems; (4) relatively low capacity capable of supplying shutdown cooling

with normal (or tech spec maximum) primary system leakage. Because of the high degree of isolation and protection envisioned for such a system, it has been referred to as a "bunkered" system.

An advantage of such a system is that it would be a small system with a limited number of components and limited exposure to damage and therefore could be relatively easily isolated and protected. There may be another advantage in application to some existing designs. If as the result of evaluating an existing design, the required changes such as cable tray relocation or installation of barriers between existing cables are found to be expensive or require extensive down time, installation of such a separate new isolated system may have merit. A major dis46 advantage is that the concept is not fully developed, and therefore may involve unforeseen problems. There may also be unforeseen advantages of such a system. Because of this, the Review Group has no specific recommendations regarding the relative merit of such a system, and suggests that a modest engineering evaluation of the concept might be useful.

### ・Control Room Considerations　制御室の考察

Improved isolation and separation requirements would probably place additional requirements on the design of the control room. Because redundant safety equipment is controlled from the control room, it is a natural confluence of redundant circuits. Generally, the indicators and controls for the redundant safety divisions are mounted in separate panels. To implement the f ire zone concept, the panels of each safety division would have to qualify as a fire zone, as would the general control room operating area. Because of the relatively small amount

of
combustible material in the panels and the control room, qualification as separate fire zones
would not be expected to result in a significant increase in cost. An additional cost could also result from extra cooling equipment for panels in the control room to allow them to be
thermally isolated from the control room.
There is one area where redundant circuits are presently permitted to be located in the same
panel. Where there is an advantage for ease of operation, manual control switches may now be
mounted on the same control board provided certain separation requirements within the panel are
met. Such redundant manual control switches should be separated by suitable fire barriers.
Where location in separate panels has the potential for inducing operating problems, other fire
barriers should be provided.

4.4 Instrumentation Required for Operator Action　作業員の行動に必要とされる器具類

This section discusses the instrumentation that provides information needed by the operator in
performing manual safety functions and in monitoring the operation of safety equipment. The
instrumentation discussed in this section provides a direct readout, such as analog and digital
indicators, or a graphical record, such as analog charts and printouts.
To the best of the Group's knowledge, the instrumentation that gave erroneous indications,
erratic indications or otherwise failed did not result in any incorrect operator actions at Browns Ferry. The effect of the instrumentation failures was that (1) the operators had to use
indirect and inferred methods to obtain needed information and (2) desired confirmatory
information was missing. There are a number of examples where indirect or inferred methods
were used to obtain needed information. In order to confirm that the control rods

remainedr inserted after the rod position indicators became inoperative, it was necessary for the operator to place the rod mode switch in the "Refueling" position and observe that the permissive light for rod withdrawal came on. Another example is that it was necessary to take grab samples and perform a laboratory analysis to measure radiation releases because portions of the on-line radiation monitoring system were inoperative.

The loss of all neutron monitoring for a period of time is an example of desirable confirmatory information not being available. In this case, neutron monitoring had been available at the time of the scram to confirm the expected decrease in reactor power. Process instrumentation measuring primary system and containment conditions was available from which the inference could be made that the core power was approximately at decay heat level, as expected. However, the spurious indication of high dry well temperature led to some concern during the fire but later evidence showed temperatures to have been acceptably low.

Existing safety criteria, standards and guides deal primarily with the instrumentation used as a part of automatically actuated safety systems. The NRC staff, however, has applied the relevant portions of the criteria developed for automatic safety systems to instrumentation used by the operator after an incident or accident to perform manual safety functions.

Historically, in standards, criteria, and safety evaluations, electrical and instrumentation systems and equipment have been divided into two classifications: safety grade and non-safety grade. Equipment and systems required to be safety grade are required to meet a number of stringent standards. There are criteria for determining which equipment and systems

must be
safety grade and which may be non-safety grade. A great deal of latitude is left to the industry in the design, manufacture and installation of non-safety grade systems and equipment.
The regulatory philosophy has been to classify as safety grade only those systems and equipment
essential to safety. The expectation has been that by minimizing the amount of safety grade
equipment much more attention could be focused on high quality design, manufacture, installation
and maintenance of the equipment that is truly important to safety.
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The approach to mechanical equipment has been somewhat different. A number of safety classifications
are defined. Each safety classification has its own set of requirements and standards.
The difference in approach between mechanical equipment and electrical and instrumentation
equipment has been discussed at length in industry standards groups and within the NRC staff.
The IEEE Nuclear Power Engineering Committee appointed a subcommittee to consider definitions
and requirements for other safety categories for instrumentation. Unfortunately, progress has
been slow.
The Review Group urges the NRC staff and industry standards groups to accelerate their efforts
to develop standards and requirements for instrumentation required for operator information and
action. An additional category should be considered to cover this instrumentation; the concept
of defining a minimum of systems and equipment as safety equipment should not be abandoned.
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## 5.0 TVA ACTIONS AFFECTING THE INCIDENT　事件に影響を及ぼしたTVAの

行動

In this chapter, the Review Group considers how the licensee's actions before, during and after the fire affected the result, and what lessons can be learned from these actions. Confronted by unexpected and (at the time) inexplicable plant situations and forced to work in dense smoke, the TVA operating staff is believed by the Review Group to have behaved in exemplary fashion.

As has been noted many times and places, the reactors were shut down and cooled down without damage from the fire, nobody was seriously injured, and the public health and safety were not jeopardized in any way.

The TVA organization for design, construction, operation, and QA is discussed in Section 5.1.

Section 5.2 considers how QA lapses contributed to the fire and its consequences. Actions of the operating staff are the subject of Section 5.3.

## 5.1 TVA Organization　TVA の構成

### 5.1.1 General　全般的な構成

The Tennessee Valley Authority, a corporate agency of the Fed Government, has fifteen offices and divisions of which one has overall responsibility and operates the plant, one designed and constructed the plant and two provide support services to the plant (47). The overall responsibility for the TVA power program, including the operation of Browns Ferry and other power plants, is assigned to the Office of Power. However, the plant security and radiological hygiene support services are provided through the Division of Reservoir Properties and the Division of Environmental Planning, respectively. The design and construction of major TVA projects, including Browns Ferry, is the respnsiblity of the Office of Engineering Design and Construction.

The primary responsibility and authority for reactor operation and safety is vested in the Plant
Superintendent and the plant operating staff. The Plant Superintendent assures that construction
has been satisfactorily completed and that plant systems and components meet the established
acceptance criteria before operation. He also verifies that modifications or revisions are correctly made and do not degrade plant performance or design objectives. He certifies and
implements operating procedures, work instructions, and checklists. He is also responsible for
the adequacy and completeness of the operating and maintenance logs and the training and qualification
of plant personnel. The Plant Superintendent reports to the Chief of the Nuclear Generator Branch in the Division of Power Production.

The Office of Engineering Design and Construction performs the design and construction functions
that an outside architect-engineering firm usually does for most electric utility companies.

### 5.1.2 Quality Assurance Organization and QA Program　品質保証の構成と計画

In addition to the responsibilities described in the preceding section, the various TVA organizational
units have the responsibility to assure that Browns Ferry is designed, constructed, operated and maintained to adequate standards of quality. The NRC requires applicants to
establish at the earliest practicable time, consistent with the schedule for accomplishing the
activities, a quality assurance (QA) program which complies with the requirements of Appendix B
to 10 CFR Part 50. (For a discussion of NRC activities and procedures in this area, see Section
6.2.4.)

#### 5.1.2.1 Design and Construction

The quality assurance functions for the design and construction of the Browns Ferry plant are
performed by three organizational elements. The Manager of the Office of Engineering

Design and
Construction has the overall responsibility for quality assurance during design and construction.
Reporting directly to him is a QA Manager and QA staff, which is responsible for the development,
coordination, implementation, monitoring, and maintenance of the QA program, and for auditing
all QA programs for design and construction. Quality assurance in design is executed by the QA
staff reporting to the Director of Engineering Design. This staff also audits suppliers and the
Design branches and projects.
QA in construction is executed by the Director ofConstruction. The Construction Engineer for
each project, who reports to the Project Manager, is assigned primary responsibility for quality
assurance of his project. He is assisted by the Quality Control Committee which consists of the
construction engineer, unit supervisors, and other project supervisors.
The quality assurance program for the operation, maintenance and modification of nuclear power
plants is supervised by the QA Manager and QA staff within the Office of Power. A QA coordinator
resident at each nuclear plant site reports to the Office of Power QA Manager, independent 1
of plant management.
The Plant Superintendent has the line responsibility for QA at an operating plant, subject to
audit through the QA coordinator. He executes this responsibility through the plant QA staff,
and is advised by the Plant Operating Review Committee.
The regulations pertaining to quality assurance (10 CFR Part 50, Appendix B) were made effective
in July 1970, long after the construction of Browns Ferry had begun. TVA then developed a QA
program which was intended to meet these regulations. That QA program was in effect

during the
major portion of construction and included a QA program to be followed during operation.r
The description of the Browns Ferry QA program for operations is on pages 24-30 of Appendix D,
FSAR. It was judged to be acceptable then; it would not be acceptable by today's standards.
In August 1974, TVA agreed (3) to implement an improved plan, recently developed for another TVA
facility, at Browns Ferry at least 90 days before fuel loading of Unit 3. More recently,
implementation was promised (4) in conjunction with the Restoration Plan, which includes its own
extensive QA program stated by the licensee to conform to current requirements.

## 5.2 Lapses in Quality Assurance at Browns Ferry　ブラウンズフェリーの品質保証における過失

Investigation of the Browns Ferry fire has revealed lapses in QA in design, construction, and
operation. Listed below are some of the items which should have been prevented, or revealed and
rectified, by an effective QA program:

1. The design of the fire seals was inadequate, because it was based on inadequate testing.
2. The design for the indicating lamp circuits did not provide adequate isolation.
3. The construction of some of the fire seals was not completed in accordance with the design.
4. Some openings between the control room and the cable spreading room were not sealed at all. LI
5. The testing and resealing operation (with the candle and the flexible foam) was not recognized
to be hazardous and performed with proper precautionary measures.
6. The occurrence of several small fires did rnot elicit improved precautions.
7. Operation of the CO system in the cable spreading room was known to be impaired without
adequate compensatigg precautions being taken.

Quality Assurance programs, provided to catch and rectify imperfections, are inevitably themselves

imperfect. There were many errors that the QA programs that did not catch and rectify. In a
review like this one, no mention is made of all the things that were designed, constructed, or
operated correctly, or whose errors were caught and rectified by the QA programs being assessed.
Lacking this information, it has not been possible to be quantitative about the errors or how
good the Browns Ferry QA program was. Similarly, it is niot possible to say quantitatively how
good the QA program ought to have been. It is also worth noting that the NRC (and predecessor
AEC) licensing and inspection program was not effective in catching and rectifying these errors,
either. This is discussed further in Section 6.3. The Review Group nonetheless believes that
the causes, course, and consequences of the fire are evidence of substantial inadequacies in the
Browns Ferry QA program before the fire.
Reference (49) states that a revised QA program will be used by TVA for the restoration program.
The Review Group has not evaluated the acceptability of the revised QA program, but recommends
that it be reevaluated by TVA and NRC in the light of the experience of the Browns Ferry fire.
It would be well for TVA and NRC to examine the QA lapses revealed by the fire-'and consider
whether the revised program is likely to have led to catching and fixing of these errors.
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The Review Group believes strongly in the necessity for an effective QA program at each plant.
The QA program should be a complete system and a management tool. There tends to be excessive
emphasis on records associated with QA programs. Such records are worth while only to the
extent that they facilitate and assure quality in the actual design of the plant, in the

equipment
as constructed, and in the actual operating functions.
This lesson from the Browns Ferry fire is applicable to all plants, including those operating,
under construction, and proposed. Licensees, QA programs, and NRC evaluation of these programs, 7
should be reviewed in this light. Operating QA programs in older reactors, known not to conform
to current standards, should be upgraded promptly. All licensees should review their QA programs
for the kinds of lapses revealed at Browns Ferry. The NRC bulletins sent out following the
fire (18) initiated this review. The NRC inspection program should be upgraded also. (See
Section 6.3). In particular, the licensee QA programs and the NRC licensing and inspection
programs should all include explicit reference to fire prevention, fire fighting, and consequence
mitigation in their written procedures, and these procedures should be implemented with effectiveness.

### 5.3 Plant Operating Staff　施設運転職員

Some of the lessons learned from the actions of the operating staff are discussed in other parts
of this review. These include fire fighting (Section 3.5), fire prevention and readiness (Section
3.5.5), reactor scram (Section 4.1.1), and operating QA (Section 5.2). The Review Group's
overall evaluation of the operating staff's response to the fire is given in the introduction to
Chapter 5.
In the following sections, the Review Group has found some other lessons from the incident and
how the plant operating staff coped with it.
The Plant Superintendent has the primary responsiblity and authority for the operation and
safety of the plant. Although staff and support services are provided by the other

personnel,
the Operations Section is responsible for all plant operations including pre-operational testing, fuel loading, startup, and operational testing. It also provides the nucleus of emergency teams such as the plant rescue and fire fighting organizations.
The minimum shift complement required by the Technical Specifications for operation of two
Browns Ferry units is a crew of ten. The crew consists of a Shift Engineer, two Assistant Shift
Engineers, two Unit Operators, four Assistant Unit Operators, and a Health Physics Technician.
The Shift Engineer and at least one Assistant Shift Engineer have Senior Reactor Operator licenses.
The other Assistant Shift Engineer and the two Unit Operators have Reactor Operator licenses. At the time of the fire the onsite operations organization exceeded these requirements
of the Technical Specifications.
The Emergency Plan provides for augmenting the shift complement as needed during an emergency.
A call-in system can augment the staff with off-duty staff members, including craftsmen and
specialists as needed. Outside help, such as the Athens Fire Department, is also available.
The Review Group suggests that available personnel--specifically the Athens Fire Department--
were not used as effectively as they could have been during the Browns Ferry fire. Efficient
use of this manpower would likely have freed some operations personnel for use in restoration of
some systems, although it is recognized that plant personnel would be required to guide and
assist the outside firefighters.

### 5.3.1 Radiological Monitoring　放射性物質のモニタリング

#### 5.3.1.1 Onsite　敷地内

Measurements made onsite and offsite confirmed that there was no abnormal release of radioactivity
above the small amount associated with normal shutdown.

During the fire, radionuclides released to the environs were below the plant technical specification
limits. No radiological overexposures to plant personnel or Athens Fire Department personnel occurred as a result of the fire. Reactor water isotopic analysis did not show any
changes that would indicate increased or excessive fuel leakages.
As a result of the fire, certain fixed radiological monitoring equipment was rendered inoperable.
Additionally, reactor building ventilation systems were inoperable from approximately 12:45 p.m.
until 4:00 p.m.; however, some flow through the vents was induced by natural draft. During the
fire and during the time that the reactor building ventilation system radiation monitors were
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out of service, "grab" (quick collection) samples were taken approximately every hour and
analyzed to determine the concentrations of any radioactive material being released from the
reactor buildings. Gamma spectrum analyses of samples taken inside the plant and the reactor
building ventilation ducts indicated that the only radioactive isotope of significance was rubidium-88, for which the makimium level measured was 35% of Ma~ximum Permissible Concentration
(MPC). This decreased to less than 5% of MPC when ventilation was restored after the fire was
extinguished.
Utilizing reactor building ventilation grab sample results, coupled with data from other operable
building vent monitors and stack monitoring data, dose estimates were calculated. The maximum dose in any one sector surrounding the plant was estimated conservatively to be 1.8
millirem at the site boundary. No abnormal contamination levels were found.

5.3.1.2 Offsite　敷地外

The TVA Radiological Emergency Plan (63) states that the TVA Environs Emergency

Staff shall
assist the Alabama Department of Public Health in evaluating the extent of a radiologicalr
emergency if one should occur and its effect on the population and the environment.
The TVA Environs Emergency Director is responsible for evaluating the information obtained to
determine whether a hazard exists to the public or the environment, ensuring coordination of
activities with the Alabama Department of Public Health, NRC and other appropriate agencies,
and ensuring comprehensive monitoring throughout the emergency.
The Supervisor of the Health Physics staff for TVA (who is also the Environs Emergency Director)
was notified about the plant emergency at 3:00 p.m. on the day of the fire. Environmental air
particulate samples in the environs around the plant were taken by TVA radiological assessment
personnel commencing at about 5:00 p.m. until shortly before midnight the same day. Some of
these were grab samples while others were taken from fixed sampling devices that had been in
place since March 14, 1975. Radioactivity values obtained from these samples did not differ
greatly from routine environmental sample results and approximate background levels.
Alternate, or emergency (battery) power supplies were not provided for the fixed in-plant radiological
monitoring equipment whose normal power supply was rendered inoperable by the fire.
Consideration should be given to providing alternate or emergency power supplies. Alternatively,
if portable monitors are to be used, the manpower required for this function must be included in
minimum shift complements.
TVA radiological assessment personnel in the field, conducting offsite environmental surveillance,
responded well to centralized control from the TVA Environs Emergency Center. Sample collection

and evaluation appeared to be well coordinated and efficiently carried out because of this
centralized control. However, tardiness on the part of plant personnel in notifying the Environs
Emergency Director contributed to a delay in commnencing offsite radiological monitoring activities,
which had no significance because radioactivity releases were within normal limits. Apparently,
because the fire did not fall into one of the four incident classification categories (all
associated with postulated radiological releases) in the TVA and Alabama emergency plans, a
delay of over two hours in notifying the Environs Emergency Director occurred, which in turn
delayed the start of offsite radiological monitoring activities. A "standby" classification
appears to be necessary to cover those incidents (like the fire) with potential for later triggering
one of the four major Incident classification categories.
Prompt radiological assessment in the surrounding environment is often important. In this case,
the importance was accentuated because one of the State of Alabama local air samplers at Decatur,
Alabama (downwind at the time) was inoperative and not available. Prompt radiological assessment
in the surrounding environment by TVA could also have been important because the Alabama Department
of Public Health did not field a radiological assessment team in the inmmediate vicinity of
the plant site (see Section 7.2-1)..
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# 6.0 ROLE OF U.S. NUCLEAR REGULATORY COMMISSION　原子力規制委員会の役割

## 6.1 Introduction　導入

The Nuclear Regulatory Commission (NRC) must consider the extent to which its own policies,
procedures, criteria, contributed to the Browns Ferry incident. In this chapter, the

Review
Group evaluates the actions of the NRC before, during, and after the fire and recommends some
improvements for the future.
The Review Group has consulted with cognizant NRC management during itt review, and is aware
that programs to implement recommendations contained in this report are being developed
in several areas.

### 6.1.1 Responsibility for Safety　安全性に関する責任

The NRC is responsible for assuring the health and safety of the public and the safe operation
of Browns Ferry and all other reactors. NRC provides this assurance of public safety through
the establishment of safety standards, evaluation of the safety of plants, and inspection and
enforcement programs. The licensee, TVA*, has the responsibility for the safe design, construction,
and operation of its plant within the framework of the NRC regulatory program. If
the NRC were to become too closely involved in the licensee's operations, this might have an
adverse effect on the licensee's view of his safety responsibilities. In other words, it is
the licensee's responsibility to operate the reactor safely, and it is NRC's responsibility
to assure that he does so.

## 6.2 Organization　構成

An organization chart of the NRC is shown in Figure 3. As fas as the Browns Ferry fire is
concerned, the relevant parts of the agency are the Office of Inspection and Enforcement (IE)
and the-Office of Nuclear Reactor Regulation (NRR); the Office of Standards Development has
the lead in developing standards in all areas, including those affecting the fire.

### 6.2.1 IE　調査是正部門

This organization's inspection program provides most of the onsite contact between the licensee
and the NRC. Information from inspections, routine and non-routine, announced and

unannounced,
is fed back to IE and NRR in Bethesda Headquarters as well as to the licensee management. IE
is also responsible for enforcement actions and other functions not relevant to this report.

### 6.2.2 NRR　原子炉規制部門

This organization's mission is to make licensing decisions; its output is the licenses issued,
together with their Technical Specifications and the NRC Safety Evaluation Reports (SER) that
set forth the safety assessment behind them. These licensing decisions are based on a large
body of technical information. Information regarding the design and evaluation of the particular
facility and operation under consideration is furnished by the licensee and its contractors and
suppliers in the Safety Analysis Report (SAR). This is underlain by industry and NRR knowledge
and experience with other relevant applications and analyses, together with IE confirmation of
onsite information. Research information and the technology available are the fundamental basis
for all safety evaluation.

### 6.2.3 NRC Organization - Application to Unusual Events and Incidents　緊急対策部門

While the licensee has prime responsibility for the safety of the plant and makes the necessary
decisions during and following an incident, the NRC has an overall responsibility to assure
The fact that TVA is a U.S. Government agency in no way affects its status as an NRC licensee.

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FIGURE 3
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that the licensee is fulfilling its responsibility. Both IE and NRR participate in the review of safety-related unusual events and incidents that may occur in operating reactors.

IE personnel describe their role as making sure that all requirements are complied with. IE responses to emergencies are governed by written procedures. During an incident, inspectors (onsite or in the Regional Office, as appropriate) pay special attention to the licensee's need for internal safety review and approval, as appropriate, of special operations and configurations.

Additionally, the onsite inspector must make judgments based on personal observations,

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augmented as appropriate by consultation with his supervision, regarding the acceptability of actions taken by the licensee to assure that adequate safety is maintained.

NRR personnel view their role in an emergency as providing help to IE, and through IE to the licensee, as needed and requested, in the form of information and evaluation of the licensee's response to the emergency and plant safety. NRR is viewed by both NRR and IE personnel as being

responsible for resolution of safety problems on the plant involved and recognition and resolution
of generic safety problems raised by the incident.
In the event of an incident, the IE inspector contacts the licensee and investigates. He assures
that the initial and continuing safety evaluation made by the licensee is complete and correct.
He may request aid from both IE and NRR management and technical support personnel at the Region
Office and NRC Headquarters. If the cause of the incident is understood and there are no significant
design or operational inadequacies, IE will authorize the plant to return to or continue
operation. If there are unresolved safety questions, or if changes in the Technical Specifications
or the FSAR are required, NRR evaluates the necessary changes.
As can be seen, the functions of NRR and IE during incidents follows the general division of
functions described in Sections 6.2.1 and 6.2.2.
ZE inspects, determines compliance with, and enforces regulations, license conditions, and
Technical Specifications, and reviews operating procedures and data. NRR decides on License and
Technical Specification changes that may be needed or operation outside previously reviewed or
licensed conditions.
Normally, this division of functions requires no formal direction and the actions of both groups
are coordinated through telephone conversations, meetings and memos at the various working
levels.
However, in the past, some confusion has arisen and the need to formally define the IE and NRR
responsibilities for an incident was perceived. As a result, the division of responsibilities
between the two organizations and the designation of a "lead responsibility" were set forth by
the then Director of Regulation, in a memorandum which is included in Appendix B. As

discussed
in Section 6.4.2, the division and delegation of responsibility in the Browns Ferry fire led to
a delay in an independent safety evaluation, by NRC. This indicates to the Review Group a need
for improved NRC procedures for the safety review of incidents.

### 6.2.4 NRC Organization for Quality Assurance 品質保証部門

Since quality assurance (QA) lapses played an important role in the conditions that led to the
Browns Ferry fire, it is instructive to set forth the procedure used by NRC to evaluate licensees'
QA programs today. The NRC review of the Browns Ferry QA program predated this procedure and is
discussed in Section 6.3.2.

Appendix B to 10 CFR Part 50 contains the NRC QA criteria; it is supplemented by a number of
Regulatory Guides, ANSI Standards, and NRC Standard Review Plans.

Present-day QA review activity by NRC begins approximately one year before application is made
for a construction permit (CP). At that time, representatives of IE and NRR visit a prospective
applicant and discuss QA requirements. When the Preliminary Safety Analysis Report (PSAR) is
submitted for review for docketing, an intensive 9-day review by NRR of the QA program for
activities already under way (design and procurement, mostly) is followed immediately by an IE
inspection of the actual implementation of the program. Acceptability of the application for
docketing is not adjudged unless and until the QA program is satisfactoiry. The reason for this
early attention is the applicant's need to design and purchase long-lead items long before
actual onsite construction begins.

NRR review of the PSAR includes the QA Program described and the IE inspection record of QA performance of the applicant and his vendors and contractors on other plants. IE again inspects the QA procedures and implementation as applied to ongoing work before a CP is granted.

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During construction, IE inspections include QA aspects of major activities. Chapter 17 of each applicant's Final Safety Analysis Report (FSAR) is required to lset forth the proposed QA program for station operation, including operation, maintenance, repair, refueling, and modification. This proposed program is reviewed in NRR for compliance with rules and acceptability as a framework. IE inspectors review the program details and assess its implementation, both by auditing and spot-checking the procedures and other paperwork and by reviewing its application to other reactors owned by the licensee at the plant being reviewed and at other plants, and to the reactor under review during preoperational testing.

The Review Group believes that licensee QA is central to implementing licensee responsibility for the safe operation of his reactors. The efficacy of the operating QA program in actually achieving safety in operation depends not on the quantity of paper produced by the program but on whether it is actually used to perform its functions.

### 6.2.5 Evolution of Regulatory Requirements　規制部門

The preceding discussions of organization and procedure are based on practice at the time of writing (Fall 1975). The NRC procedures described differ somewhat from those earlier applied to Browns Ferry, but the differences are not significant to the lessons to be learned from the incident. By contrast, differences in safety technology and acceptance criteria of the present

day from those used for review of Browns Ferry are highly significant.
In general, knowledge and understanding increase with experience. The experience obtained from
the design, construction, and operation of numerous reactors between 1966 and today has led to
the changes in criteria. This review and the changes resulting from implementation of its
recommendations will be another step in the learning process.
For each increment of new knowledge, it is necessary to decide whether it must be applied to
earlier, plants. Guidance is provided by the Commission's regulations, 10 CFR 50.109:
"(a) The Coimmission may, in accordance with the procedures specified in this chapter,
require the backfitting of a facility if it finds that such action will provide substantial,
additional protection which is required for the public health and safety or
the common defense and security. As used in this section, "backfittlng" of a production
or utilization facility means the addition, elimination or modification of
structures, systems or components of the facility after the construction permit has
been Issued.
"b) Nothing in this section shall be deemed to relieve a holder of a construction permit r
or a license from compliance with the rules, regulations, or orders of the Commission.
"(c) The Commission may at any time require a holder of a construction permit or a license
to submit such Information concerning the addition or proposed addition, the elimination
or proposed elimination, or the modification or proposed modification of
structures, systems or components of a facility as it deems appropriate."
In the following discussions, therefore, and in its recommendations, the Review Group has been
mindful of changing criteria and has tried to explain clearly the time frame for each consideration
where this is relevant.
Each of the Review Group's recommendations that is relevant to existing plants is evidently a
recommendation for backfitting. Implementing such a recommendation must be decided plant-byplant,
using the criteria just cited. The actual measures taken on each plant will depend on

the plant design as it exists, and also on the nature of the improvements that are deemed to be
needed. In each case, it would be expected that there exist alternative means of achieving the
desired results. The Review Group's recommendations are not intended to specify or foreclose
any alternative, but rather to delineate the need for changes and their objectives.

### 6.3 NRC Action Before the Fire　火災以前の NRC の行動

The licensing history of the Browns Ferry Nuclear Station is given in Reference (48).

As with all power reactors, the Browns Ferry units underwent detailed safety assessments before the construction permits (CP) were issued and again before the operating licenses (OL) were issued.

Units 1 and 2 received OLs on June 26, 1973, and June 28, 1974; Unit 3 is not yet licensed to operate.

The OL review process includes detailed review of Licensee-furnished information and analysis by the NRR staff and by the independent Advisory Committee on Reactor Safeguards.

The results of this assessment are given in the SER (48).

Development of Technical Specifications and their bases proceeds during this time.

The Technical Specifications establish the limiting conditions and parameters governing the entire operation of the plant, plus reporting requirements.

Reference (60) is a collection of NRC inspection documents that constitutes an inspection history.

Periodic inspections covered the Browns Ferry construction, operation, and QA program.
As each unit neared completion IE inspections additional to those associated with plant design and construction were directed to the operating QA program, audit and review of the operating procedures including emergency procedures, review of the preoperational

and hot functional tests, culminating in a finding by IE that the unit had been constructed in accordance with the FSAR, that the operating organization and procedures were in order, and that the plant was technically ready for operation.

This finding by IE plus the favorable safety evaluation by NRR were the basis of each OL.

Since some aspects of the facility design, the QA program, the operations by the licensee, and the execution of the Emergency Plan have been found wanting (see earlier chapters and the IE (Investigation Report), it is instructive to consider how this took place, and whether future improvements in NRC activities could decrease the liability to such lapses in the future.

A discussion of NRC criteria related to fire prevention and control is given in Section 3.2. At the time of the Browns Ferry licensing reviews, very little was available in the way of criteria or guidance.

This was mirrored by the absence of significant attention to fire prevention and control in both licensing review and inspection programs until more recently.

Thus although some attention was paid to mitigating the consequences of fires, the NRC program in fire prevention and control was essentially zero.

More recently, too late for the Browns Ferry design, the NRC program has made some progress, and still more improvement is planned for the future.

Information regarding fire prevention and control is now called for in SARs; Regulatory Guide 1.70, issued in September 1975, sets forth this information requirement.

Guidance for regulatory review of fire prevention and control is now given in Standard Review Plan 9.5.1, "Fire Protection System," (April 1975) which includes detection, extinguishing systems, assistance from offsite fire departments, structural design of fire prevention systems, control of combustible materials, and operating considerations.

Criteria for separation of redundant electrical cables, to mitigate the effects of any fire that might occur, are under development as discussed in Section 4.3.4. Some research programs related to fires in electrical cables are discussed in Section 3.4. In addition to the Bulletins and inspections (18, 23, 52) after the fire, IE has revised inspection plans to include prevention and control in the NRC inspection program.

At the present time, therefore, NRC has programs in fire prevention and control research, standards and criteria, licensing, and inspection.

The Review Group believes that these efforts should be continued, expanded as needed and as recommended in various sections of this report, and coordinated to form a more coherent regulation program for fire-related matters in a timely manner.

### 6.3.1 Design and Operating Criteria　設計及び運転時における要件

The facility apparently conformed to applicable criteria and guides when it was approved, yet design deficiencies are now apparent.

Some criteria and guides are now known to need improvement, and also the conformance was not complete in some cases.

The need for improvement of design and operating criteria and guides in various areas is discussed at some length in the technical parts of this report.

A list of the areas is as follows:

1. Fire prevention: establishment of design basis fire; application to fire zone rating and protection requirements (Sections 3.3.1 and 3.3.2).

2. Comprehensive standard for fire protection design criteria (Section 3.2).

3. Development of standard combustibility tests for cables, seals; acceptance criteria (Sections 3.4, 3.4.1 and 3.4.2).

4. Development of tests for effectiveness of coating materials to decrease cable fire hazard (Section 3.4.1).

5. Development of standard tests and acceptance criteria for fire detectors (Section 3.5.1).

6. Development of standards for ,fire protection and other aspects of ventilation systems (Section 3.5.3).

7. Development of standards for conduct and evaluation of fire fighting drills (Section 3.5.5).

8. Improved criteria for physical separation of redundant cables (Section 4.3.4); region of fire influence, fire zones.

9. Standards for intermediate quality class of instruments (between non-safety and IEEE-279) for post-accident monitoring (Section 4.4).

### 6.3.2 Quality Assurance　品質保証

The Browns Ferry QA program for operations is on page 24-30 of Appendix D, FSAR. It was judged to be acceptable then; it would not be acceptable by today's standards.

In one sentence, the SER (48) finds it "meets all the requirements" of 10 CFR Part 50, Appendix B, the only guidance then available.

As described in Section 5.1.2.1, the TVA program for QA at Browns Ferry is being upgraded.

It takes time to write, staff, and implement a substantially improved QA plan.

But the length of time NRC has allowed TVA for development and implementation of the upgraded program seems excessive to the Review Group.

In view of the great importance of operating QA to the maintenance of safety, the Group recommends that NRC proceed promptly with any remaining QA upgrading needed now in operating reactors.

### 6.3.3 Inspection of Licensee Operations　運転許諾者の運転手順の視察

The fire revealed operating deficiencies.

Examples cited in the NRC Investigation Report (5) include failure to coordinate adequately the fire-fighting activities, the efforts to restore equipment operability, the activities construction and operating personnel performed during the fire.

These deficiencies, of course, could not have been specifically evaluated by NRC in spectors prior to the fire.

Other deficiencies included inadequate communication and management response to several previous small fires.

To the extent that these deficiencies might have been reflected in written procedures, routine operating activities, or poor operating practices, they should have been observed and evaluated by NRC inspectors.

For many of the items cited above, there are no clear cut requirements or regulations against which the inspector can compare the licensee's performance.

The statements that operators should "do a good job" or that activities involving various parts of site organizations should be "well coordinated" are general and provide no specific basis for inspection.

Additionally, individual items which might indicate departure from good practice or safe operation may not of themselves be of sufficient importance to require strong remedial action.

On the other hand, inspectors can and do identify general areas of poor performance or marginally safe practices, but without specific requirements, enforcement actions are very difficult to justify.

Reference (60), the inspection history of Browns Ferry, contains a number of examples of an NRC inspector pointing out areas that he considered to be poor practice.

Although most of the examples of poor practice did not contribute to the Browns Ferry fire or its consequences, they do illustrate an inspection difficulty.

In many of these cases there were no applicant commitments, NRC requirements, or applicable industry standards to support the inspector's contentions.

In these cases, the NRC inspector requested guidance from NRC Headquarters.

The documented response to the inspector's requests contained in Reference (60) is undoubtedly not as specific as the inspector would have desired.

The Review Group understands that additional oral guidance was provided. In many of the areas discussed by the inspector, and many others, enforceable, documented guidance on "good practice" is still generally unavailable.

It is stated by IE to be present practice to resolve issues raised by inspectors and to document the resolution.

Inspectors are more effective when there are enforceable criteria and requirements against which to inspect.

Industry standards have been developed and adopted by the NRC staff covering areas of good practice that were not available for Browns Ferry.

The Review Group recognizes, however, that inspectors will continue to have difficulties because enforceable standards of good practice will not be available in all areas.

Inspectors will continue to identify instances they consider to be poor practice.

Although there are procedures for these issues to be resolved by NRC management, these procedures should be reevaluated.

In the reevaluation, the NRC staff should determine whether the procedures are effective in providing prompt incorporation of good suggestions into the inspection and enforcement program and into the licensing review.

The Review Group believes the inspectors' lack of attention to fire protection reflected a similar lack in the licensing safety evaluation.

Construction permit safety evaluations now being performed in accordance with the Standard Review Plan include much greater emphasis on fire protection than was the case in the Browns Ferry safety evaluation.

Efforts are now underway to modify the Standard Review Plan to take the Browns Ferry fire experience into account.

Present and future safety evaluations provide more specific fire protection requirements and criteria for the inspector to inspect against.

The inspection program is being expanded to reflect the improved licensing review of fire protection.

### 6.4 NRC Action During and After the Fire　火災時及び火災後の NRC の行動

Much of the information on which this section is based came from personal conmmunications from
the NRC personnel involved to one or more members of the Review Group.

#### 6.4.1 During the Fire and the First 24 Hours Afterwards　火災時及び最初の 24 時間

The IE Region II duty officer was notified at 4:00 p.m. by the licensee and inspectors were
dispatched to the site. They arrived late that evening. The NRC Region Office in Atlanta is
relatively close to Browns Ferry. Other offices, especially in the West, are farther from some
of the reactor sites. Therefore, even using the fastest transportation available, several hours
will, in general, be the minimum time required for inspectors to reach a site after being notified.
It would be desirable to develop alternate modes of transportation for emergency use to ensure
that undue delays are not encountered.
As far as the Review Group was able to judge, the NRC inspectors at the site and in the Region
II Office carried out their mission during and immediately following the incident in an exemplary
fashion.
The group of JE and NRR management and technical personnel gathered at NRC Headquarters had a

mission principally precautionary and informational in nature. They quite properly believed
that their role was to stay knowledgeable as the incident ran its course, to consider various
alternatives available for various possible contingencies, to act as a source of information to
government people, and to be helpful to Region 11 or the licensee if needed, e.g., for technical
consultation.' Reference material was quickly assembled accessible to a Headquarters emergency
center, to be ready in the unlikely event that Headquarters action would be needed. In this
incident, since no need was indicated, the only consideration for the Review Group is the test
that was performed of the system by the event.

The Group believes that the Headquarters cadre actually assembled on March 22-23 was knowledgeable
and functioned well. It is not clear that qualified back-up personnel would have been available
in the unlikely event the emergency had been significantly prolonged. The Group suggests that
some attention be given to assuring that enough management and technical talent are available so
that unexpected prolongation of an incident will not find the Headquarters cadre too tired to
function as well as it could.

The use by NRC inspectors of commiercial public telephone commnunication from the site to Region
Headquarters was not always satisfactory in this incident; telephone lines were in short supply.

At other sites, there may not be any phone lines available to NRC inspectors during an incident
or emergency.

There is no ideal solution for the communication problem. The onsite staff is struggling with
the fire or other incident, but there are many people who need current information for

readiness
and/or action. On paper, the chains for information look great. (Two such chains are (1) Plant
operators - TVA Central Emergency Control Center (which has parts in three different locations)-
press and local governments; (2) Plant operators - onsite NRC inspectors - Region Il Office -
NRC Headquarters - government officials.) The well-known game of "password" shows how poorly
information is transmitted through such chains. Section IV of the NRC Inspection Report tells
of some specific shortcomings. The Review Group was informed of one instance where two people
at Region II Headquarters were receiving contradictory information on telephones, one from the
NRC inspector at the site, the other from the TVA center.
The Review Group believes that improved communications facilities are feasible and should be
provided. The Group has been told that transportable (suitcase) two-way radios are being considered
for purchase. The Group recommends that the problem deserves a deeper study and more
expertise than it is able to bring to bear on it, and that a systems study (who should communicate
with whom, when and how?) is at least as important as purchase of equipment to supplement
the demonstrated problems of relying on public telephone lines.
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During the incident, the safety decisions were made by the plant operating staff, as is proper.
Presumably, If the NRC onsite inspectors, Region I1 Office staff, or the Headquarters cadre had
felt the need of questioning any decision, this would have been communicated to the operating
staff with whatever force or urgency would have been appropriate. The Review Group is

not aware
of any such communications during~this incident. The Group has no recommendations for any
change (except improved communitations) in this NRC approach to safety during the course of an
incident. Distance, inevitable communication and information difficulties, and the unexpected
things that occur, mandate the ad hoc, responsive, admonitory NRC stance. One does the best one
can in the circumstances; the Gi-u-Felieves that the NRC groups did very well.

### 6.4.2 After March 23, 1975　1975 年 3 月 23 日以降

During the first 6 weeks of this period, IE had the lead responsibility for NRC action on Browns
Ferry. A group of NRC inspectors were detailed to the site throughout this period; during
critical times, around-the-clock inspection coverage was maintained.
The role of the onsite inspectors, as perceived by them and their management, is to stay knowledgeable
about what is going on--to watch and communicate with the licensee and with Region II
Office and NRC Headquarters. The inspector should be as helpful as his judgment and his primary "
responsibility allow, without infringing the licensee's safety responsibility. The Review Group
understands that a certain amount of admonishment of licensee staff by the inspector is par for
the course. The inspectors also feel a responsibility to have an informed opinion about the
safety of the plant and to communicate this view to their management.
After the Browns Ferry fire, an important and time-consuming Job for the inspectors was to
conduct the NRC investigation, which was started immediately. The Investigation Report includes
the reports of 171 interviews with participants in the incident. Another job was keeping Headquarters
informed regarding-the still-changing status of the plant, and relaying information
about the incident (as it was uncovered and pieced together) to the concerned and

curious.

It is the Review Group's impression that the onsite inspectors were very concerned with plant safety, and took pains to stay informed. As temporary repairs were made and safety readiness was improved, the inspectors expressed increasing concern that procedures should be implemented for developing, reviewing, approving, and documenting any changes. Concern was also expressed regarding the potential for unreviewed "improvements" to decrease the overall safety of the facility. The inspection team at the site included technical specialists (operators, electrical, instrumentation) as needed.

However,-an IE management individual has stated that the inspection function needs the added technical evaluation capability of NRR as part of the NRC effort in an emergency and its after- r math. For this reason, even during the first few hectic days, the inspectors at the site con- L sulted with NRR staff regarding plant safety and the acceptability of some proposed changes. In this view, IE does not have the ability to do a complete technical review of plant safety. The continuous informal consultation between IE and NRR staffs is needed so the inspection and the licensing staffs can each perform its function. (See Section.6.2.3).

Beginning with the NRC inspectors at the site on the evening of March 22, the NRC evaluation of the safety of Browns Ferry changed with time in accordance with the needs for safety assessment and decisions. The onsite inspectors and the cadres at both the Region Office and the NRC Headquarters followed closely the safety problems of the fire and its early aftermath. NRC Headquarters personnel visited the site for firsthand briefing on March 24. Other visits

followed
for investigation and safety review.
The evaluation and monitoring of both the safety of the plant and the response of the licensee
continued with IE taking the lead responsibility.
NRR staff members consulted viewed their role as helping IE, who "had the lead responsibility."
In the view of most everyone the Review Group talked with, NRR was indeed helpful to IE during
this period, but was most careful not to "take the lead." Although IE was generally aware of
the safety of the plant, neither IE nor NRR conducted anything like a complete technical review
of the safety of Browns Ferry during this interval.
On April 15, TVA requested changes in plant technical specifications stated to be necessary
because of the fire. Minor changes were proposed to the Limiting Conditions for Operation and
an associated section of the Surveillance Requirements, and were generally intended to describe
more properly the actual plant status and capabilities. Normally, request for changes in
Technical Specifications would be reviewed by NRR and accepted, rejected or modified. However,
in this case, NRR took no immediate action.
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The prevailing view in NRR appeared to be that none should be taken until IE transferred the
"lead responsibility" or identified the portions of the problem to be handled by NRR in accordance
with the previously discussed memo concerning lead responsibility. (See Section 6.2.3).
Although NRR took no action relative to the immediate status of the plant, on April 17, the
Acting Director of NRR sent a letter to TVA, setting forth information requirements and conditions
that would have to be fulfilled before TVA would be permitted to begin the various steps
of reconstructing the plant. These information requirements included TVA design

information and
safety analysis for the proposed changes involved in each step. The amendments to the license
and the technical specifications, their TVA safety analyses (3), and their NRR safety evaluations
(9), are the results so far of this effort.

A decision to turn over lead responsibility was made and finally accomplished on May 5, 1975.

Just prior to and in anticipation of the turnover, NRR personnel went to the plant with the
purpose of reviewing the safety of the plant in detail. As a result, numerous changes were made
to the Technical Specifications just after the turnover of lead responsibility. These changes
were not trivial. They included the following: F

1. Testing of Unit 3 equipment was stopped until the evaluation of the effect of such testing
on Units I and 2 could be made.
2. Certain changes needed to improve plant safety were required to be implemented promptly.
3. Routine maintenance proposed by TVA for core cooling equipment to take advantage of the
forced outage was not allowed.
4. Requirements for monitoring instrumentation and periodic surveillance were revised to be
consistent with the plant configuration.
5. Requirements for availability of safety equipment and energy sources were revised consistent
with safety needs of the shut down reactors and with the plant configuration.
6. The required shift operating complement was increased to account for the many remote manual
safety operations made necessary by the fire damage.

These revised technical specifications deemed by NRR to be needed would have been just as valid
before the "transfer of lead responsibility" as after. Although some of the information which

formed the basis for the Technical Specification changes was developed over a period of time after the fire, most was certainly available well before the changes were made. Thus, the Review Group believes that there was an unnecessary delay during the six weeks of March 22 - May 5 before the detailed safety review of the post-fire configuration and the concomitant specification changes were accomplished.

After NRR accepted "lead responsibility," the NRR licensing and inspection functions and interrfaces caused no unusual problems. The Review Group has not evaluated the TVA proposals and NRR evaluations that constitute part of the still incomplete licensing process for restoration of Browns Ferry. Neither has it probed any further into the concomitant inspection program.

It is evident to the Review Group that the division of responsibility between NRR and IE did not function adequately during the period just after the Browns Ferry fire. Whether the failure occurred because of or in spite of the management directive regarding lead responsibility is unclear. In any case, someone should have seen to it that a complete evaluation of the safety of the plant was performed no matter who may have been designated as having "lead responsibility."

The Review Group recommends that the procedure followed by NRR and IE in evaluating the safety of the Browns Ferry plant from March 22 to May 5 be revised so as to ensure more timely, comprehensive and detailed safety evaluation of a plant in difficulties. The concept of "lead responsibility" should be clarified, to delineate how the ongoing licensing, inspection and reporting responsibilities are to be coordinated and where the decision making lies. Consideration

should be given to designating a named individual to be in charge of an incident review. For the Browns Ferry incident, there was an IE Chief Investigator, an NRR Project Manager, an -
NRR Task Force Leader, and an NRR Task Force Coordinator--plus a Review Group Chairman.

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# 7.0 RESPONSE OF OTHER GOVERNMENT AGENCIES　他政府機関の反応

## 7.1 Summary　概要

The TVA Radiation Emergency Plan was implemented at 3:20 p.m., March 22, 1975, to the extent
that TVA notified designated State agencies, which in turn notified local government personnel
and principal support agenices. Several individuals could not be contacted, particularly at
the local level, and the States' attempt to notify these local officials was stopped in less than one hour after it commenced.

No action was required of any one except for initiation of environmental air sampling around
the site by the State of Alabama Environmental Health Laboratory. TVA radiological assessment
personnel conducted radiological monitoring in the immnediate vicinity of the plant environs.r

The State of Alabama conducted air sampling by devices located several miles from the plant
site. No radiation emergency existed.

## 7.2 State Governments　州の行政機関

### 7.2.1 Alabama　アラバマ

According to the Alabama Radiation Emergency Plan (64), the State Health Department will determine
the classification of an incident in one of four categories, all based upon varying degrees of radiological release from the facility. The Alabama Department of Public Health, located in
Montgomery, has the responsibility to maintain liaison with the Browns Ferry operators and to
keep the State of Alabama Civil Defense Department informed of planning and

emergency conditions.
The Health Department is responsible for all radiological and health aspects pertaining to an
incident. The Civil Defense Department coordinates all activities of other supporting State
and County agencies involving actual operations (evacuation, etc.).
On March 22, 1975 at 3:20 p.m. (over 2 hours after the start of the fire), the Director of Radiological Health for the State of Alabama Department of Public Health (DRH) was notified by
the TVA Environs Emergency Director located at Mussel Shoals, Alabama that the Brown's Ferry
nuclear plant had a fire in the cable spreading room and that both operating reactor units had
scrammed. An attempt was made to notify the State Health Offices at 3:40 p.m. without success.
At 3:45 p.m. the Alabama DRHl notified the Alabama Civil Defense Department and subsequent toF
that the "Tni-County" Health Officer, of the fire and also that there had been no release of
radioactive materials. The tni-counties consist of Limestone, Lawrence and Morgan Counties.
The State Civil Defense Department was advised that radiation levels were not above permissible
levels but that the Civil Defense Department emergency plan notification procedures should be
carried out. The "-duty" representative attempted to contact the State Civil Defense Director
or his assistant and the three local government (county) Civil Defense representatives and
sheriffs. He was only partially successful and the "duty" representative discontinued all notification attempts after less than one hour from having been notified. Alabama and the
involved local governments should reassess and strengthen notification methods and procedures
between State and local government agencies who may be called upon to respond to an emergency.

Periodic contact with exchanges of information Was maintained between the Alabama DRN and the
TVA Director of the Central Emergency Control Center (CECC) during and subsequent to the fire.
Sometime between 4:45 and 9:45 p.m., the Governor of Alabama was notified by the State Health
officer. The Governor's main concerns were: (1) whether or not additional State resources
were needed, especially the National Guard; (2) availability of adequate electrical power in
northern Alabama; and (3) whether or not sabotage was involved. The Governor was informed that
no additional resources were required; electrical power was adequate, and that the cause of the
fire had not been determined as of that time.
The Alabama Highway Patrol was not officially notified by the Department of Public Health or by
TVA. A representative of the Highway Patrol did become aware of the fire via local police
radio and offered his assistance to security guards at the site but no action wa-s requested.
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Since there was no release of radioactivity. and the incident was not of in a type clearly classified the TVA and State emergency plans, standby action was not required of many of the offsite support agencies. The Alabama DRH did perceive that the core cooling system was degraded and
that it must be watched, the ability to monitor plant leakage was questionable, and that confirmation
was needed that the main steam isolation valves had indeed been closed.
A "standby" classification appears to be desirable to cover incidents like the fire that have a potential for triggering one of the radiological accident classification categories in the
emergency plans. This "standby" classification would require that the licensee notify the principal State or local agency of the plant status, and would recommend that the pertinent
offslte agencies who would be required to respond to a particular emergency be

contacted,
appraised of the situation, and directed to assume an alert condition until further notice.
They would remain in this condition until either the plant was verified to be in a quiescent
condition or one of the radiological accident classification categories was realized, requiring
further action by offsite emergency response personnel.
Response on the part of the State Department of Public Health (specifically the DRH) appears to
have been basically in accordance with the provisions of the State Radiation Emergency Plan.F
However, environmental air surveillance around the plant site by the State did not commence
until sometime shortly before 5:45 p.m. when the Alabama Health Laboratory Director reported
that environmental air sampling was being conducted at the Athens Water Treatment Plant, the
Athens Sewage Treatment Plant in Hillsboro, and in Rogersville, Alabama. These locations are
several miles from the plant site. An air sampler owned by the State had become inoperative
and was removed for repair from the Decatur, Alabama air sampling station, which was In the
downwind sector from the plant. No replacement sampler was immediately available but at about
9:00 p.m. on the day of the fire, air sampling was instituted at this station using an air
sampler from another State agency (Air Pollution Control Commission). On March 24th, the State
collected water samples and milk samples from areas surrounding the site. Thermoluminescent
dosimeters located at fixed monitoring stations around the plant site were collected and analyzed.

### 7.2.2 Tennessee　テネシー

The Tennessee Department of Public Health (Assistant Director of Radiological Health - ADRH) was notified of the Browns Ferry fire at 8:15 p.m., March 22 from the CECC. He was told by the CECC representative that a fire in the cable tray room had "wiped-out Units 1 & 2."[1] The CECC representative also advised the Tennessee ADRH that the first and second alternates for core cooling were "gone" and the third alternate was considered. The Tennessee ADRH was also told that one alternate for the core cooling system left was to pump river water through the reactors and circulate it to and from some ditches for cooling. He was also told that smoke was everywhere.

The Tennessee DRH notified the Tennessee Civil Defense Department concerning existence of the fire. The Tennessee ADRH contacted the Alabama DRHt at 8:35 p.m. and exchanged information concerning the fire.

Tennessee Department of Public Health officials were unduly alarmed by the unfortunate language used by a CECC representative to describe the incident. CECC spokesmen need to use more careful phraseology in communicating the facts surrounding any incident without inciting undue alarm or apprehension on the part of offsite agencies.

Neither the NRC or any other Federal agency has any legal authority to require that State and local governments develop or improve Radiological Emergency Response Plans in support of fixed nuclear facilities. NRC regulations require that the nuclear facility licensee prepare an emergency plan and that an emergency preparedness interface be developed among the nuclear facility and of State and local officials and agencies.

However, the regulations stop short of requiring plans of the States and local governments themselves. The approach of NRC and other Federal agencies toward solving this problem has been to provide training, publish emergency planning guidance and persuade the States

and local
governments to accept and follow the emergency planning guidance.
A Federal interagency group with responsibilities for nuclear incident emergency planning
conducts training programs for State and local government personnel.
The NRC, which has lead agency responsibility for helping States develop radiological emergency
response plans, can neither require States to prepare adequate plans nor provide monetary
incentives to States; instead the NRC must use persuasion to get voluntary cooperation. Since
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intensifying its efforts in this area in mid-1974, the NRC has made progress in developing
revised guidelines for radiological emergency planning, developing training programs, and in
evaluating State plans. However, it is not yet clear whether the NRC approach of working with
States on a voluntary basis will result in improved radiological emergency plans for protecting
the public health and safety. . ý .
The Review Group is concerned about this problem, but does not have the knowledge or resources
to pursue it. Lapses in notification and response were revealed by the Browns Ferry fire, butU
no response was really needed in most cases. The Group can only recommend continued efforts to
overcome the organizational, financial, and Constitutional problems involved.

## 7.3 Local Governments　地域の行政機関

### 7.3.1 Limestone County, Alabama

The Limestone County Civil Defense Coordinator on the day of the fire could not be located by
the Alabama Civil Defense duty officer. He received information concerning the fire nearly 2
days later. He also indicated that his copy of the Alabama Radiation Emergency Plan was notF

up-to-date and he had not received any information concerning the plan in several years.

The Limestone County Sheriff was not officially notified of the fire except that he did receive
some information after the fire was extinguished. The State of Alabama Civil Defense Department
did attempt to notify him at 4:08 p.m. on the day of the fire but no answer was received. The
Sheriff did not have a copy of the Alabama Radiation Emergency Plan and had received very
little information concerning his emergency responsibilities in the past two years.

### 7.3.2 Lawrence County, Alabama

The Lawrence County Civil Defense Coordinator was officially notified by the Alabama CD at 4:10
p.m. Pertinent information concerning the fire was forwarded to the coordinator, but no specific action was requested of the Coordinator. An attempt to notify the Lawrence County
Sheriff by Alabama Civil Defense Department was made at 4:08 p.m. but no answer was received.
The Sheriff was not reached and no further attempts to contact him were made.

### 7.3.3 Morgan County, Alabama

The Morgan County Civil Defense Coordinator was officially notified by the Alabama Civil Defense
aJepartmekt at 4:05 p.m. However, the Coordinator was already at the Browns Ferry plant site
when he received official notification because he had learned of the fire approximately 30r
minutes after it had started from a local police radio system. No action was taken by the Coordinator to contact the Alabama Civil Defense Department nor was any action apparently
requested of him.

The Morgan County Sheriff was officially notified by the Alabama Civil Defense Department at
4:05 p.m. No specific action was requested of the Sheriff except that he not inform the public
in order to avoid alarming the population. The Sheriff was newly elected (January 20th,

1975)
and had not been briefed on the Alabama Radiation Emergency Plan, nor did he have a copy of it.
He recommended that the principal support agencies in Morgan County should meet with the State
of Alabama Department of Public Health and define the emergency responsibilities and update the
plan.

### 7.3.4 Athens Fire Department

The Athens Fire Department was contacted by TVA at 1:09 p.m. The Fire Department arrived at
the site at 1:30 p.m., were issued film badges and dosimeters and were ready to assist by 1:45
p.m. The Athens Fire Chief examined the fire area and about 2:00 p.m. he recommended the use
of water to fight the fire. The Fire Department crew remained at the plant and was helpful to
the operating staff. In particular, Athens Fire Department equipment was used to recharge air
breathing apparatus.
The fire was extinguished at about 7:45 p.m. The Athens Fire Department departed the plant at
9:50 P.M.

### 7.3.5 Tni-County Health Department

The Tri-County Health Officer was notified by the Alabama DRH at 3:55 p.m. DRH informed the
officer of the status of the reactor and of his opinion of the situation. No action was taken
by or required of the Tni-County Health Department.
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### 7.3.6 Drills and Exercise

With respect to drills and exercises, NRC regulations merely levy upon the licensee the requirement for providing an opportunity for participation in the drills by "other persons
whose assistance may be needed in the event of an emergency."
NRC's Regional IE Offices require that an emergency preparedness exercise, requiring

implementation of the licensees' emergency plan, be conducted by the licensee prior to obtaining an operating license. As a part of this exercise, the Interface indicating the capability for emergency response support on the part of the States and local governments is checked by IE inspectors. However, the IE inspectors do not inspect State and local government emergency response capabilities since they have no legal authority to do so. NRC regulations (10 CFR Part 50, Appendix E) merely require that a supportive interface between the utility and the State and local governments exists.

Although drills have been conducted involving TVA Browns Ferry personnel and the State over the past several years, the drills apparently did not involve extensive local government participation, if any. This can be gleaned from remarks made by two separate county officials that they had not received any information concerning the Alabama Radiation Emergency Plan in several years. The local governments' capability to respond appears to be extremely weak and is in need of Improvement.

The Review Group recommends that drills and exercises to test the emergency Interface between TVA, the State of Alabama and its local governments should be instituted on a regular basis, at least annually. Where needed, other licensees should also institute adequate regular exercises to promote maintenance of emergency response capability by local governments. The Review Group has not studied the question whether drills involving the general public should be instituted and has no recommendation on this subject.

## 7.4 Federal Agencies　連邦政府機関

### 7.4.1 Energy Research and Development Administration (ERDA)

ERDA has prime responsibility for Implementing its Radiological Assistance Plan and the Federal rIensteproangseensc yt o Riandciiodloengitcsa lo cAcusrsriisntagn ce Plan. These plans provide for radiological assistance In Federal agency or contractor operations, NRC licensed operations, operations of State and local government agencies, and in the activities of private users or handlers of radioactive materials.

At 7:00 p.m. on March 22nd, ERDA received a call from NRC requesting that the ERDA Emergency Action Coordination Team (EACT) activate the ERDA Emergency Operations Center (EOC) in Germantown, Maryland in connection with the incident at Browns Ferry. Specifically, NRC requested that ERDA notify its radiological assistance teams to be alerted in the event that assistance was needed.

The EOC was activated at 8:10 p.m. by ERDA representatives. The ERDA Oak Ridge and Savannah River Operations Offices were informed of the incident and asked to alert their radiological assistance teams. The EOC was secured at 4:00 a.m. after it had been determined that the situation at Browns Ferry was under control.

### 7.4.2 Other Federal Agencies

Several Federal agencies, including the NRC, have nuclear incident emergency planning responsibilities assigned in a Federal Register Notice dated January 24, 1973 (54). Two of these agencies also have radiological emergency response capabilities for responding to a radiological incident.

The Environmental Protection Agency (EPA) and the Department of Health, Education and Welfare's Bureau of Radiological Health (Food and Drug Administration) (FDA-BRH) can field

radiological
assistance teams to assist in radiological incidents. The Defense Civil Preparedness Agency
(DCPA) can provide extensive resources to cope with disaster situations and possesses large
quantities of radiological survey instruments. EPA was the only agency to be notified of the
Browns Ferry fire at or near the time it occurred. This notification was received from the
Health Department of the State of Alabama. Since no radiological release affecting offslte
areas occurred, there was no action required of these agencies.

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However, because of the nature of the fire at Browns Ferry with its potential for creating a
radiological release affecting offsite areas, It would also have been prudent for the State of
Alabama to notify FDA-BRH and DCPA Regional Offices to alert them in case their assistance was
required (short of implementing the Interagency Radiological Assistance Plan - IRAP). If the
IRAP was implemented by ERDA, these notifications to these agencies would in all likelihood
have automatically occurred since all three are signatories to the IRAP, and have committed
their resources to the IRAP.

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## REFERENCES　参考文献

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Fire, Part 1"
containing testimony given September 16, 1975, and backup material including the entire text of
the NRC Investigation Report and license amendments with their Safety Evaluation Reports. This
will be referenced as JCAE, p. xxx.
The NRC Investigation Report is JCAE, pp. 218-685.
TVA has submitted to NRC its "Plan for Evaluation, Repair, and Return to Service of Browns
Ferry Units I and 2 (March 22, 1975, Fire)," dated April 13, 1975, with 35 amendments to date.
This will be referenced as TVA Plan, p. xxx.
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2. "Appointment of Special Review Group," NRC Announcement No. 45, March 26, 1975 (reproduced
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3. TVA Plan
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b. Reproduced in jCAE, pp. 218-685.
6. JCAE, pp. 210-217.
7. JCAE, pp. 918-936.
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## APPENDIX　附則

APPENDIX A_UNITED STATES NUCLEAR REGULATORY COMMISSION

APPENDIX B_UNITED STATES ATOMIC ENERGY COMMISSION

APPENDIX C_FEASIBILITY OF RETROFITTING EXISTING DESIGNS TO PROVIDE REDUNDANT CABLE SPREADING ROOMS