A PROGRAM OF COMPLIANCE TO NRC BULLETIN NO. 88-08 FOR THE VIRGIL C. SUMMER NUCLEAR POWER PLANT

September 1988

PART 1
ACTION PLAN

South Carolina Electric and Gas Co.
Jenkinsville, South Carolina

1.0 PLAN OF ACTION

The SCE&G overall plan of action to address NRCB 88-08 is outlined in figure 1-1. All of the items in figure 1-1 have been completed except for the implementation of the inservice inspection and monitoring plans. The inservice inspection and monitoring plans, as well as their contingencies, are discussed below and will be implemented during the current outage. (The basis for the SCE&G overall plan is discussed in Section 2.0.)

These plans are complementary in assuring plant safety. The inservice inspection plan includes examination of the most critical locations for thermal stratification and abnormal thermal cycling. The contingency plan calls for additional inspections if significant indications are found. The monitoring plan determines if thermal stratification and abnormal thermal cycling are occurring in any unisolable pipe section and the likelihood for it to have occurred in the past. Again the contingency plan calls for evaluations to be made to assure plant safety should the monitoring yield evidence of excessive thermal stratification and abnormal thermal cycling.

1.1 Inspection

During the current refueling outage SCE&G will inspect per the guidelines of NRCB 88-08, Supplement 2. A total of nineteen locations will be inspected. The inspection plan is as follows:

1. Perform UT inspections on Loop A cold leg and Loop C hot leg safety injection lines. A total of nine locations will be inspected which includes seven welds and base metal areas of two elbows.

2. Perform UT on one weld on each of the following lines at the most critical location based on susceptibility evaluations:

Loop A hot leg SI
Loop B hot leg SI
Loop B cold leg SI
Loop C cold leg SI
Normal charging line
Alternate charging line
Pressurizer spray line (at auxiliary spray line interface)

A total of seven locations will be inspected.

3. Perform PT on the auxiliary spray line on two welds and one socket weld fitting. A four inch section of the pressurizer spray line, noted above, next to the connection point of the auxiliary spray system will be inspected by UT techniques.

4. Visually inspect all areas of unisolable piping where insulation has been removed.

5. Visually inspect the auxiliary spray line from the check valve to the pressurizer spray line interface.

The specific locations for UT are shown in figures 1-2 through 1-10.

As described in section 1.2, SCE&G intends to determine the future requirements for inspection of unisolable piping based on the monitoring results obtained during plant operation following the current outage.

1.2 Monitoring

During the current outage, one cross-section of each of the nine unisolable pipe sections will be instrumented with resistance temperature detectors on the top and bottom of the pipe, as shown in figure 1-11. The locations for instrumentation are also shown in figures 1-2 through 1-10 which are the most critical locations for each line based on the heat transfer and fluid flow evaluations. The instrumentation will be positioned close to the reactor coolant legs which will have a temperature of over 400°F at approximately 100% power. The temperature data will be recorded and used as a basis for determining if thermal stratification and abnormal thermal cycling are occurring.

1.3 Contingency Plan

A contingency plan will be implemented as necessary depending on inspection and monitoring results. Specific plans of action include:

1. If significant flaw indications suggestive of thermal stratification and cycling are found during the inspection described above in any given unisolable section inspected, all the remaining locations of that line will be inspected and the other lines reevaluated. The ASME Code Section XI criteria will be used to establish either acceptability for continued service or the need to repair or replace.

2. If monitoring while at power following the current outage yields evidence of excessive thermal stratification and abnormal thermal cycling, evaluations will be made to assure plant safety. Appropriate actions will be taken based on the results of the evaluation.

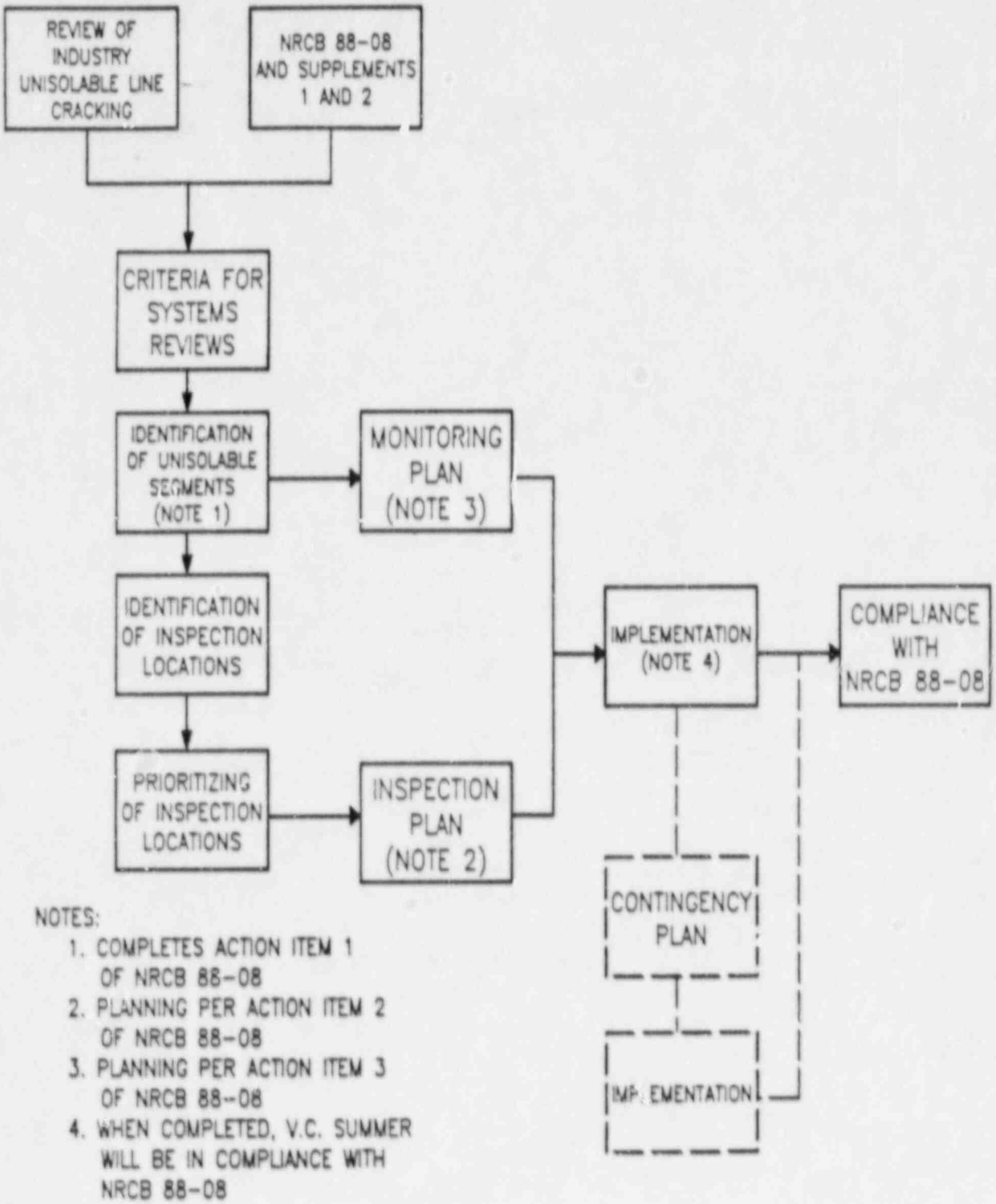
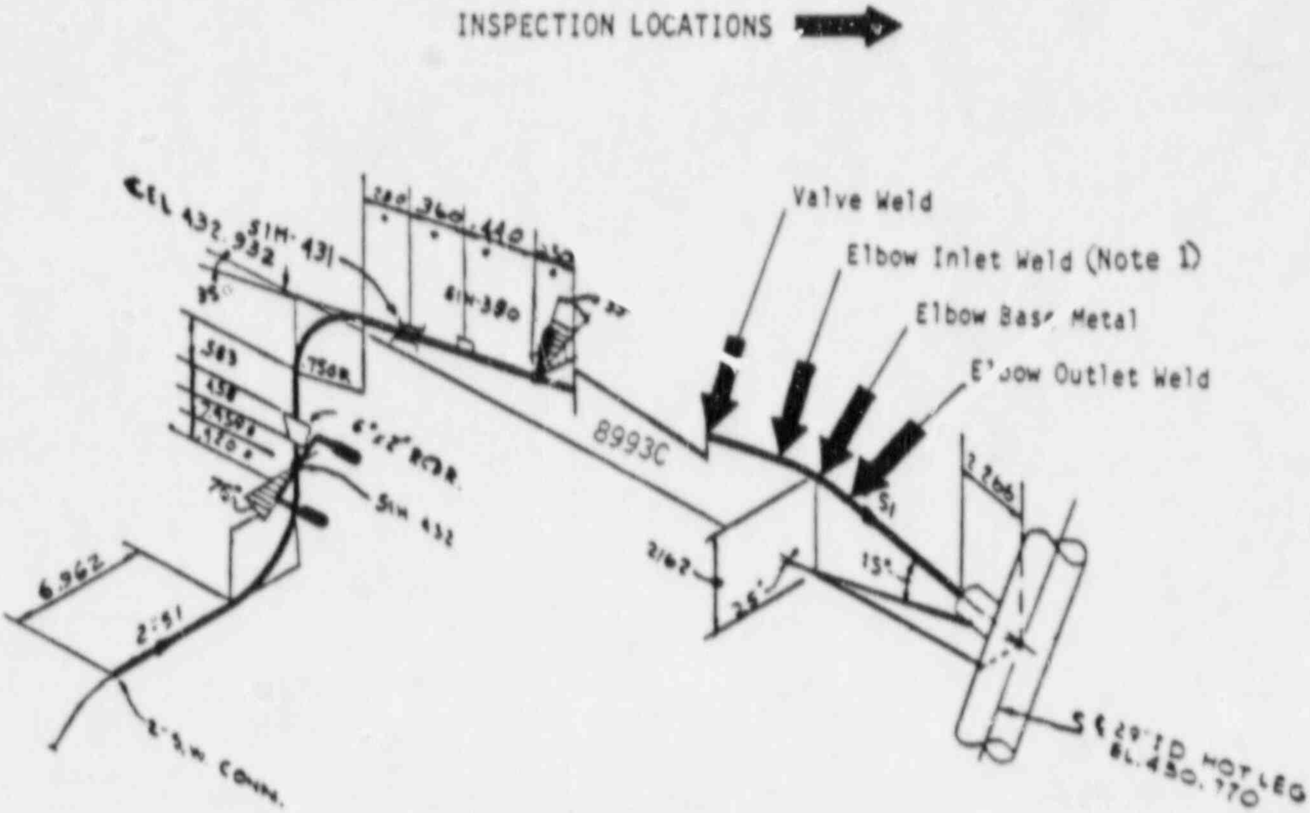
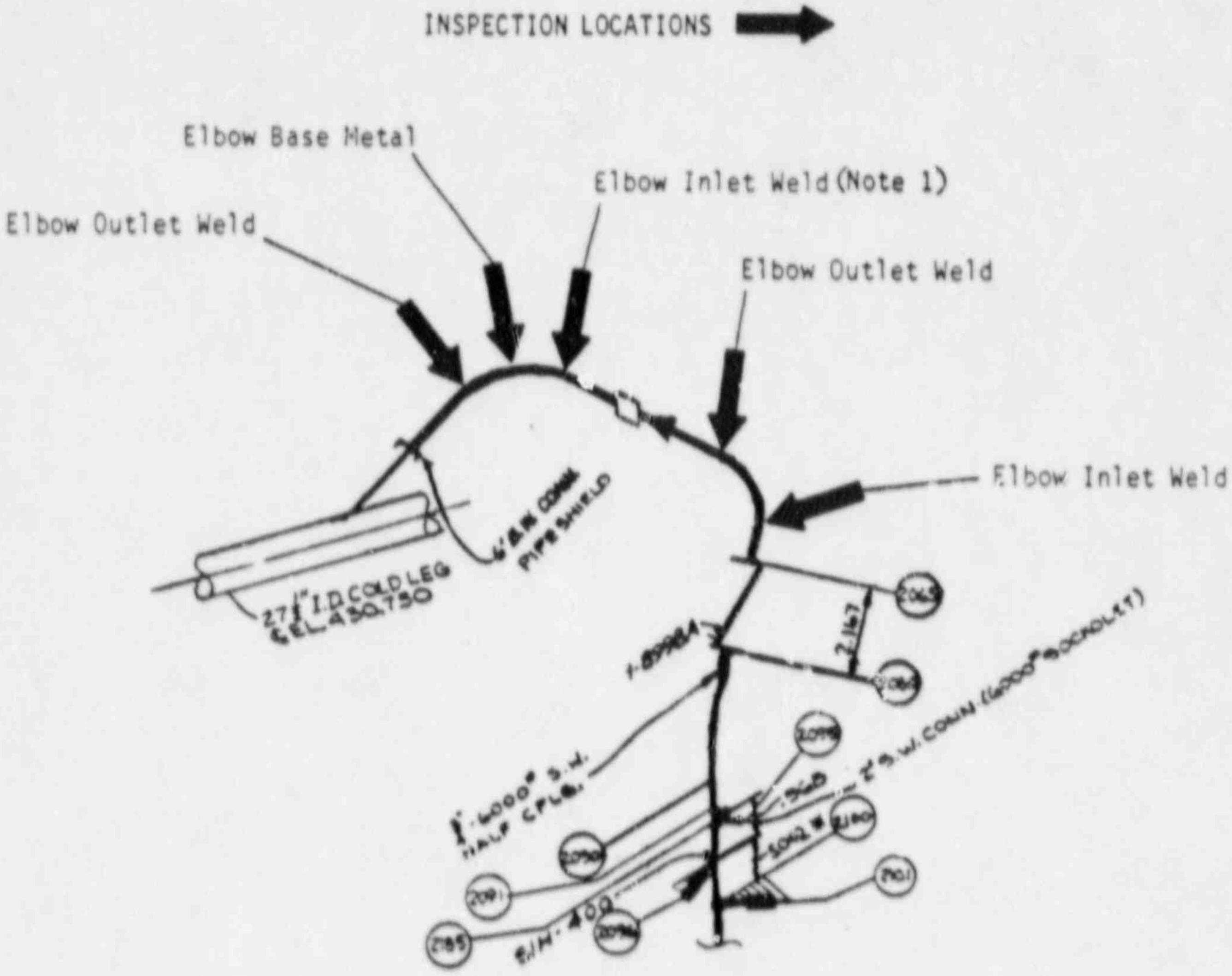


Figure 1-1. Outline of SCE&G's Plan of Action to Address NRCB 88-08 for the Virgil C. Summer Plant



Note 1: This is the location for temperature monitoring.

Figure 1-2. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Loop C Hot Leg Safety Injection Line



Note 1: This is the location for temperature monitoring.

Figure 1-3. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Loop A Cold Leg Safety Injection Line

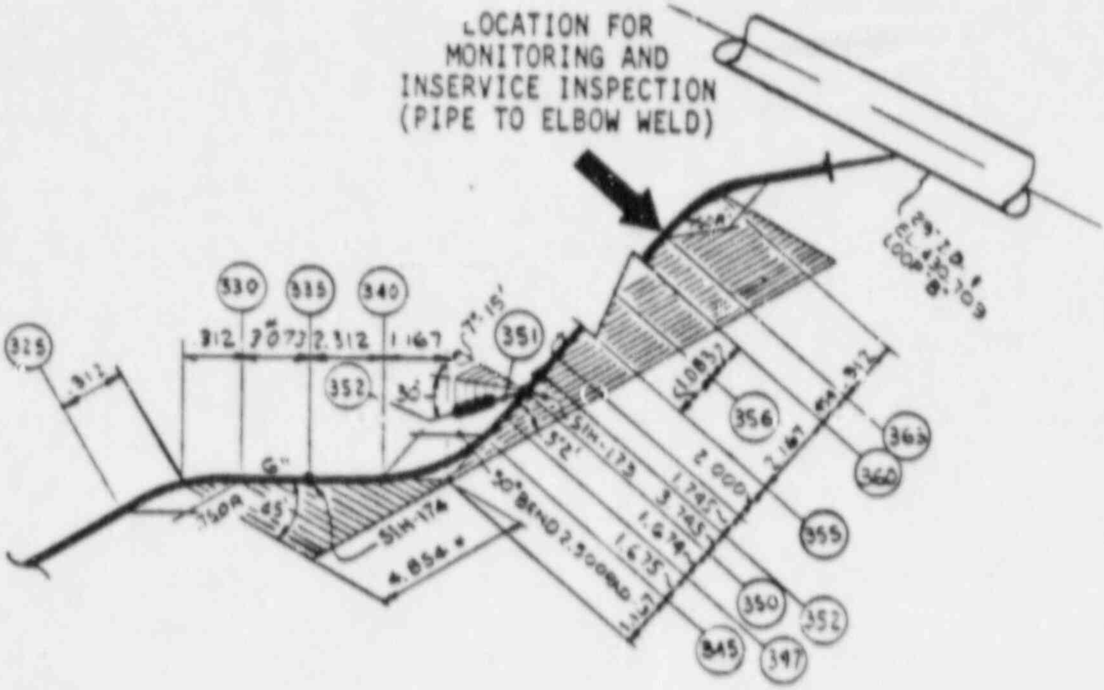


Figure 1-4. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Loop B Hot Leg Safety Injection Line

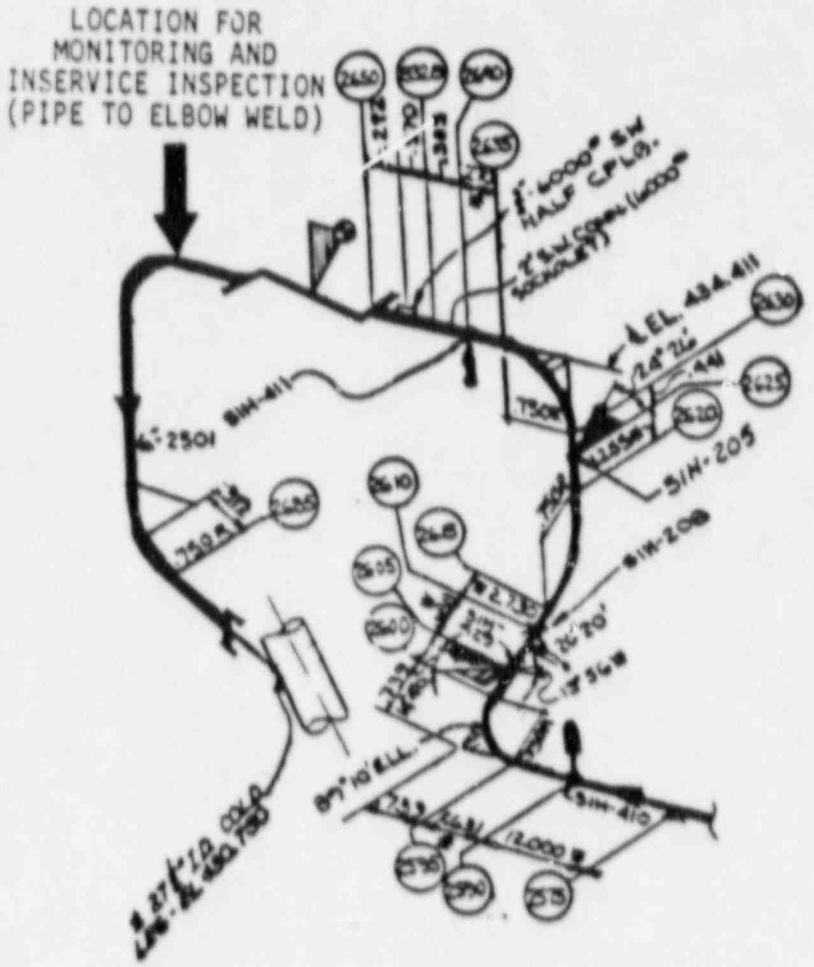


Figure 1-5. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Loop B Cold Leg Safety Injection Line

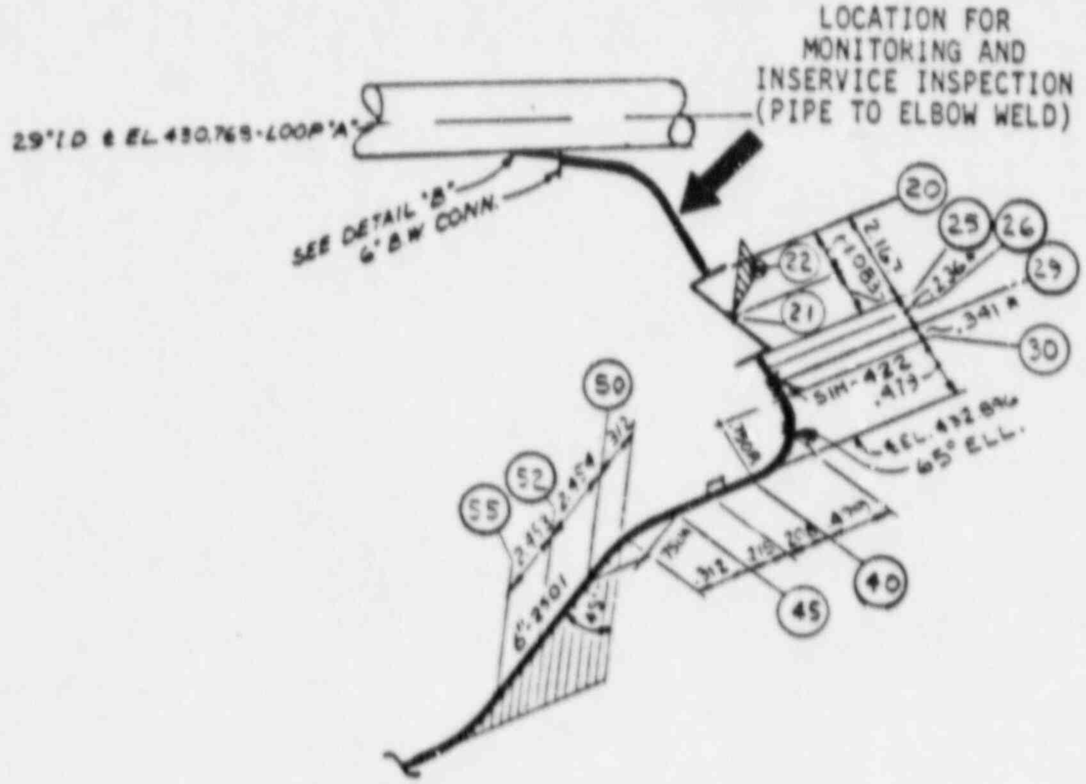


Figure 1-6. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Loop A Hot Leg Safety Injection Line

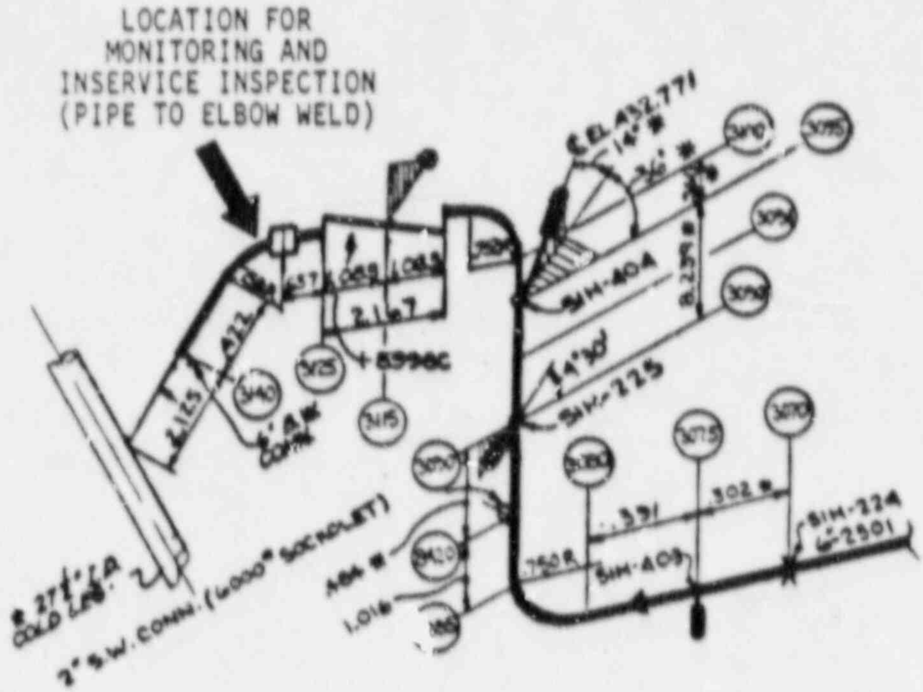


Figure 1-7. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Loop C Cold Leg Safety Injection Line

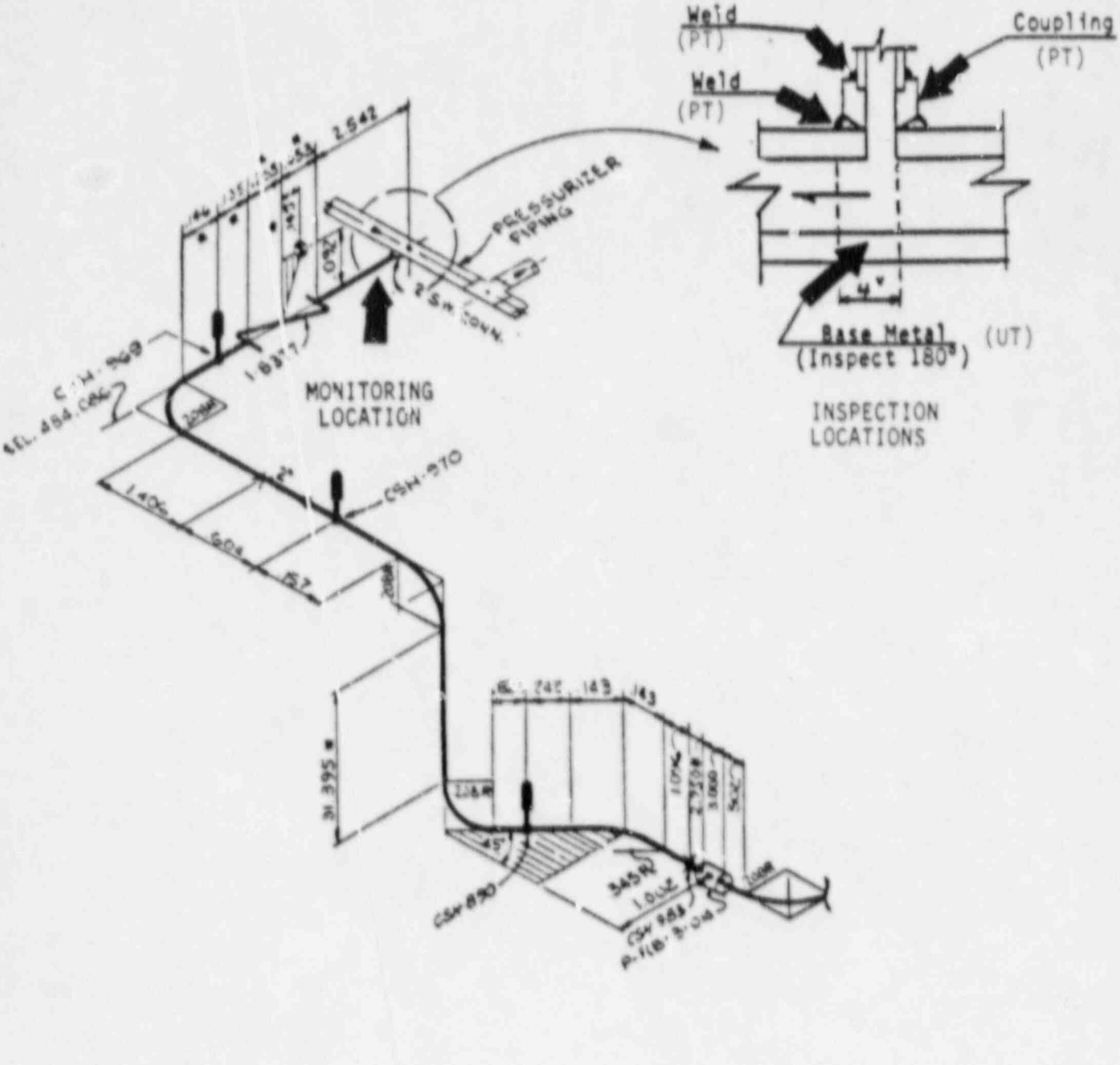


Figure 1-8. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Auxiliary Spray Line

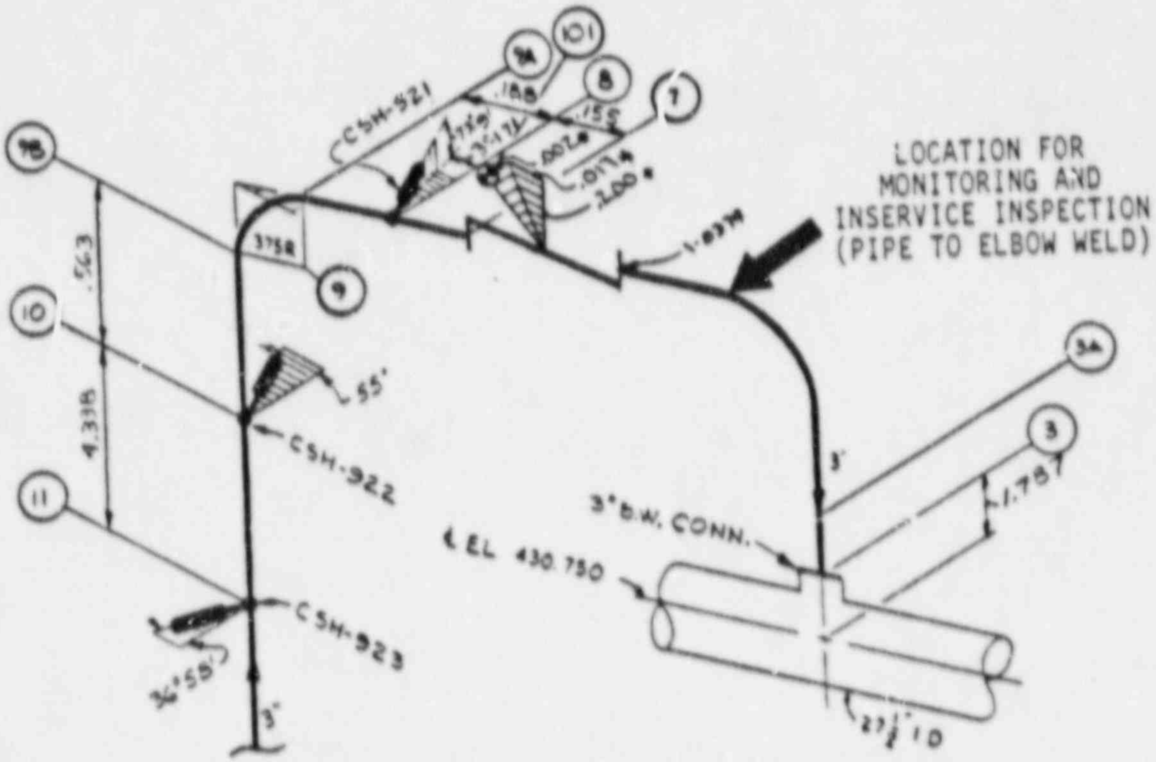


Figure 1-9. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Alternate Charging Line

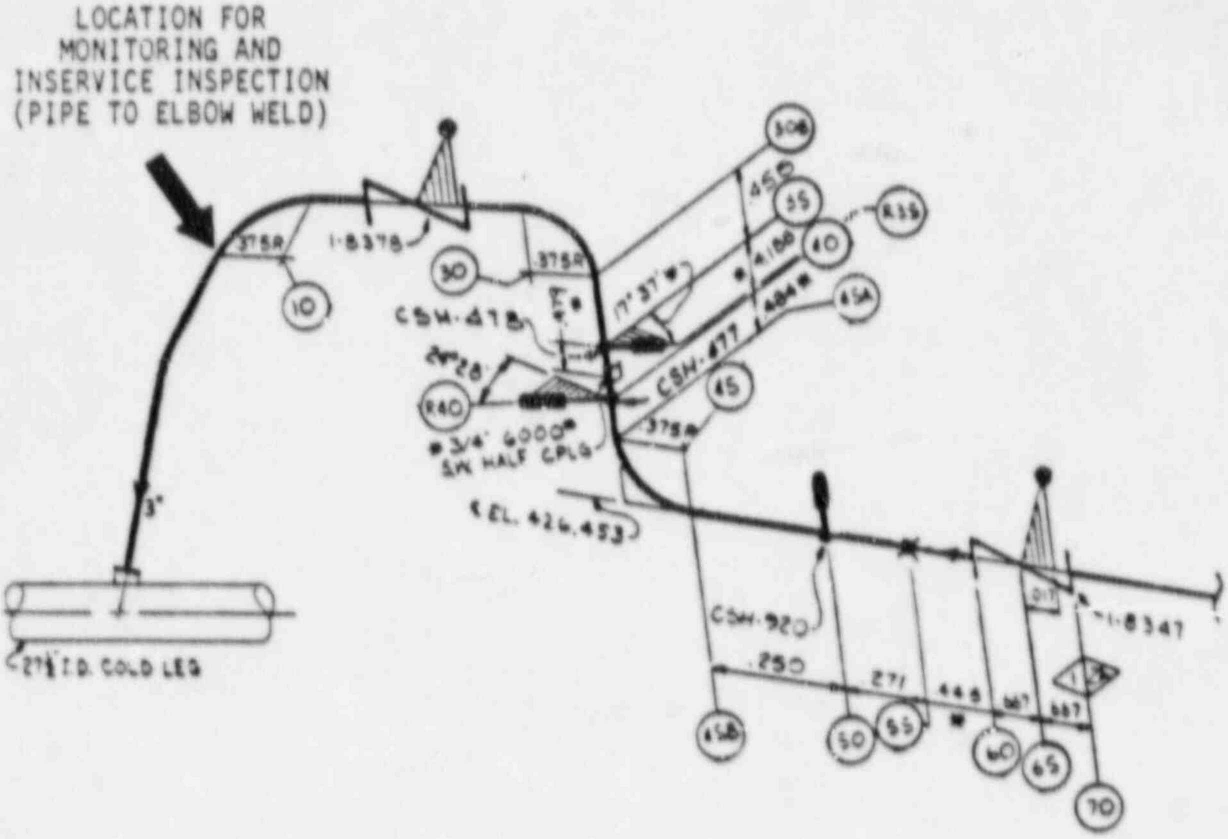


Figure 1-10. Locations for Inservice Inspection and Monitoring on the Unisolable Section of the Normal Charging Line

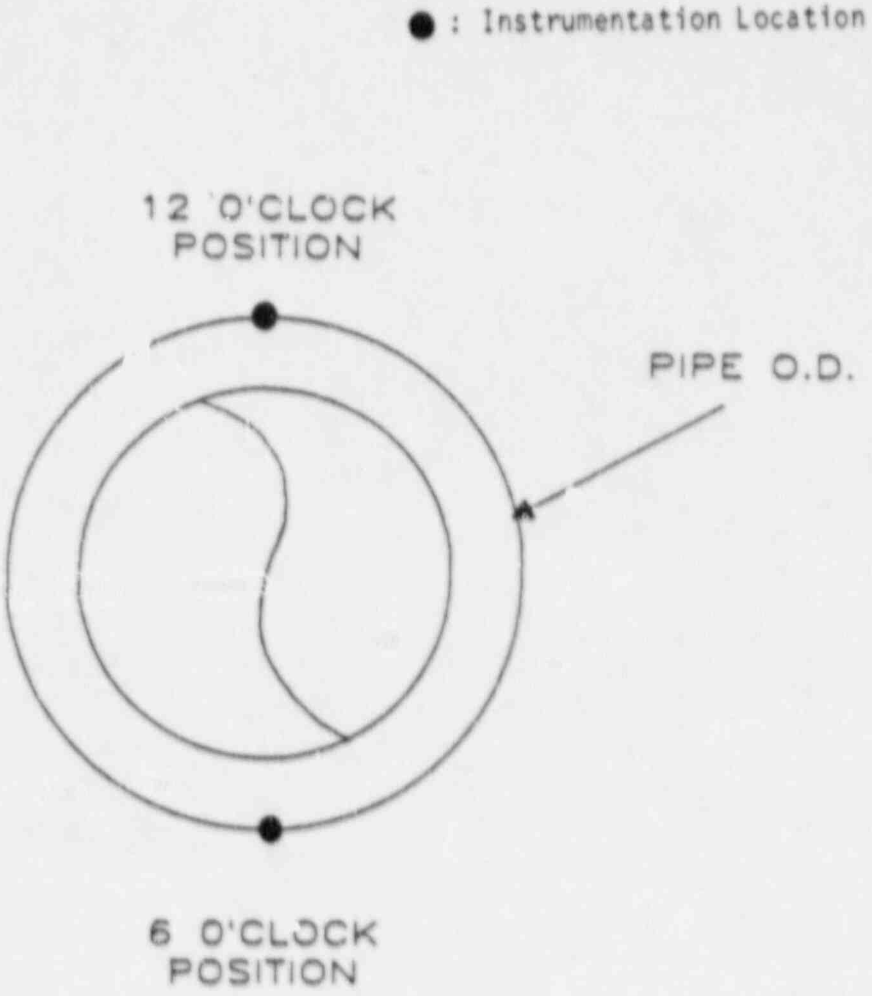


Figure 1-11. Mounting Locations for Temperature Sensors

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PART 2
BASES FOR PLAN OF ACTION

South Carolina Electric and Gas Co.
Jenkinsville, South Carolina

2.0 BASES FOR PLAN OF ACTION

2.1 Identification of Unisolable Pipe

By the definition of NRCB 88-08 an unisolable pipe segment of an auxiliary piping system is that part which extends from the closest check valve to the entrance of the main line to which the auxiliary line connects. Based on this definition, a review of the piping attached to the reactor coolant system was performed to identify any unisolable piping. Nine auxiliary systems were found to contain such piping. The nine systems are identified in table 2-1. (See FSAR figure 6.3-1 sheet 1 for the SI system, figure 9.3-16 sheet 1C for the CVCS, and figure 5.1-1 sheet 1 for the RC system.)

2.2 Potential Locations for Inservice Inspection

As-built plant isometric drawings were used to identify potential locations for in-service inspection. A study of the flow and heat transfer characteristics led to an identification of forty-one (30 weld metal and 11 base metal) potential locations for inservice inspection. The lines which contain the potential locations are identified in table 2-1 with the number of weld and base metal potential locations. From the 41 potential locations for inservice inspection, 19 have been selected for inspection as described in Part 1. The selection was made based on the prioritization procedure discussed below. From the studies made it is concluded that the inspection of 19 (16 are UT, 3 are PT) of the 41 locations assures plant safety.

2.3 Prioritization of Potential Locations Identified for Inservice Inspection

The actual implementation of an inservice inspection program requires careful planning and scheduling to avoid any unnecessary extension of the outage subject to meeting all safety requirements. Because of the low number of incidents of abnormal thermal cycling pipe cracking in industry and the monitoring program described in the next section, it is prudent to prioritize the potential locations for inservice inspection. This allows the selection of a representative sample reflecting the best engineering judgment and state-of-the-art information that will provide a high degree of confidence that the most critical locations, as defined below, are examined. It is judged that this can be done without compromising plant safety. If significant flaw indications suggestive of thermal stratification and cycling are indicated, additional inservice inspection requirements will be determined based on the results of this sampling. The monitoring program is complementary in that it determines if excessive thermal stratification and abnormal thermal cycling are occurring. If monitoring determines that thermal stratification or cycling is occurring, then appropriate evaluations will be made. Industry experience, discussed later, lends additional assurance that plant safety is not compromised. Indeed, the source of thermal stratification or cycling can be identified through the monitoring program and eventually eliminated without compromising plant safety.

Based on the current understanding of abnormal thermal cycling there are several factors that can be used in prioritizing the potential locations for inservice inspection. Given these factors, the potential for thermal cycling and cracking by fatigue can be assessed quantitatively. The factors are given below followed by the assessment.

The prioritization is arrived at from the factors discussed. Based on each of the factors, a priority is assigned to each of the selected lines. Through an evaluation of the cumulative effects of the priority rating due to various factors, the lines and locations are prioritized.

Factors for Assessing Thermal Cycling

Summarized in the following are the various factors for consideration and a brief discussion of how the priority ratings are assigned.

Primary Factors:

1. Positive In-Surge Pressure, ΔP, on check valve.

   If the primary loop piping pressure is less than that of the upstream side of the check valve, an in-surge of a colder water could result. The reactor coolant piping leg with the lowest pressure has the greatest potential for thermal cycling, all else being equal.

The unisolable piping sections judged to have the highest ΔP will be given a priority rating of 1; the second highest, a 2; etc. If two segments are judged to have the same ΔP, they will be given the same rating.

2. Temperature Difference, ΔT, in the Primary Loop Piping and Auxiliary Line

   Thermal stress is a function of ΔT. The unisolable piping section judged to have the highest ΔT will be given a priority rating of 1; the second highest, a 2; etc. If two segments are judged to have the same ΔT, they will be given the same rating.

3. Industry History of Cracking

   The two instances of pipe cracking (the Farley Unit 2 and Tihange Unit 1) occurred in safety injection lines. Therefore safety injection lines are given a priority rating of 1. All other unisolable piping sections will be given a priority rating of 2.

Other Factors:

1. Local Geometry

   Elbows used in the unisolable piping are welded to straight pipe sections. Such welds and elbows are discontinuities which intensify stresses.

   With the exception of the auxiliary pressurizer spray system, all of the other systems utilize elbows in the unisolable section. Therefore, the geometry will not affect the prioritization of the systems.

2. Radiation Exposure

   Radiation exposure (ALARA) must be given careful consideration for ISI recommendations. Based on plant radiation exposure records, the expected dosage for ISI for all the SI systems are approximately equal with the exception of the hot leg of loop A. Therefore, radiation exposure does not affect prioritization of the systems.

3. Plant Age

   Since abnormal thermal cycling is a time dependent phenomena, the older the plant the greater the potential for fatigue damage and crack initiation, all else being equal. Plant age, of course, applies equally to all systems in Virgil C. Summer. However, it should be noted that Virgil C. Summer began commercial operation in January 1984 whereas Joseph M. Farley Unit 2 and Tihange Unit 1 began commercial operation in July 1981 and September 1975, respectively.

To obtain the order of priority for inspection the priority ratings are added. The piping segment having the smallest sum has the first priority for inspection; the next smallest, the second priority, etc.

Since Farley Unit 2 experienced a cold leg SI unisolable pipe crack while that at Tihange Unit 1 was related to the hot leg, cracking is assumed to be equally probable between the two legs. A prioritization for a given leg among the loops can be made if related pressures can be established.

Based on measured mass flow rates for the three loops of the Virgil C. Summer plant, an analysis was made to estimate pressures in the loops. A ranking of the loops was established from the results as given below.

1. The highest hot leg pr sure will bo in Loop A.
2. The lowest hot leg pressure will be in Loop C.
3. The highest cold leg pressure will be in Loop C.
4. The lowest cold leg pressure will be in Loop A.
5. Loop B is intermediate between Loops A and C.

The piping legs with the lowest pressures, of course, define the safety injection lines with the highest priority among that particular set of loops.

The normal charging, alternate charging and auxiliary spray piping systems are of smaller pipe diameter than the safety injection lines, and thus are less likely to experience stratification. The pressure difference across the isolation valves for these lines is very small, from a half to two orders of magnitude lower than for the safety injection lines, thus significantly reducing the likelihood of leakage into the unisolable portion of these lines. Also, the temperature difference between leakago and RCS fluid is potentially smaller in these lines because they each have flow from a heated source (regenerative heat exchanger). Thus, these lines are all given a lower priority (higher number) than the safety injection lines for both ΔP and ΔT.

An extensive arrangement study of the various SI systems suggested that in selecting temperature differences, ambient temperature (120°F) should be selected for the cold side stratification and RCL temperature (555°F for the cold leg and 619°F for the hot leg) for the unisolable pipe water temperature.

The ΔP's and ΔT's for the nine unisolable segments are given in table 2-2.

Based on the above discussion, a prioritization of the nine unisolable pipe segments as potential candidates for thermal stratification and abnormal thermal cycling was made and is given in table 2-3.

Table 2-3 was used as the basis for selecting the nineteen locations for inservice inspection as described in Part 1. Specifically, all of the potential locations for inservice inspection in the two unisolable piping sections found to be most susceptible to abnormal thermal cycling are to be inspected by ultrasonic testing (UT). A study was made to determine the most critical location for abnormal thermal cycling in each of the seven remaining segments using industry experience as a guide. The pipe cracks in Farley Unit 2 and Tihange Unit 1 both occurred in the first downstream discontinuity past the check valve of the unisolable safety injection pipe. In general, this location was judged to be the critical location. UT is also to be performed at these critical locations. UT is to be performed on the pressurizer spray line across from the auxiliary spray line and PT on the critical locations of the auxiliary spray line. The locations for UT are given in figures 1-2 through 1-10 of Part 1.

2.4 Additional Justification for Inservice Inspection Based on Prioritization

2.4.1 The Contingency Plan

The contingency plan of Part 1 calls for additional examinations and evaluations should any indications be found indicative of abnormal thermal cycling fatigue. Thus it can be reasonably concluded that if no such indications are found at any of the locations examined, then there are no indications in the potential locations for inservice inspection which were not examined.

2.4.2 The Monitoring Program

All nine unisolable segments are to be monitored for thermal stratification and abnormal thermal cycling. To date valve maintenance has consisted only of repacking several valves and correction to a bonnet leak on the auxiliary spray line. Thus, if no abnormal thermal cycling is observed during the monitoring ofa line whose isolation valve has not been affected by maintenance then, it can reasonably be concluded that no abnormal thermal cycling has occurred. Any abnormal thermal cycling observed would be no less severe than that of previous service. The contingency plan of Part 1 provides for evaluation and action should thermal stratification and abnormal thermal cycling be observed.

2.4.3 Plant Safety

Abnormal thermal cycling fatigue cracking has been experienced at Farley Unit 2 and Tihange Unit 1. In both instances leakage occurred without pipe break (i.e., a leak-before-break condition existed) with no safety consequences. Other related industry experience has been similar. Thus it can be reasonably concluded that limited breaks (the crack remains stable when the wall is penetrated) of the type typical of abnormal thermal fatigue cracks do not pose a plant safety problem.

2.4.4 Safety in Age and Number

Of the nearly 200 PWR's in the free world, over 60% are older than Virgil C. Summer. No abnormal thermal cycling fatigue cracks have occurred in plants younger than Virgil C. Summer. The incident rate is around 2 percent in older plants. In terms of total unisolable piping systems, the incident rate is around 0.2%. It may be concluded that Virgil C. Summer would not reasonably be expected to experience an abnormal thermal cycling fatigue crack in the upcoming cycle.

TABLE 2-1

POTENTIAL LOCATIONS IDENTIFIED FOR INSERVICE INSPECTION

Piping System		Locations Welds	Base Metal
Normal Charging		5	2
Alternate Charging		3	1
Auxiliary Spray		2	2
Loop A Cold Leg SI		4	1
Loop B Cold Leg SI		4	1
Loop C Cold Leg SI		3	1
Loop A Hot Leg SI		3	1
Loop B Hot Leg SI		3	1
Loop C Hot Leg SI		3	1
	Total	30	11

TABLE 2-2

TEMPERATURE AND PRESSURE DIFFERENCES AS A BASIS FOR PRIORITIZATION

System	ΔP (psi)	ΔT (°F)
Loop C Hot Leg SI	(1)[a,b]	499
Loop A Cold Leg SI	(1)[a,b]	435
Loop B Hot Leg SI	(2)[a,b]	499
Loop B Cold Leg SI	(2)[a,b]	435
Loop A Hot Leg SI	(3)[a,b]	499
Loop C Cold Leg SI	(3)[a,b]	435
Auxiliary Spray	67	<435[c]
Alternate Charging	4	<435[c]
Normal Charging	4	<435[c]

a The ΔP's for all the SI lines are greater than 300 psi.

b The operating pressures for the loops were compared relative to each other based on SCE&G's flow data. (_) indicates the ranking by pressure among the various loops for a particular leg. For example (1) indicates the lowest pressure (i.e., the highest ΔP across the SI isolation valve), etc. This ranking also takes into account the industry pipe crack experience (cold leg SI at Farley Unit 2 and hot leg SI at Tihange Unit 1).

c These systems receive flow from the regenerative heat exchanger during normal plant operation. The actual temperature of the water depends on the flow rate.

TABLE 2-3

PRIORITIZATION OF PIPING SYSTEMS FOR INSPECTION CONSIDERATIONS

System	Considerations			Total	Overall Priority
	ΔP[a]	ΔT	Industry History of Cracking		
Loop C Hot Leg SI	1	1	1	3	1
Loop A Cold Leg SI	1	2	1	4[b]	2
Loop B Hot Leg SI	2	1	1	4[b]	3
Loop B Cold Leg SI	2	2	1	5	4
Loop A Hot Leg SI	3	1	1	5	4
Loop C Cold Leg SI	3	2	1	6	5
Auxiliary Spray	4	3	2	9	6
Alternate Charging	5	3	2	10	7
Normal Charging	5	3	2	10	7

[a] This prioritization also takes into account the industry pipe crack experience (cold leg SI at Farley Unit 2 and hot leg SI at Tihange Unit 1).

[b] For diversity Loop A Cold Leg SI is given second priority.