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October 19, 1982

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Byron Station Units 1 and 2
Braidwood Station Units 1 and 2
Turbine Missile Study
NRC Docket Nos. 50-454, 50-455,
50-456, and 50-457

References (a): August 18, 1982, letter from T. R. Tramm to H. R. Denton.

(b): September 2, 1982, letter from T. R. Tramm to H. R. Denton.

Dear Mr. Denton:

This is to provide advance copies of revised FSAR information regarding protection against possible turbine missiles at Byron and Braidwood stations. NRC review of this information should close Outstanding Item 2 of the Byron SER.

Enclosed are revisions to several pages of the turbine missile analysis report transmitted in reference (a) and revised in reference (b). The changes are generally editorial in nature and were made primarily to correct typographical errors and enhance the clarity of the text. The overall results of the analysis have not been altered. Text revisions are indicated by vertical bars in the right-hand margin. Corrections to the fault tree are described in the attachment.

Please address questions regarding this matter to this office.

One signed original and fifteen copies of this letter and the enclosures are provided for your use.

Very truly yours,

F. G. Lentine
for T. R. Tramm
Nuclear Licensing Administrator

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Enclosures

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CORRECTIONS TO FAULT TREE

IN SECTION C.4

Figure Number	Location of Correction	Correction
C.4-1	All event blocks	Description expanded
C.4-2	Top event block in fault tree branch	Description expanded
	Upper center of page; circular event symbol	"Turbine trip" changed to "Missle ejection after turbine failure".
C.4-3	Top event block in fault tree branch	Description expanded
	Upper center of page; circular event symbol	"Turbine trip" changed to "Missile ejection after turbine failure".
C.4-4	Below OR gate at top of page; event block right-of-center	"Loss of radiological control" changed to "Loss of reactivity control"
C.4-6	Middle of page; left-of-center	Area designation 11.3A-1 changed to 11.3D-1
C.4-8	Bottom right hand corner of page	Second area designation from right side changed from 11.3-0 to 11.2-0
C.4-10	Bottom center of page	Fifth area designation from right side changed from 11.2-0 to 11.3-0
C.4-12	Upper right of center; below event block which reads "Failure of RHR HX".	Area designation 11.3F-1 changed to 11.3E-1.
	Triangle-shaped symbol at lower left corner of top event block.	Previously blank; now contains the number "9".
C.4-14	Below top event block in fault tree branch	AND gate changed to OR gate

After a missile exits the turbine, it may impact various floors and walls of the plant. The impact area of each missile at each impact is assumed to be uniformly distributed between the minimum and maximum impact areas, as shown in the table. The assumption of an independent random variable at each impact also accounts fo the rotational motion of the missile within the plant.

The initial direction of the missile at the time of ejection is defined by two random angles, Θ_v and Θ_h. Θ_v is the vertical angle measured from the vertical axis in the plane of the disc and Θ_h is the deflection angle measured from the plane of the disc. For the disc in the first quadrant, Θ_v is assumed to be a random variable with a range of 0° to 90°. For discs in the remaining quadrants, Θ_v is established by adding 90° to the Θ_v for the disc in the preceding quadrant. This implies that only one random variable is required to define Θ_v for all disc segments. The vertical angles for all the fragments are selected randomly within the respective quadrants. Figure C.2-2 schematically represents the vertical angles for the discs and the fragments.

The range of deflection angles for the discs and the fragments was obtained from Reference 2. For each LP unit, the Θ_h's for the inner discs and fragments vary from -5° to +5°; for outer fragments, Θ_h varies from 5° to 25° (or from -25° to -5°, as applicable). These angles are shown schematically in Figure C.2-3. Within the specified range, all values of the random variable under discussion are considered equally likely; therefore, a uniform density function is used to define the probability law of exit angles.

C.2.4 Frequency of a Plant Damage State

Let ζ denote a plant damage state such as the loss of cold shutdown capability or a radiological release of a certain level. Precise expressions for ζ in terms of various equipment failures are defined from the plant logic. On the assumption that turbine missile generation can occur at any of the three speed conditions ω_i, i = 1,2,3, and using the theorem of total probability, the frequency of this damage may be expressed as:

$$f(\zeta,\Delta t) = \sum_{i=1}^{3} f_2\ (\zeta|\omega_i)\ f_1\ (\omega_i,\Delta t) \qquad \text{(C.2-1)}$$

in which

$f\ (\zeta, \Delta t)$ = frequency of damage state ζ per year for a selected inspection time Δt.

$f_1\ (\omega_i, \Delta t)$ = frequency of missile generation per year at speed condition ω_i and inspection time Δt.

$f_2\ (\zeta | \omega_i)$ = conditional frequency of damage state ζ, given missile generation at speed condition ω_i.

For this report, Δt measures accumulated turbine operating time since last inspection.

Using plant logic, ζ may be expressed as

$$\zeta = \bigcup_{j=1}^{m} \zeta_j \qquad (C.2-2)$$

where

ζ_j = minimal cut sets of the ζ-fault tree

$\bigcup_{j=1}^{m}$ = operation of union on events ζ_j.

From Equation C.2-2, the following expression can be established:

$$f_2\ (\zeta | \omega_i) \leq \sum_{j=1}^{m} f_2\ (\zeta_j | \omega_i) \qquad (C.2-3)$$

The conditional frequencies $f_2\ (\zeta_j | \omega_i)$ are estimated by a simulation process in which missiles are generated and traced through the plant spaces as described in Subsection C.2.5. With these conditional frequencies available, $f_2\ (\zeta | \omega_i)$ is calculated using Equation C.2-3. Then, the frequency of the damage state can be evaluated using Equation C.2-1 and the data given in Table C.2-1. Because Equation C.2-3 presents the upper bound of $f_2\ (\zeta | \omega_i)$, it follows that the estimate of damage state frequencies is conservative.

C.4 FAULT TREE FOR PLANT DAMAGE STATES

C.4.1 General

In previous sections, the turbine missile generation mechanisms and frequencies, and the structural plant model through which simulated missile trajectories and structural penetrations occur were discussed. In the following, the consequences of turbine missiles impacting various plant equipment and initiating an accident is examined.

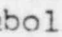
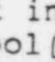
In this analysis, fault trees are developed to determine the sequence of failure of plant components from turbine missile impact that could lead to accidents beyond the current design basis as defined in Regulatory Guide 1.115. These accidents referred to as damage states in this report are summarized in Table C.4-1. The relationship of our definitions to the specific criteria given by Regulatory Guide 1.115 is also presented in this table. Fault trees also include the failure of various components required to mitigate accidents to start on demand. Minimal cut sets of the developed trees are used in Section C.5 to quantify the probability of the plant damage states.

C.4.2 Damage States C and M

A turbine missile could initiate many plant events. While the exact sequence of events can become quite involved, only a limited number of key functions must be examined to ask the questions necessary for determining if the consequences would be beyond the results considered in the plant design basis. When the disc ruptures to form the missile, the turbine will trip. After the turbine trip, two accident scenarios can be identified which would be more severe than the design basis. The first scenario, designated as C, involves missiles penetrating containment and striking components and/or subsystems within containment. This is assumed to result in a LOCA. The additional element in C involves the opening left in the containment wall created by the turbine missile. This would prevent complete containment of the LOCA which is beyond design basis. For this analysis, a LOCA will be assumed when any single component or system within the containment is struck by a missile. This assumption is conservative because many of these targets are not part of the reactor coolant system, and consequently, LOCA would not directly follow a turbine missile strike. Targets representing important equipment, such as reactor compartment fan coolers, main steam and feedwater lines, and containment spray risers, were included even though damage to these components would not cause a LOCA. This conservatism was included to avoid considering in detail the failure of backup systems in the fault tree.

The second scenario involves missiles striking plant components outside of containment resulting in loss-of-hot-shutdown capability, but in response to the requirements of Regulatory Guide 1.115, this scenario will also address loss-of-cold-shutdown capability and is designated as M. Thus, for this analysis, an accident beyond design basis is assumed if M or C occurs.

The plant logic for M and C is presented by means of a fault tree. The master fault tree is given in Figure C.4-1. Further branch expansions for M are shown in Figures C.4-2 through C.4-14. The branch for C is shown in Figure C.4-2, and it simply consists of the 20 components/equipment listed as containment targets 1.1 through 1.4.3 in Table C.3-1. Each event in the fault tree represents an important plant component or components, the failure of which is assumed to result in failure to achieve cold shutdown or LOCA.

The circle below each event in the fault trees represents the space designation in which one or more of those components are located or through which cabling or piping are routed. Turbine missile entry into a space is assumed to result in failure of all components in that space. The symbol  represents an OR condition whereby the failure of any event in the branch would result in failure of the branch. The symbol  indicates an AND condition such that all events immediately below the branch must fail in order for the branch to have failed. In this way, the fault tree can be interpreted as indicating the space combinations which, if penetrated by a turbine missile, will lead to M or C. This assumption is conservative because, in most cases, the components of interest do not consume the entire space in which they are located, and a missile entering the space may not necessarily impact the component. In addition, failure of the components may not necessarily result in the assumed accident.

It is noted that operator interdiction is not included in the fault tree. This is a conservative assumption as including recovery actions would result in lower failure frequencies. It has been shown in Reference 1, that for certain components, failure to start on demand is significant, thus, this is included in the fault tree where appropriate. Table C.4-2 lists the median frequency and assessed range of these special conditions.

Before proceeding, it is important to note some points in the fault tree logic. It is assumed that for the large pumps, failure of the control room or DC power does not mean failure to start or stop the pumps. The switchgears for these pumps can be operated mechanically. Also, it is again pointed out that conservatism is involved when the containment is breached.

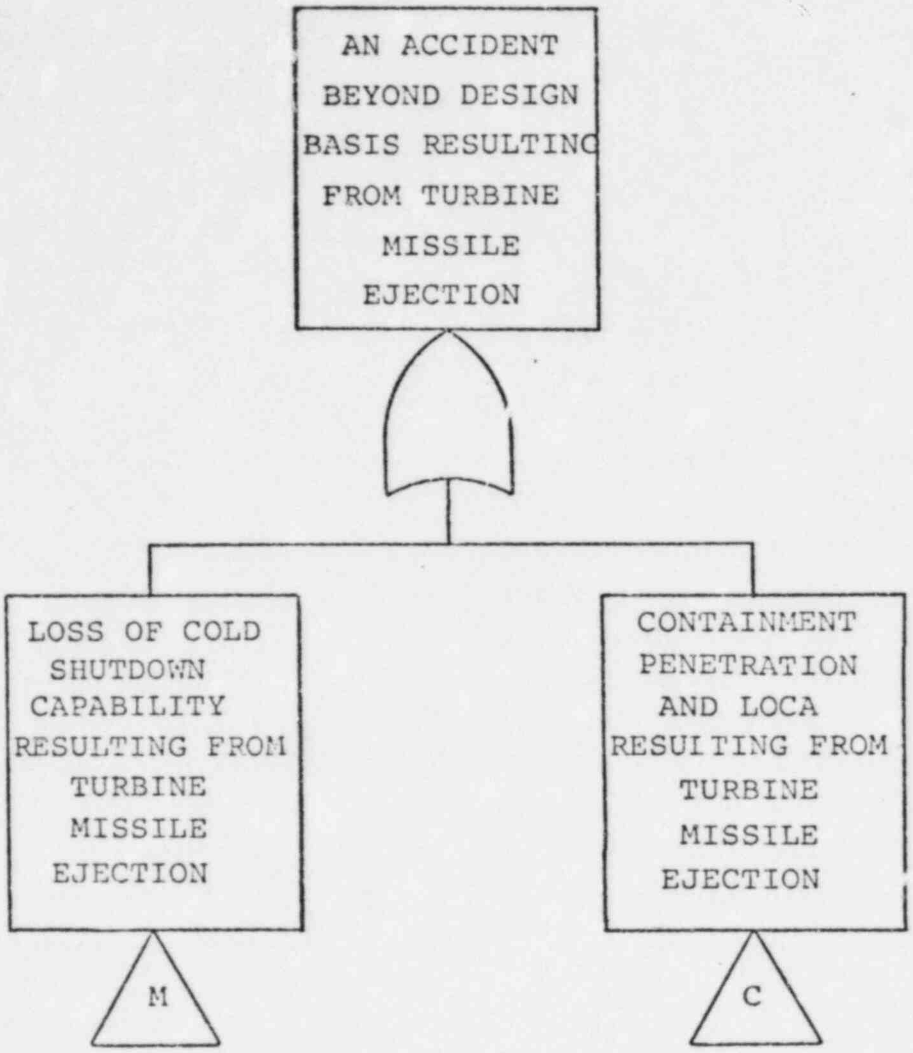


FIGURE C.4-1: TURBINE MISSILE FAULT TREE

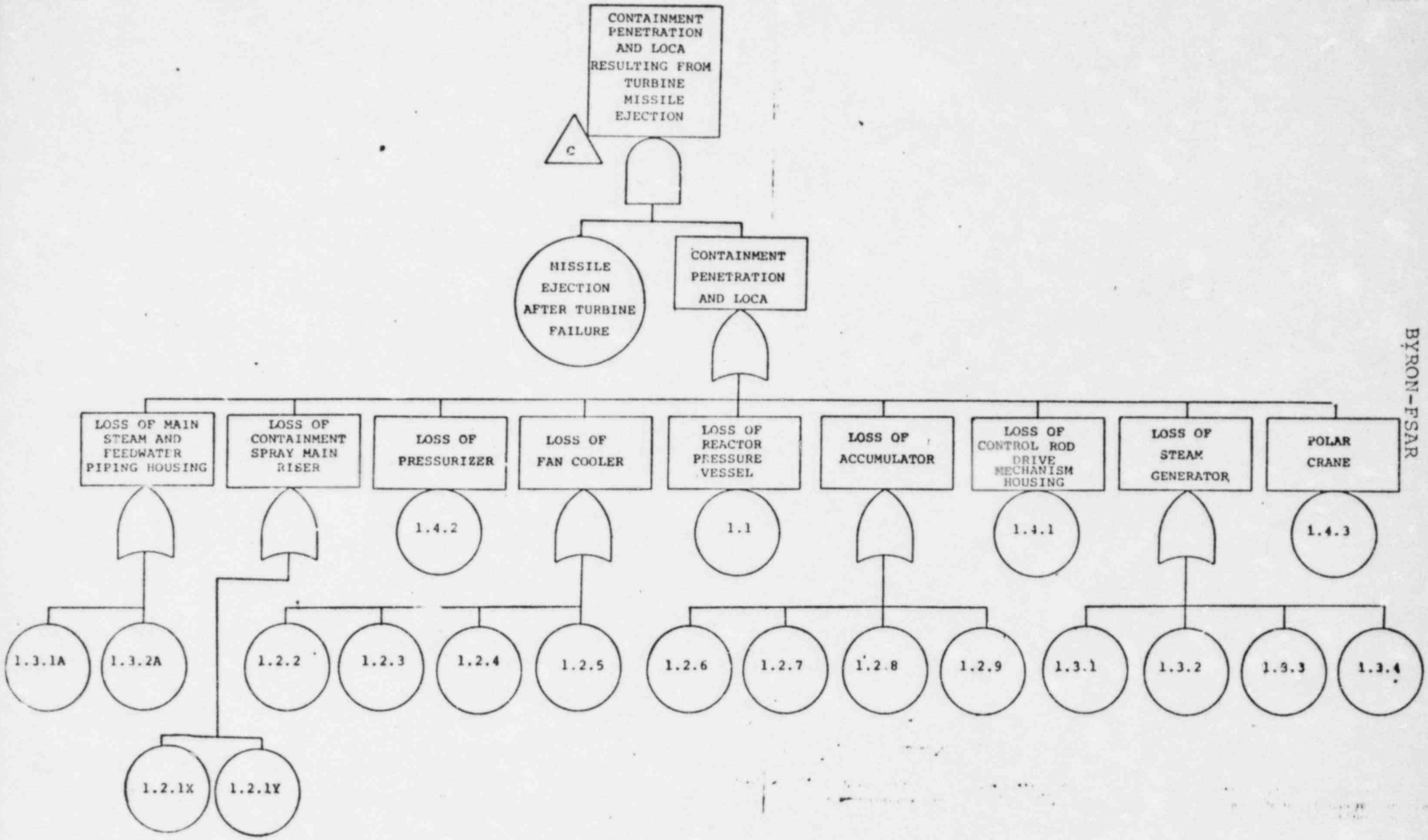


FIGURE C.4-2: LOCA RESULTING FROM BREACH OF CONTAINMENT

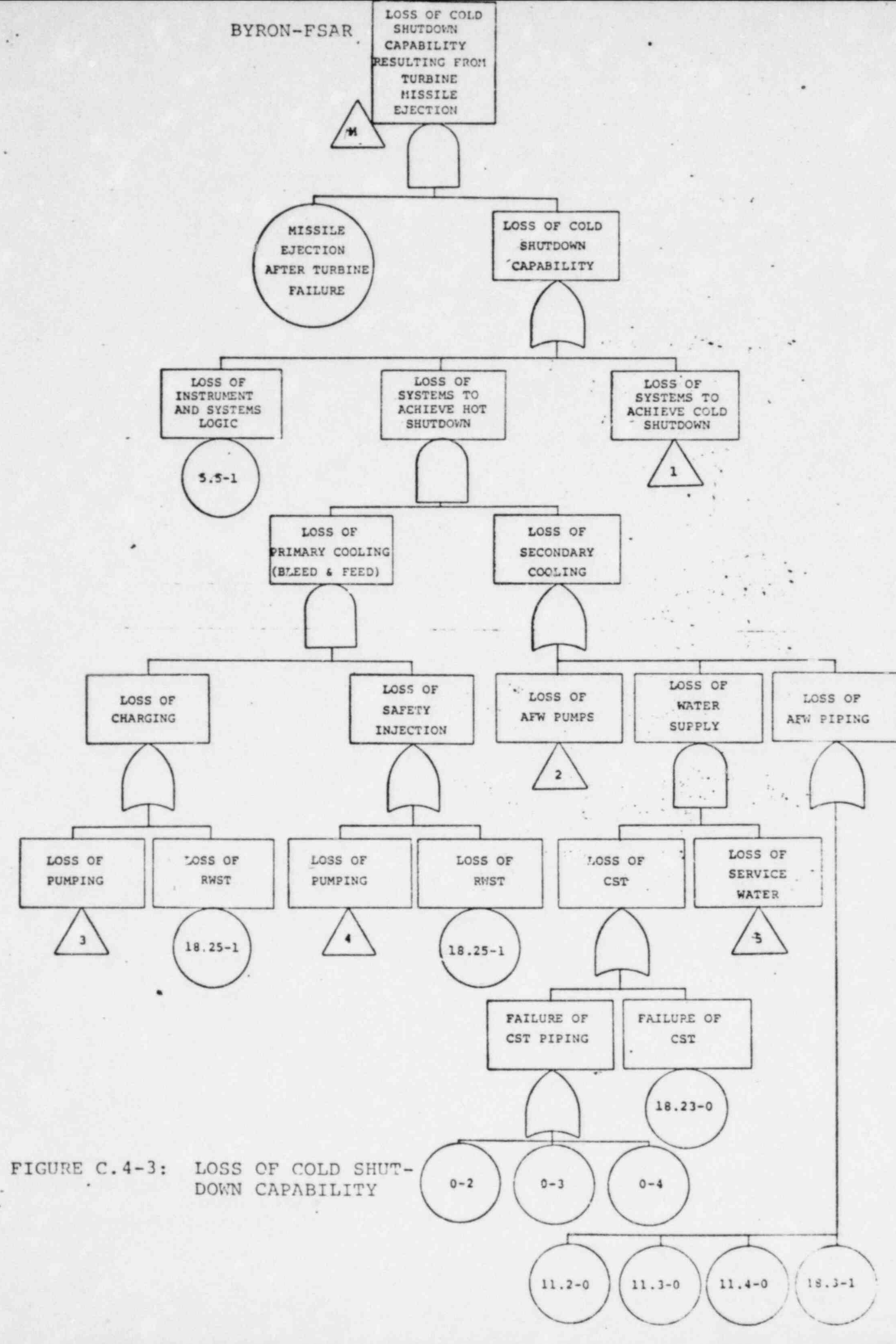


FIGURE C.4-3: LOSS OF COLD SHUT-DOWN CAPABILITY

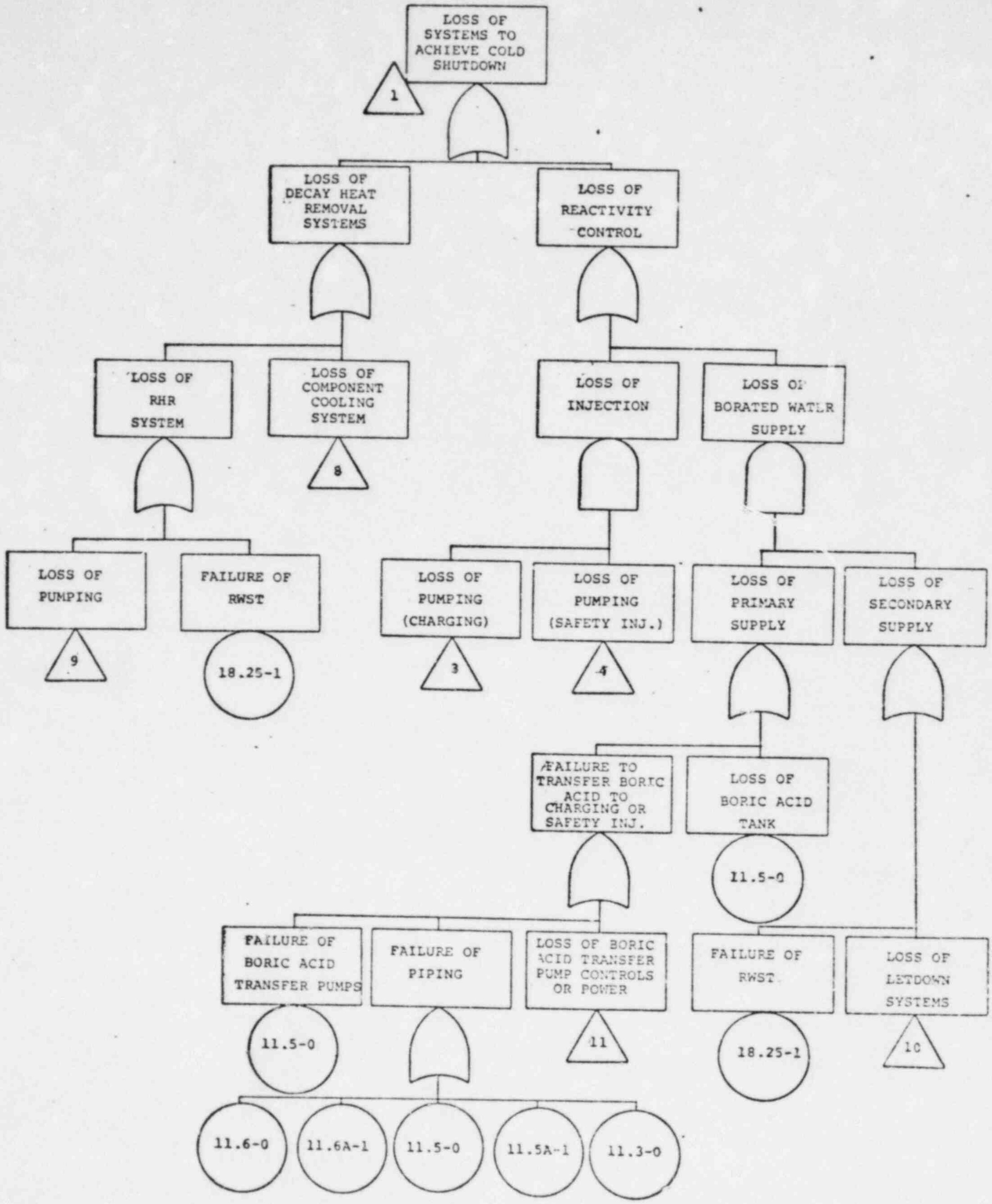
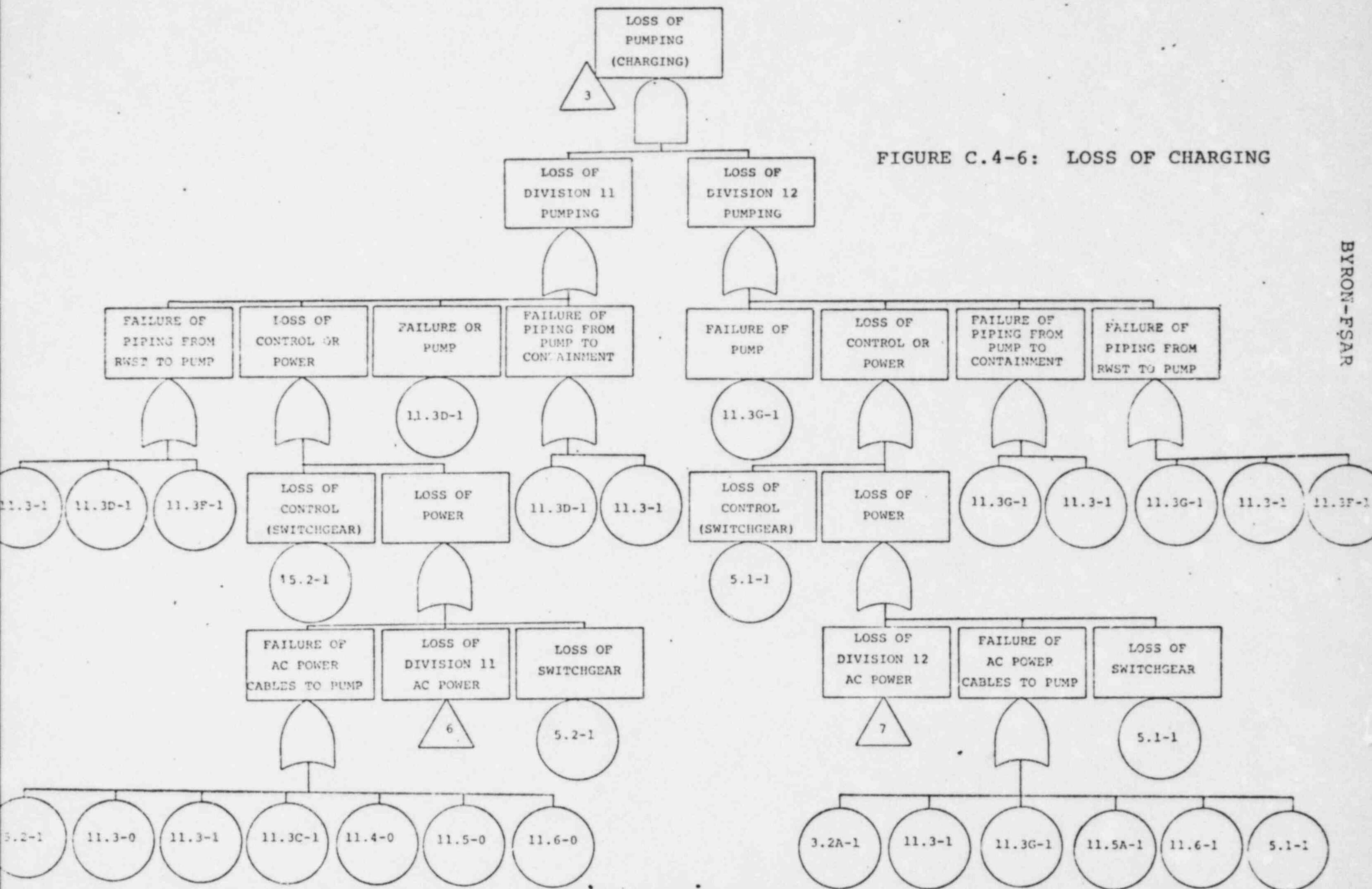


FIGURE C.4-4: LOSS OF SYSTEMS TO ACHIEVE COLD SHUTDOWN

FIGURE C.4-6: LOSS OF CHARGING



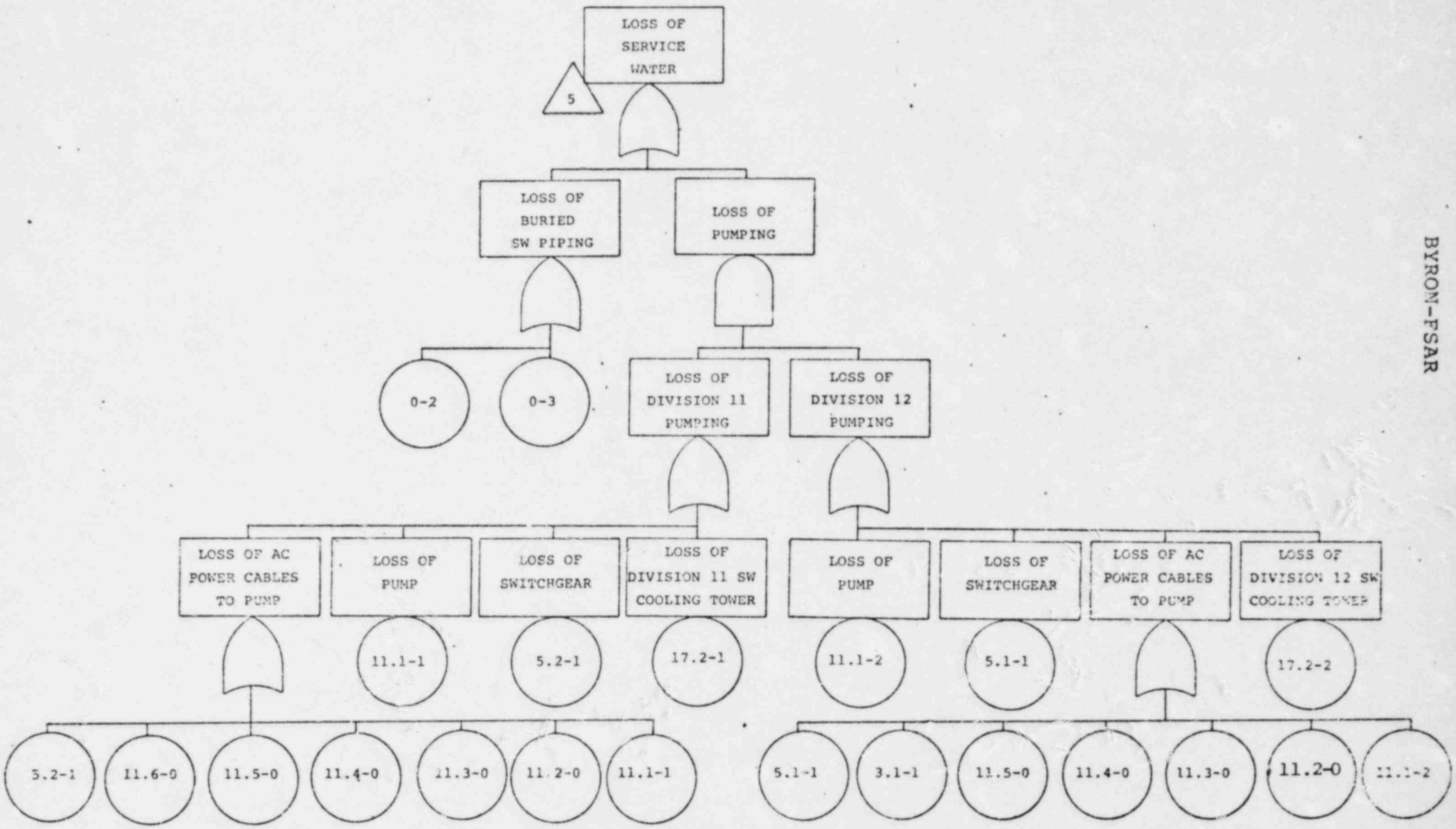


FIGURE C.4-8: LOSS OF SERVICE WATER

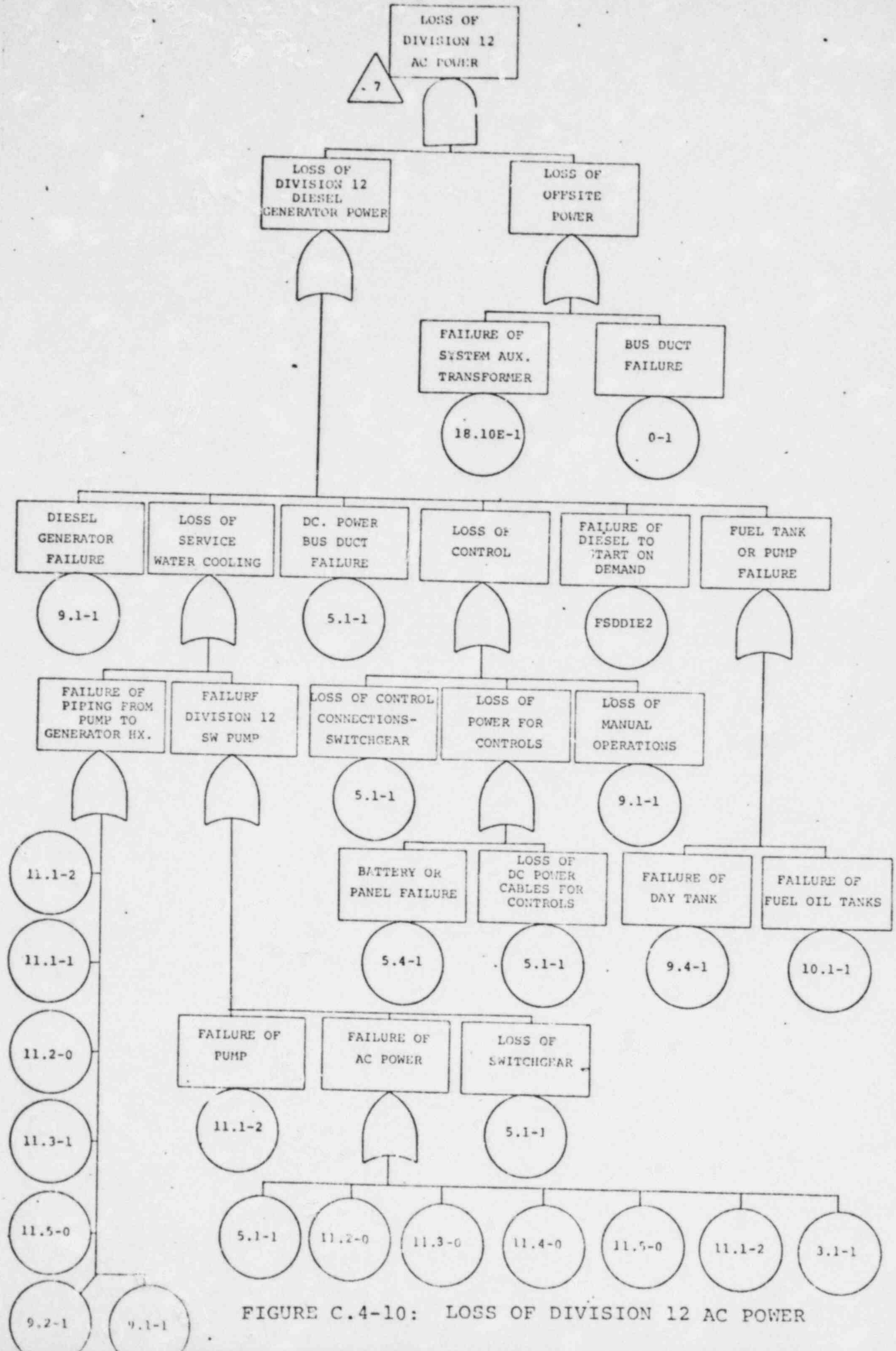


FIGURE C.4-10: LOSS OF DIVISION 12 AC POWER

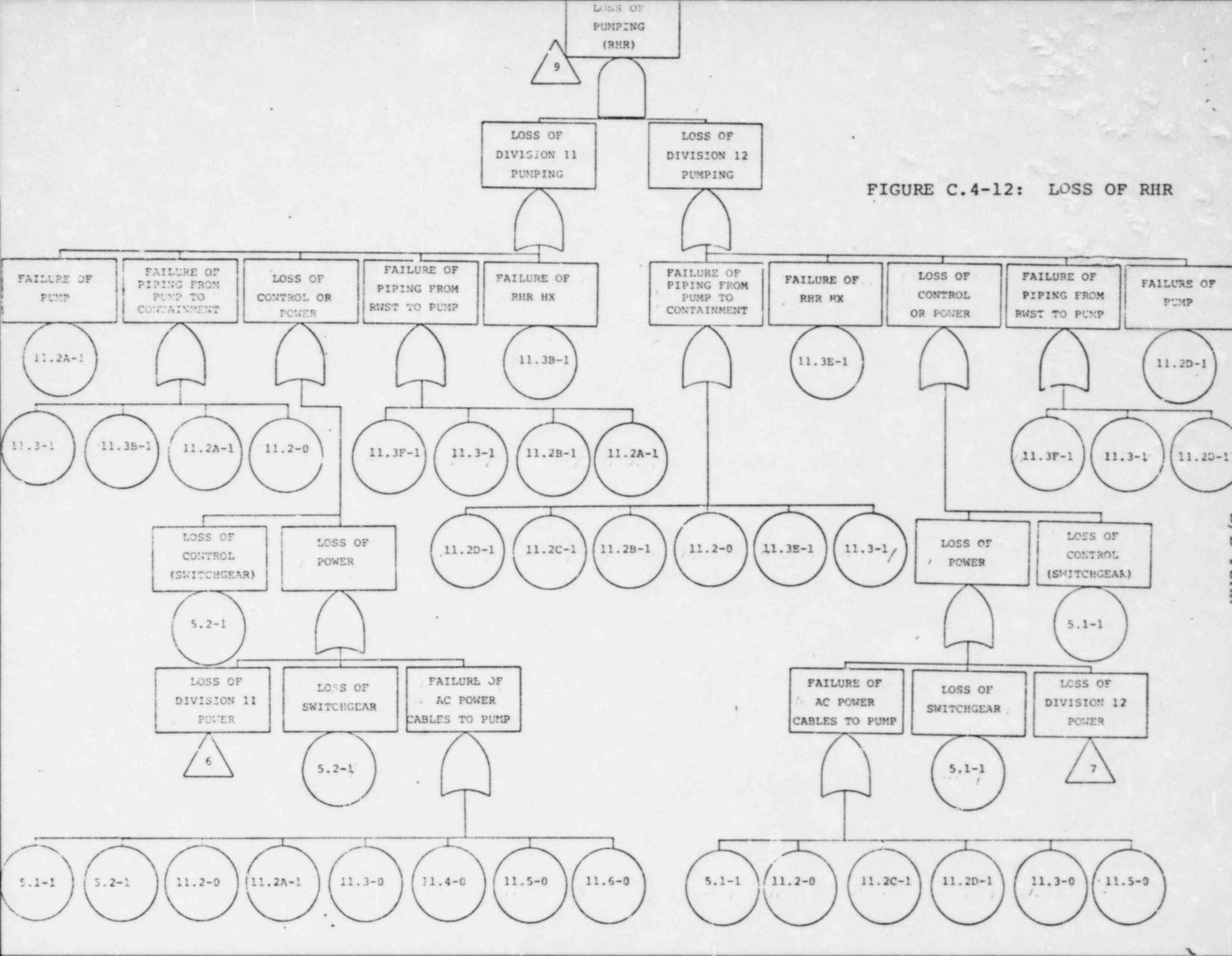


FIGURE C.4-12: LOSS OF RHR

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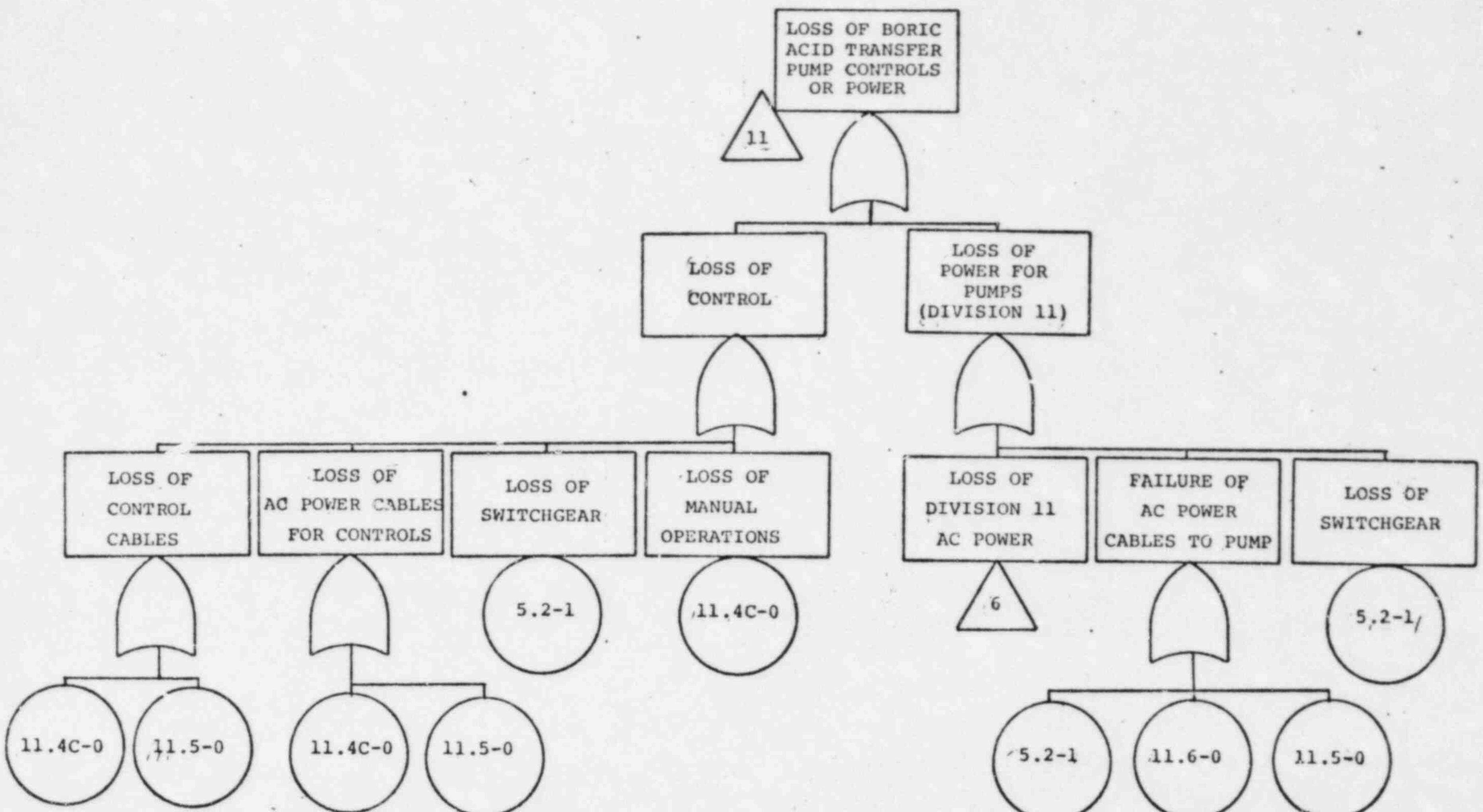

FIGURE C.4-14: LOSS OF BORIC ACID TRANSFER PUMP CONTROL OR POWER