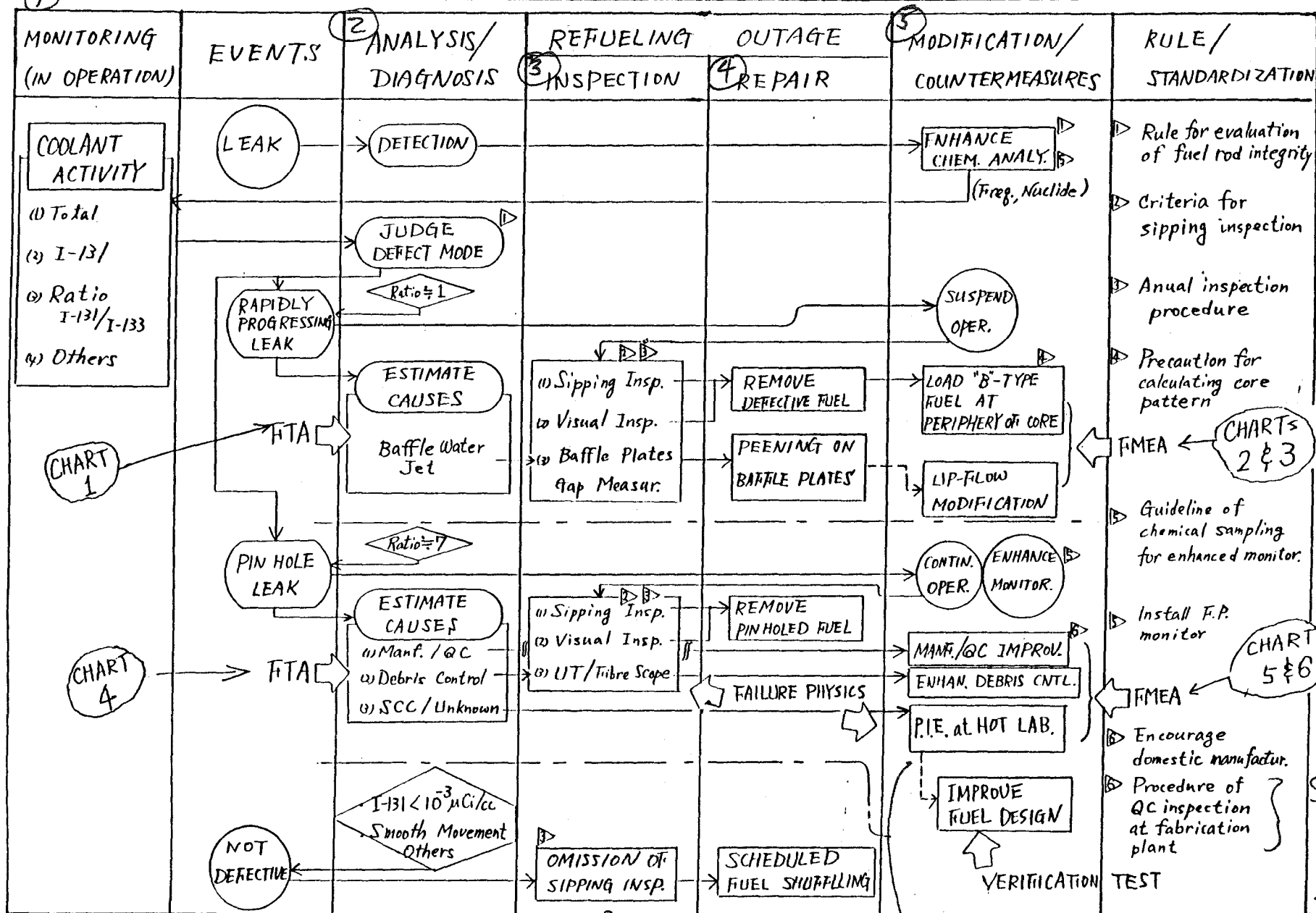




4.5 YRS

Saves Time

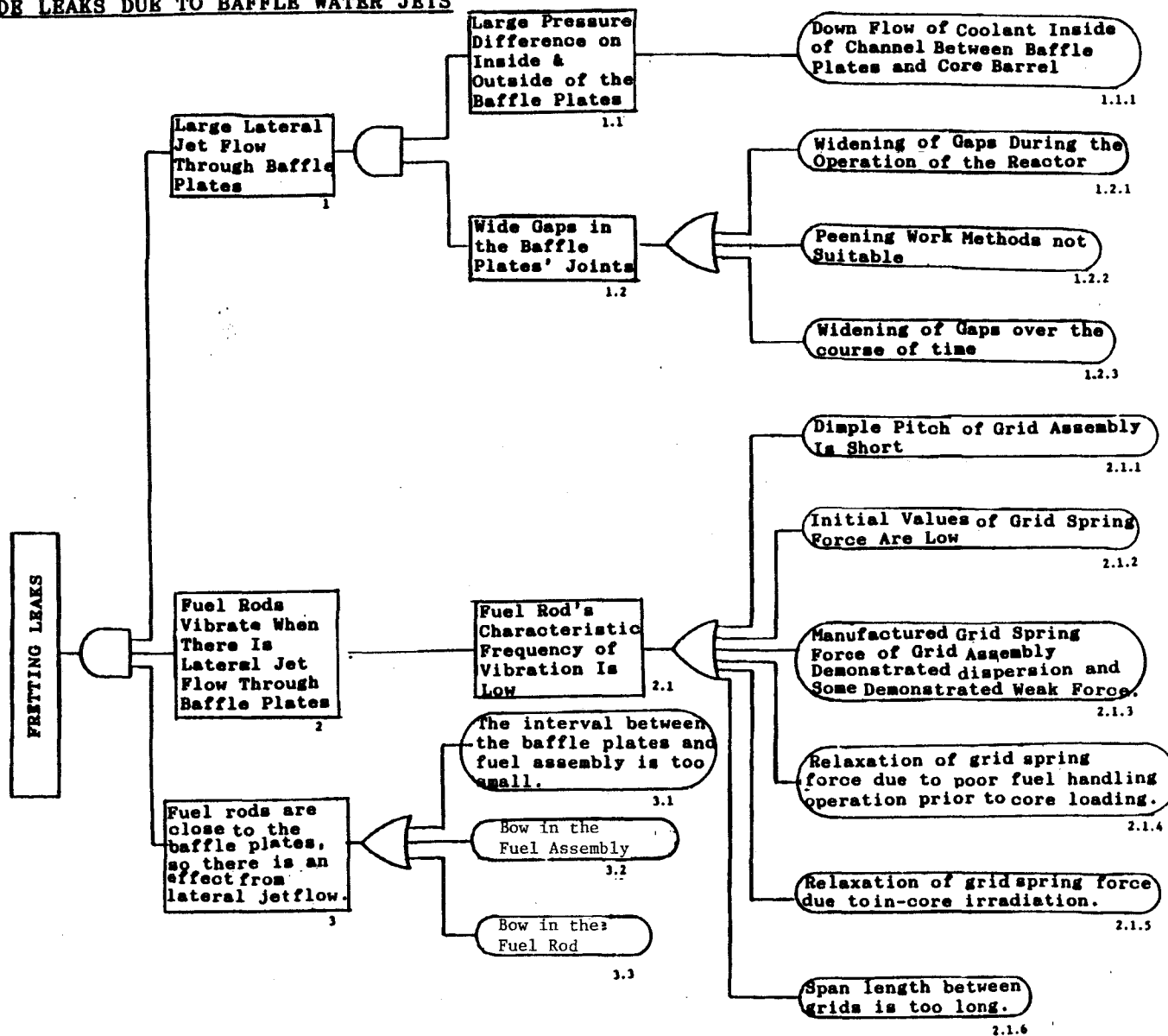
FUEL SHUFFLING

Post Irradiation Experimentation

Supplied by Karsin to Manuf.

FAULT TREE DIAGRAM ANALYSIS CONCERNING FRETTING MODE LEAKS DUE TO BAFFLE WATER JETS

CHART 1



FMEA CONCERNING FRETTING LEAKS

CHART 2.1

Factors			Understanding the Current Status of Factors		Understanding the Degree of Effect Due to Failures		Countermeasure
Primary Factors	Secondary Factors	Tertiary Factors	Evaluating Factor Possibility	Evaluating Current Status of Factors	Evaluating Degree of Effect (M/F Evaluation)	Level of Degree of Effect	
Large Lateral Jet Flow Through Baffle Plates 1	Large Pressure Difference on Inside & Outside of the Baffle Plates 1.1	Down Flow of Coolant Inside of Channel Between Baffle Plates and Core Barrel 1.1.1	There is the * possibility of M/F becoming larger due to the pressure difference on the inside & outside.	Results of Evaluation done from analysis of inside & outside pressure differences showed that the down flow, when compared against the up flow, is 9 times greater.	When compared against the up flow, the M/F during down flow is 17 times greater (3 Loops).	I (One of the fundamental factors, and the degree of effect is extremely large.)	* Up Flow System Construction * Design Change on Lower Nozzle of Fuel Assembly (Reduces the difference in pressure on the inside & outside of the baffle plates after up flow.)
	Wide Gaps in the Baffle Plates' Joints 1.2	Widening of Gaps During the Operation of the Reactor 1.2.1	Due to the difference of pressure and temperature on the inside & outside of the baffle plates, there is the possibility of gaps widening.	Evaluation results of analysis regarding gap widening showed that the center jet type increased from less than 0.05mm when it is cold, to 0.18mm (3 Loops) when it is hot. (In the corner jet type, on the other hand, the gap narrows.)	If the widening gaps during times of high temperature are considered, M/F is seven times larger (3 Loops).	I	Remodeling the core's internal structure is difficult, so no countermeasure is assigned.
		Peening Work Methods not Suitable 1.2.2	Due to unsuitable peening work, there is the possibility of gaps widening.	After peening work, measurements of the gaps are taken and controlled so as to be less than 0.05mm.	No effect.	—	—
		Widening of Gaps over the Course of Time 1.2.3	Possible (Details unknown)	In one year, the widening of gaps averaged mm (3 Loops).	In one year, the M/F increased approx. 30% (3 Loops)	III	Peening

Degree of Effect Legend

Increased Quantity (or decreased qty.) of lateral jet flow over the lateral jet resistance value.

I 5 or more times (1/5 or below)

II 2 - 5 times (1/2 - 1/5)

III 1.1 - 2 times (1/1.1 - 1/2)

↓ Flow

 ↗ RESISTANCE

$m \cdot v$

 A

FMEA CONCERNING FRETTING LEAKS

CHART 2.2

Factors			Understanding the Current Status of Factors		Understanding the Degree of Effect Due to Failures		Countermeasure
Primary Factors	Secondary Factors	Tertiary Factors	Evaluating Factor Possibility	Evaluating Current Status of Factors	Evaluating Degree of Effect (M/F Evaluation)	Level of Degree of Effect	
Fuel Rods Vibrate When There Is Lateral Jet Flow Through Baffle Plates 2	Fuel Rod's Characteristic Frequency of Vibration Is Low 2.1	Dimple Pitch of Grid Assembly Is Short 2.1.1	The rotation resistance of the grid assembly is small. There is a some possibility of having a low characteristic frequency of vibration.	The estimated characteristic frequency of vibration by test analysis using the dimple pitch as a parameter.	Confirmed by test.	III	Extend dimple pitch of the grid assembly.
		Initial Values of Grid Spring Force Are Low 2.1.2	Same as above.	From testing and analysis, the grid spring force is set at a nominal value, and estimation of characteristic frequency of vibration is conducted. The B-Type design fuel, when compared against A-Type, is 11% greater (15x15 Type).	In case grid spring force is set at a nominal value, critical M/F of Type B is greater than that of A by 35% (15x15 Type). (Confirmed by Test)	III	Adopt B-Type Fuel
		Manufactured Grid Spring Force of Grid Assembly Demonstrated Dispersion and Some Demonstrated Weak Force. 2.1.3	Same as above.	Evaluated characteristic frequency of vibration through test analysis using grid spring force as a parameter.	Effect on critical M/F due to dispersion of grid spring force is very small.	—	—

COUNTERMEASURE FLOWCHART AGAINST FRETTING MODE LEAKS

CHART 3

OBJECTIVESPRIMARY MEANSSECONDARY MEANSTERTIARY MEANS

Countermeasure Menu	Effectiveness Scale Factor (x10)	Cost (x7)	Degree of Difficulty (x3)	Total Score (points)	Implementation Feasibility	Implementation Dates
a) Implementation of Up Flow Construction (1.1.1)	8	△	△	90	○	1983-1985
b) Implementation of Peening Work (1.2.3)	8	△	○	66	△	Under Implementation Since 1976
c) Improvement of Lower Nozzle After Implementation of Up Flow Construction	x	○	○	30	x	-
d) Span Length Expansion of Dimple Pitches of Grid Assembly (2.1.1)	○	○	○	66	○	1984
e) Attach Anti-Vibration Clips (2.1.6)	○	○	x	85	x	-
f) Adoption of B-Type Fuel (2.1.2 - 2.1.5) (2.3)	○	○	○	80	△	Under Implementation Since 1981
g) Use of Stainless Rods (2.1)	○	○	x	85	x	-

Prevent Fretting Mode Leaks
(Prevent Leaks in Baffle Plates
Due to Lateral Jet Flow.)

Countermeasures
for Core Barrel

Minimize the
Lateral Jet Flow
Through the
Baffle Plates
(1)

Minimize Pressure
Gap Between Inside
and Outside of
Baffle Plates
(1.1)

Shorten the
Existing Gaps
Between the
Welded Baffle
Plates (1.2)

Countermeasures
for Fuel Rods

Reduce the
Vibration of
Fuel Rods
(2)

Increase the
Characteristic
Frequency of
Vibrations inherent
in Fuel Rods
(2.1)

Reduce the
Effect of
Lateral Jet Flow
Through Baffle
Plates (2.3)

Reduce the Warp
in the Fuel Rods
(2.3)

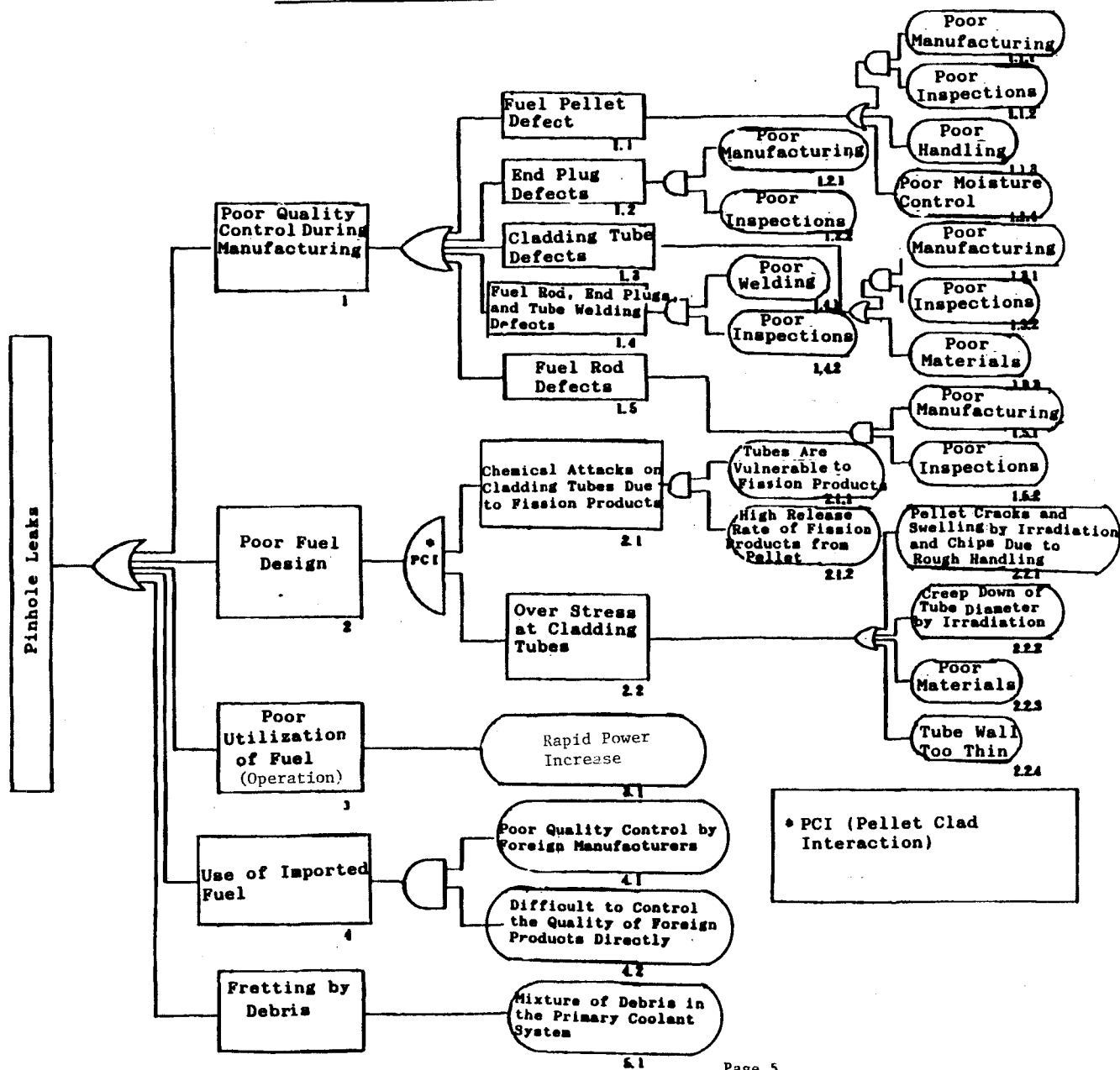
Legend Used in the
Effectiveness Column

Number in Parenthesis
Corresponds to FTDA

	Effectiveness in Decreasing Lateral Jet Flow Through Baffle Plates	Effectiveness in Increasing Lateral Jet Flow Resistance Value
●	Below 1/5	5 times or more
○	1/2 - 1/5	2 - 5 times
○	1/1.1 - 1/2	1.1 - 2 times

Points ●: 8 ○: 3
○: 5 △: 1
x: 0

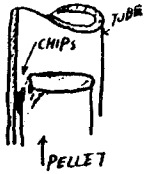
Legend ○: Permanent Measures
△: Temporary Measures until
Implementation of Up Flow
Construction
x: Impossible to
Implement

PINHOLE LEAKS FAULT TREE DIAGRAM

FMEA CONCERNING PINHOLE LEAKS

Rev. 1

CHART 5.1

Factors			Understanding the Current Status of Factors		Understanding the Degree of Effect Due to Failures		Countermeasure
Primary Factors	Secondary Factors	Tertiary Factors	Evaluating Factor Possibility	Evaluating Current Status of Factors	Evaluating Degree of Effect	Level of Degree of Effect	
QC Failure During Fabrication 1	Fuel Pellet Defects 1.1	Processing Failure 1.1.1	There is the possibility that the pellets will chip depending on the UO ₂ powder and sintering conditions.	Possibilities are low since powder and sintering conditions are checked at the manufacturing stage both before and after the processing of each lot.	When pellet chips get between the tube and the pellet, large amounts of local stress occur, which causes pinhole leaks.	II 	Currently technical improvements are not expected nor do specific countermeasures exist. Therefore, careful handling and inspections need to be conducted.
		Insufficient Inspections 1.1.2	There is the possibility of incomplete inspections.	Insufficient inspections are possible due to mere external inspections being done.	Same as above.	II	Enforce pellet external inspection. (Along with mechanization)
		Handling Failures 1.1.3	There is the possibility that pellets will chip during or after the pellets are inserted into the tubes.	Avoid excess stress on the pellets when inserting them into the tubes. If the pellets do happen to chip, try to keep the particles from getting into the fuel rod. After insertion rods are handled using a longitudinal rod holding device which prevents excessive bending.	No effect.	—	—
		Improper Moisture Control 1.1.4	There is the possibility that the pellets baking might be insufficient.	Moisture control was conducted according to QC specifications. -1971 30ppm 1972-1981 15ppm	Hydride occurs in the tube due to moisture in the fuel rod, which can cause pinhole leaks.	II	Enforce pellet moisture control. (Since 1982 the level is kept at 10ppm)

Degree of Effect Legend

I Very High
II High
III Medium
IV Low

FMEA CONCERNING PINHOLE LEAKS

CHART 5.2

<i>Factors</i>			<i>Understanding the Current Status of Factors</i>		<i>Understanding the Degree of Effect Due to Failures</i>		<i>Countermeasure</i>
<i>Primary Factors</i>	<i>Secondary Factors</i>	<i>Tertiary Factors</i>	<i>Evaluating Factor Possibility</i>	<i>Evaluating Current Status of Factors</i>	<i>Evaluating Degree of Effect</i>	<i>Level of Degree of Effect</i>	
	End Plug Defects 1.2	Processing Failures 1.2.1	There is the possibility that unsuitable end plug manufacturing methods are being used.	Possibilities are low because of the controls of cleaning fluids, lubricating oil, and plug materials.	No effect.	—	—
		Insufficient Inspections 1.2.2	There is the possibility that inspections are not complete.	There is no possibility since external inspections were conducted on the whole lot.	No effect.	—	—
	Tube Defects 1.3	Manufacturing Failures 1.3.1	There is the possibility that unsuitable tube manufacturing methods are being employed.	There is a possibility that a small amount of early stage defects remain with the current technological level.	Built-in defects in raw tube cause "stress corrosion cracks" (SCC). PCI causes the pinhole leaks.	II	Currently appropriate countermeasures do not exist. Inspections and material control need to be conducted.
		Insufficient Inspections 1.3.2	There is the possibility that inspections are not being done completely.	It is possible to overlook slant defects because of current inspection techniques.	Same as above.	II	Enforce standards and improve inspections techniques for tube defects.
		Defective Materials 1.3.3	There is the possibility that tube materials contain impurities and that alloy elements are not mixed sufficiently in materials.	Material composition is checked on a mill sheet for each lot. No abnormalities are discovered in the microtissue in a metalography test.	No effect.	—	—

FMEA CONCERNING PINHOLE LEAKS

Factors			Understanding the Current Status of Factors		Understanding the Degree of Effect Due to Failures		Countermeasure
Primary Factors	Secondary Factors	Tertiary Factors	Evaluating Factor Possibility	Evaluating Current Status of Factors	Evaluating Degree of Effect	Level of Degree of Effect	
Poor Fuel Design 2	Chemical Effect of Cladding Tubes Due to Fission Products 2.1	Cladding Tubes Tend to Be Affected Easily by Fission Products 2.1.1	Strong likelihood of SCC sensitivity exists because cladding tubes are made out of a alloy metal.	Average quantity of Iodine released from pellet and operating reactor is approx. 0.001-0.013mg/cm ³	Results of ex-core SCC test indicates that SCC breakage is possible from approx. 10 ³ mg/cm ³ iodine quantity.	I	Zirconium Liner Tube (pure metal)
		Large Amounts of Fission Products are Discharged from the Pellets. 2.1.2	Discharged rate of fission products increases due to increased pellet temperature during irradiation.	Centerline temperature of the pellet becomes approx. 1800 degrees Centi- grade during operation, and therefore, release rate of iodine is 10-40 times that of the aforementioned. It corresponds to 1000 C to 1200 C Pellet Temperature.)	Same as above.	I	Center Hollowed Pellet 
	Excess Stress of Cladding Tubes 2.2	Due to Irradiation and Rough Handling, Pellet Transformations, Cracks, and Chips 2.2.1		Irradiation creates hour-glassing of the pellet and approx. 10-15 cracks around the outer pellet. Post-irradiation examination by monitoring fuel indicated unlikely chipping possibilities.	Pellet's hour-glassing, cracks, and chips creates localized excess stress to cladding tubes, and consequently leads to pinhole leaks.	III	Smaller Length/Diameter Ratio Pellet (as Anti-formation Measure) Champhered Pellet (as Anti-chipping Measure)

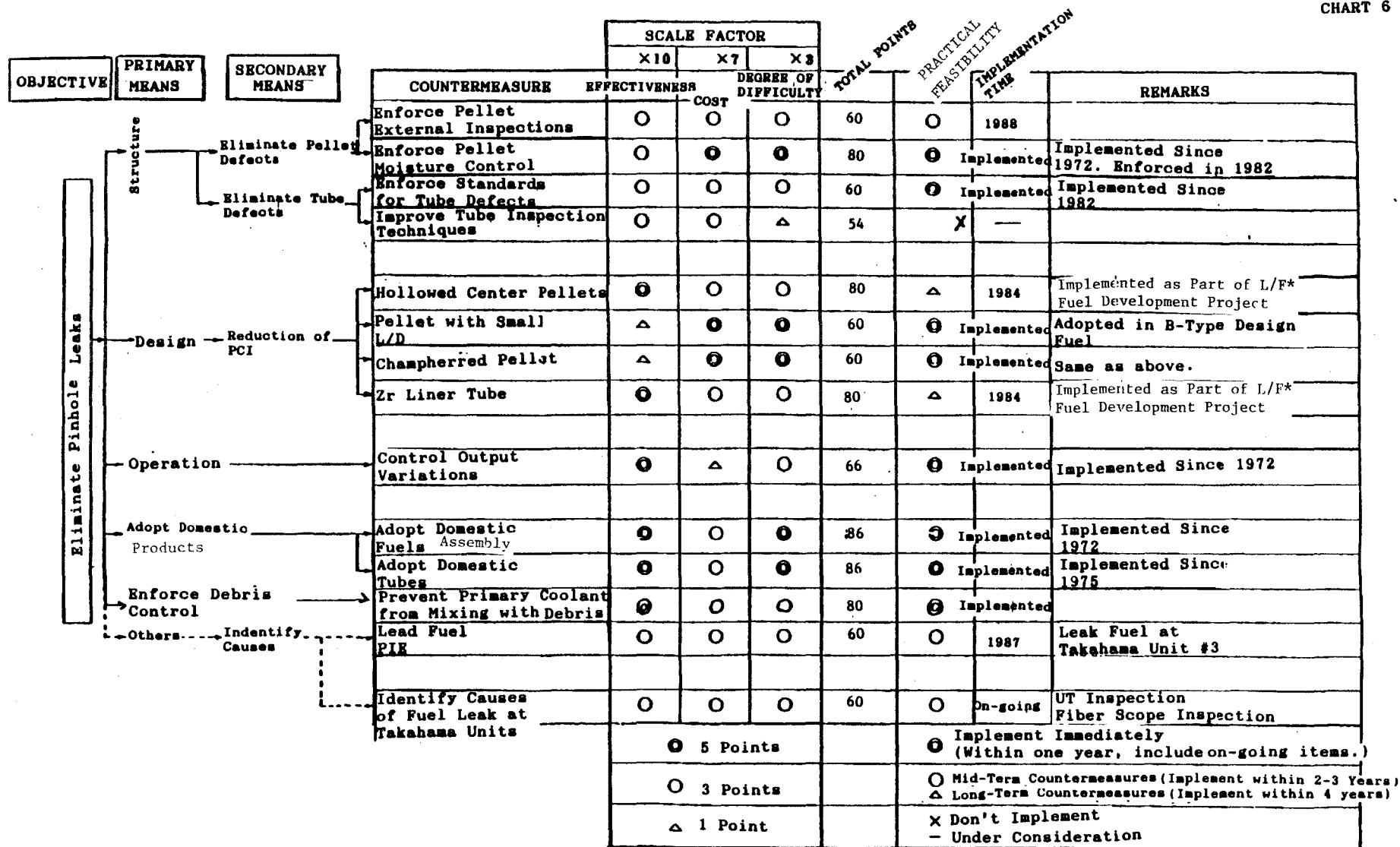
FMEA CONCERNING PINHOLE LEAKS

CHART 5.4

Factors			Understanding the Current Status of Factors		Understanding the Degree of Effect Due to Failures		Countermeasure
Primary Factors	Secondary Factors	Tertiary Factors	Evaluating Factor Possibility	Evaluating Current Status of Factors	Evaluating Degree of Effect	Level of Degree of Effect	
Utilization of Imported Fuel 4	Low Quality Control Level of Foreign Manufacturers 4.1		There is the strong probability that foreign manufacturers' concepts and attitudes toward QC are poor.	Imported fuel contains 26 pinhole leak spots while domestic fuel contains no pinhole leak spots.	Fretting type pinhole leaks are caused by poor quality control.	I	Adoption of Domestic Fuel and Cladding Tubes Products
	Difficult to Directly Control Quality 4.2		It is difficult to control quality because of inadequate information from foreign manufacturers and also contract limitations.	Same as above.	Same as above.	I	Same as above.
Fretting Caused by Debris 5	Debris Mixed in with Coolant 5.1		There is the possibility that Debris may come into contact with the cladding tubes after getting caught in the assembly.	There is the possibility that debris might be mixed with the primary cooling water during a periodic over-haul inspection, caught in the assembly, and then come into contact with the cladding tubes.	After Coming into contact with the cladding tubes, debris creates fretting type pinhole leaks.	I	Strengthen the Control of Debris in Coolant

PINHOLE LEAK COUNTERMEASURE TREE DIAGRAM

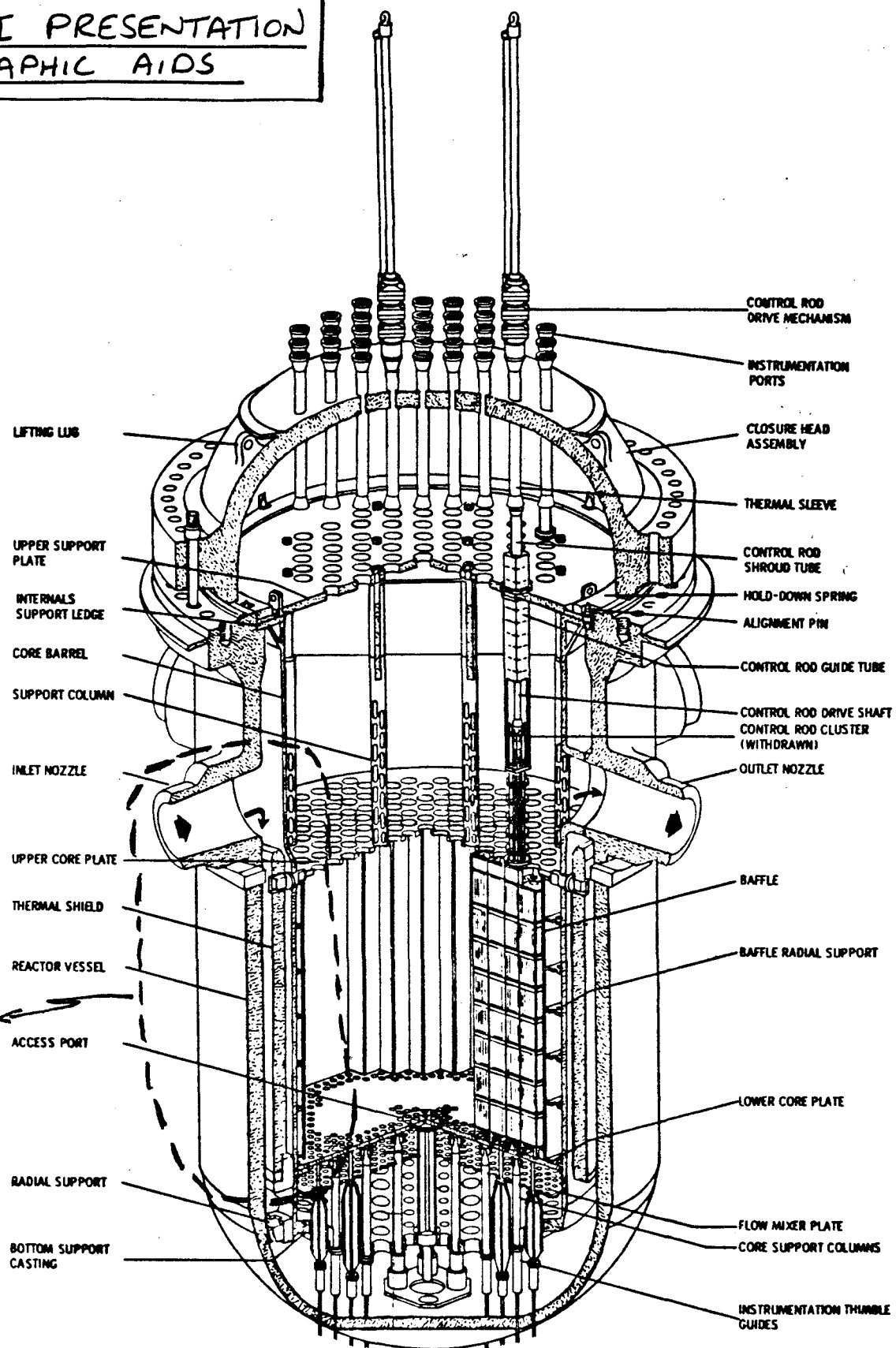
CHART 6



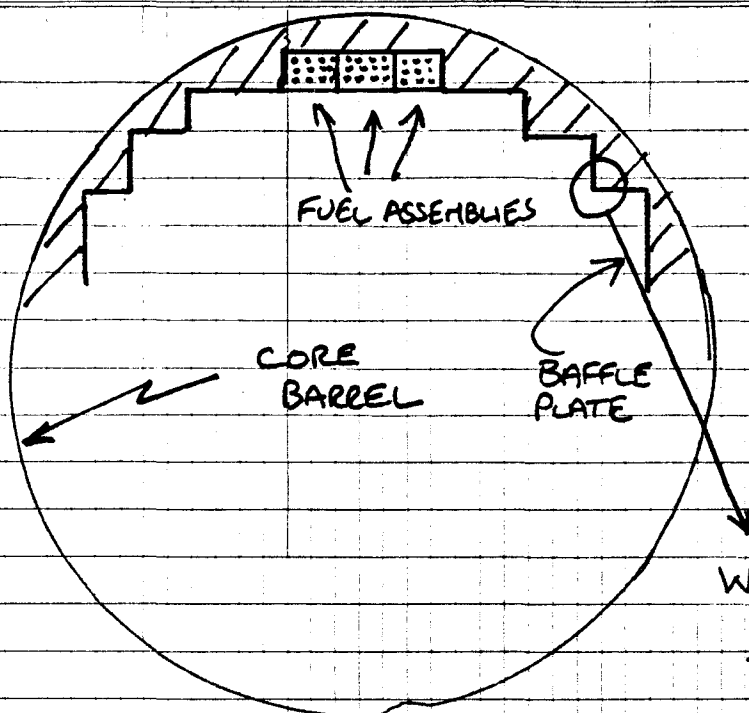
* L/F -- Load-Follow

KANSAI PRESENTATION

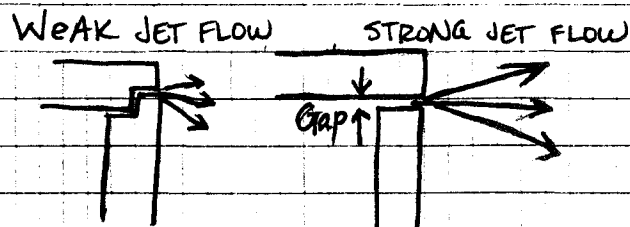
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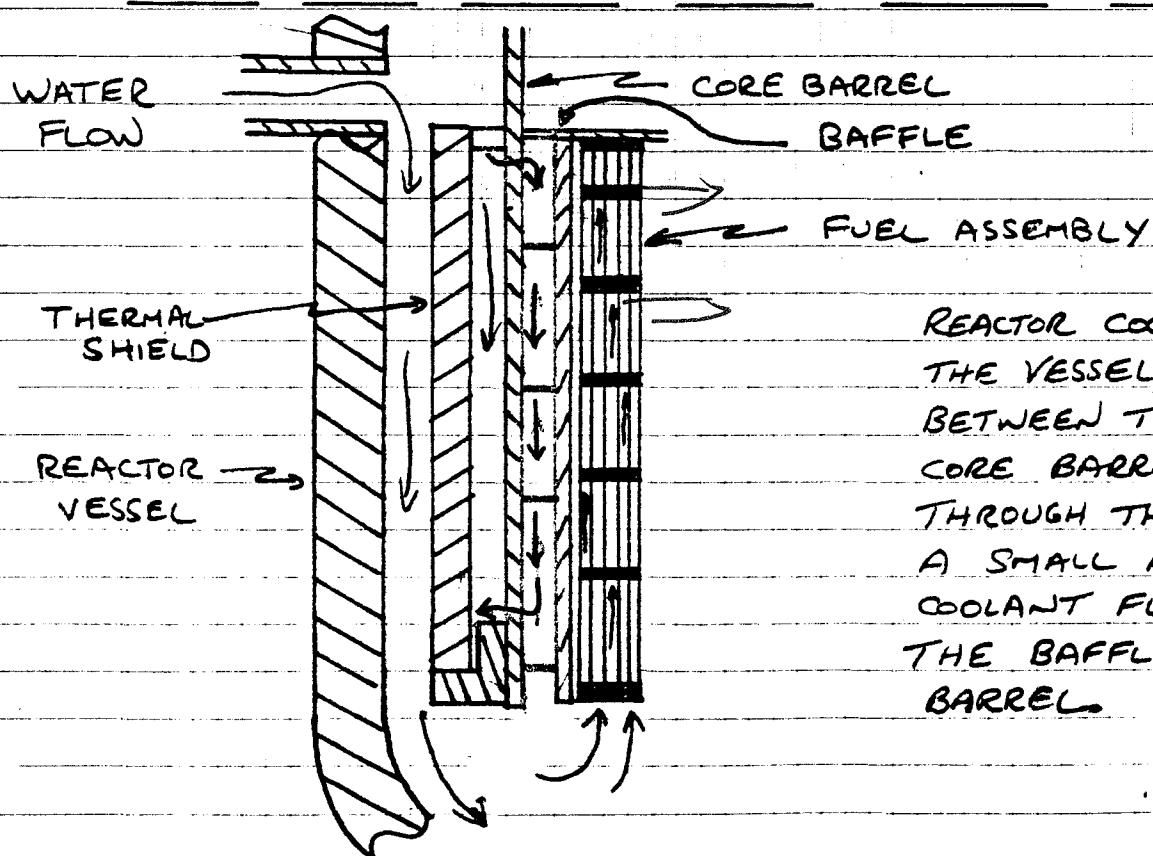
REACTOR VESSEL INTERNALS
FIG. 3.2.3-2



- FUEL ASSEMBLIES ARE SQUARE IN CROSS-SECTION
- CORE BARREL IS CIRCULAR IN CROSS-SECTION
- BAFFLE PLATE 'MATES' FUEL ASSEMBLIES, CORE BARREL AND PROVIDES LATERAL SUPPORT TO FUEL.



TOP VIEW - REACTOR CORE SUPPORT



REACTOR COOLANT ENTERS THE VESSEL, FLOWS DOWN BETWEEN THE VESSEL & CORE BARREL, THEN UP THROUGH THE FUEL ASSEMBLY. A SMALL AMOUNT OF COOLANT FLOWS DOWN BETWEEN THE BAFFLE AND CORE BARREL.

COOLANT FLOW - REACTOR CORE

Revision 1

