

INTERNATIONAL ATOMIC ENERGY AGENCY

INTERNATIONAL WORKING GROUP
ON
LIFE MANAGEMENT OF NUCLEAR POWER
PLANTS

SPECIALIST MEETING ON
CRACKING IN LWR RPV
HEAD PENETRATIONS

PAPER: "SPANISH RPV HEAD PENETRATIONS. REGULATORY STATUS"

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Philadelphia, USA
2 - 4 May 1995

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ABSTRACT.

The paper presents the actual status of inspection results on the spanish PWR RPV CRD head penetrations (CRDH's), after two years of a whole program of inspections in all affected plants.

Actual situation of penetrations pertaining to ALMARAZ 1 and 2, ASCO 1 and 2 and VANDERBILLOS 2 NPP's show any damage in those CRDH's inspected in 1993 and 1994 (roughly 20 out of 65 CRDH's at each unit). The paper presents a summary of CRDH characteristics, inspection methods and results obtained in each plant.

TRILLO NPP has a different CRDH design (KWU-SIEMENS type) and for that reason is not considered an affected plant nor has conducted any inspection up to now.

JOSE CABRERA (ZORITA) NPP has shown extensive damage, both in the lower side (weldment to the vessel) and in the upper free span area, near bimetallic weldment to SS 304, in active and non-active penetrations and also in the vent nozzle. The paper comments extensively on the CRDH materials general data, root-cause analysis and structural analysis of degraded zones, inspection results, repair actions and other additional actions applied up to now.

Finally, the paper deals with the *regulatory actions taken by CSN on this topic*, both for those NPP's actually non affected by the IGSCC phenomenon in the RPV CRDH's and for the specific safety case of ZORITA NPP.

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1.- ALMARAZ 1/2, ASCO 1/2 AND VANDELLOS 2
RPV HEAD PENETRATIONS.

1.1.- GENERAL DATA.

* 65 PENETRATIONS: 57 OR 52, ACTIVE (CRDH) WITH THERMAL SLEEVE

4, ACTIVE (THERMOCOUPLES) NOT SLEEVED

4 OR 9, RESERVE (PLUGGED) NOT SLEEVED

* MATERIALS: TUBE, INCONEL 600 M.A. (SB-167)

UPPER PART, S.S. 304

VESSEL HEAD, C.S. 302 B

" CLADDING, S.S. 308

WELD BUTTERING, INCONEL 182

" MATERIAL, INCONEL 182

* DIMENSIONS: TUBE INNER DIAMETER, 69,85 MM.

TUBE THICKNESS, 15,875 MM.

TUBE LENGTH, 870 - 923 MM. (MIN)

1497 - 1668 MM. (MAX)

1.- ALMARAZ 1/2, ASCO 1/2 AND VANDELLOS 2
RPV HEAD PENETRATIONS.

1.2.- SUMMARY OF INSPECTION RESULTS.

* INSPECTION SCOPE AND TECHNIQUES:

ALL INSPECTIONS PERFORMED WITH ROBOTIZED EQUIPMENT:

-	ALMARAZ 1	-> FRAMATOME/BW,	SEPT. 93
-	ASCO 1	-> ABB REAKTOR,	JUNE 93
-	ALMARAZ 2	-> PETAVA PROJECT,	FEBR. 94
-	ASCO 2	-> PETAVA PROJECT,	MARCH 94
-	VANDELLOS 2	-> PETAVA PROJECT,	MAY 94

* RESERVE PENETRATIONS:

INSIDE ECT (MRPC); WELD AREA \pm 2,0"

CRDH'S SELECTED FROM THREE OUTERMOST CIRCLES

SCOPE: . ALMARAZ 1, 4 CRDH'S

. ASCO 1, 4 CRDH'S

. ALMARAZ 2, 4 CRDH'S

. ASCO 2, 9 CRDH'S

. VANDELLOS 2, 2 CRDH'S

RESULTS: NO DAMAGE

1.- ALMARAZ 1/2, ASCO 1/2 AND VANDELLOS 2
RPV HEAD PENETRATIONS.

1.2.- SUMMARY OF INSPECTION RESULTS (CONT'D).

* ACTIVE PENETRATIONS (TC'S):

INSIDE ECT (MRPC); WELD AREA \pm 2,0"
 # TC'S ARE LOCATED IN OUTERMOST CIRCLES
 # SCOPE: . ALMARAZ 1, 0 TC'S
 . ASCO 1, 4 TC'S
 . ALMARAZ 2, 4 TC'S
 |
 . ASCO 2, 4 TC'S
 . VANDELLOS 2, 2 TC'S
 # RESULTS: NO DAMAGE

* ACTIVE PENETRATIONS (CRDH'S):

INSIDE ECT (GAP SCANNER / "SABLE"); WELD AREA \pm 2,0"
 # CRDH'S SELECTED FROM THREE OUTERMOST CIRCLES
 # SCOPE: . ALMARAZ 1, 16 CRDH'S
 . ASCO 1, 12 CRDH'S
 . ALMARAZ 2, 12 + 2 CRDH'S
 . ASCO 2, 5 + 2 CRDH'S
 . VANDELLOS 2, 16 CRDH'S
 # RESULTS: NO DAMAGE

2.- JOSE CABRERA RPV HEAD PENETRATIONS.2.1.- GENERAL DATA.

- * 37 PENETRATIONS: 17, ACTIVE (CRDH) WITH THERMAL SLEEVE
- 2, ACTIVE (THERMOCOUPLES) NOT SLEEVED
- 1, ACTIVE (S.I.S. NOZZLE) NOT SLEEVED
- 17, RESERVE (PLUGGED) NOT SLEEVED
-
- * MATERIALS:
- | | |
|-----------------|---------------------------|
| TUBE, | INCONEL 600 M.A. (SB-167) |
| UPPER PART, | S.S. 304 |
| VESSEL HEAD, | C.S. 302 B |
| " CLADDING, | S.S. 308 |
| WELD BUTTERING, | INCONEL 182 |
| " MATERIAL, | INCONEL 182 |
-
- * DIMENSIONS:
- | | |
|----------------------|---------------------------|
| TUBE INNER DIAMETER, | 69,9 MM. |
| TUBE THICKNESS, | 15,85 MM. |
| TUBE LENGTH, | 395 (MIN) - 730 (MAX) MM. |

2.- JOSE CABRERA RPV HEAD PENETRATIONS.

2.2.- SUMMARY OF INSPECTION RESULTS.

* INSPECTION SCOPE AND TECHNIQUES:

ALL INSPECTIONS PERFORMED WITH ROBOTIZED EQUIPMENT
SPANISH DESIGNED, PETAVA PROJECT, JAN. TO MAY 94.

* RESERVE PENETRATIONS:

17 INSPECTED FULL LENGTH, BOTTOM TO BIMETALLIC WELD
ALL INSIDE ECT (MRPC)
ALL OUTSIDE UT (P-SCAN AND MANUALLY) AND INSIDE UT (TOFD)

* ACTIVE PENETRATIONS (TC'S AND S.I.S. NOZZLE):

3 INSPECTED FULL LENGTH, BOTTOM TO BIMETALLIC WELD
ALL INSIDE ECT (MRPC)
OUTSIDE UT (P-SCAN OR MANUALLY) -> NQ 23 (SIS), 30 (TC)
INSIDE UT (TOFD) -> NQ 30

* ACTIVE PENETRATIONS (CRDH'S):

17 INSPECTED PART LENGTH, BOTTOM TO 60 - 225 MM.
ALL INSIDE ECT (GAP SCAN)
12 OUTSIDE UT (P-SCAN); 5 CENTRAL UT INTERFERED
INSIDE UT (TOFD) -> NQ 10, 15, 17, 20.

2.- JOSE CABRERA RPV HEAD PENETRATIONS.

2.2.- SUMMARY OF INSPECTION RESULTS (CONT'D).

* RESERVE PENETRATIONS:

16 PENETRATIONS DAMAGED IN VESSEL-TO-TUBE WELD AREA

- DEFECTS ARE AXIAL + CIRCUMFERENTIAL CRACKS NETWORK
- CIRCUMFERENTIAL CRACKS LOCATED ON UPPER BORDER OF WELD AREA
- CRACK LENGTHS, UP TO 48 MM. (AXIAL), 1582 (CIRC)
- CRACK DEPTHS, UP TO WALLTHROUGH

12 PENETRATIONS ALSO DAMAGED IN FREE TUBE AREA

- DEFECTS ARE ISOLATED AXIAL CRACKS
- CRACK LENGTHS, UP TO 118 MM.
- CRACK DEPTHS, UP TO WALLTHROUGH

PENETRATIONS NO 2, 3, 4 SHOW ONLY AXIAL CRACKING IN WELD AREA

PENETRATION NO 5 IS FREE OF DEFECTS

MOST AFFECTED -> PERIPHERICAL PENETRATIONS

2.- JOSE CABRERA RPV HEAD PENETRATIONS.

2.2.- SUMMARY OF INSPECTION RESULTS (CONT'D 2).

* ACTIVE PENETRATIONS (TC'S AND SIS NOZZLE):

PENETRATIONS NO 23 (SIS), 34 (TC) ARE FREE OF DEFECTS

PENETRATION NO 30 (TC):

- . 7 AXIAL CRACKS IN WELD AREA
- . CRACK LENGTHS, 5 - 21 MM.
- . CRACK DEPTHS, SHALLOW UP TO 4,4 MM.

* ACTIVE PENETRATIONS (CRDH'S):

10 PENETRATIONS SHOW DAMAGE IN VESSEL-TO-TUBE WELD AREA

NO DAMAGE IN FREE TUBE AREA

DEFECTS ARE ISOLATED AXIAL OR CIRCUMFERENTIAL CRACKS

ONLY 3 CRDH'S (NO 10, 15, 17) SHOW "SIGNIFICANT" CRACKS:

- . ECT PHASE/AMPLITUDE SIGNAL DISCRIMINATION

SOFTWARE ANALYZED =>

- . CRACK LENGTHS, 6 - 22 MM. (AXIAL), 24 - 800 (CIRC)
- . CRACK DEPTHS, 3 - 7,5 MM.

2.- JOSE CABRERA RPV HEAD PENETRATIONS.

2.3.- ROOT CAUSE ANALYSIS.

* METALLOGRAPHIC EXAMS ON 2 SAMPLES:

- # 1 FROM FREE AREA, CRDH NQ 36 (W STC, USA)
- # 1 FROM LOWER BORDER WELD AREA, CRDH NQ 37 (CIEMAT, SPAIN)

* EXAMINATION RESULTS:

- # PENETRATION ALLOY 600 MICROSTRUCTURE SIGNIFICANTLY SENSITIZED
 - # GOOD GRAIN BOUNDARY CARBIDE COVERAGE
 - # SULFUR PRESENCE INSIDE CRACKS FRACTURE SURFACES
- * NPP CHEMISTRY RECORDS SUGGEST THAT SIGNIFICANT POTENTIAL FOR ACID SULPHATES AND OTHER SULFUR REDUCED SPECIES ENVIRONMENT EXISTED:
- # DURING SERVICE OPERATION DUE TO RESINS INTRUSIONS IN AUG.80 AND SEP.81 (CATIONIC DEMINERALIZER RETENTION MESH FAILURES)
 - # FROM OCT.82 THROUGH DEC.83 NPP WAS IN PLANNED SHUTDOWN FOR MAJOR MODIFICATIONS =>
 - RPV HEAD SETTLED ON STAND IN AIR ENVIRONMENT (O₂)
 - POLITHIONATES (TIOSULPHATES + TETRATHIONATES) FORMED

2.- JOSE CABRERA RPV HEAD PENETRATIONS.2.3.- ROOT CAUSE ANALYSIS (CONT'D).* STRUCTURAL INTEGRITY ANALYSIS:

FEM ANALYSIS ON A PERIPHERAL PENETRATION WHOLE LENGTH

BOTH VESSEL-TO-TUBE WELD AND FREE TUBE AREAS SHOW
HIGH AXIAL AND HOOP STRESSES OF ABOUT Y.S. ORDER, 60 KSI

CLASSIC LEFM AND LIMIT LOAD ANALYSIS:

- . CRITICAL TW CRACK LENGTHS -> 166 MM. (AX), 2419 (CIRC)
- . CRITICAL CRACK DEPTH -> $A/T < 0,75$ (MAX. 12 MM.)
- . CRACK GROWTH ESTIMATIONS (P. SCOTT CURVE) -> 3,5 MM/YEAR

* FINAL ROOT CAUSE CONCLUSIONS:

NO PWSCC MECHANISM

IGA + SCC, SULFUR REDUCED SPECIES INDUCED, MECHANISM

DIFFERENT DAMAGE DEPENDING ON THERMAL SLEEVE

- . RESERVE PENETRATIONS MORE AFFECTED

16 RESERVE PENETRATIONS WILL EXCEED ASME IWB-3600 CRITERIA
($A/T < 0.75$, AX; < 0.56 , CIRC) DURING NEXT CYCLE => REPAIR

4 ACTIVE PENETRATIONS WILL EXCEED ASME CRITERIA IN 1,0 TO
2,8 YEARS => REPAIR

REST (7) OF ACTIVE PENETRATIONS WILL BE UNACCEPTABLE IN
3,3 YEARS => NO REPAIR, BUT CONTINUOUS SURVEILLANCE

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2.- JOSE CABRERA RPV HEAD PENETRATIONS.

2.4.- REPAIR METHODOLOGIES.

* REPAIR SCOPE AND TECHNIQUES:

ALL REPAIR TECHNIQUES PERFORMED WITH ROBOTIZED EQUIPMENT:

- EDM -> SPANISH PETAVA PROJECT, JAN. TO MARCH 95.
- CAPS -> WESTINGHOUSE, OCT. 94 TO JAN. 95

* RESERVE PENETRATIONS:

PLUGGED 16 CRDH'S, ALL BUT NO 5

INSTALLED HEMISPHERICAL CAPS ATTACHED TO THE "OLD" WELDMENT

CAPS AND "NEW" WELD ACT AS PRIMARY PRESSURE BARRIER

CAP MATERIALS: INCONEL 690 TT (SB-166), INCONEL 182

FINAL HYDROSTATIC TEST AT 151 BARS

* ACTIVE PENETRATIONS:

REPAIRED 4 CRDH'S: NO 10, 15, 17 (2 AREAS) AND 30

ELIMINATED CRACKS BY ELECTROEROSION (EDM)

DIMENSIONS OF "BATHTUB LIKE" EXCAVATIONS,

- CRDH NO 10: DEPTH 6,53 MM.; 49 MM.(AX.) BY 590 (ARC)
- CRDH NO 15: DEPTH 5,70 MM.; 59,5 MM. BY 1090
- CRDH NO 17: DEPTH 7,90 MM.; 41,6 MM. BY 44,50
DEPTH 6,30 MM.; 47,7 MM. BY 1020
- CRDH NO 30: DEPTH 6,85 MM.; 86,6 MM. BY 690

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2.- JOSE CABRERA RPV HEAD PENETRATIONS.

2.5.- ADDITIONAL ACTIONS.

* ANALYSIS AND/OR INSPECTIONS SCOPE OF RCS COMPONENTS WITH POSSIBLE SULFUR INDUCED SCC:

- # COMPONENTS:
- RPV BOTTOM MOUNTED INSTRUM. NOZZLES
 - RPV HEAD VENT NOZZLE
 - RPV UPPER INTERNALS
 - CRDH'S INTERNALS
 - SG TUBES, TUBESHEET AND PARTITION PLATE
 - PRESSURIZER PENETRATIONS
 - FUEL ELEMENTS
 - CONTROL RODS

- # MATERIALS:
- INCONEL 600, X-750, 718, 82, 182
 - AUSTEN. SS. (FORGED, WELD MAT., DUPLEX)
 - MARTENSITIC SS. 403, 410
 - STELLITE-6, HAYNES-25

* ANALYSIS AND/OR INSPECTIONS RESULTS:

- # ALL COMPONENTS INSPECTED BUT ONE ARE FREE OF DEFECTS
- # RPV HEAD VENT NOZZLE DEFECTIVE (SAME ROOT CAUSE) =>
- REPAIRED BY INCONEL 690 TT PLUGGING (ACTUALLY IN PROCESS)
 - VENT FUNCTION NOW THROUGH ONE ACTIVE CRDH

3.- REGULATORY ACTIONS TAKEN BY CSN.

3.1.- ALMARAZ 1/2, ASCO 1/2 AND VANDELLOS 2
RPV HEAD PENETRATIONS.

* ADDITIONAL ACTIONS REQUESTED:

ALMARAZ 1/2 NPP'S:

- RPV HEAD REPLACEMENT SCHEDULED BY UTILITY IN 1996/97
- DUE TO INSPECTION RESULTS AND SUSCEPTIBILITY STUDIES
NO ADDITIONAL INSPECTION REQUESTED BY CSN

ASCO 1/2 NPP'S:

- NO RPV HEAD REPLACEMENT SCHEDULED BY UTILITY
NOR REQUESTED BY CSN
- ADDITIONAL INSPECTION REQUESTED BY CSN IN 1995/96
- FUTURE ACTIONS DEPENDING ON INSPECTION RESULTS

VANDELLOS 2 NPP:

- NO RPV HEAD REPLACEMENT SCHEDULED BY UTILITY
NOR REQUESTED BY CSN
- FUTURE ACTIONS (ADDITIONAL INSPECTION) IN STUDY BY CSN

3.- REGULATORY ACTIONS TAKEN BY CSN.

3.2.- TRILLO RPV HEAD PENETRATIONS.

* ANALYSIS:

- # KWU-SIEMENS HAS DIFFERENT CRDH'S DESIGN AND MATERIALS
- # NOT CONSIDERED UP TO NOW AS AFFECTED NPP
- # NO CRDH'S INSPECTION PERFORMED NOR REQUESTED BY CSN

3.3.- JOSE CABRERA RPV HEAD PENETRATIONS.

* ADDITIONAL ACTIONS REQUESTED:

- # IMPROVE RPV HEAD LEAK DETECTION SYSTEMS (NO N-13 METHOD)
- # PSI (BASELINE) ON CAPS REPAIR AND EDM EXCAVATION REPAIR FOR FUTURE INSPECTIONS =>
NEXT INSPECTION IN 1996 REFUELING SHUTDOWN
- # SPECIFIC SULFUR AND OTHER AGGRESIVE CHEMICAL SPECIES CONTROL DURING NEXT CYCLE OPERATION
- # SPECIFIC STUDY ON EDM EFFECTS FOR INCONEL MICROSTRUCTURAL PROPERTIES
- # COMPLETE DURING NEXT REFUELING SHUTDOWN INSPECTION ON REST OF RCS COMPONENTS (RPV BOTTOM MOUNTED INSTRUM. NOZZLES AND S.G. PARTS)
- # RPV HEAD, SHORT TO MEDIUM TERM, REPLACEMENT REQUESTED

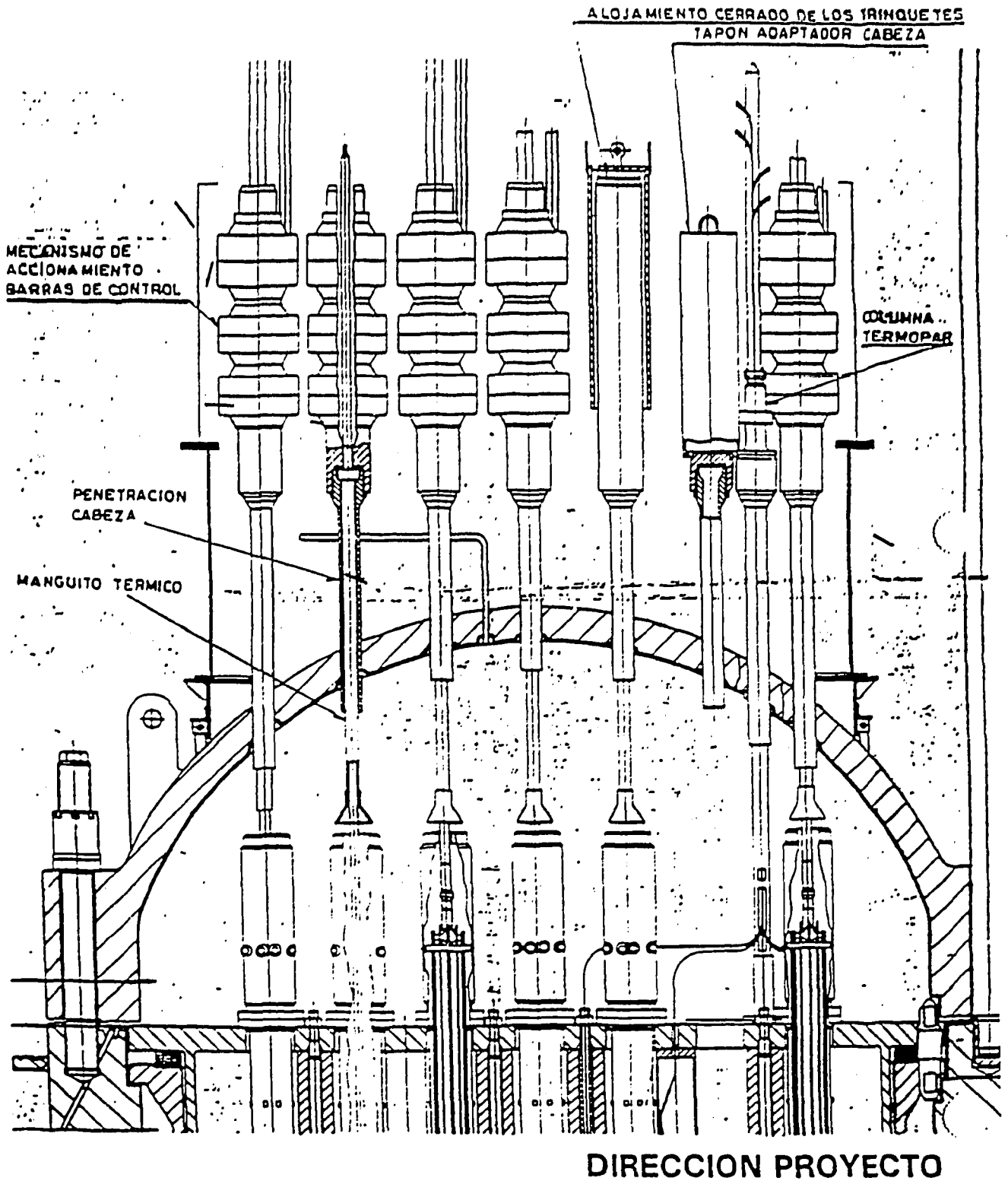
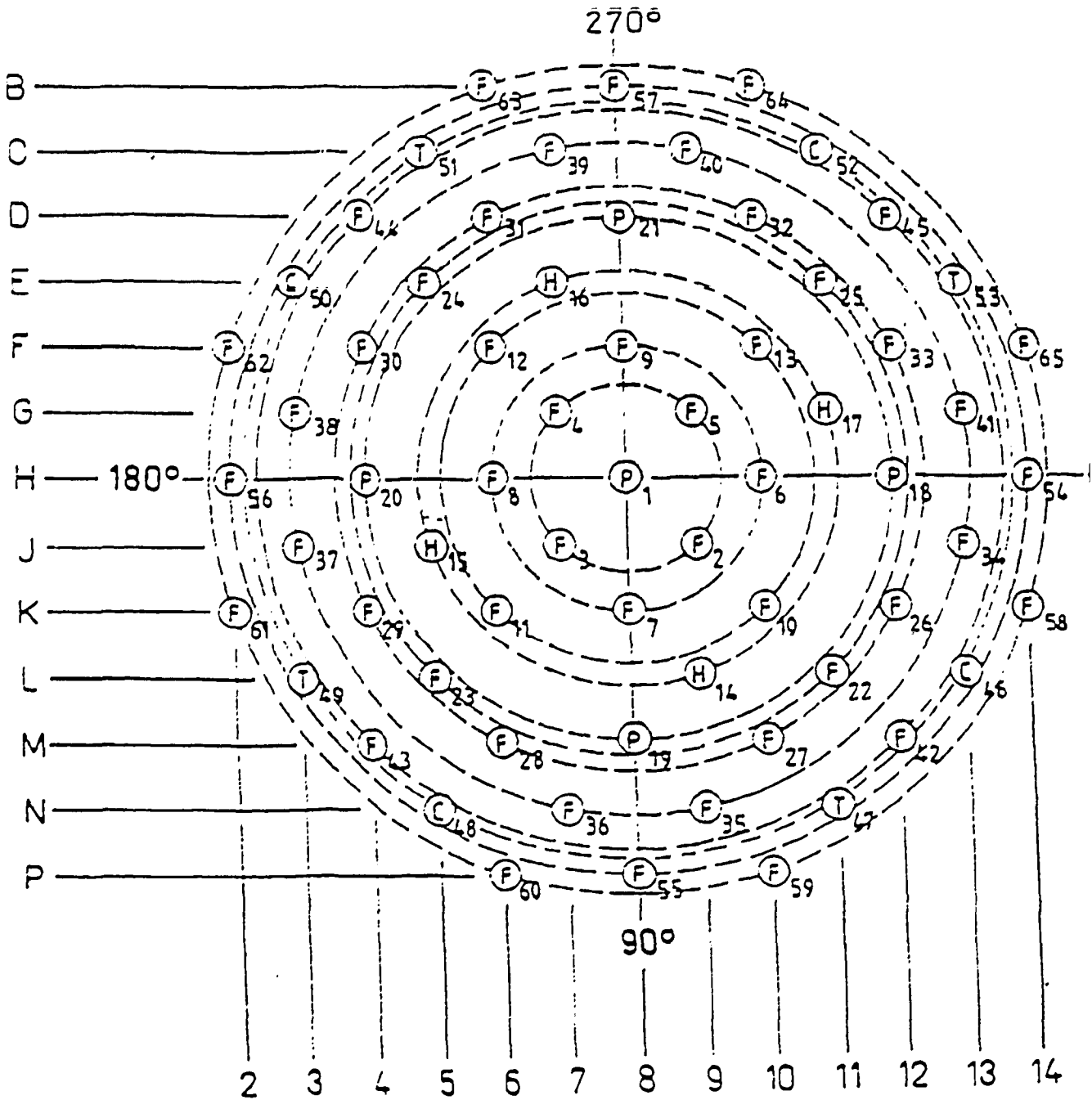


Fig. 1

FIGURE 1: ASCO & ALMARAZ RV HEAD PENETRATIONS



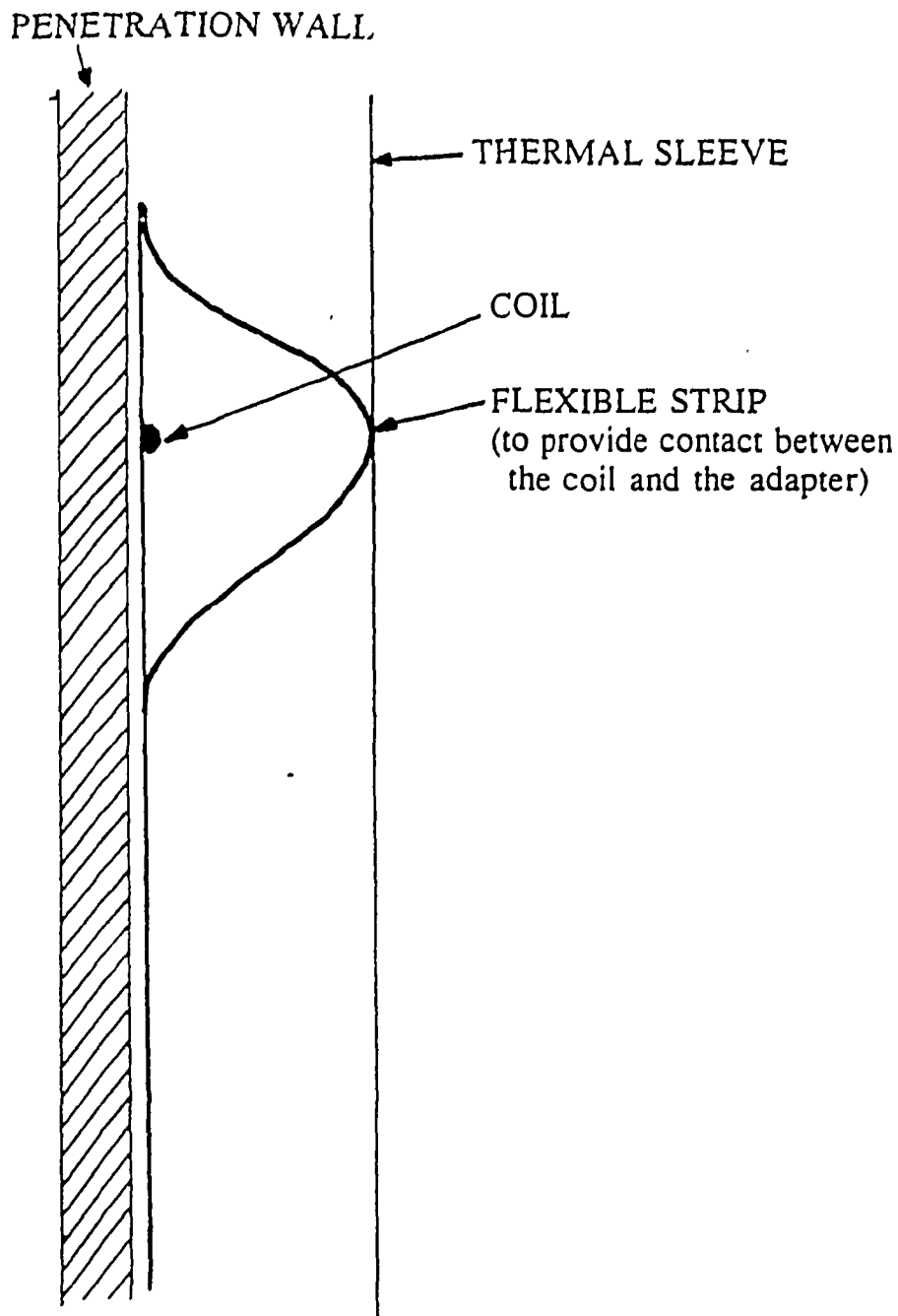


FIGURE 5: BLADE PROBE (ALMARAZ NPP)

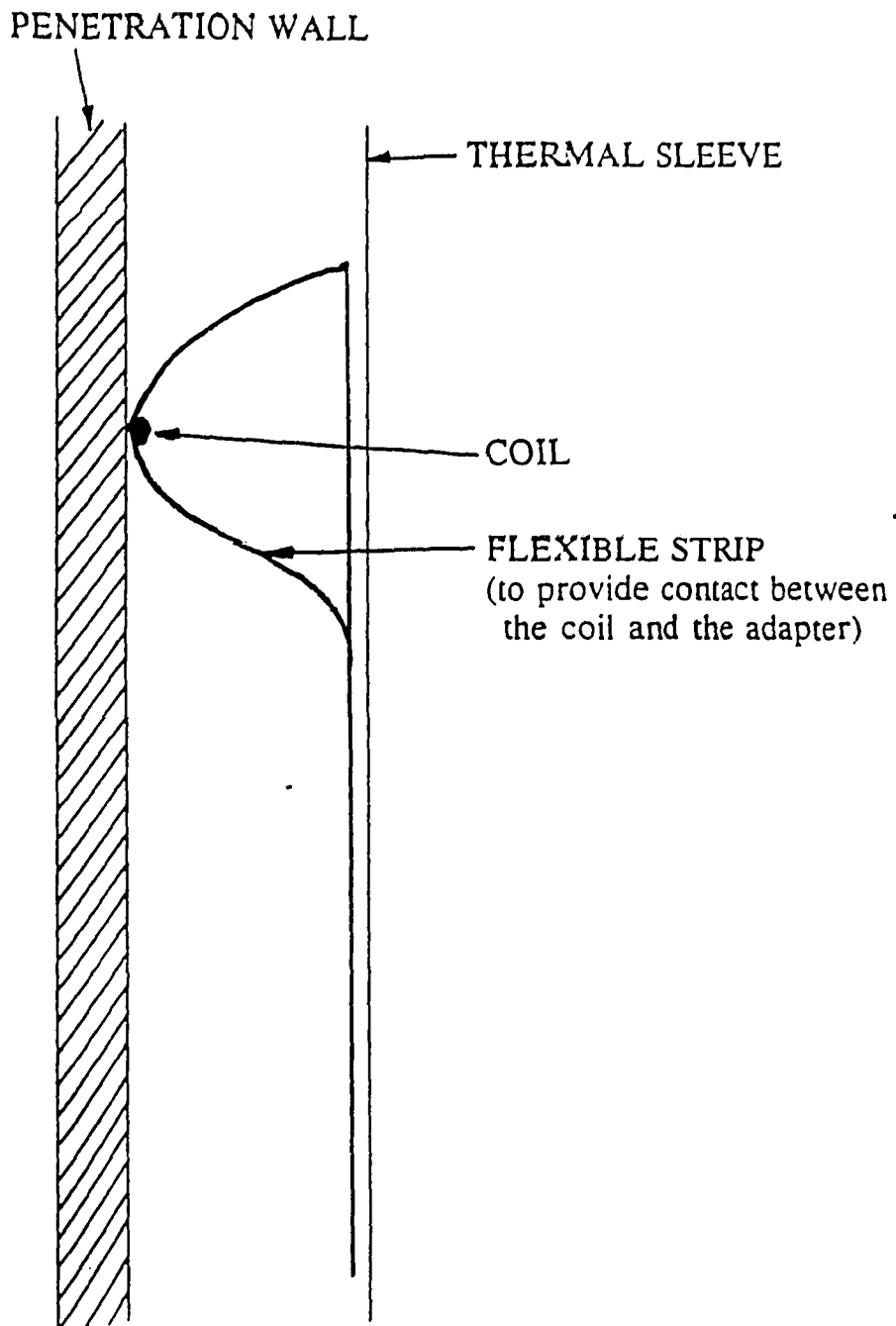
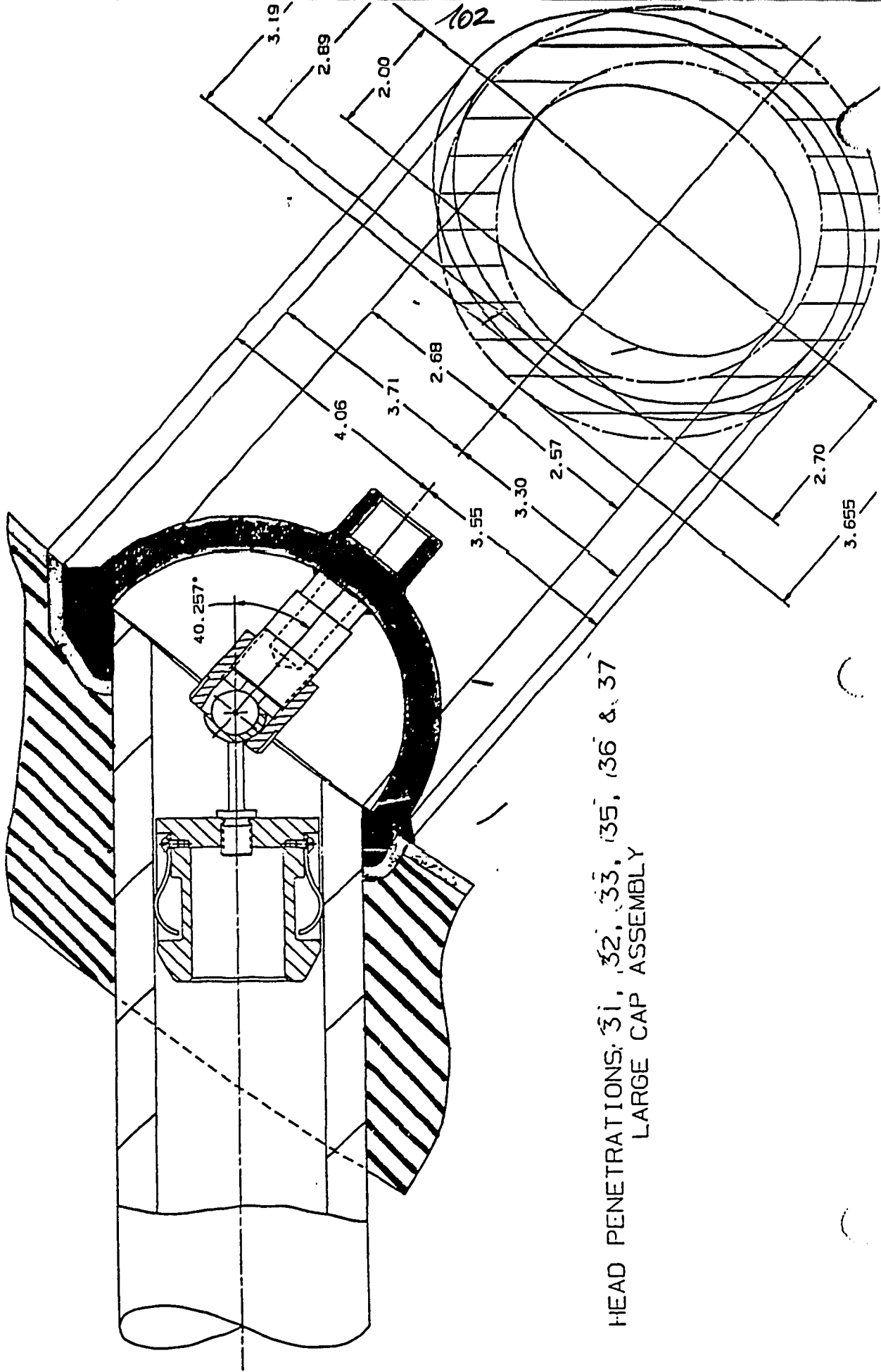


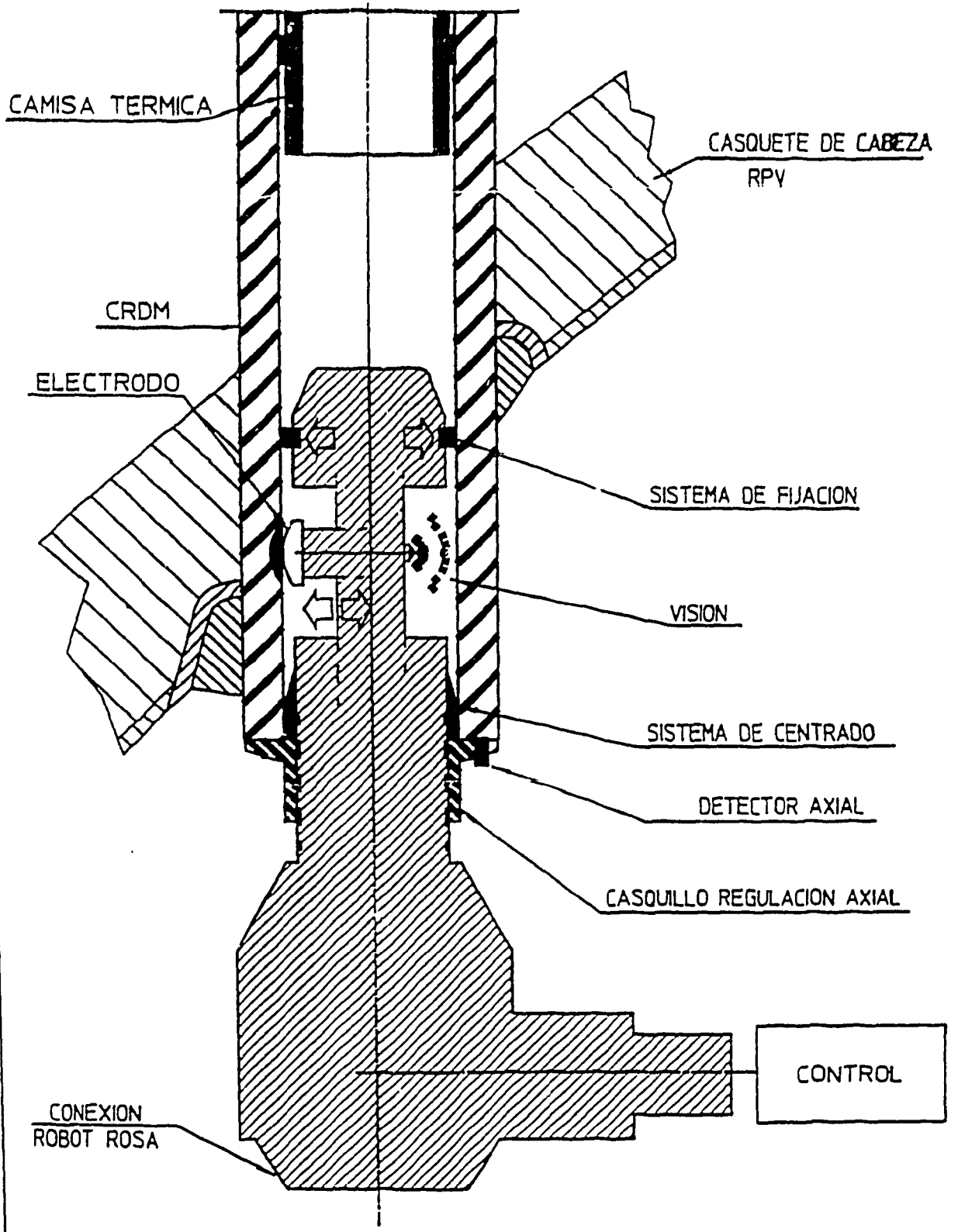
FIGURE 4 Bis: GAP SCANNER PROBE (ASCO NPP)



HEAD PENETRATIONS: 31, 32, 33, 35, 36 & 37
LARGE CAP ASSEMBLY

HERRAMIENTA PARA RESANADO DE DEFECTOS

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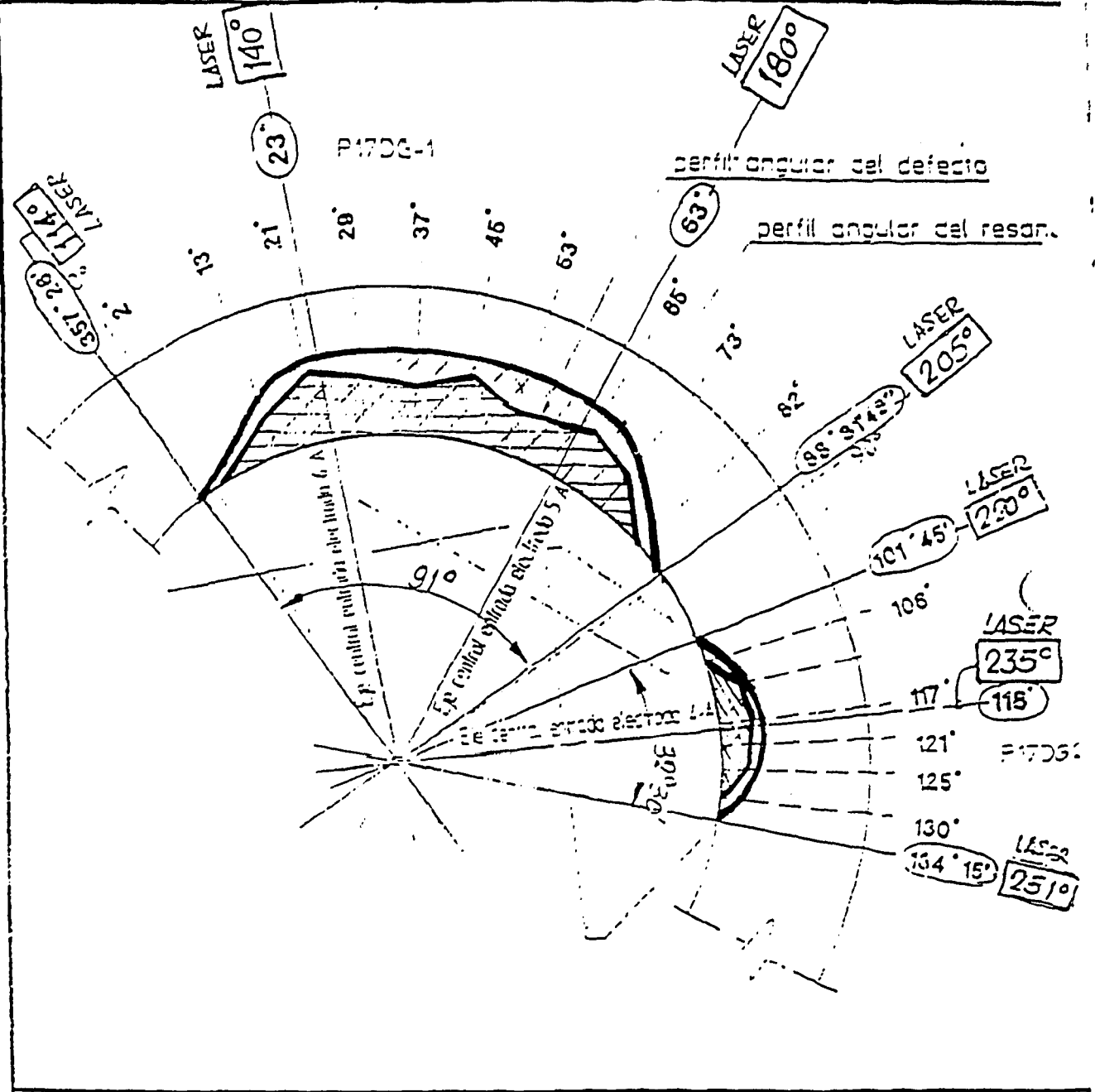
EQUIPOS NUCLEARES

Fig 5

PENETRACION N° 17

MWA Sheet 7 DE 7

CONTRATO Job n°	4CMB	CLIENTE UNION Customer FENOSA	IPP.- 4CMB-X17	REV.-1	OPERACION Operation 15 y 16
OBJETO Object:	CONTROL DIMENSIONAL DEL NUEVO POSICIONAMIENTO DE EJES DE LOS ELECTRODOS G.A. 5A y 4A (LASER)			PLANO Drawing:	4CMB.010.103 Rev. - 4



ASESORIAS EXTERNAS			ENSA		
CLIENTE Customer	CA. A. S. S.	FECHA Date	PREPARADO Prepared by	RESOLUCION DATE	CAVOC ASSESS
FECHA Date	26/01/95	FECHA Date	FECHA Date	26/01/95	

Fig. 10