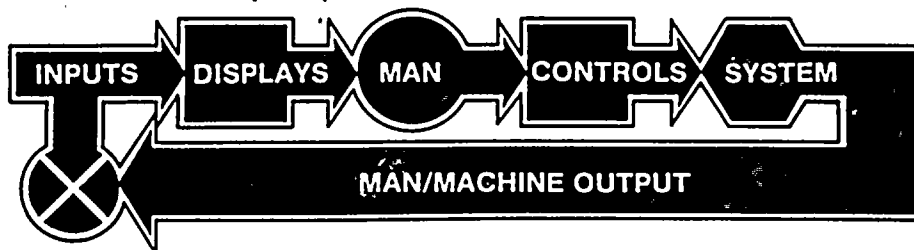


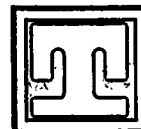
PALO VERDE NUCLEAR GENERATING STATION CONTROL ROOM HUMAN FACTORS STUDY

EXECUTIVE SUMMARY REPORT
SUPPLEMENT NO. 1



PREPARED FOR:
ARIZONA PUBLIC SERVICE COMPANY
AND
BECHTEL POWER CORPORATION

JUNE 1983



**TORREY
PINES
TECHNOLOGY**

A Division of GA Technologies Inc.

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- o W. Dove - Principal Nuclear Engineer
- o R. Pearce - Principal Nuclear Engineer

1. INTRODUCTION

The purpose of this supplement is to update the DCRDR⁽¹⁾ by providing the results of the following reviews as presented in the following reports:

- o GA-C17155 Control Room Operator Personnel Survey
- o GA-C17154 Review of the ERFDADS Terminal CRT Display and the ESFAS Annunciator Window Box (1-J-RKN-5C)
- o GA-C17156 Control Room Validation
- o GA-C17159 Control Room Equipment Organization and Storage, and Performance of Operator Control Room Functions While Wearing/Using Protective Equipment
- o GA-C17072, Review of Foxboro 250 Series Controllers and Indicators

-
1. Palo Verde Nuclear Generating Station Control Room Human Factors Study, Executive Summary Report, GA-C16398, Torrey Pines Technology, June 1981.

1.1 OBJECTIVE

The objective of this supplemental review was to:

- o Complete review of the items deferred in the DCRDR using NUREG-0700 guidelines as appropriate to identify, prioritize and correct discrepancies.
- o Review items identified in the Control Room Design Review/Audit (CRDR/A)¹ by the NRC using the above approach.
- o Verify that the control room modifications have not introduced any new Human Engineering Discrepancies (interviews, control room validation and Foxboro 250 Series Indicators and Controllers).

1. Audit performed on September 15 through September 17, 1981. Audit report submitted to Arizona Public Service by the NRC in a transmittal letter from Mr. Frank J. Miraglis to Mr. E. E. Van Brunt, Jr., dated October 18, 1981.

1.2 PROGRAM DESCRIPTION

The review program established for the DCRDR was continued for this supplemental review as indicated in Figure 1-1. The specific task additions were:

- o Human Factors

- ERFDADS Terminal CRT Display
- ESFAS Annunciator Window Box (1-J-RKN-5C)
- Control Room Equipment: Organization and Storage, and Performance of Operator Control Room Functions while Wearing/Using Protective Equipment
- Foxboro 250 Series Indicators and Controllers

- o Operator Preparedness

- Operator Survey

- o Systems Factors

- Control Room Validation

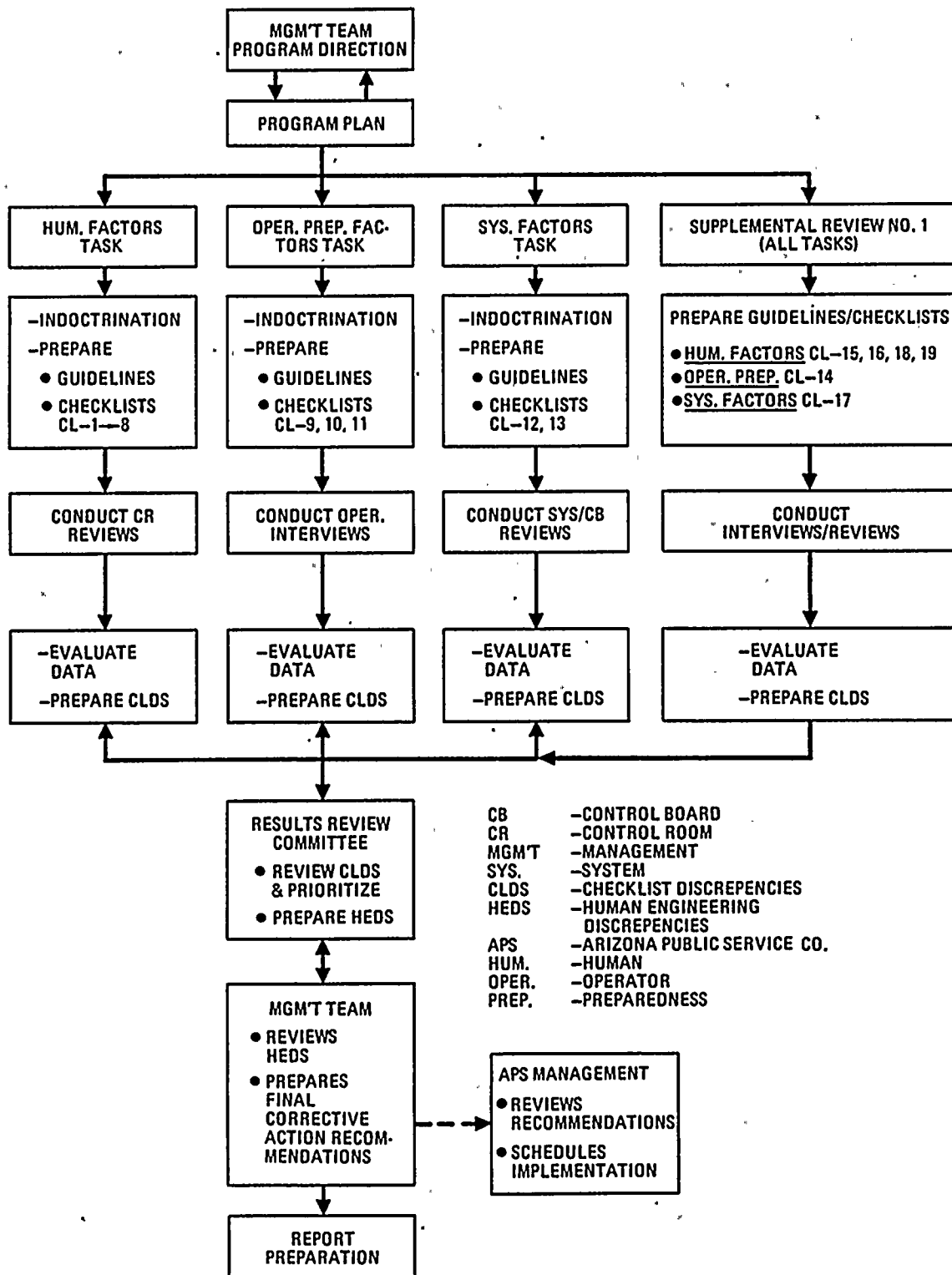


Fig. 1-1. Program for the Detailed Control Room Design Review of the Palo Verde Nuclear Generating Station

2. METHODOLOGY

The methodology of the original DCRDR program was used in the supplemental review of the control room.

2.1 BACKGROUND

2.1.1 Photographic Support

Prior to the start of this supplemental review, colored photographs were taken of all sections of the main control board of the simulator control room to account for upgrades implemented since the start of the DCRDR.

2.2 GUIDELINES AND CHECKLISTS

The guidelines and checklists used in this supplemental review are summarized in Table 2-1.

2.2.1 Human Factors (CL-15, 16, 18, 19)

The guidelines and checklists used in the supplemental human factors review were developed as follows:

- o Reviewed the guidelines contained in Section 6.0 of NUREG-0700 and selected those considered applicable for the supplemental review.
- o Reviewed NUREG-0835 (draft) and selected guidelines considered applicable for the supplemental review.
- o Formulated all guidelines into checklists (see Table 2-1).

2.2.2 Operator Preparedness (CL-14)

The guidelines and checklists used in the supplemental operator preparedness review were developed as follows:

- o Reviewed the guidelines contained in NUREG-0700 and selected those considered appropriate for this supplemental review:
 - Formulated the selected guidelines into CL-14, Operator Survey, Part 1.
- o Reviewed the contents of CL-9, 10 and 11 from the DCRDR with the guidelines contained in NUREG-0700.
 - Selected and revised those CL items considered appropriate and formulated Part 2 of CL-14 (see Table 2-1).

2.2.3 System Factors (CL-17)

The supplemental systems factors review using the selected events was comprised of the following elements:

- o Task analysis.
- o Guideline and checklist development.
- o Observations and validation.

2.2.3.1 Task Analysis

The task analysis was conducted as follows:

- o Reviewed results of the system factors task performed in the DCRDR.
- o Reviewed and discussed plant operating procedures with operating personnel to determine the most comprehensive events for control room validation.
 - Selected Plant Startup from Cold Shutdown because of the broad range of activities that are required by the operator in this procedure.
 - Selected Small Break LOCA due to the required rapid action and complex situations that could result. This event has the highest potential for operator error.
- o Tabulated operator tasks and step sequences for each event.
- o Performed an analysis of each selected event using traffic link diagrams and operator sequence diagrams.

2.2.3.2 Guidelines and Checklist (CL-17)

The guidelines contained in Section 6.0 of NUREG-0700 were reviewed and those found appropriate for validation were formulated into CL-17,⁽¹⁾ Control Room Validation (see Table 2-1).

2.2.3.3 Observations and Validation

Checklist 17 was applied to the results of the task analysis and a list of observations (potential discrepancies) was compiled for evaluation during the validation.

2.2.4 Human Engineering Discrepancy Disposition Criteria

The human engineering discrepancy disposition criteria used in the DCRDR to prioritize the discrepancies was reviewed by the Management Team. For non-safety items, the viability of implementation was weighed against work windows available prior to fuel loading. As a result, the implementation requirement for Category B was modified from "Mandatory - Prior to Fuel Loading" to "Mandatory - Prior to or at First Refueling" (Table 2-2).

1. Checklist 12 identified for this task in the DCRDR was not developed.

TABLE 2-1

GUIDELINE/CHECKLIST SUMMARY

			GUIDELINES/NO. OF ITEMS										
			NUREG-0700										
DCRDR TASK ⁽¹⁾	CHECKLIST		CONTROL ROOM WORKSPACE (6.1)	COMMUNICATIONS (6.2)	ANNUNCIATOR WARNING SYSTEM (6.3)	CONTROLS (6.4)	VISUAL DISPLAYS (6.5)	LABELS AND LOCATION AIDS (6.6)	PROCESS COMPUTERS (6.7)	PANEL LAYOUT (6.8)	CONTROL-DISPLAY INTEGRATION (6.9)	OTHER	TOTAL
	NO.	TITLE											
OP	14	Operator Survey	16	1	11	13	10	17	3	5		23 ⁽²⁾	99
HF	15	ERFDADS Terminal CRT Display							133			29 ⁽³⁾	162
HF	16	ESFAS Annunciator Window Box (1-J-RKN-5C)			88								88
SF	17	Control Room Validation								2			2
HF	18	Control Room Equipment and Storage	12	1		1							14
HF	19	Foxboro 250 Series Indicators and Controllers	1			2	77	1					81

1. OP - Operator Preparedness
HF - Human Factors
SF - System Factors
2. Derived from CL-9, 10, 11 used/deferred in DCRDR.
3. Derived from NUREG-0835 (draft).

TABLE 2-2
HUMAN ENGINEERING DISCREPANCY DISPOSITION CRITERIA

Category	Description	Implementation
A	Safety	Mandatory-Prior to Fuel Loading
B	Reliability (90% Availabiilty Criterion)	Mandatory-Prior to or at First Refueling
C	Reliability-Enhancement	Mandatory-Convenient Outage
D	Minor	Non-Mandatory

Category D discrepancies were not considered as human engineering discrepancies and will be reviewed as plant betterment items.

2.3 DATA COLLECTION

2.3.1 Human Factors

The human factors data was collected in four parts by a Human Factors Engineer:

- o Executed CL-15, ERFDADS Terminal CRT Display, aided by three (3) APS operational programmers.
- o Executed CL-16, ESFAS Annunciator Window Box (1-J-RKN-5C), aided by an APS operator.
- o Executed CL-18, Control Room Equipment and Storage, through:
 - Review of the design drawing "Control Building Equipment Location Plan." The physical locations in the control room were reviewed, aided by APS Operations personnel, to support interpretation of the design drawing.
 - Observing operator performance during a simulated event comprised of a dropped control rod, loss of an instrument bus and failure of both FW pumps.
- o Executed CL-19, Foxboro 250 Series Indicators and Controllers , aided by an APS Instrumentation and Control Engineer.

2.3.2 Operator Preparedness

The operator preparedness data was collected by a Human Factors Engineer:

- o Executed Part 1 of CL-14, Operator Survey

- Issued to 12 APS operators at random for written responses.
- Interviewed 12 APS operators at random to clarify responses.
- o Executed part 2 of CL-14 in the same manner as part 1, using 11 APS operators at random.

2.3.3 System Factors

The systems factors data was collected by two (2) Systems Engineers:

- o Observed and discussed the plant startup procedure performance on the control room simulator performed by an APS operating crew (SRO and 2 ROs).
- o Repeated the above for the small break LOCA event using a different operating crew.

2.4 DATA EVALUATION

The data collected by each of the three (3) supplemental reviews was evaluated against their respective guidelines and checklists format. Discrepancies identified were documented and processed through the Results Review Committee and the Management Team using the forms and procedures established in the DCRDR.

In addition, the Foxboro 250 Series Indicators and Controllers data collected was evaluated against:

- o Seven (7) HEDs (Nos. 7, 83, 100, 101, 102, 103, 104 and 105) identified in the DCRDR for implementation of corrective action.

1007, 1008, 1009, 1010, 1011, 1012, 1013, 1014, 1015, 1016, 1017, 1018, 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027, 1028, 1029, 1030, 1031, 1032, 1033, 1034, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1042, 1043, 1044, 1045, 1046, 1047, 1048, 1049, 1050, 1051, 1052, 1053, 1054, 1055, 1056, 1057, 1058, 1059, 1060, 1061, 1062, 1063, 1064, 1065, 1066, 1067, 1068, 1069, 1070, 1071, 1072, 1073, 1074, 1075, 1076, 1077, 1078, 1079, 1080, 1081, 1082, 1083, 1084, 1085, 1086, 1087, 1088, 1089, 1090, 1091, 1092, 1093, 1094, 1095, 1096, 1097, 1098, 1099, 1100, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1109, 1110, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1118, 1119, 1120, 1121, 1122, 1123, 1124, 1125, 1126, 1127, 1128, 1129, 1130, 1131, 1132, 1133, 1134, 1135, 1136, 1137, 1138, 1139, 1140, 1141, 1142, 1143, 1144, 1145, 1146, 1147, 1148, 1149, 1150, 1151, 1152, 1153, 1154, 1155, 1156, 1157, 1158, 1159, 1160, 1161, 1162, 1163, 1164, 1165, 1166, 1167, 1168, 1169, 1170, 1171, 1172, 1173, 1174, 1175, 1176, 1177, 1178, 1179, 1180, 1181, 1182, 1183, 1184, 1185, 1186, 1187, 1188, 1189, 1190, 1191, 1192, 1193, 1194, 1195, 1196, 1197, 1198, 1199, 1200, 1201, 1202, 1203, 1204, 1205, 1206, 1207, 1208, 1209, 1210, 1211, 1212, 1213, 1214, 1215, 1216, 1217, 1218, 1219, 1220, 1221, 1222, 1223, 1224, 1225, 1226, 1227, 1228, 1229, 1230, 1231, 1232, 1233, 1234, 1235, 1236, 1237, 1238, 1239, 1240, 1241, 1242, 1243, 1244, 1245, 1246, 1247, 1248, 1249, 1250, 1251, 1252, 1253, 1254, 1255, 1256, 1257, 1258, 1259, 1260, 1261, 1262, 1263, 1264, 1265, 1266, 1267, 1268, 1269, 1270, 1271, 1272, 1273, 1274, 1275, 1276, 1277, 1278, 1279, 1280, 1281, 1282, 1283, 1284, 1285, 1286, 1287, 1288, 1289, 1290, 1291, 1292, 1293, 1294, 1295, 1296, 1297, 1298, 1299, 1300, 1301, 1302, 1303, 1304, 1305, 1306, 1307, 1308, 1309, 1310, 1311, 1312, 1313, 1314, 1315, 1316, 1317, 1318, 1319, 1320, 1321, 1322, 1323, 1324, 1325, 1326, 1327, 1328, 1329, 1330, 1331, 1332, 1333, 1334, 1335, 1336, 1337, 1338, 1339, 1340, 1341, 1342, 1343, 1344, 1345, 1346, 1347, 1348, 1349, 1350, 1351, 1352, 1353, 1354, 1355, 1356, 1357, 1358, 1359, 1360, 1361, 1362, 1363, 1364, 1365, 1366, 1367, 1368, 1369, 1370, 1371, 1372, 1373, 1374, 1375, 1376, 1377, 1378, 1379, 1380, 1381, 1382, 1383, 1384, 1385, 1386, 1387, 1388, 1389, 1390, 1391, 1392, 1393, 1394, 1395, 1396, 1397, 1398, 1399, 1400, 1401, 1402, 1403, 1404, 1405, 1406, 1407, 1408, 1409, 1410, 1411, 1412, 1413, 1414, 1415, 1416, 1417, 1418, 1419, 1420, 1421, 1422, 1423, 1424, 1425, 1426, 1427, 1428, 1429, 1430, 1431, 1432, 1433, 1434, 1435, 1436, 1437, 1438, 1439, 1440, 1441, 1442, 1443, 1444, 1445, 1446, 1447, 1448, 1449, 1450, 1451, 1452, 1453, 1454, 1455, 1456, 1457, 1458, 1459, 1460, 1461, 1462, 1463, 1464, 1465, 1466, 1467, 1468, 1469, 1470, 1471, 1472, 1473, 1474, 1475, 1476, 1477, 1478, 1479, 1480, 1481, 1482, 1483, 1484, 1485, 1486, 1487, 1488, 1489, 1490, 1491, 1492, 1493, 1494, 1495, 1496, 1497, 1498, 1499, 1500, 1501, 1502, 1503, 1504, 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515, 1516, 1517, 1518, 1519, 1520, 1521, 1522, 1523, 1524, 1525, 1526, 1527, 1528, 1529, 1530, 1531, 1532, 1533, 1534, 1535, 1536, 1537, 1538, 1539, 1540, 1541, 1542, 1543, 1544, 1545, 1546, 1547, 1548, 1549, 1550, 1551, 1552, 1553, 1554, 1555, 1556, 1557, 1558, 1559, 1560, 1561, 1562, 1563, 1564, 1565, 1566, 1567, 1568, 1569, 1570, 1571, 1572, 1573, 1574, 1575, 1576, 1577, 1578, 1579, 1580, 1581, 1582, 1583, 1584, 1585, 1586, 1587, 1588, 1589, 1590, 1591, 1592, 1593, 1594, 1595, 1596, 1597, 1598, 1599, 1600, 1601, 1602, 1603, 1604, 1605, 1606, 1607, 1608, 1609, 1610, 1611, 1612, 1613, 1614, 1615, 1616, 1617, 1618, 1619, 1620, 1621, 1622, 1623, 1624, 1625, 1626, 1627, 1628, 1629, 1630, 1631, 1632, 1633, 1634, 1635, 1636, 1637, 1638, 1639, 1640, 1641, 1642, 1643, 1644, 1645, 1646, 1647, 1648, 1649, 1650, 1651, 1652, 1653, 1654, 1655, 1656, 1657, 1658, 1659, 1660, 1661, 1662, 1663, 1664, 1665, 1666, 1667, 1668, 1669, 1670, 1671, 1672, 1673, 1674, 1675, 1676, 1677, 1678, 1679, 1680, 1681, 1682, 1683, 1684, 1685, 1686, 1687, 1688, 16

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- o Six (6) audit findings⁽¹⁾ (Nos. 5.14, 5.16, 5.19, 5.20, 5.21, 5.25) identified in the CRDR/A for implementation of corrective action.

1. Audit finding 1.2 is addressed in HEDs 100 and 101, audit finding 5.13 is addressed in HED 83, and audit finding 5.17 is addressed in HED 7; therefore, these were not repeated.

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3. RESULTS

3.1 CHECKLIST DISCREPANCY SUMMARY

The three tasks identified 38 checklist discrepancies as summarized in Table 3-1. This total was reduced to 34 by the Results Review Committee/Management Team reviews due to similarities in discrepancies identified by the separate tasks or in the DCRDR.

3.2 HUMAN ENGINEERING DISCREPANCY SUMMARY

Categories A, B, and C in Table 3-1 were classified as HEDs, as in the DCRDR, which totaled 25. The remaining 9 were assigned Category D which were non-HEDs.

A summary of the HEDs is presented in Table 3-2 and the detailed discrepancies and evaluations are contained in Supplement 1 to the Technical Report (GA-C16411).

3.3 CORRECTIVE ACTION EVALUATION (FOXBORO 250 SERIES)

The evaluation of corrective actions provided by the Foxboro 250 Series Controllers and Indicators found that:

- o For the seven (7) HEDs in the DCRDR:
 - HEDs 83 and 100 remain outstanding
 - HEDs 7, 101, 102, 103, 104 and 105 had been corrected.
- o All six (6) CRDR/A discrepancies had been corrected.

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TABLE 3-1

CHECKLIST DISCREPANCY SUMMARY

Checklist	Number of Occurrences	Discrepancy Categories			
		A	B	C	D
CL-14 Operator Survey	26	5	4	9	8
CL-15 ERFDADS CRT	7	0	1	5	1
CL-16 ESFAS Annunciator	1	0	0	1	0
CL-17 Control Room Validation	3	0	0	3	0
CL-18 Control Room Equipment	1	1	0	0	0
CL-19 Foxboro 250 Series	0(2)	0	0	0	0
Pre-RRC/MT ⁽¹⁾ Review Totals	38	6	5	18	9
Post-RRC/MT Review Totals	34	5	4	16	9

1. RRC - Results Review Committee
MT - Management Team

2. Thirteen (13) items were deferred to the Operator Survey (CL-14) and discrepancies from these items are contained therein.

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TABLE 3-2A

HUMAN ENGINEERING DISCREPANCY SUMMARY

CATEGORY A

(Safety; Mandatory Implementation Prior to Fuel Loading)

HED NO.	DISCREPANCY	CORRECTIVE ACTION
128	Color discrimination on annunciator windows difficult	Study and select optimum hue saturations (>95%)
129	Inadequate distinction between MSIV and FWIV switches (B06)	Study and select a coding scheme (color, shape, demarcation) or improve labeling
134	Insufficient operator comprehension of alarm priorities by color	Provide operator training
137	Missing and inconsistently placed labels on several boards	Add and relocate labels; QA all boards for conformance
145	SCBA air bottle replenishment, exchange and status inadequate	Post instructions sign at bottle rack.

TABLE 3-2B

HUMAN ENGINEERING DISCREPANCY SUMMARY

CATEGORY B

(Reliability - 90% Availability Criterion; Mandatory
Implementation Prior to or at First Refueling)

HED

<u>NO.</u>	<u>DISCREPANCY</u>	<u>CORRECTIVE ACTION</u>
123	Inadequate radio communication coverage in parts of auxiliary and containment buildings	Install repeaters or a backup system
130	Inadequate distinction between Units 2 and 3 buss controls on B01	Study and select proper enhancement, and provide additional B01 training
135	Insufficient operator comprehension of alarm clearing actions	Provide training on annunciator controls
139	Lack of consistent abbreviations among CRT, panels and procedures	Change CRT abbreviations to those used on annunciator and panels

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TABLE 3-2C

HUMAN ENGINEERING DISCREPANCY SUMMARY

CATEGORY C

(Reliability - Enhancement; Mandatory Implementation
at Convenient Outage)

HED NO.	DISCREPANCY	CORRECTIVE ACTION
124	Mimic lines not adhering to panel (B01)	Secure mimic lines
125	Controls on TRACOR Westronic recorders too high (B07)	Evaluate during operation and relocate trend line selector switch if warranted
126	Parallax on Foxboro indicators not located in direct line of sight	Minimize impact through operator training and if warranted, relocate indicators
127	Inadequate distinction among HVAC controls for auxiliary, fuel and control buildings (B02)	Study labeling techniques to provide operator aids

REF	EXPLANATION	REMARKS
101	1. Investigation of the on the basis of the the (101) (101)	1. Investigation of the
102	2. Investigation of the on the basis of the	2. Investigation of the
103	3. Investigation of the on the basis of the	3. Investigation of the
104	4. Investigation of the on the basis of the	4. Investigation of the
105	5. Investigation of the on the basis of the	5. Investigation of the
106	6. Investigation of the on the basis of the	6. Investigation of the

TABLE 3-2C (continued)

HED NO.	DISCREPANCY	CORRECTIVE ACTION
131	Lack of indication of plant multiplexer failure related to circuit breakers (B01)	Provide alarm
132	Inconsistent use of PSIG and PSIA on Foxboro displays	Determine proper units and rescale displays
138	Glare on Foxboro displays from overhead lighting	Install diffusers on overhead lights
140	Improper use of punctuation in statements on CRT displays (ERFDADS CRT)	Reprogram displays
141	Parameter time history display on CRTs reads opposite to normal reading pattern of left to right (ERFDADS CRT)	Reverse time history display
142	Page designation on CRT display not in accordance with station policy (ERFDADS CRT)	Reprogram page designation
143	Lack of 'standby' indication on CRT display (ERFDADS CRT)	Provide for a 'standby' indication after 2 second delay

REF NO.	DESCRIPTION	EFFECTIVE PERIOD
144	<p>Letter sent to the Board of Directors dated 1961 for the Board of Directors (1961)</p>	<p>and horizontal to the window 1961</p>
145	<p>Operational difficulties in location which are excessive movement between flow indicator within the flow indicator a. down ceiling, above ceiling plant startup</p>	<p>stand, testing and 1961</p>
146	<p>Excessive operator travel between 204 (pressure pressure and level) and 205 (lock level) during small power 100%</p>	<p>to the extent of the 1961</p>
147	<p>Excessive operator travel between 205 (flow) and 206 (pressure) pressure and level, during small power 100%</p>	<p>to the extent of the 1961</p>
148	<p>Excessive operator travel between 206 (pressure) and 207 (level) during small power 100%</p>	<p>to the extent of the 1961</p>

TABLE 3-2C (continued)

<u>HED NO.</u>	<u>DISCREPANCY</u>	<u>CORRECTIVE ACTION</u>
144	Letter size too small on panel label for ESFAS Annunciator (B05)	Add horizontal label to window box
146	Operator difficulty in locating switch and excessive movement between flow indicator and switch at B02 while isolating shutdown cooling loops during plant startup	Study design and procedure for relocation or annotation
147	Excessive operator travel between B04 (pressurizer pressure and level) and B05 (loop delta-T) during small break LOCA	Provide training on use of properly located displays
148	Excessive operator travel between B02 (SI flow) and B04 (pressurizer pressure and level) during small break LOCA	Provide training or use of properly located displays
149	Lack of identical T_h and T_c scales requires mental computation of delta-T	Study use of PAM trend recorder on B02 and of providing delta-T display on B04

4. CONCLUSIONS

4.1 HED CORRECTIVE ACTIONS

Corrective Actions for most HEDs (Table 3-2) have been identified and submitted to APS management for implementation scheduling according to their category. The remaining HEDs require additional study to identify or implement the corrective action.

4.2 REMAINING WORK

The remaining work to complete the DCRDR is the control room environmental review.

4.3 GOOD HUMAN ENGINEERING PRACTICE - EXAMPLES

- o Use of hierarchical labeling
- o Continuous display of primary parameters on CRT
- o Three levels of system parameter details display on CRT
- o Use of priority by color on annunciators
- o Demarcation of systems and subsystems on control boards

