5717

TVA 10697 (DNE 6-86)

DNE CALCULATIONS

ORIGINAL QA Recor

Page 1

TITLE Fire Hazard Analysis of Unit 2 Appendix R Cables in Boric Acid Tank Area Elev. 690 Auxiliary Building

PLANT/UNIT SQNP / UNIT 2

PREPARING ORGANIZATION NE/N-M/Tech Prgs

KEY NOUNS (Consult RIMS DESCRIPTORS LIST) Appendix R, Fire prot, RCS Pressure Control, Aux Bldg

BRANCH/PROJECT IDENTIFIERS
SQN-00-D052
EPM-AMJ-073190

Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in.

Rev	(for RIMS' use)	RIMS accession number
R0	900822A0033	B87 900809 009
R __		
R __		
R __		

APPLICABLE DESIGN DOCUMENT(S)
SQN-DC-V-24.0
CAQR SQP900260

SAR SECTION(S) NA

UNID SYSTEM(S) NA

	Revision 0	R1	R2	R3
ECN No. (or indicate Not Applicable)	NA			
Prepared	A. Maniez, Jr.			
Checked	B. Vindy Singh			
Reviewed	RES 8/3/90			
Approved	R. E. Daniel			
Date	8/3/90			
Use form TVA 10534 if more space required: List all pages added by this revision.				
List all pages deleted by this revision.				
List all pages changed by this revision.				

Safety-related? Yes ☐ No ☒ *

Statement of Problem

The existing routing for the Appendix R RCS Pressure Control, Secondary Side Pressure Control, and RCS Inventory Control cable for unit 2 traverses an area that is not provided with automatic detection and suppression. In order to comply with the separation requirements of 10CFR50 Appendix R section III.G.2, an analysis is required to assess the adequacy of the existing partial area suppression and detection for the hazards in the area.

Abstract

* An independent review has been performed because the calculation evaluates external factors that could affect the function of safety-related equipment.

These calculations contain an unverified assumption(s) that must be verified later. Yes ☐ No ☒

Direct Design Input
This calculation is essential

The present routing of the unit 2 RCS Pressure Control cable, Secondary Si Pressure Control cable, and RCS Inventory Control cable conduits in the are of the Boric Acid tanks on elevation 690 of the auxiliary building was analyzed. This area has only partial fire suppression. The redundant safety-related cables are located at the wall and ceiling above. This calculation establishes that there are insufficient combustibles in the unsprinklered area to pose a significant fire hazard to the one hour UL rated fire wrapped cables. This is within the bounds of TVA deviation 12 having low combustibility loading and no fire detection and/or automatic suppression. <u>This space does not present a significant fire exposure to redundant safe shutdown components.</u>

Pages for R0

Calc Body	= 11
Appendices A1 thru J5	= 34
Total	= 45

9102010036 910128
PDR ADOCK 05000327
P PDR

☐ Microfilm and store calculations in RIMS Service Center

☒ Microfilm and return calculations to Calc File

Microfilm and destroy ☐

Address: DSD A1 - NE/ N-M

cc: RIMS, SL 26 C-K

TVA

Title: Fire Hazard Analysis of Unit 2 Appendix R Cables in Boric Acid Tank Area Elev. 690.0 Auxiliary Bldg.	REVISION LOG SQN-00-D052 EPM-AMJ-073190

Revision No.	DESCRIPTION OF REVISION	Date Approved
0	Initial issue. For Corrective Action to CAQR SQP900260.	

Legibility evaluated and
accepted for issue.
FOR EACH PAGE.

8/3/90
Signature Date

CALCULATION DESIGN VERIFICATION (INDEPENDENT REVIEW) FORM

SQN-00-D052 EPM-AMJ-073190
Calculation Number

0
Revision

Method of design verification (independent review) used (check method used):

1. Design Review X
2. Alternate Calculation ________
3. Qualification Test ________

Justification (explain below):

Method 1: In the design review method, justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies included for confidence, etc.).

Method 2: In the alternate calculation method, identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 3: In the qualification test method, identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

This calculation constitutes an engineering analysis per NRC Generic Letter 86-10 enclosure 1 item 5, for existing fire protection equipment. The scope of this calculation is to evaluate the partial area suppression and detection coverage such that a single fire in the area cannot damage the Appendix R cables identified by CAQR SQP900260 (Unit 2 - RCS Pressure Control, Unit 2 - Secondary Side Pressure Control, and Unit 2 RCS Inventory Control) on elevation 690 in the auxiliary building located just north of column line A12 to south of column line A13 and from column line Q to column line R. This sheet documents an independent review of the calculation performed. The questions addressed in the checklist (Attachment 10 to NEP 3.1) serve as the basis of the Independent Review. No deficiencies were noted when responding to the questions. This engineering calculation is a reasonable and conservative evaluation based on TVA Mechanical Design Standard DS-M17.4.1 "Fire Hazard Analysis", on NFPA 13 Automatic Sprinkler systems (National Fire Protection Association) code, the results of High Pressure Fire Protection Hydraulic Calculation AB-26-ABMO (B25870908815), and accepted fire protection engineering practice.

PRS 8/13/90

Design Verifier
(Independent Reviewer)

3 Aug 90
Date

TABLE OF CONTENTS

PURPOSE

The purpose of this calculation is to evaluate the absence of full area automatic fire suppression and detection for the Boric Acid Tank Area containing the Appendix R Cables (CAQR SQP900260 identified four Trained cables) being routed through the auxiliary building on elevation 690 in the area between column lines A11 to A13 and from Q to R. These cables are in conduit and are wrapped with a one-hour fire wrap.

In order to evaluate the effects of a fire in this area, a detailed fire hazard analysis has been performed in accordance with the guidelines set forth by the NRC in 10CFR50 Appendix R, Section II.B, NUREG 0800 CMEB 9.5-1, Section C.6 and Generic Letter 86-10, enclosure 1, item 5. This calculation will justify the existing routing by proving that the level of combustibles in the area having no automatic fire suppression and detection is very low and thereby does not constitute the potential for a credible fire capable of disabling the existing cable.

ASSUMPTIONS

Transient combustibles will be controlled in accordance with PHYSI-13.

SOURCES OF DESIGN INPUT INFORMATION

1. 10CFR50 Appendix R, NUREG 0800, and NRC Generic Letter 86-10
2. TVA drawings 47W491-21(rev.E),-63(rev.C)
3. TVA CCD drawings 1,2-47W920-4(rev. 1), -5(rev. 0)
4. ARSK drawings, series 90, 100, 200, 300, 400, 500, 600, 700, 800, & 900. (Presently unissued drawings kept in EEB but to be under another number)
5. PHYSI 13 rev.55
6. Fire Hazard Analysis Walkdown Procedure (Instruction No. SMI-0-26-7 R0)
7. FAX from Anamet Inc., R. Picard dated Jul 26, 1990 (Attached, page G2)
8. TVA Mechanical Design Standard DS-M17.4.1 rev.0, "Fire Hazard Analysis"
9. Hydraulic Calculation AB-26-ABM0 rev.1,(RIMS B25870908 815)
10. SER (RIMS L44860606620) on Appendix R with approved deviation number 11 & 12 regarding 20' separation with no intervening combustibles in the auxiliary building & areas with insignificant combustibles.
11. FHA Calculation EPM-MHS-053089 Rev. 1 (B87 900725 001), Eval. of Neutron Source Range Cables on elevation 690.0 in the Auxiliary Building
12. CAQR SQP900260 - recognized that 1 hour wrapped Appendix R cables were in an area without sprinklers that did not have a documented FHA.
13. Manville - Thermal/Acoustical Insulation products Bulletin IND-3211 7-84. (pages D1)
14. Fire Protection Handbook, by A.E. Cote & J.L. Linville, 16th Edit., 1986 (pages J1 through J5)
15. Thermal Insulation, by John F. Malloy, 1969 Edit. (page E3)

CONVERSION FACTOR

To convert from MJoules/Kg to BTU/lb, multiply:

Factor = (1E6 J/MJ) (BTU/1055.04J) (Kg/2.2046lb) =
= 430 (BTU/lb)/(MJ/Kg)

DOCUMENTATION OF ASSUMPTIONS

- None -

ANALYSES

The area in question was determined by comparison of the cables to be protected. Per the CAQR SQP900260 the following cables are involved;

Cable No.	Description	Channel/Train	Interaction No.
2PM2087II	U2 - RCS Pressure Control	II / B	49
2PM2080I	U2 - RCS Pressure Control	I / A	49
2PM2084I	U2 - Secondary Side Pressure Control	I / A	51
2PM1086III	U2 - RCS Inventory Control	III / A	92

The RCS Pressure Control cables, as the name describes, are the instrument sensing lines which return the pressure signal of RCS (Reactor Coolant System) pressure to the Main Control Room. This is an essential signal for proper reactor control during both operation and shutdown.

The Secondary Side Pressure Control cable is a return signal of the pressure in the secondary side or Main Steam side. It is an essential signal also for proper reactor control during both operation and shutdown in providing information of sufficient heat removal capability by the secondary side.

The RCS Inventory Control provides the signal indicating the level in the pressurizer and is used in conjunction with other instrumentation signals to ascertain the amount of reactor coolant in the system. This is also critical to reactor control during both operation and shutdown in providing information of sufficient heat removal capability from the reactor via the reactor coolant.

Pages A1 through A3 show the routing of these cables in this area.

The train B RCS Pressure Control cables were selected as the target cables because they are routed closer to the Q line wall and will create a lesser area to analyze. Only a single train need be considered as 10CFR50 Appendix R section III.G.2 requires a "means of ensuring that one of the redundant trains is free of fire damage..."

The RCS Pressure Control train B cable 2PM2087II becomes the target component for this calculation since the space bounds the same space needed for cables 2PM2084I & 2PM1086III. If the RCS cable 2PM2087II can be analyzed to reasonably prove that there is insufficient combustibles to compromise it, then cables 2PM2084I & 2PM1086III are also protected. Page F1 is the data sheet prepared for these cables.

ANALYSES (Cont')

(The application of the Appendix R III.G.2.c criteria was cited by the CAQR, reference 12, as not in compliance for this area. Paragraph III.G.2.c requires that these redundant trains be in a one-hour barrier (or wrap) and have both suppression and detection systems installed in the area. Another Appendix R requirement often used instead is Paragraph III.G.2.b which requires that redundant cables must be separated by more than 20 feet, have no intervening combustibles, and have both a suppression and detection systems installed in the area.)

A general layout of the area includes three large tanks containing boron water solution and associated pumps, piping, and electrical equipment that are part of the CVCS, Chemical Volume and Control System. Pages B1 and B2 are sketch maps of the area. The numbered arrows indicate the location of photos on pages B3 through B6 of the area. Also, page B7 is a layout of the RCA (Radialogical Controlled Area) boundary in this vicinity.

(This area was inspected on May 23, 1990 and again on Jun 29, 1990. During the period of Jul 9 to Jul 19 of 1990 it was visited for preparing the sketch maps and pictures attached.)

The target area required for analysis is shown on page C1. This represents what is needed to protect the train B RCS Pressure Control cable assuring "that one of the redundant trains is free from fire damage." The double line is 20 feet from the outermost corners of the cable to a recognized fire boundary wall. These cable corners are identified by an arrow. If this calculation can reasonably prove that there is insufficient combustibles in this area of influence to compromise this cable, then paragraph III.G.2 of 10 CFR 50 Appendix R is satisfied. However, the area of influence can be further reduced. Page C2 shows the sprinklers located just West of R column line. A portion of the subject area is sprinklered which complies with Sequoyah's deviation criteria (Attachment 1 of Fire Protection for Appendix R, SQN-DC-V-24.0) establishing enhanced sprinkler coverage for intervening combustibles in the 20 foot zone of influence. This deviation number 11 (RIMS L44860606620) to Appendix R section III.G.2 requirements was approved by the NRC on May 29, 1986. Page F2 is the data sheet prepared for these sprinklers. Therefore, the analysis herein need only address the remaining area. This remaining area is the area of influence. It is shown on page C4 and its amount of square feet is calculated on page C5. The area of influence is completely within the RCA boundary.

Per reference 9, the total flow from all the sprinkler heads located in the immediate adjacent area (which includes the seven sprinkler heads within the area of influence) is 826 gallons per minute. This results in an average actual delivered density of 0.55 gpm per square foot based on 1500 square feet. Note that this exceeds the maximum density required by NFPA 13 for Extra Hazard Group 2 (the most severe classification), which is 0.37 gpm per square foot. The design classification is Ordinary Hazard Group 2 and requires 0.16 gpm per square foot for [illegible] fire area.

ANALYSES (Cont')

This area of influence contains many non-combustibles. Those most notable which are the numerous cables inside conduits and the pipe insulation on CVCS piping. Page F3 is the data sheet prepared for these non-combustibles. Cables inside fire rated conduits are considered non-combustibles as noted by Question 3.6.2 of NRC letter 86-10. The pipe insulation consists of calcium-silicate which is non-combustible. See page D1 noting flame spread, fuel contributed, and smoke spread all equals zero.

In-situ combustibles consists of two items as shown the data sheet on page F4. The first, tank insulation, consists of loose, flexible, fiberglass insulation covered with an aluminum jacket. Briefly, its only contributing combustible is the resin used to bond the fiberglass. This resin can be made of many substances but a conservative synthetic butyl rubber of very high heat combustibility value was used. Pages E1 through E5 of this calculation describes and calculates in detail the contribution of heat of combustion from this source. As noted, the contribution of heat from this source is very conservative but further, the insulation's metal jacket would restrict the fire intensity to even a lesser affect on the target RCS cable. It would cause a slower, low temperature, smoldering effect which would consume most of the combustible material before escaping the jacket to affect the target. Note that the 2 inch thickness spreads the volume out considerably so that only a limited amount is in close proximity to the target. The result is that a much smaller effective actual fire contribution is expected than calculated.
The second combustible is the waterproof flexible wrap on the flexible conduit at various electrical connections in the area. Pages G1 and G2 of this calculation describes and calculates in detail the contribution of heat of combustion from this source. It also is very conservative because less than 40 exists. Actually, less than 20 flexible conduits are visible in the area of influence from the RCA boundary.

The amount of transient combustibles in the Auxiliary Building is the responsibility of the Fire Protection Manager and is controlled in accordance with SQA 66 Plant Housekeeping and Physical Security Instruction (PHYSI 13). It is conservatively encompassed as two aluminum-plastic ladders and a 5 gallon container of Heptane. The transient fire load has been calculated on page H1 and H2.

SUMMARY OF RESULTS

IN-SITU		BTU
Tank Insulation - (2-1/3 tanks in the area of influence. see page C1 ; see page E2)	2.333 tanks x 855,000 =	1,995,000
Waterproof Flexible Wrap on Conduit - (40 conduits, 64 lbs, see page G1)		465,000
TRANSIENTS		
Ladders - (40 lbs each, see page H1)	2 ladders x 746,500 =	1,493,000
Heptane - (5 gallon container, see page H2)		800,000
	Total	4,753,000

Combustible Floor Loading

The total combustible load is (Area from page C5) :

$$4{,}753{,}000 \text{ BTU} / 456 \text{ Ft}^2 = 10{,}423 \text{ BTU/Ft}^2$$

CONCLUSIONS

The RCS Pressure Control cable, Secondary Side Pressure Control cable, and RCS Inventory Control cable all have a one hour UL rated fire wrap. Per Fire Protection Handbook, Table 7-9B, page J5, the fire severity for one hour equates to 80,000 BTU/Ft^2. The total combustible floor loading is 10,423 BTU/Ft^2 implying that the extent of a fire is limited to an average of:

10,423/80000 = 0.1303 hours or 7.82 minutes.

Based on this value, the one hour wrapped cable should easily survive any credible fire in the area. Therefore, there is insufficient combustibles in this area of influence to compromise this cable.

Considering that the tabulation of combustibles represents a conservative bounding (conservatisms were noted in the individual tabulations of this calculation), the fire severity is actually much less than this 7.82 minutes.

It is reasonable to conclude that the cables in this area will be unaffected from any credible fire. Even so, the fire fighting personnel could be expected to be in attendance of a fire in this area within one hour. This location being on elevation 690 on unit side of the Auxiliary Building is easily accessible for fire fighting control. This general area can be reached in less tha~~t~~n AJ 8/1/90 a minute from the main entrance door to the Auxiliary Building. It is immediately adjacent to the aisleway. Although unnecessary, this is further assurance of cable operability.

This analysis has shown that the existing route of the train B RCS Pressure Control cable, the train A Secondary Side Pressure Control cable, and the train A RCS Inventory Control cable each with a one hour wrap and the absence of any significant combustible material is adequately protected. This is within the bounds of TVA deviation 12 having low combustibility loading and no fire detection and/or automatic suppression. This space does not present a significant fire exposure to redundant safe shutdown components and complies with the intent of the separation requirements of 10CFR50 Appendix R section III.G.2 for the unprotected area of the Boric Acid Tanks.

SQN-00-D052

EPM-AMJ-073190

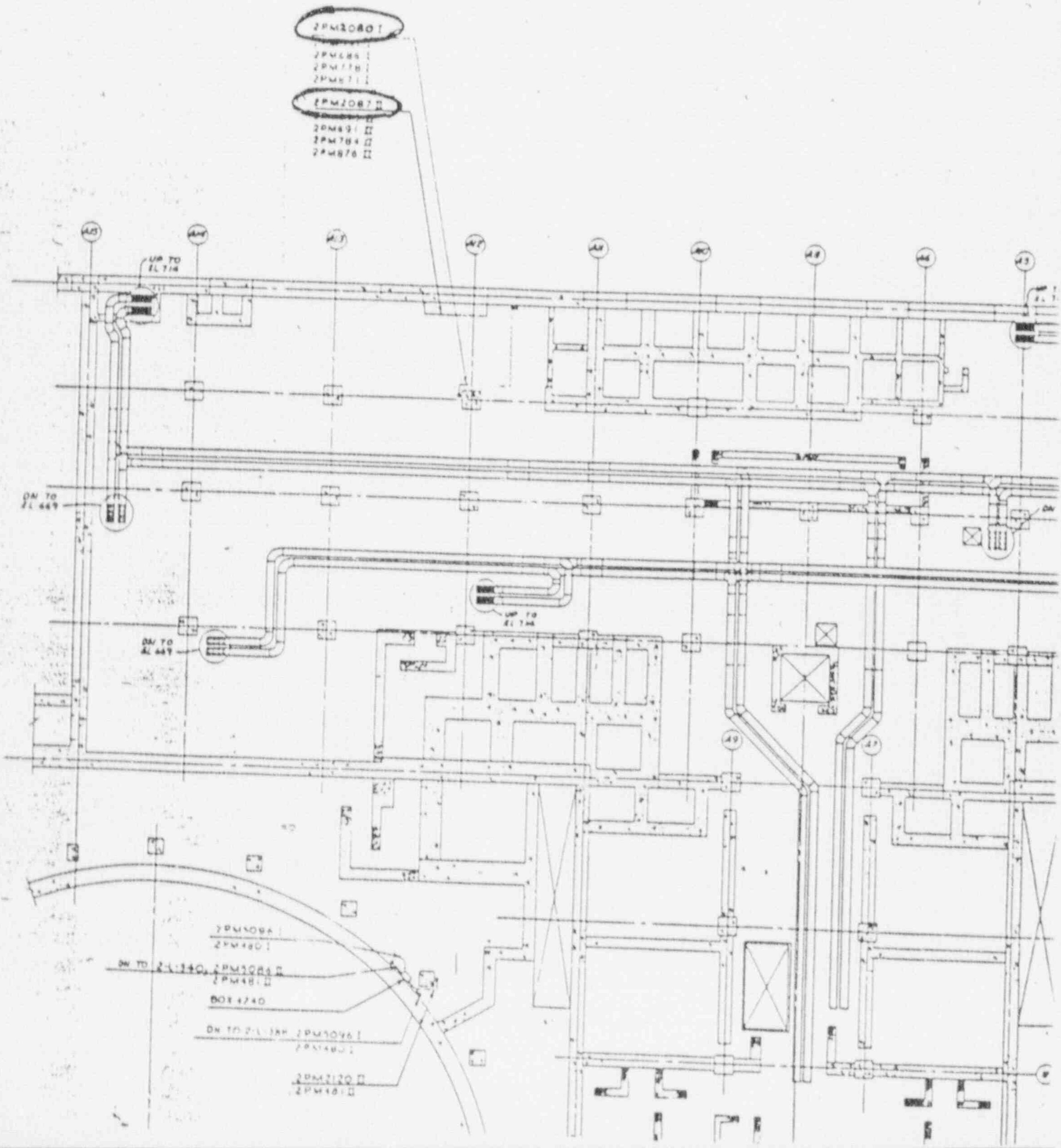
SHEET A1

COMPUTED AMJ DATE 7-31-90

CHECKED BVS DATE 3Aug90

APPENDIX R CABLE ROUTING

APPENDIX A

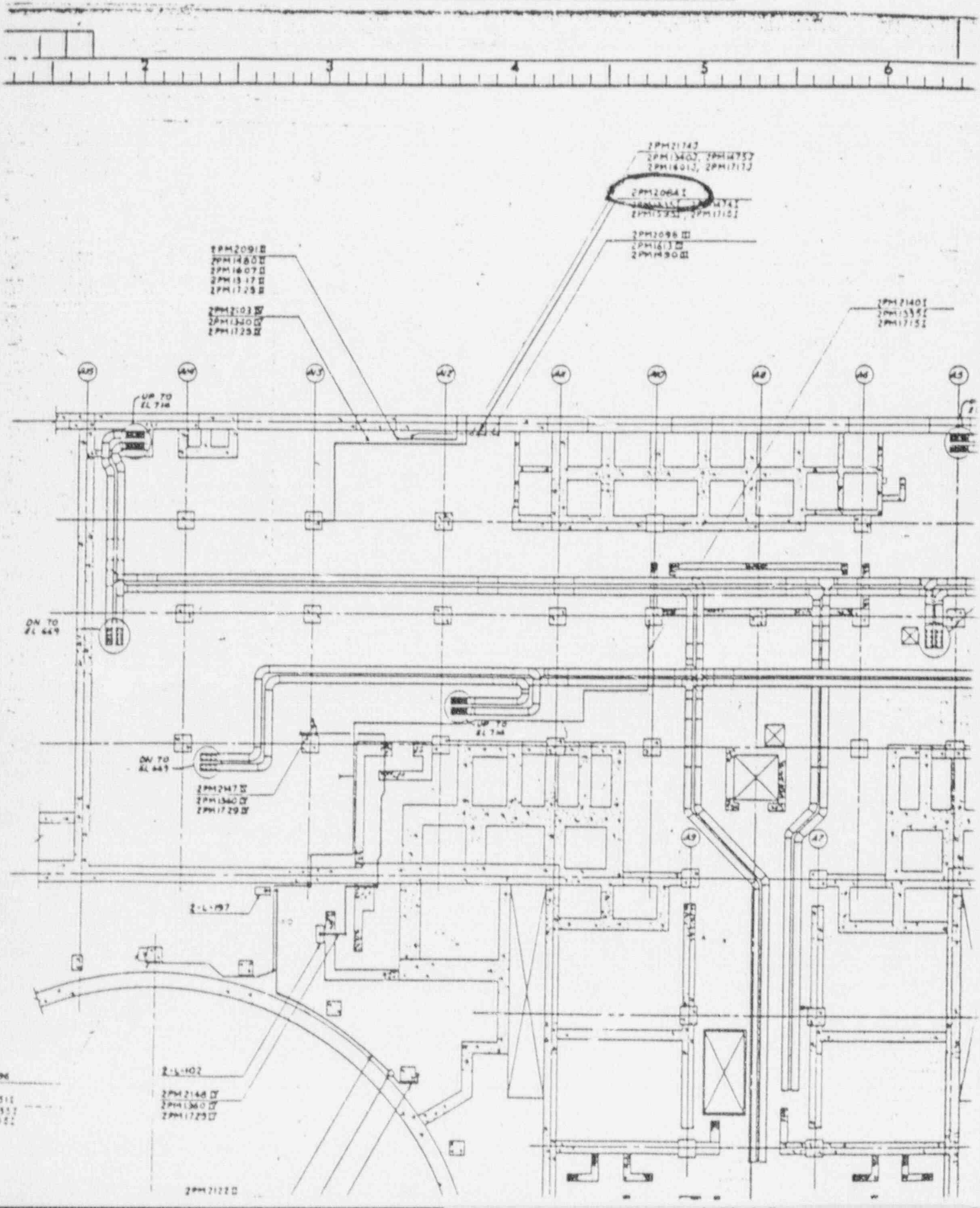


SQN-90-0052 SHEET A2

EPM-AMJ-073190 COMPUTED PMJ DATE 7-31-90

APPENDIX R CABLE ROUTING CHECKED BWS DATE 3Aug 90

APPENDIX A



SQN-00-D052

EPM-AMJ-073190

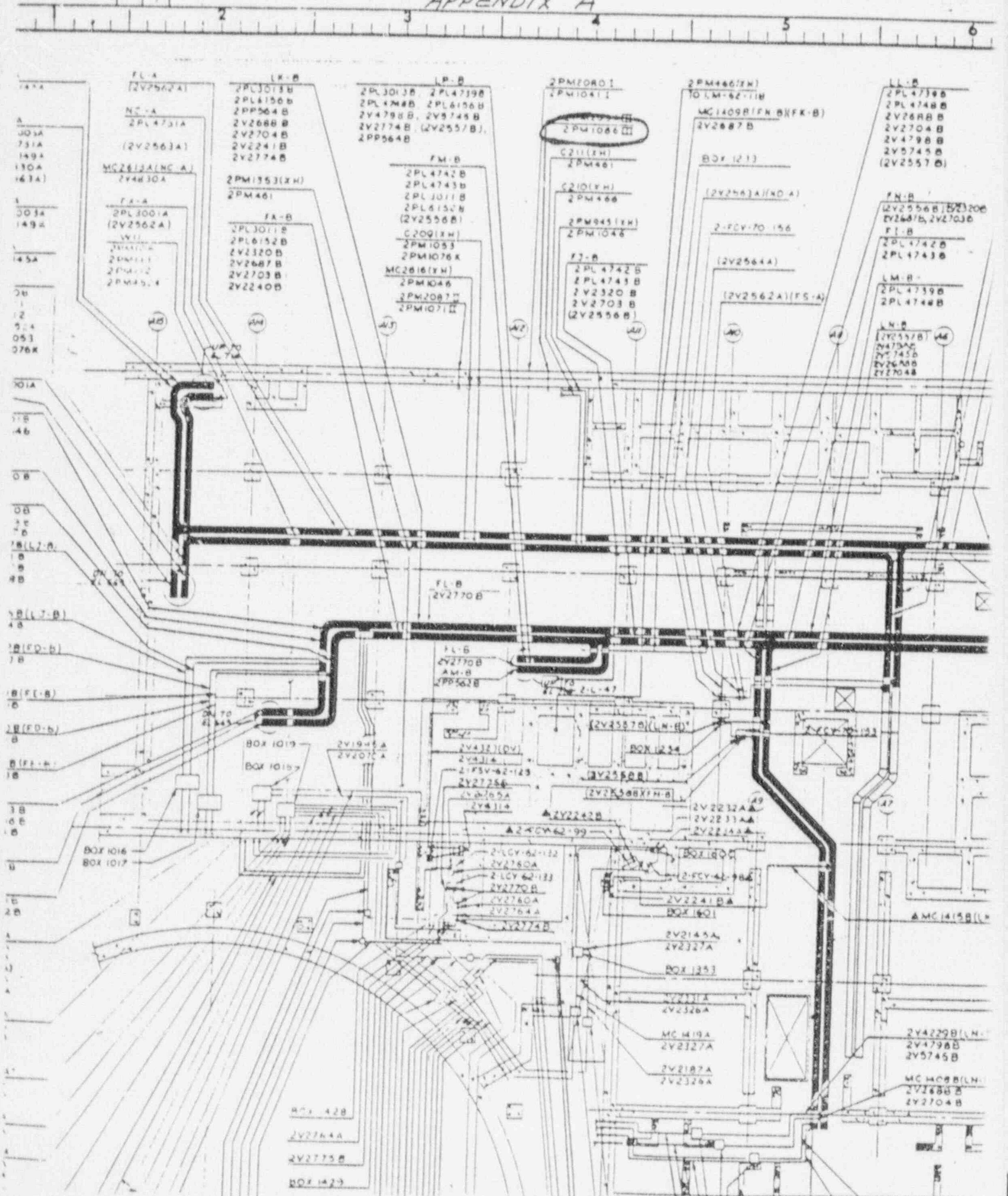
SHEET A3

COMPUTED AMJ DATE 7-31-9

CHECKED BVS DATE 3 Aug 9

APPENDIX R CABLE ROUTING

APPENDIX A



SQN-00-D052

EPM-AMJ-073190

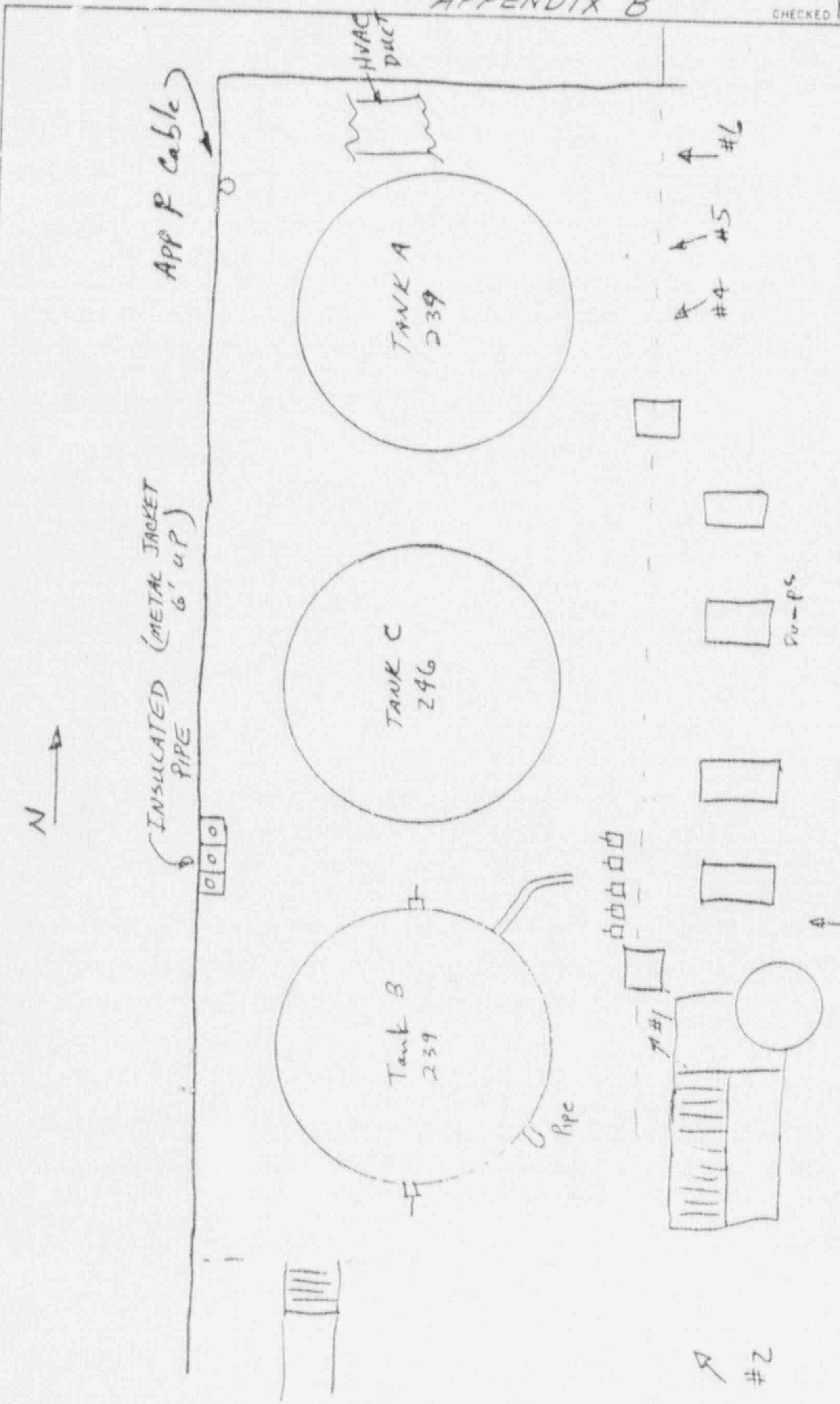
SHEET 81 OF

SKETCH MAPS & PHOTOS

APPENDIX B

COMPUTED amj DATE 7-31-90

CHECKED DWS DATE 3Aug90



SQN-00-D052 SHEET B2 OF

EPM-AMJ-073190

SKETCH MAPS & PHOTOS

APPENDIX B

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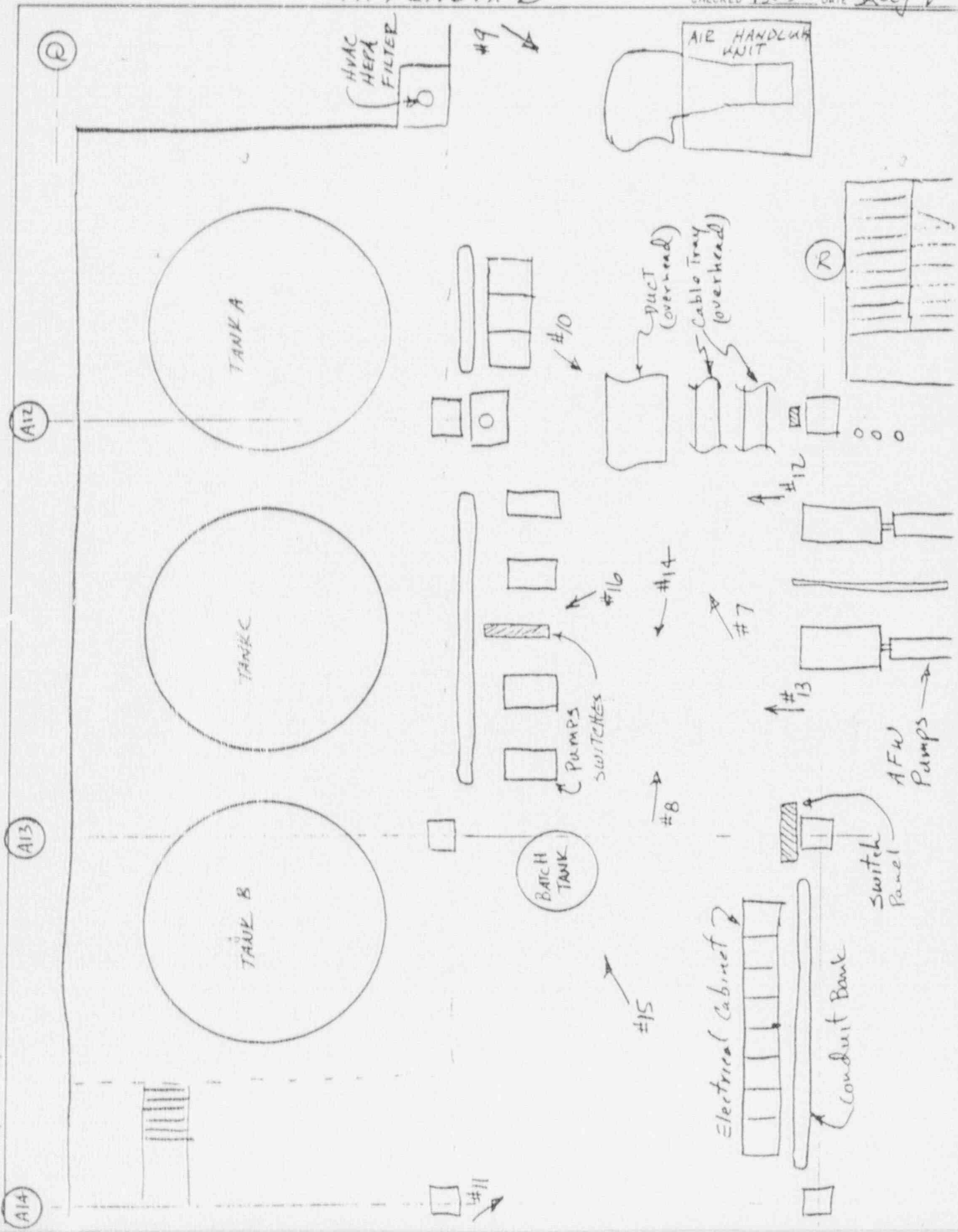


TVA 11030 (WM-7-75)

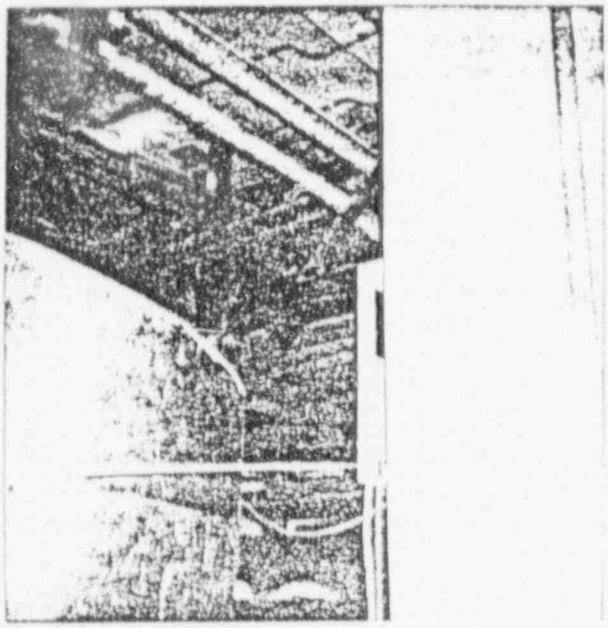
SQN-00-D052 SHEET B3

EPM-AMJ-073190 COMPUTED amj DATE 7-31-

CHECKED RUS DATE 3Aug'

SKETCH MAPS & PHOTOS

APPENDIX B



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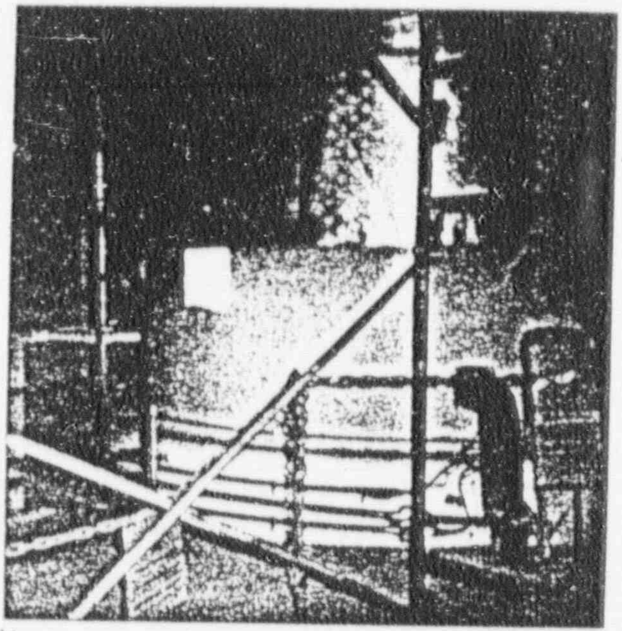

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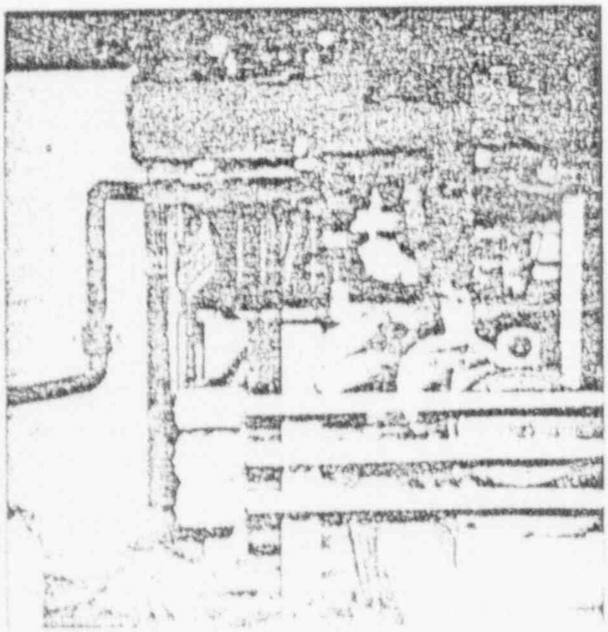

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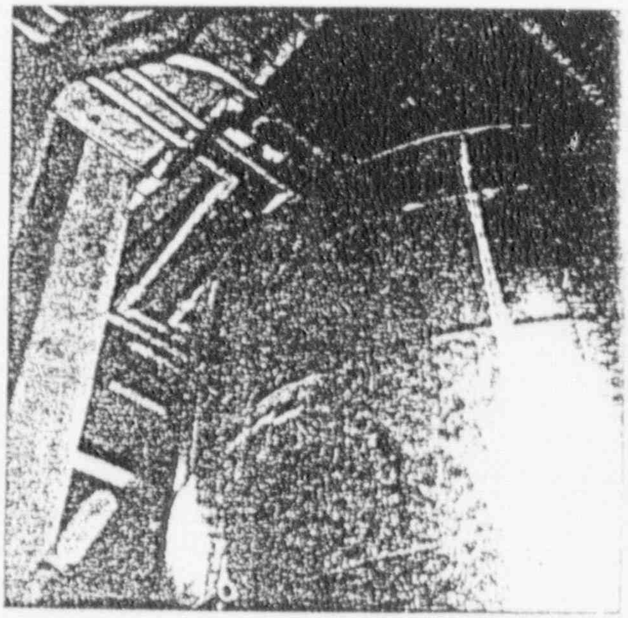
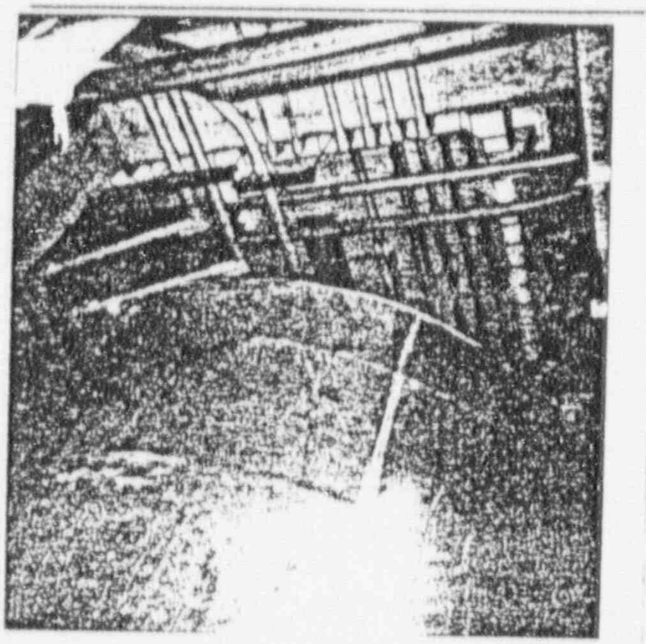


LOOKING AT TOP LEFT TANK



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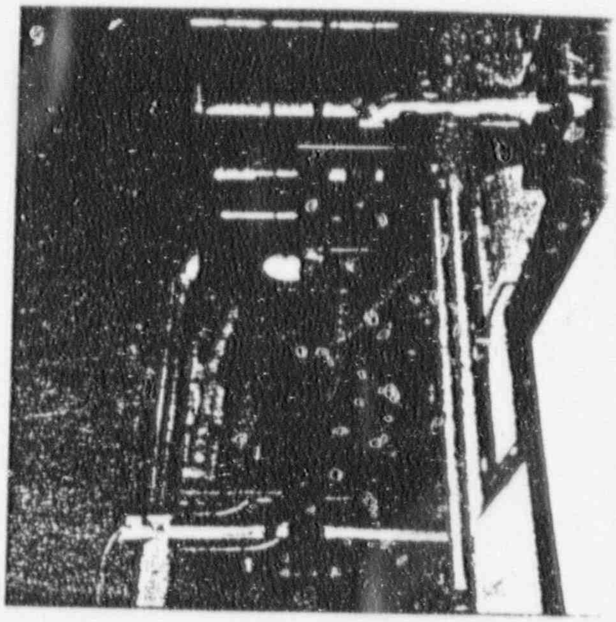

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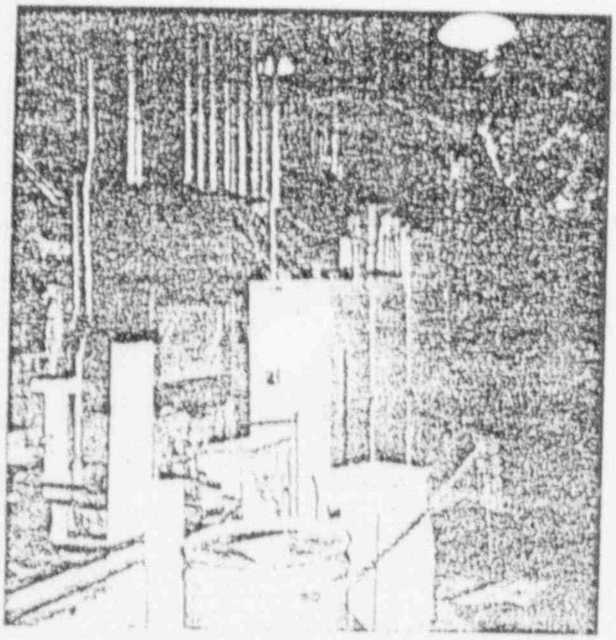

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SQN-00-D052 SHEET B5

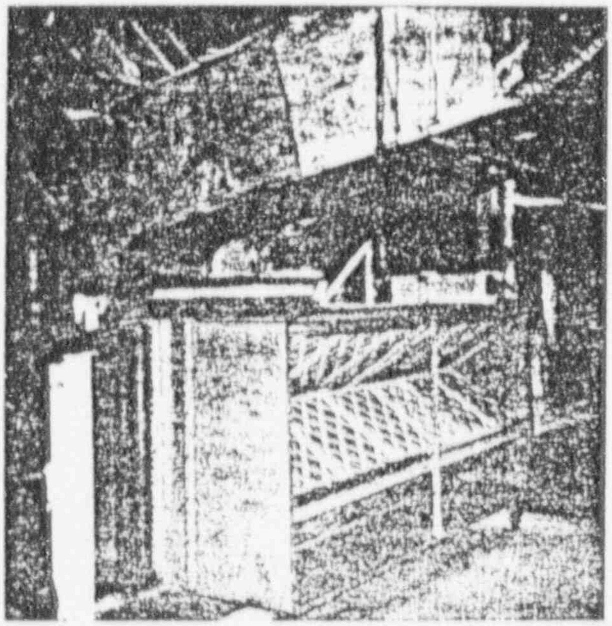
EPM-AMJ-073190

COMPUTED AMJ DATE 7-31-9

CHECKED BVS DATE 3 Aug

SKETCH MAPS & PHOTOS

APPENDIX B



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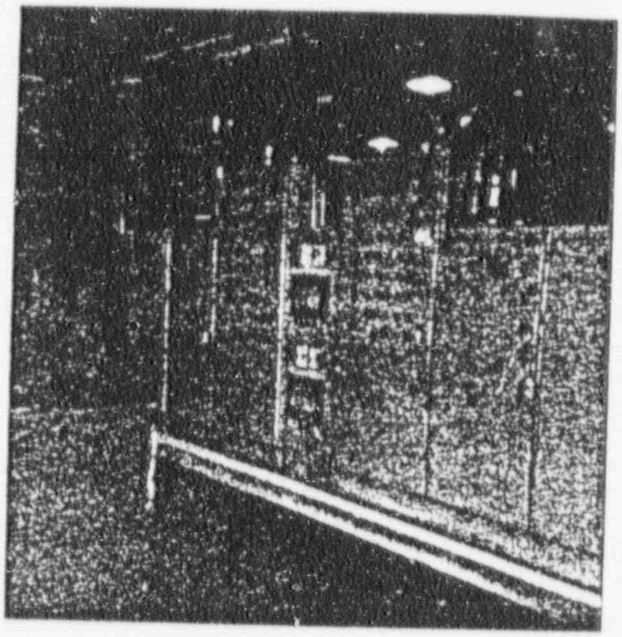

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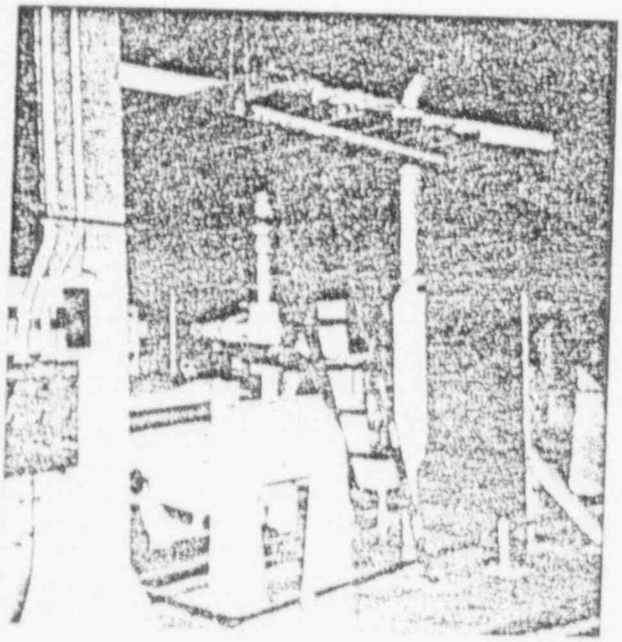

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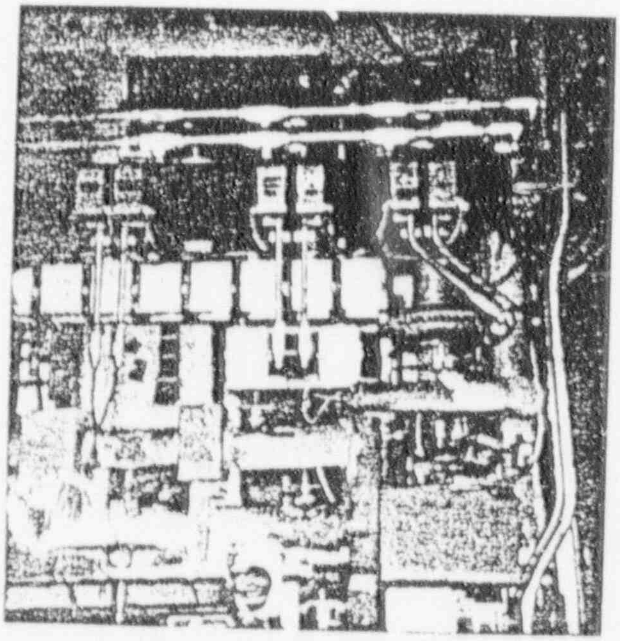

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SQN-00-D052

EPM-AMJ-073190

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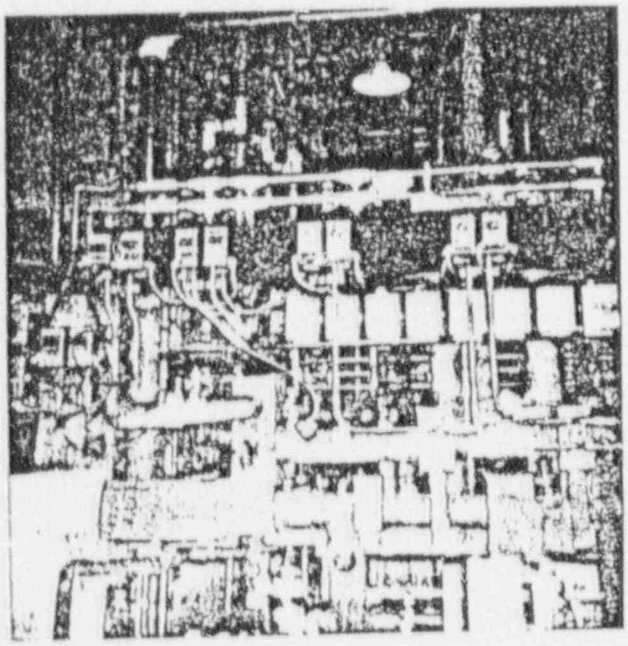
CHECKED BVS DATE 3Aug

SKETCH MAPS & PHOTOS

APPENDIX B



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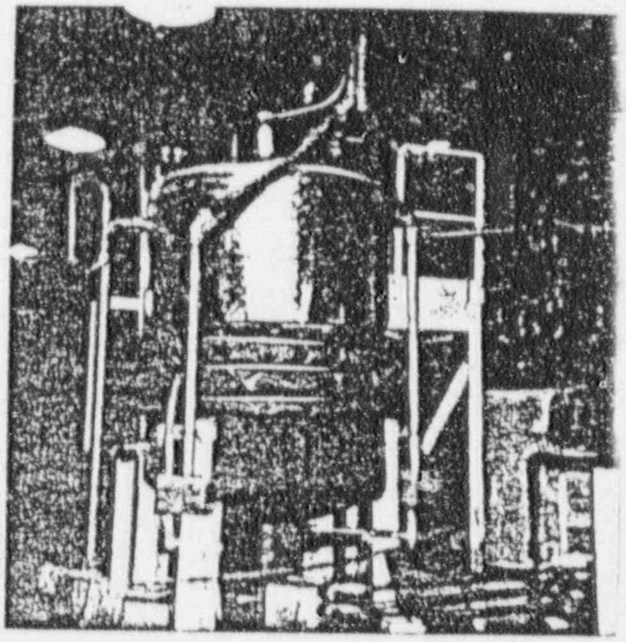

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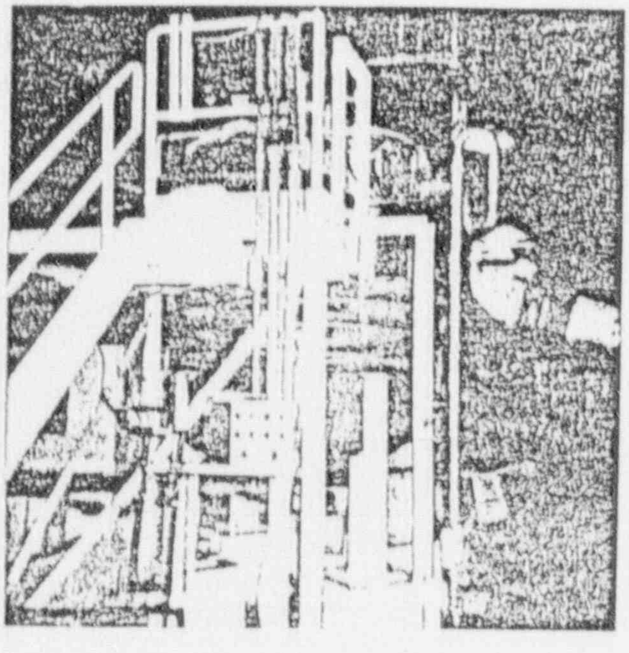

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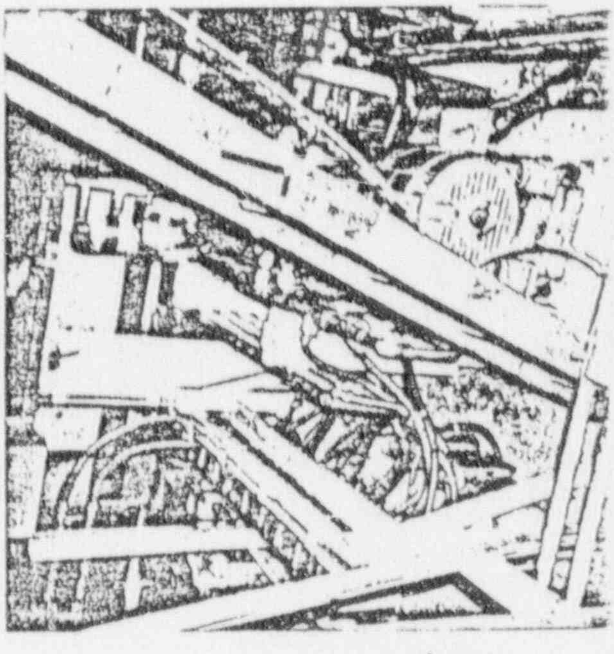

#16 Pump switches on rack ← [illegible]

SQN-00-D052
EPM-AMJ-073190 SKETCH MAPS & PHOTOS
APPENDIX B

SHEET B7
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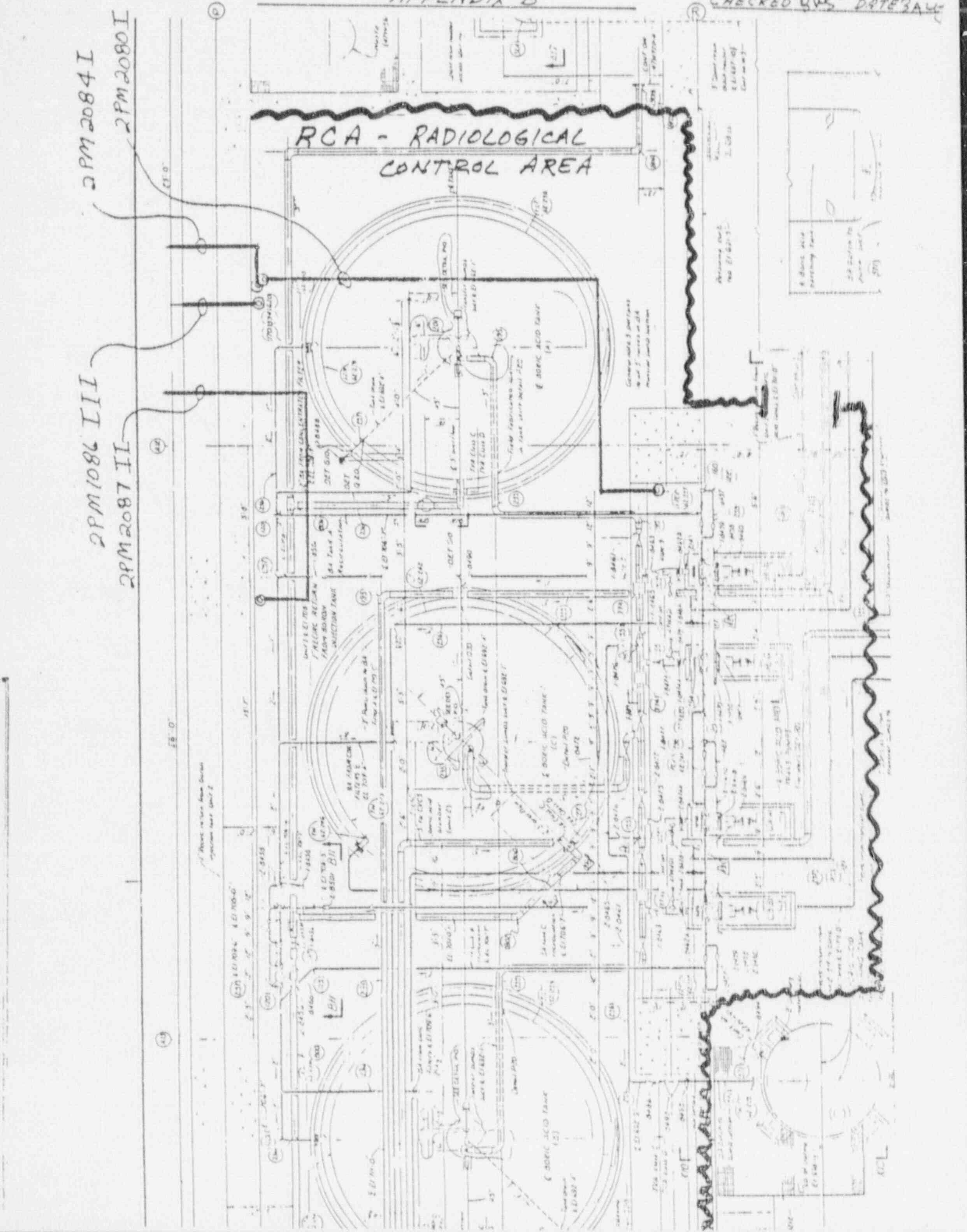
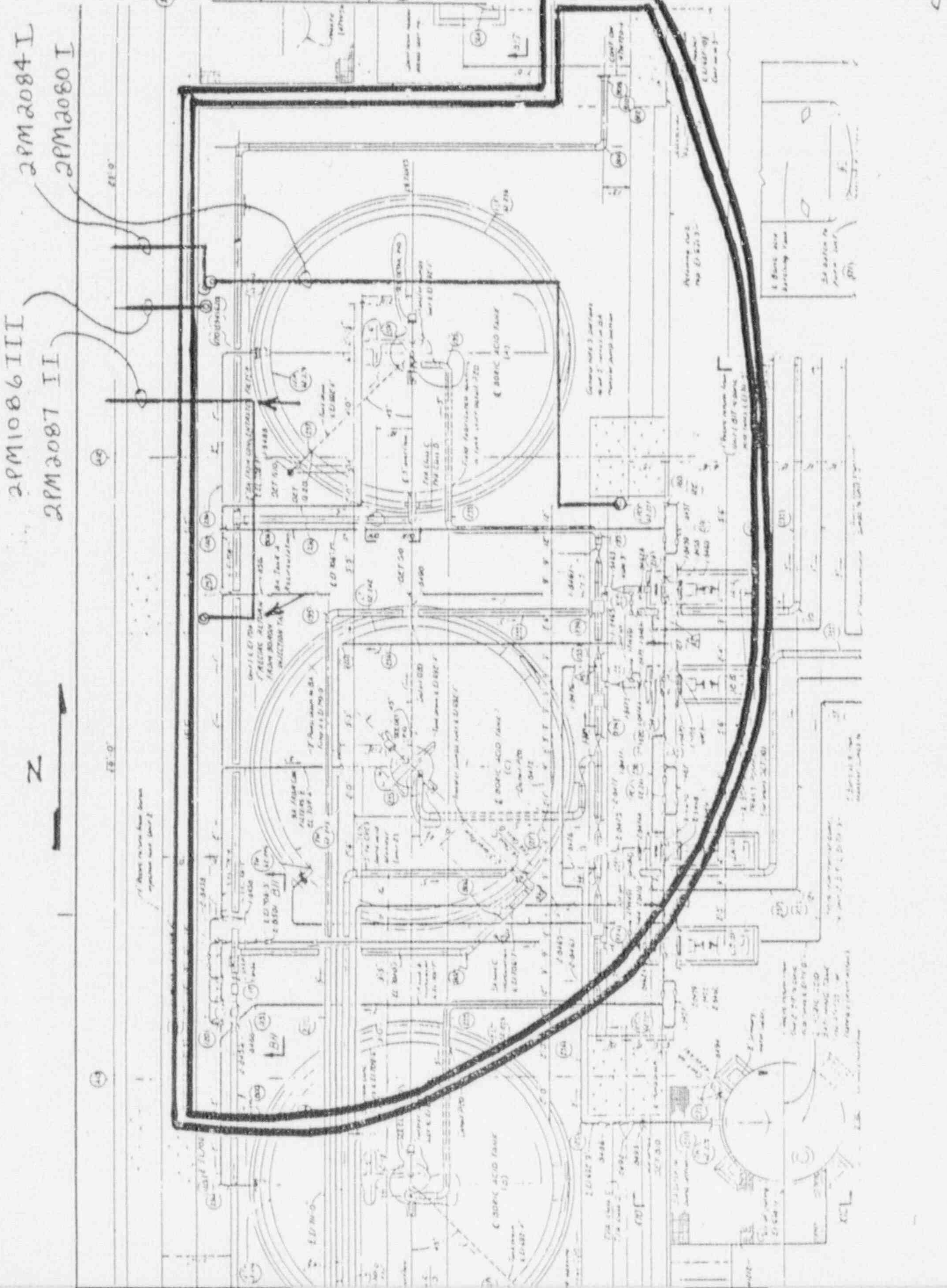
CHECKED [illegible] DATE 3AU



SQN-00-D052
EPM-AMJ-073190

FIRE AREA DETERMINATION LAYOUTS
APPENDIX C

SHEET C1
COMPUTED AMJ DATE 7-31
CHECKED DUS DATE 3 Aug



SQN-00-D052
EPM-AMJ-073190

SHEET C2

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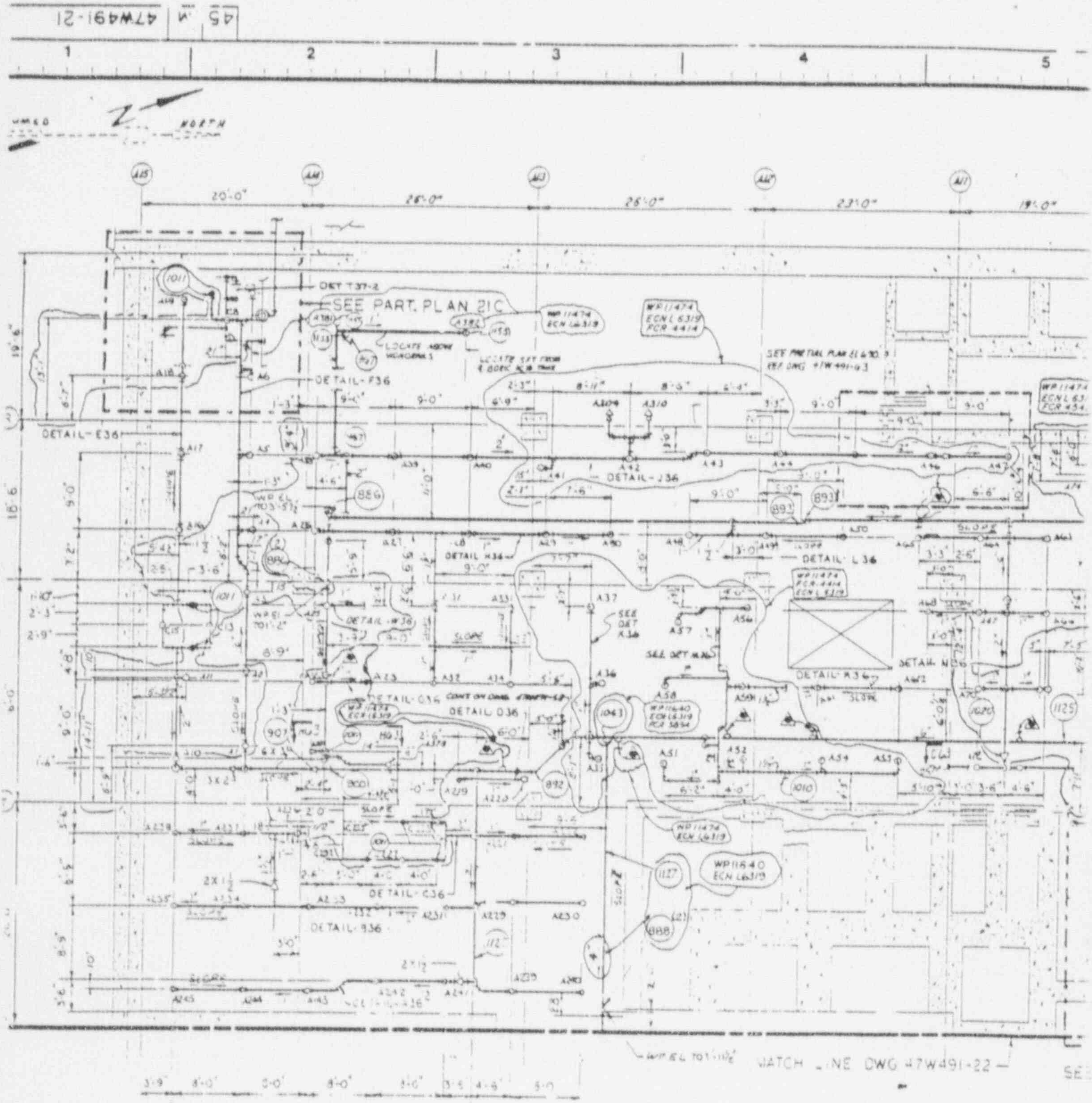
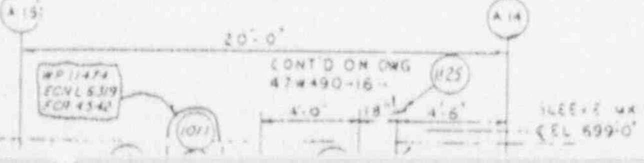
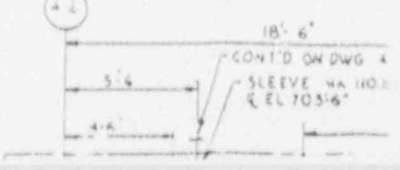
FIRE AREA DETERMINATION LAYOUTS

APPENDIX C







EPM-AMU-073190

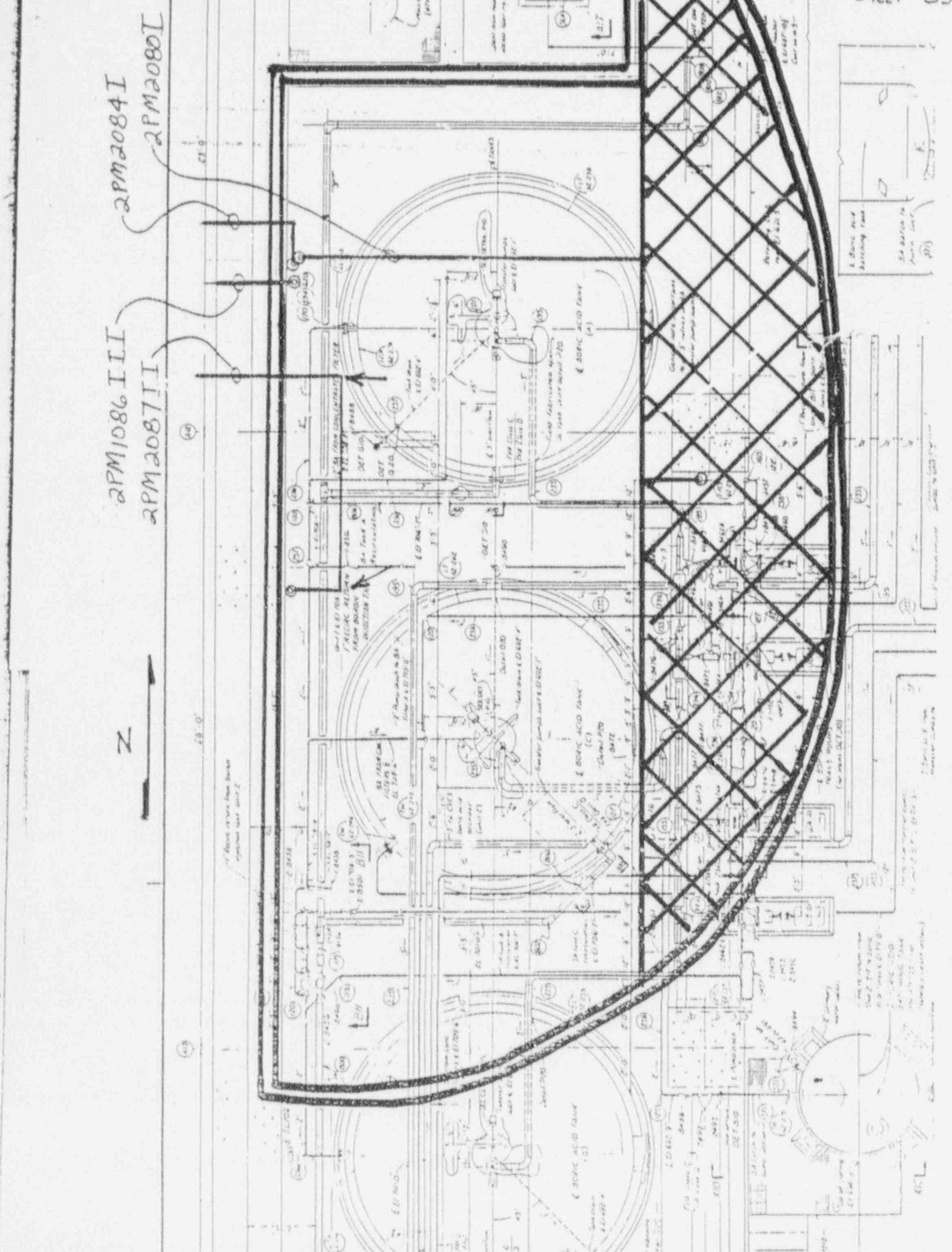
FIRE AREA DETERMINATION LAYOUTS

APPENDIX C

COMPUTED CTM DATE 7-31-

CHECKED BUS DATE 3 Aug

Sheet C3

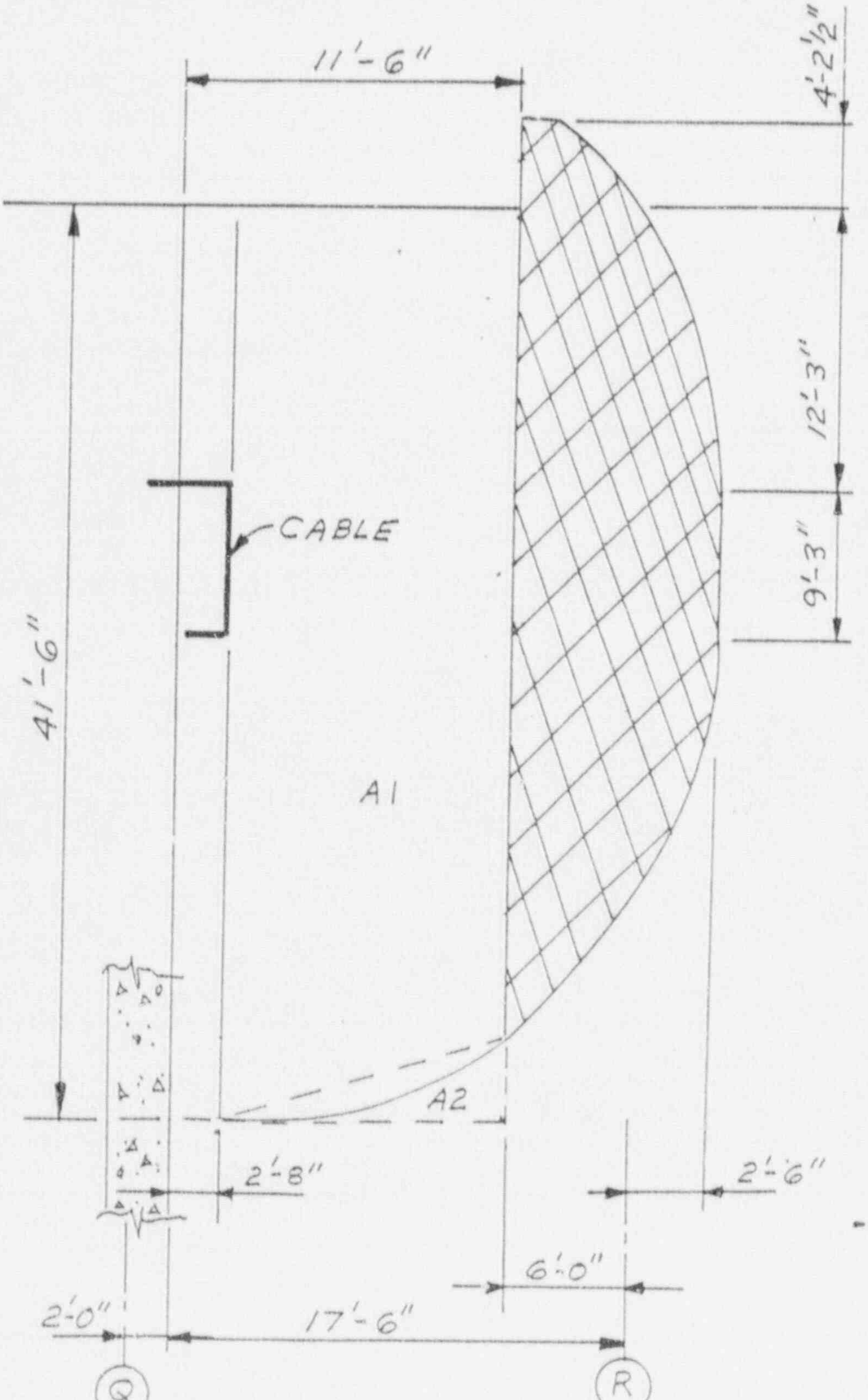


SQN-00-D052 SHEET C4 OF
EPM-AMJ-073190

FIRE AREA DETERMINATION LAYOUTS
APPENDIX C

COMPUTED amj DATE 7-31-90
CHECKED Bvs DATE 3Aug90

AREA OF CONCERN APPROXIMATED



FIRE AREA DETERMINATION LAYOUTS
APPENDIX C

amj 7-31-90
BKS 3Aug90

<u>AREA OF COMBUSTIBLE</u>

$$= \overset{A1}{\left(41.5' \times 11.5'\right)} - \overset{A2}{\left(\frac{1}{2}\,b\,h\right)}$$

$$= 477.25 - \left(\frac{1}{2} \times \frac{11.5}{\tan 27^{\circ}} \times 11.5\right)$$

$$= 455.76 \text{ OR } \boxed{456 \text{ FT}^2}$$

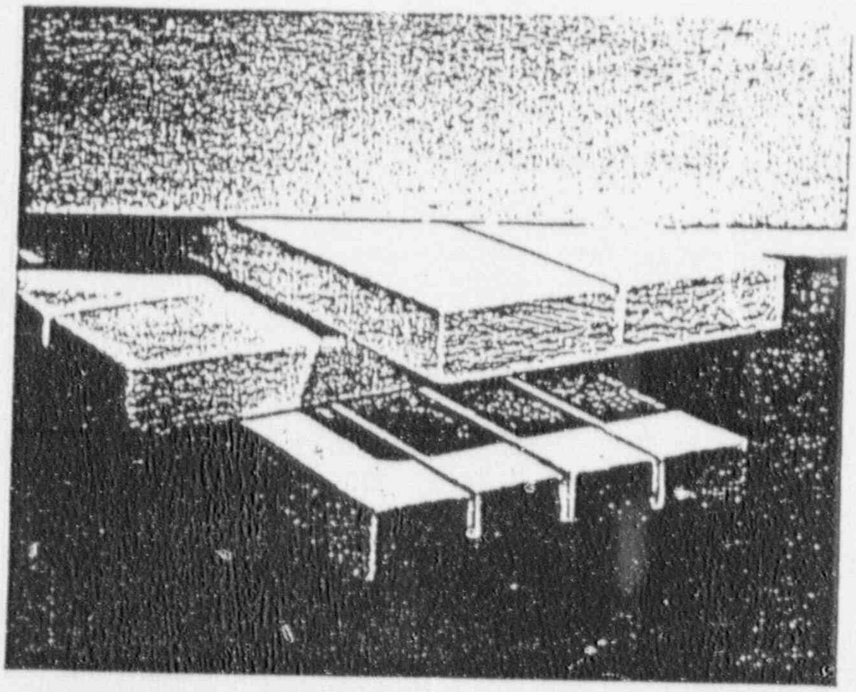
SQN-00-0052
EPM-AMJ-073190

SHEET D1 OF

CALCIUM-SILICATE COMBUSTIBILITY SHEET
APPENDIX D

COMPUTED amj DATE 7-31-90
CHECKED Bvs DATE 3 Aug 90

Manville Specification Data Thermo-12™



Surface Burning Characteristics when tested to (ASTM E84)

Flame Spread	0
Fuel Contributed	0
Smoke Developed	0

Block Insulation Standard Sizes

Length, inches	*Thickness, inches	Width, inches
36	1½, 2, 2½, 3, 3½, 4 and 5	12, 18

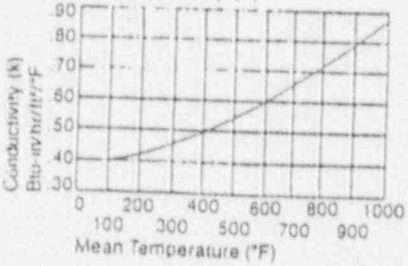
*Thicknesses over 5" on special order.

Scored Block Insulation

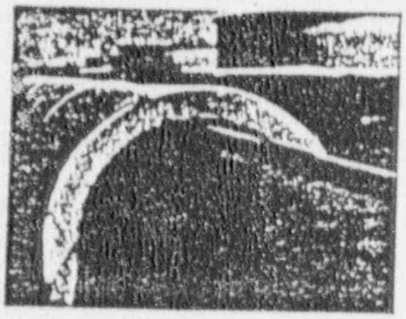
Insulation Thickness in Inches	Minimum Diameter in Inches	
	Triple Scored Block	Single Scored Block
1½	30	95
2	40	125
2½	50	155
3	60	190
3½	70	220
4	—	250

Note: For special sizes and curved blocks consult your nearest Manville sales office.

Thermal Conductivity (k)



*As tested in accordance with ASTM C177 Guarded Hot Plate and ASTM C518 Rapid Heat Meter.



Physical Properties

Density (dry)	10 lbs per cu ft
Flexural Strength (Based on 1½" thickness of block tested in accordance with ASTM C203)	60 psi
Compressive Strength	200 psi to produce 5% compression (based on 1½" thickness of block)
Linear Shrinkage	1.1% after 24-hr. soaking period at 1200°F
Maximum Service Temperature	1500°F

Compliance with Outside Specifications Pipe and Block Insulation

ASTM C533, Type I
ASTM C795
MIL-I-24244
MIL-I-2781E to 1200°F (pipe)
MIL-I-2819F (block)
  Class 2 to 1200°F
  Class 3 to 1500°F
U.S. Coast Guard Certificate of Approval
  164.009/163/0

When ordering material to comply with any Government Specification, a statement of that fact must appear on the purchase order. Government regulations prohibit the certification of compliance after shipment has been made.

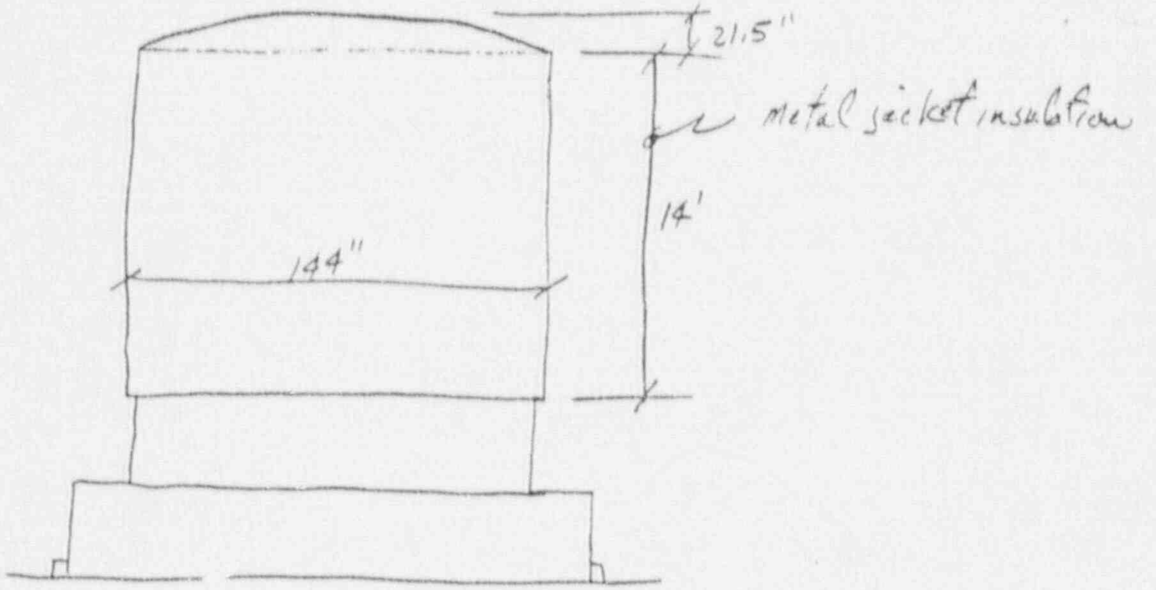
SQN-00-D052
EPM-AMJ-073190

SHEET E1 OF

TANK INSULATION COMBUSTIBLES
APPENDIX E

COMPUTED AMJ DATE 7-31-90
CHECKED BVS DATE 3Aug90

Fire Load of tank insulation



REFERENCE: W (Westinghouse) CONTRACT # 91934
DRWG # 617F659, attached sheet E5.

Insulation is loose packed, flexible sheets; Refer to
"Thermal Insulation" by J.F. Malloy, table 31 on
attached sheets E3 AND E4.
Numbers 44 to 47 are typical of this type of insulation.
A maximum density is 4 lbs/FT³.
Flame spread ≤ 25 smoke density ≤ 50
Insulation thickness is 2 inches.

Volume of insulation on side of tank =

$$\pi D h t = \pi (12')(14')(2/12) = 88.0\ FT^3$$

Volume of insulation on top of tank = Area × thickness

$$= \frac{\pi}{4}\left[s^2 + 4h^2\right] \times \text{thickness} = \pi/4\left[(12')^2 + 4\left(\frac{21.5\text{ in}}{12}\right)^2\right] \times 2\text{ in}/12$$

$$= 20.5\ FT^3$$

SQN-00-D052 SHEET E2 OF

EPM-AMJ-073190

TANK INSULATION COMBUSTIBLES COMPUTED amj DATE 7-31-90

APPENDIX E CHECKED BVS DATE 3Aug90

Total Volume of insulation for 1 tank =
88.0 + 20.5 = 108.5 FT^3 per tank

Weight = 108.5 FT^3 x 4 lbs/FT^3 = 434 lbs

Conservatively the resin bond of the fiberglass insulation is 10% of its weight, therefore,

Weight of resin = 434 x 10 = 43.4 lbs/tank

A conservative value for the Heat of combustion for this resin is 45.8 MJ/kg. This presumes the resin is composed of mostly synthetic butyl rubber which is the highest value for all common resin constituants. (Fire Protection Handbook, Table 5-11C.) PG J4

Thus, each tank's insulation contributes:

Heat of Combustion = 43.4 x 45.8 x 430* = 855,000 BT

(Note: The value use is approximately 3.4 times greater than the reasonable maximum of actual resin. Since resin cemistry is often a proprietory vendor, information this very conservative value is used)

*430 (BTU/lb)/(KJ/kg) is a conversion factor

SQN-00-D052
EPM-AMJ-073190

TANK INSULATION COMBUSTIBLES
APPENDIX E

SHEET E3 OF
COMPUTED DATE 7-31-90
CHECKED BVS DATE 2Aug9

Thermal Insulation

JOHN F. MALLOY
Mechanical Engineer
Charleston, West Virginia

VAN NOSTRAND REINHOLD COMPANY
New York Toronto London Melbourne

1969 Edition

SQN-00-D052
EPM-AMJ-073190

SHEET E4 OF

TANK INSULATION COMBUSTIBLES
APPENDIX E

COMPUTED AMJ DATE 7-31-90
CHECKED BVS DATE 3Aug90

TABLE 30 Rigid and semi-rigid insulations (continued)

Material identification number	Generic type and brief description of insulation material	Form	Maximum temp limits °F		Density lb/ft³	Abrasion resistance % weight loss by tumbling		Alkalinity pH	Capillarity	Combustibility			Compressive strength lb/in.² at % deformation	Hygroscopic expansion % volume after test	Linear shrinkage max % at max temp. F	Specific heat Btu per lb per °F	Tensile strength lb/in.²	Thermal diffusivity sq ft/hr (calculated)	Water absorption % vol. 24 hr sub-mersion	Water vapor transmission perm-inch
			Continuous	Short		1st 10 min run	2nd 10 min run			Flame spread index	Smoke developed index	Noncombustible								
37	Polyurethane foam	Block Board PC	250	250	1.5 to 2.5	3 to 15		6.5 to 7.5	None	Comb.	Comb.	Comb.	40 to 85			.25	38 to 42	.011 to .031	1.5 to 3	1.5 to 2
38	Polyurethane foam self-extinguishing	Block Board PC	200 to 250	300	1.6 to 4.0	5 to 20		6.5 to 7.5	None	Approx 25 and up	less than 500		18 to 100		2% Exp. at 250 F	.23	20 to 125	.011 to .027	2 to 3	1.2 to 2.7
39	Rubber resin cellular foam	Block and PC	220	220	5 to 8				None	less than 50	Approx 500		40 at 10%		7 to 10 at 220	.19 to .27	82		1	0.1
40	Siliceous fibers and binder, with factory applied aluminum facing	4 × 8 Panels	450	[illegible]	4				will wick			NC			0	.2				
41	Vinyl chloride cellular foam. Self extinguishing	Block and PC	212 to 275	212 to 275	1.5 to 3				None	less than 20	less than 100		28 to 50 at 5%		.00025 Exp. Co.		60		4.5	11 to 16
42	Wood fiber and binder	Board	175	175	15 to 18				will wick					14	5.4		500 parallel to grain		7.8 to 5.4	

[illegible]

TABLE 31 Flexible insulations

Material identification number	Generic type and brief description of insulation material	Form	Maximum temp limits °F		Density lb/ft³	Abrasion resistance % weight loss by tumbling		Alkalinity pH	Capillarity	Combustibility			Compressive strength lb/in.² at % deformation	Hygroscopic expansion % volume after test	Linear shrinkage max % at max temp. F	Specific heat Btu per lb per °F	Tensile strength lb/in.²	Thermal diffusivity sq ft/hr (calculated)	Water absorption % vol. 24 hr sub-mersion	Water vapor transmission perm-inch
			Continuous	Short		1st 10 min run	2nd 10 min run			Flame spread index	Smoke developed index	Noncombustible								
43	Asbestos braided inner and outer tubing filled with glass fiber	Seamless flexible tube	500	500	10 to 14			7 to 8	will wick			NC		5 90°F 90 RH	0	.24		.21		
44	Glass fibrous with organic binder. Available with various facings	Flexible Roll or sheets	400	400	.6 to 1.5			[2]8.5 to 9	Dry	25 or less	50 or less		Up to .03 at 10%	2 125°F 95 RH	0	.20				
45	Glass fibrous with organic binder. Available with various facings	Flexible sheets	400	400	1.5 to 2.0			[2]8.5 to 9	Neg.	25 or less	50 or less		Up to .03 at 10%	2 125°F 95 RH	0	.20				
46	Glass fibrous with organic binder. Available with various facings	Flexible sheets	[illegible]	400	2 to 3			[2]8.5 to 9.0	Neg.	25 or less	50 or less		Up to .07 at 10%	2 125°F 95 RH	0	.20				
47	Glass fibrous with organic binder. Available with various facings	Flexible sheets	400	400	3 to 4			[2]8.5 to 9.0	Neg.	25 or less	50 or less		Up to .5 at 10%	2 125°F 95 RH	0	.20				
48	Polystyrene cellular foam. Flexible	Roll form	165	165	0.8 to 1.2			6.5 to 7.5	None				7 at 5%	1					1	1.0 to 2.4
49	Rubber resin cellular foam. Flexible	Sheet and PC	220	220	5 to 11				None				3 to 8 at 25%	3.5 to 10	3.6				.8 to 1.2	.05 to .38

[2] Also less than 0.6% of Na₂O

Note: Material Numbers 43 through 48 are all sufficiently flexible to bend 180 degrees around a ½ inch O.D. mandrel.

SQN-00-0052

EPM-AMJ-073190

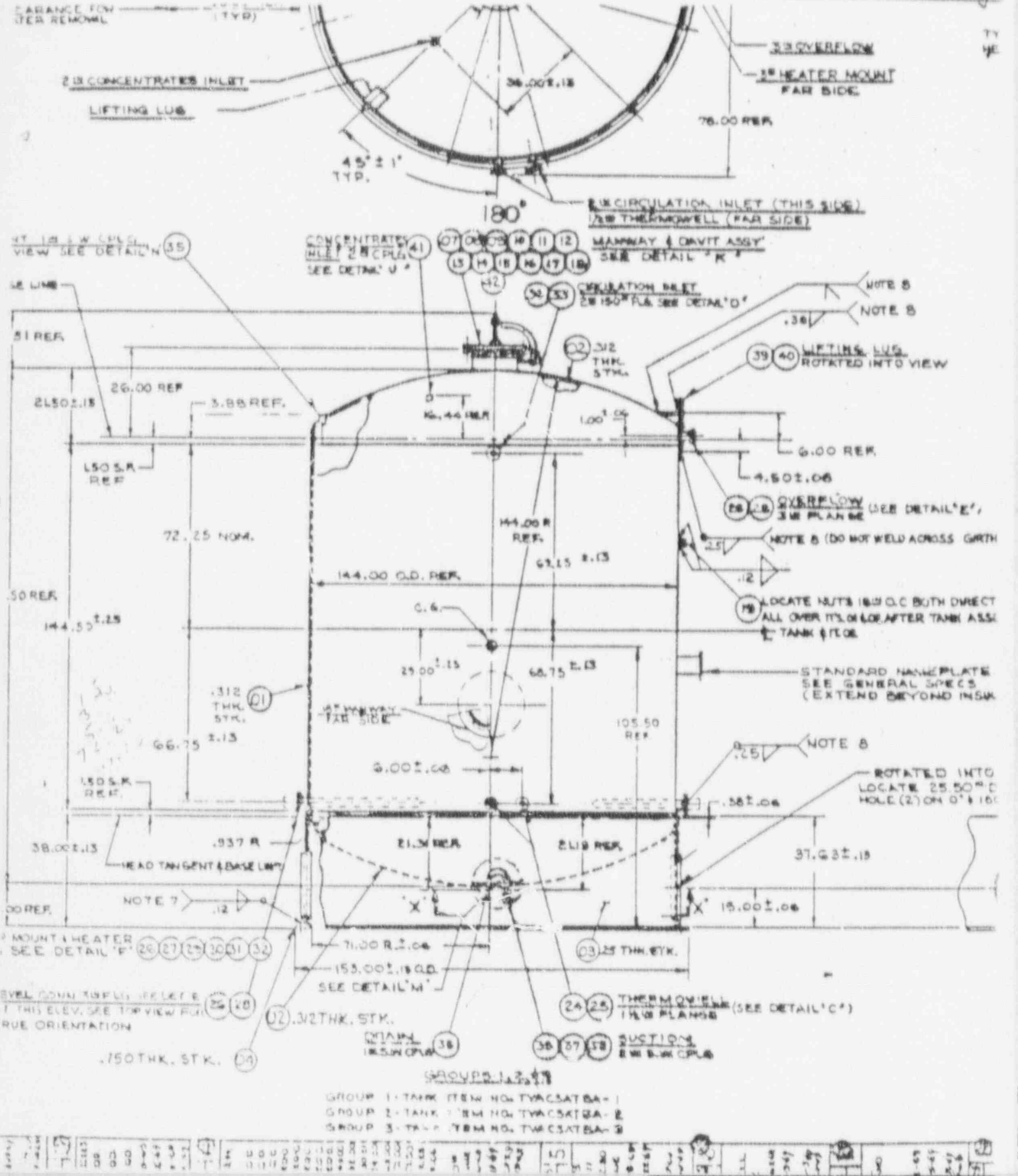
SHEET E5 OF

TANK INSULATION COMBUSTIBLES

APPENDIX E

COMPUTED AMJ DATE 7-31-

CHECKED BVS DATE 3Aug



SQN-00-D052 SHEET F1

EPM-AMJ-073190 COMPUTED AMJ DATE 7-31-

CHECKED RLB WEE DATE 3Aug 9

DATA SHEETS

APPENDIX F

SQN
SMI-0-26-7
Page 8
Revision ~~0~~ 1

ATTACHMENT 2
Page 1 of 1

FIRE HAZARD ANALYSIS DATA COLLECTION FORM

PLANT: SEQUOYAH UNIT: 2 Page ____ of ____

BUILDING: AUXILIARY Prepared by A. Marinez Jr date 7-19-90

ELEVATION: 690.0' Checked by date 19 Jul 90

Room Name: BORIC ACID TANK AREA

Room Number: EL 690-A1, Q Line to 3'-2" E of R and 15'-0" N of A12 Line to 2'-0" S of A13.

Drawings Used:

TARGET

Item	Quantity	Location	Measurement	Remarks
APP R Cable 2PM2080 I	1 conduit < 3" ø	EL 710 A11-A12/Q-R	26 Ft Long* < 3" ø	1 hour UL Wrap
APP R Cable 2PM2087 II	1 conduit < 3" ø	EL 710 A11-A13/Q-R	14 Ft Long* < 3" ø	
APP R Cable 2PM2084 I	1 conduit < 3" ø	EL 710 A11-A12/Q-R	10 Ft Long* < 3" ø	
APP R Cable 2PM1086 III	1 conduit < 3" ø	EL 710 A11-A12/Q-R	10 Ft Long* < 3" ø	

*Estimates of ± 2 feet distance based on visual sightings from 20-30 ft away.

SQN-00-0052

EPM-AMJ-0731190

SHEET F2

COMPUTED AMJ DATE 7-31-

CHECKED BWS DATE 3 Au

DATA SHEETS

APPENDIX F

SQN
SMI-0-26-7
Page 8
Revision ~~0~~ 1

ATTACHMENT 2
Page 1 of 1

FIRE HAZARD ANALYSIS DATA COLLECTION FORM

PLANT: SEQUOYAH UNIT: 2 Page ____ of ____

BUILDING: AUXILIARY Prepared by A Muniz J date 7-19-90

ELEVATION: 690.0' Checked by Edwin E. date 19 Jul 90

Room Name: BORIC ACID TANK AREA

Room Number: EL 690-A1, Q Line to 3'-2" E of R and 15'-0" N of A12 Line to 2'-0" S of A13.

Drawings Used:

Sprinklers

Item	Quantity	Location	Measurement	Remarks
#A12 thru A46	5 heads	ELEV 712'-6 3' E of R		Covers area 7' each side of head.
#A309 & A310	2 heads	ELEV 712'-6" 1' W of R	11-1" N of A13	For water curtain

Notes: Heads A12-A46; credit taken for only 6'-4" each side of heads in this case.

Head A309 & A310; No credit taken because these only provide a water curtain barrier for switches & valve on R column line.

0723Q/pr

SQN-00-D052

EPM-AMJ-073190

SHEET F3

COMPUTED AMJ DATE 7-31-90

CHECKED BKS DATE 3Aug90

DATA SHEETS

APPENDIX F

SQN
SMI-0-26-7
Page 8
Revision ~~0~~ 1

ATTACHMENT 2
Page 1 of 1

FIRE HAZARD ANALYSIS DATA COLLECTION FORM

PLANT: SEQUOYAH UNIT: 2 Page ____ of ____

BUILDING: AUXILIARY Prepared by A Maniz J date 7-19-90

ELEVATION: 690.0' Checked by date 19 Jul 90

Room Name: BORIC ACID TANK AREA

Room Number: EL 690-A1, Q Line to 3'-2" E of R and 15'-0" N of A12 Line to 2'-0" S of A13.

Drawings Used:

Non-Combustibles

Item	Quantity	Location	Measurement	Remarks
Conduits	Numerous 1"ø to 6"ø	Ceiling, wall, & Floor A11-A13/Q-R	NA	FULLY ENCLOSED CABLES — NON COMBUSTIBLE
Pipe Insul	Numerous 1"ø to 3"ø	Various A11-A13/Q-R	NA	CALSIUM-SILICATE NON-COMBUSTIBLE

SQN-00-0052 SHEET F4

EPM-AMU-073190 COMPUTED [illegible] DATE 7-31-9

CHECKED BWS DATE 3 Aug 9

DATA SHEETS

APPENDIX F

SQN
SMI-0-26-7
Page 8
Revision ~~0~~ 1

ATTACHMENT 2
Page 1 of 1

FIRE HAZARD ANALYSIS DATA COLLECTION FORM

PLANT: SEQUOYAH UNIT: 2 Page ____ of ____

BUILDING: AUXILIARY Prepared by A. Moreira J date 7-19-90

ELEVATION: 690.0' Checked by [illegible] date 19 Jul 90

Room Name: BORIC ACID TANK AREA

Room Number: EL 690-A1; Q Line to 3'-2" E of R and 15'-0" N of A12 Line to 2'-0" S of A13.

Drawings Used:

Combustibles

Item	Quantity	Location	Measurement	Remarks
Tank Insulation	2⅓ Tanks (see note)	3 pieces one directly beneath cond.	2 in thick 12 ft Diameter	
Conduit Cover "Sealtite"	<40	Various A11-A13/Q-R	1/8" Thick (max) 1" ϕ - 4 ft long	Water tight covering over flexible metal ~~in conduit~~

note: 2 complete tanks are within the analyzed fire area. 1/3 of another tank also in the area.

0723Q/pr

SQN-00-D052 SHEET 61 OF

EPM-AMJ-073190

WATERPROOF FLEXIBLE WRAP ON CONDUIT COMPUTED AMJ DATE 7-31-90

APPENDIX G CHECKED BHS DATE 3Aug90

FIRE LOAD OF WATERPROOF WRAP ON FLEXIBLES

Each conduit has 4 feet of flexible connection which is covered with flexible PVC (poly-vinyl chloride or poly-vinyl choride-acetate). It varies in thickness but is a maximum of 1/8" average thickness. It is fused or molded to the flexible conduit. A typical vendor, ANAMET INC, was contacted and confirmed the Watertight flexible covering to be PVC. Also, the vendor supplied the average thickness and weight per foot for two of the heavier types of some 15 different style. (See pg G2 for details received from ANAMET vendor) Using the 2"ϕ information as conservative values for the 40 or less conduits in this area of 1"ϕ, at 400 lbs/1000 ft or 0.4 lbs/ft the total weight of PVC is:

WT of PVC = 4 ft × 40 × 0.4 lbs/ft = 64 lbs

From Fire Protection Handbook, Table 5-11B (pg J3), the Heat of Combustion is:

Heat of Combust. = 64 lbs × 16.9 MJ/kg × 430* = 465 000 BTU

*430 (BTU/lb)/(MJ/kg) → see conversion factor

DATE: 7/26/90

TIME SENT: ______

TELEFAX MESSAGE FROM:

ANAMET INC.
P.O. Box 2618
Waterbury, Conn. 06725

FAX No. (203) 573-1505
Confirming No. (203) 574-8953

This Telefax comprises, including this page, 1 page/s.

TO: AUGIE MANIEZ

FROM: R. PICARD

SUBJECT: SEALTITE CONDUIT

DEAR AUGIE

1. ANAMETS TYPE U.A., C.W., D.L., QR.H., HAVE IN 2" CONDUIT SIZE, A COVER THK. OF .090 AND A COVER WT. OF 400LBS/MFT.
2. ANAMETS TYPE E.A., H.C., OB & HCX. HAVE IN 2" SIZE A COVER THK. OF .082 AND A COVER WT. OF 375LBS/MFT

REGARDS,
ROGER

SQN-00-D052 SHEET H1 OF

EPM-AMJ-073190

TRANSIENT COMBUSTIBLES CALCULATION COMPUTED AMJ DATE 7-31-90

APPENDIX H CHECKED BPS DATE 3Aug90

HEAT OF COMBUSTION OF TRANSIENTS.

The controlled use of transients combustibles within the Auxiliary Bldg is the responsibility of SQN's Fire Protection Manager per Physical Security Instruction, PHYSI 13. Therefore, it is reasonable that the estimated transient combustibles will be safely used, stored, and controlled.

The area in question was inspected on May 23 1990 and again on Jun 29 1990. The previous statements/conclusions were substantiated by the inspection. Per these inspections, a conservative estimate of the combustibles present at any given time in this space is:

2 - plastic ladders

1 - 5 gal of Heptane

Ladder -

Composed of plastic sides with aluminum rungs. The amount of plastic is conservatively 40 lbs/Ladder. Polyethelyne is a conservative plastic compenent material, per Fire Protection Handbook, Table 5-11B, pg

Ht of Comb = 43.4 MJ/kg

1 Ladder = 40 lbs x 43.4 x 430* = 746,500 BTu

* 430 (BTU/lb) / (KJ/Kg) → see conversion factor

TVA 11030 (WM-7-75)

SQN-00-D052 SHEET H2 OF

EPM-AMJ-073190

TRANSIENT COMBUSTIBLES CALCULATION COMPUTED DMJ DATE 7-31-90

APPENDIX H CHECKED BVS DATE 3Aug90

Heptane - A conservative choice for a flammable liquid, heptane represents a worst case of any solvent, paint, cleaner, etc that might be used. It's density is approxiomately the same as gasoline but for conservatism here the density of water will be used, 8.34 lbs/gal. Its Heat of Combustion per Fire Protection Handbook, table 5-11A, pg 21, is 44.6 MJ/Kg. 5 Gallons is a conservative amount to be used.

$$\text{Ht of Comb} = 5\ \text{gal} \times 8.34\ \text{lbs/gal} \times 44.6 \times 430^{*}$$

$$= 799{,}800\ \text{BTU}$$

* 430 (BTU/lb)/(KJ/Kg) → see conversion factor

SQN-00-D052 SHEET J1 OF

EPM-AMJ-073190

COMBUSTIBLE HEAT VALUES / RATES COMPUTED AMJ DATE 7-31-90

APPENDIX J CHECKED BVE DATE 3Aug90

TABLE 5-11A. Heats of Combustion and Related Properties For Pure, Simple Substances*

Material	Composition	W Molecular Weight	Δh_c^u Gross (MJ/kg)	Δh_c^l Net (MJ/kg)	$\Delta h_c^l/r_o$ (MJ/kg O_2)	r_o Oxygen-fuel Mass ratio	T_b Boiling temp. (°C)	Δh_v Latent Heat of Vaporization (kJ/kg)	C_{pl} Liquid Heat Capacity (kJ/kg-°C)	C_{pv} Vapor Heat Capacity (kJ/kg-°C)
cyclopropane	C_3H_6	42.08	49.70	46.57	13.61	3.422	−32.9	—	1.92	1.33
(decahydronaphthalene) → *cis*-decalin										
cis-decalin	$C_{10}H_{18}$	138.24	45.49	42.63	12.70	3.356	195.8	309	1.67	1.21
n-decane	$C_{10}H_{22}$	142.28	47.64	44.24	12.69	3.486	174.1	273	2.19	1.65
diacetylene	C_4H_2	50.06	46.60	45.72	15.89	2.877	10.3	—	—	1.47
(diamine) → hydrazine										
diborane	H_6B_2	27.69	79.80	79.80	23.02	3.467	−92.5	—	—	1.75
dichloromethane	CH_2Cl_2	84.94	6.54	6.02	10.65	0.565	39.7	330	1.18	0.60
diethyl cyclohexane	$C_{10}H_{20}$	140.26	46.30	43.17	12.58	3.422	174.		1.67	
diethyl ether	$C_4H_{10}O$	74.12	36.75	33.79	13.04	2.590	34.6	360	2.34	1.52
(2,4 diisocyanotoluene) → toluene diisocyanate										
(diisopropyl ether) → *iso*-propyl ether										
dimethylamine	C_2H_7N	45.08	38.66	35.25	13.24	2.662	6.9	—	—	1.60
(dimethyl aniline) → xylidene										
dimethyldecalin	$C_{12}H_{22}$	166.30	45.70	42.79	13.15	3.254	220.	260		
(dimethyl ether) → methyl ether										
1,1-dimethylhydrazine (UDMH)	$C_2H_8N_2$	60.10	32.95	30.03	14.10	2.130	25.	578	2.73	
dimethyl sulfoxide	C_2H_6SO	78.13	29.88	28.19	15.30	1.843	189.	677	1.89	1.14
1,3 dioxane	$C_4H_8O_2$	88.10	26.57	24.58	9.66	2.543	105.	404		
1,4 dioxane	$C_4H_8O_2$	88.10	26.83	24.84	9.77	2.543	101.1	406	1.74	1.07
ethane	C_2H_6	30.07	51.87	47.49	12.75	3.725	−88.6	—	—	1.75
ethanol	C_2H_6O	46.07	29.67	26.81	12.87	2.084	78.5	837	2.43	1.42
(ethene) → ethylene										
ethyl acetate	$C_4H_8O_2$	88.10	25.41	23.41	12.89	1.816	77.2	367	1.94	1.29
ethyl acrylate	$C_5H_8O_2$	100.12	27.44	25.69	13.39	1.918	100.	290		1.14
ethylamine	C_2H_7N	45.08	38.63	35.22	13.23	2.662	16.5	—	2.89	1.61
ethyl benzene	C_8H_{10}	106.16	43.00	40.93	12.93	3.165	136.1	339	1.75	1.21
ethylene	C_2H_4	28.05	50.30	47.17	13.78	3.422	−103.9	—	2.38	1.56
ethylene glycol	$C_2H_6O_2$	62.07	19.17	17.05	13.22	1.289	197.5	800	2.43	1.56
ethylene oxide	C_2H_4O	44.05	29.65	27.65	15.23	1.816	10.7	—	1.97	1.10
(ethylene trichloride) → trichloroethylene										
(ethyl ether) → diethyl ether										
formaldehyde	CH_2O	30.03	18.76	17.30	16.23	1.066	−19.3	—	—	1.18
formic acid	CH_2O_2	46.03	5.53	4.58	13.15	0.348	100.5	476	2.15	0.98
furan	C_4H_4O	68.07	30.61	29.32	13.86	2.115	31.4	398	1.69	0.96
α-D-glucose†	$C_6H_{12}O_6$	180.16	15.55	14.08	13.21	1.066	—	—	—	—
(glycerine) → glycerol										
glycerol	$C_3H_8O_3$	92.10	17.95	16.04	13.19	1.216	290.0	800	2.42	1.25
(glycerol trinitrate) → nitroglycerin										
n-heptane	C_7H_{16}	100.20	48.07	44.56	12.68	3.513	98.4	316	2.20	1.66
n-heptene	C_7H_{14}	98.18	47.44	44.31	12.95	3.422	93.6	317	2.17	1.58
hexadecane	$C_{16}H_{34}$	226.43	47.25	43.95	12.70	3.462	286.7	226	2.22	1.64
hexamethyldisiloxane	$C_6H_{18}Si_2O$	162.38	38.30	35.80	15.16	2.364	100.1	192	2.01	—
(hexamethylenetetramine) → methenamine										
n-hexane	C_6H_{14}	86.17	48.31	44.74	12.68	3.528	68.7	335	2.24	1.66
n-hexene	C_6H_{12}	84.16	47.57	44.44	12.99	3.422	63.5	333	2.18	1.57
hydrazine	H_4N_2	32.05	52.08	49.34	49.40	0.998	113.5	1180	3.08	1.65
hydrazoic acid	HN_3	43.02	15.28	14.77	79.40	0.186	35.7	690	—	1.02
hydrogen	H_2	2.00	141.79	130.80	16.35	8.000	−252.7	—	—	14.42
(hydrogen azide) → hydrazoic acid										
hydrogen cyanide	HCN	27.03	13.86	13.05	8.82	1.480	25.7	933	2.61	1.33
hydrogen sulfide	H_2S	34.08	48.54	47.25	16.77	2.817	−60.3	548	—	1.00
maleic anhydride†	$C_4H_2O_3$	74.04	18.77	18.17	14.01	1.297	202.0	—	—	—
melamine†	$C_3H_6N_6$	126.13	15.58	14.54	12.73	1.142	—	—	—	—
methane	CH_4	16.04	55.50	50.03	12.51	4.000	−161.5	—	—	2.23
methanol	CH_4O	32.04	22.68	19.94	13.29	1.500	64.8	1101	2.37	1.37
methenamine†	$C_6H_{12}N_4$	140.19	29.97	28.08	13.67	2.054	—	—	—	—
2 methoxyethanol	$C_3H_8O_2$	76.09	24.23	21.92	13.03	1.682	124.4	583	2.23	—
methylamine	CH_5N	31.06	34.16	30.62	13.21	2.318	−6.3	—	—	1.61
(2-methyl 1-butanol) → *iso* amyl alcohol										
(methyl chloride) → dichloromethane										
methyl ether	C_2H_6O	46.07	31.70	28.84	13.84	2.084	−24.9	—	—	1.43
methyl ethyl ketone	C_4H_8O	72.10	33.90	31.46	12.89	2.441	79.6	434	2.30	1.43
1-methylnaphthalene	$C_{11}H_{10}$	142.19	40.88	39.33	12.95	3.038	244.7	323	1.58	1.12

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Table 5-11B. Heats of Combustion and Related Properties for Plastics[a]

Material	Unit Composition	W Molecular Weight	Δh_c^u Gross (MJ/kg)	Δh_c^l Net (MJ/kg)	$\Delta h_c^l/r_o$ (MJ/kg O_2)	r_o Oxygen-fuel Mass ratio	C_{ps} Heat Capacity Solid (kJ/kg·°C)
acrylonitrile-butadiene styrene copolymer	—	—	35.25	33.75			1.41–1.59
bisphenol A epoxy	$C_{11.85}H_{20.37}O_{2.83}N_{0.3}$	212.10	33.53	31.42	13.41	2.343	
butadiene-acrylonitrile 37% copolymer	—	—	39.94				
butadiene/styrene 8.58% copolymer	$C_{4.18}H_{6.09}$	56.30	44.84	42.49	13.11	3.241	1.94
butadiene/styrene 25.5% copolymer	$C_{4.60}H_{6.29}$	61.55	44.19	41.95	13.07	3.209	1.82
cellulose acetate (triacetate)	$C_{12}H_{16}O_8$	288.14	18.88	17.66	13.25	1.333	1.34
cellulose acetate-butyrate	$C_{12}H_{18}O_7$	274.27	23.70	22.3	14.67	1.517	1.70
epoxy, unhardened	$C_{31}H_{36}O_{5.5}$	496.63	32.92	31.32	13.05	2.400	
epoxy, hardened	$C_{39}H_{40}O_{8.5}$	644.74	30.27	28.90	13.01	2.221	
melamine formaldehyde (Formica)	$C_6H_6N_6$	162.08	19.33	18.52	12.51	1.481	1.46
nylon 6	$C_6H_{11}NO$	113.08	30.1 –31.7	28.0 –29.6	12.30	2.335	1.52
nylon 6,6	$C_{12}H_{22}N_2O_2$	226.16	31.6 –31.7	29.5 –29.6	12.30	2.405	1.70
nylon 11 (Rilsan)	$C_{11}H_{21}NO$	183.14	36.99	34.47	12.33	2.796	1.70–2.30
phenol formaldehyde	$C_{15}H_{12}O_2$	224.17	27.9 –31.6	26.7 –30.4	11.80	2.427	1.70
-foam			21.6 –27.4	20.2 –26.2			
polyacenaphthalene	$C_{12}H_8$	152.14	39.23	38.14	12.95	2.945	
polyacrylonitrile	C_3H_3N	53.04	32.22	30.98	13.70	2.262	1.50
polyallylphthalate	$C_{14}H_{14}O$	198.17	27.74	26.19	9.54	2.745	
(polyamides) → nylon							
poly-1,4-butadiene	C_4H_6	54.05	45.19	42.75	13.13	3.256	
poly-1-butene	C_4H_8	56.05	46.48	43.35	12.65	3.426	1.88
polycarbonate	$C_{16}H_{14}O_3$	254.19	30.99	29.78	13.14	2.266	1.26
polycarbon suboxide	C_3O_2	68.03	13.78	13.78	14.64	0.941	
polychlorotrifluorethylene	C_2F_3Cl	116.47	1.12	1.12	2.04	0.549	0.92
polydiphenylbutadiene	$C_{16}H_{10}$	202.18	39.30	38.2	13.05	2.928	
polyester, unsaturated	$C_{5.77}H_{6.25}O_{1.63}$	101.60	21.6 –29.8	20.3 –28.5	11.90	2.053	1.20–2.30
polyether, chlorinated	$C_5H_8OCl_2$	154.97	17.84	16.71	12.45	1.342	
polyethylene	C_2H_4	28.03	46.2 –46.5	43.1 –43.4	12.63	3.425	1.83–2.30
polyethylene oxide	C_2H_4O	44.02	26.65	24.66	13.57	1.817	
polyethylene terephthalate	$C_{10}H_8O_4$	192.11	22.18	21.27	12.77	1.666	1.00
polyformaldehyde	CH_2O	30.01	16.93	15.86	14.88	1.066	1.46
poly-1-hexene sulfone	$C_6H_{12}SO_2$	148.13	29.78	28.00	14.40	1.944	
polyhydrocyanic acid	HCN	27.02	23.26	22.45	15.17	1.480	
(polyisobutylene) → poly-1-butene							
polyisocyanurate foam	—		26.3	22.2 –26.2			
polyisoprene	C_5H_8	68.06	44.90	42.30	12.90	3.291	
poly-3-methyl-1-butene	C_5H_{10}	70.06	46.55	43.42	12.67	3.426	
polymethyl methacrylate	$C_5H_8O_2$	100.06	26.64	24.88	12.97	1.919	1.44
poly-4-methyl-1-pentene	C_6H_{12}	84.08	46.52	43.39	12.67	3.425	2.18
poly-α-methylstyrene	C_9H_{10}	118.11	42.31	40.45	13.00	3.116	
polynitroethylene	$C_2H_3O_2N$	73.03	15.96	15.06	19.64	0.767	
polyoxymethylene	CH_2O	30.01	16.93	15.65	14.68	1.066	
polyoxytrimethylene	C_3H_6O	58.04	31.52	29.25	13.27	2.205	
poly-1-pentene	C_5H_{10}	70.06	45.58	42.45	12.39	3.426	
polyphenylacetylene	C_8H_6	102.09	40.00	38.70	13.00	2.978	
polyphenylene oxide	C_8H_8O	120.09	34.59	33.13	13.09	2.531	1.34
polypropene sulfone	$C_3H_6SO_2$	106.10	23.82	22.58	16.64	1.357	
poly-β-propiolactone	$C_3H_4O_2$	72.14	19.35	18.13	13.62	1.331	
polypropylene	C_3H_6	42.04	46.37	43.23	12.62	3.824	2.10
polypropylene oxide	C_3H_6O	58.04	31.17	28.90	13.11	2.205	
polystyrene	C_8H_8	104.10	41.4 –42.5	39.7 –39.8	12.93	3.074	1.40
polystyrene-foam	—		39.7	35.6 –40.8			
polystyrene-foam, FR	—		41.2 –42.9				
polysulfones, butene	$C_4H_8SO_2$	120.11	24.04–26.47	22.25–25.01	14.79	1.598	1.30
polysulfur	S	32.06	9.72	9.72	9.74	0.998	
polytetrafluoroethylene	C_2F_4	100.02	5.00	5.00	7.81	0.640	1.02
polytetrahydrofuran	C_4H_8O	72.05	34.39	31.85	13.04	2.443	
polyurea	$C_{15}H_{18}O_4N_4$	318.20	24.91	23.67	13.45	1.760	

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Table 5-11B. (continued)

Material	Unit Composition	W Molecular Weight	Δh_c^v Gross (MJ/kg)	Δh_c^l Net (MJ/kg)	$\Delta h_c^l/r_0$ (MJ/kg O_2)	r_0 Oxygen-fuel Mass ratio	C_{ps} Heat Capacity Solid (kJ/kg·°C)
polyurethane	$C_{6.3}H_{7.1}NO_{2.1}$	130.30	23.90	22.70	13.16	1.725	1.75–1.84
polyurethane-foam	—		26.1 –31.6	23.2 –28.0			
polyurethane-foam, FR	—		24.0 –25.0				
polyvinyl acetate	$C_4H_6O_2$	86.05	22.04	21.51	12.86	1.673	
polyvinyl alcohol	C_2H_4O	44.03	25.00	23.01	12.66	1.817	1.70
polyvinyl butyral	$C_8H_{14}O_2$	142.10	32.90	30.70	13.00	2.365	
polyvinyl chloride	C_2H_3Cl	62.48	17.95	16.90	12.00	1.408	0.90–1.20
polyvinyl-foam	—		22.83				1.30–2.10
polyvinyl fluoride	C_2H_3F	46.02	21.70	20.27	10.60	1.912	
polyvinylidene chloride	$C_2H_2Cl_2$	96.93	10.52	10.07	12.21	0.825	1.34
polyvinylidene fluoride	$C_2H_2F_2$	64.02	14.77	14.08	11.26	1.250	1.38
urea formaldehyde	$C_3H_6O_2N_2$	102.05	15.90	14.61	13.31	1.098	1.60–2.10
urea formaldehyde-foam	—	—	14.80				

* Sources: (Throne and Grieskey 1972; Krekeler et al 1965; Hogon 1976; NBS no date; Roff and Scott 1971; Joshi 1975; Van Krevelen 1976; Berlin et al 1969; Franz et al 1967)

Notes to Tables 5-11A, 5-11B, 5-11C, and 5-11D

Heats of Combustion: The heat of combustion is, by definition, the enthalpy of reaction when fuel and oxidant at standard conditions are reacted and form products at standard conditions. A unique value for the heat of combustion is possible only if these conditions are fully specified (Rossini 1956; Gray 1972). In normal combustion work the standard conditions are taken as:

1. Fuel and oxidant enter at 1 atmosphere pressure and 25°C (298 K) temperature. An amount of heat, which is equal to the heat of combustion, is extracted, so that the products are also at 25°C and 1 atmosphere.
2. The oxidant is gaseous oxygen.
3. The main products consist of liquid H_2O, gaseous CO_2, and gaseous N_2. There is no CO formed
4. For fuels containing sulfur, the standard products include liquid $H_2SO_4 \cdot 115H_2O$. For chlorine-containing fuels reference states consisting of either liquid HCl in water solution or gaseous Cl_2 have been used.
5. In the combustion of silicones, the silicon goes to amorphous silica, SiO_2.

The state of the fuel—gaseous, liquid or solid—is not standardized and must be specified. The heat of combustion as defined above is termed the gross or upper value and is customarily determined in an oxygen bomb calorimeter (ASTM undated a). For common materials the value is a negative number; however, customarily a minus sign is included in the definition to make heat of combustion a positive value (ASTM undated b). Heat of combustion, enthalpy of combustion, calorific value and heating value are synonyms, the latter two being used more commonly in the heating industry.

In many cases the products are not cooled down to 25°C. For modest temperature differences the change in the

Table 5-11C. Heat of Combustion of Miscellaneous Substances*

Material	Δh_c^v Gross (MJ/kg)	Δh_c^l Net (MJ/kg)
acetate (see cellulose acetate)		
acrylic fiber	30.6–30.8	
blasting powder	2.1–2.4	
butter	38.5	
celluloid (cellulose nitrate and camphor)	17.5–20.6	16.4–19.2
cellulose acetate fiber, $C_6H_{12}O_6$	17.8–18.4	16.4–17.0
cellulose diacetate fiber, $C_{10}H_{14}O_7$	18.7	
cellulose nitrate, $C_6H_9N_1O_7/C_6H_8N_2O_9/C_6H_7N_3O_{11}$	9.11–13.48	
cellulose triacetate fiber, $C_{12}H_{16}O_8$	18.8	17.6
charcoal	33.7–34.7	33.2–34.2
coal-anthracite	30.9–34.6	30.5–34.2
-bituminous	24.7–36.3	23.6–35.2
coke	28.0–31.0	28.0–31.0
cork	26.1	
cotton	16.5–20.4	
dynamite	5.4	
epoxy, $C_{11.9}H_{20.4}O_{2.8}N_{0.3}/C_{6.064}H_{7.550}O_{1.222}$	32.8–33.5	31.1–31.4
fat, animal	39.8	
flint powder	3.0–3.1	

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Table 5-11C. Heat of Combustion of Miscellaneous Substances*

Material	Δh_c^u Gross (MJ/kg)	Δh_c^l Net (MJ/kg)
fuel oil-No. 1	46.1	
-No. 6	42.5	
gasketing-chlorosulfonated polyethylene (Hypalon)	28.5	
-vinylidene fluoride hexafluoropropylene (Fluorel, Viton A)	14.0–15.1	
gasoline	46.8	43.7
jet fuel-JP1		43.0
-JP3		43.5
-JP4	46.6	43.5
-JP5	45.9	43.0
kerosene (jet fuel A)	46.4	43.3
lanolin (wool fat)	40.8	
lard	40.1	
leather	18.2–19.8	
lignin, $C_{2.8}H_3O$	24.7–26.4	23.4–25.1
lignite	22.4–33.3	
modacrylic fiber	24.7	
naphtha	43.0–47.1	40.9–43.9
neoprene, C_4H_5Cl-gum	24.3	
-foam	9.7–26.8	
Nomex (polymethaphenylene isophthalamide) fiber, $C_{14}H_{10}O_2N_2$	27.0–28.7	
oil-castor	37.1	
-linseed	39.2–39.4	
-mineral	45.8–46.0	
-olive	39.6	
-solar	41.8	
paper-brown	16.3–17.9	
-magazine	12.7	
-newsprint	19.7	
-wax	21.5	
paraffin wax	46.2	43.1
peat	16.7–21.6	
petroleum jelly ($C_{7.118}H_{12.957}O_{0.091}$)	45.9	
rayon fiber	13.6–19.5	
rubber-buna N	34.7–35.6	
-butyl	45.8	
-isoprene (natural) C_5H_8	44.9	42.3
-latex foam	33.9–40.6	
-GRS	44.2	
-tire, auto	32.6	
silicone rubber (SiC_2H_6O)	15.5–16.8	
-foam	14.0–19.5	
sisal	15.9	
spandex fiber	31.4	
starch	17.0	16.2
straw	15.6	
sulfur-rhombic		9.28
-monoclinic		9.29
tobacco	15.8	
wheat	15.0	
wood-beech	20.0	18.7
-birch	20.0	18.7
-douglas fir	21.0	19.6
-maple	19.1	17.8
-red oak	20.2	18.7
-spruce	21.8	20.4
-white pine	19.2	17.8
-hardboard	19.9	
woodflour	19.8	
wool	20.7–26.6	

* Sources: Landolt et al 1927–61; NACA 1957; Throne et al 1972; Moore 1978; Domalski et al 1978; Bostic 1973; Lobanov and Martynovskaya 1972; Ohe et al 1977; Lowrie 1983)

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tests to determine how actual building fires compared with the temperatures represented on the curve (Ingberg 1927, 1928). The tests included two actual buildings that were allowed to burn to destruction and a series of fires in fire resistive test buildings containing contents representative of office, record room, and household occupancies. The principal variable considered in these occupancy fire tests was the amount of combustible materials present, which is defined as the fire load. Although the ventilation in the test buildings was not reported, the windows were equipped with steel shutters that could be adjusted to control ventilation and maximize fire severity. The quantitative importance of ventilation on fire severity was not identified until more than 25 years after these tests. These tests conducted by the NBS provided quantitative data on the temperature history of fires that was representative of various occupancies and fire load at that period of time. Fire load was expressed as the weight of ordinary combustibles in the room divided by the floor area of the room. Loading is the average amount of ordinary combustible material per square foot (m^2) of floor area. The temperature history of the fully developed fires in the three test occupancies was approximately bounded by the standard time-temperature curve.

The NBS developed the concept of equivalent fire severity to define the severity of actual fires that had various temperature histories. This concept states that the area above a base line under the time-temperature curve of a test fire, which is expressed in degree hours, is an approximate representation of the severity of a fire involving ordinary combustibles. The base line used represents the temperature the materials can be exposed to without impairing their fire resistive capabilites. Two fires with differing temperature histories are considered to have equivalent severity when the area under their time temperature curves is similar. This concept permitted comparison of any fire test data to the standard time-temperature curve by relating the area under the test curve to the area under the standard curve.

FIRE LOAD

The original concepts of fire severity and fire load are very important even though they are technically obsolete. These concepts are the basis for many of the fire resistance requirements of building codes and for government agencies. In many cases, use of this original fire severity/fire load relationship was more severe than is indicated by more accurate analysis. Such results are conservative since the resultant error is on the safe side.

Analysis of NBS tests developed an approximate relationship between fire loading and an exposure to a fire severity equivalent to the standard time-temperature curve. The weight per square foot or square meter of ordinary combustibles [wood, paper, and similar materials with a heat of combustion of 7,000 to 8,000 Btu per lb (16 282 to 18 608 J/kg)] was related to hourly fire severity as described in Table 7-9B.

The fire severity/fire load relationship was the first method developed to predict the severity of a fire that would be anticipated in various occupancies. It was used to determine resistance required of fire barriers as well as structural components. Although the technique has its limitations, the fire severity/fire load relationship still provides an approximate but conservative estimate of the probable maximum fire severity in residential, institutional, and some commercial occupancies. Fire load should not be used as an approximate indicator of fire severity with combustibles having a high heat release rate and when fire conditions can produce temperatures significantly higher or lower than the standard time-temperature curve.

TABLE 7-9B. Estimated Fire Severity for Offices and Light Commercial Occupanices

Data applying to fire-resistive buildings with combustible furniture and shelving

Combustible Content Total, including finisn, floor, and trim psf	Heat Potential Assumed* Btu per sq ft†	Equivalent Fire Severity Approximately equivalent to that of test under standard curve for the following periods:
5	40,000	30 min
10	80,000	1 hr
15	120,000	1½ hrs
20	160,000	2 hrs
30	240,000	3 hrs
40	320,000	4½ hrs
50	380,000	7 hrs
60	432,000	8 hrs
70	500,000	9 hrs

* Heat of combustion of contents taken at 8,000 Btu per lb up to 40 psf; 7,600 Btu per lb for 50 lb, and 7,200 Btu for 60 lb and more to allow for relatively greater proportion of paper. The weights contemplated by the tables are those of ordinary combustible materials, such as wood, paper, or textiles.

† SI units: 1 psf = 4.9 kg/m^2; 1 Btu/ft^2 = 1.14 J/m^2

Fire load is a measure of the maximum heat that would be released if all the combustibles in a given fire area burned. Maximum heat release is the product of the weight of each combustible multiplied by its heat of combustion. In a normal building, the fire load includes combustible contents, interior finish, floor finish, and structural elements. Fire load is commonly expressed in terms of the average fire load, which is the equivalent combustible weight divided by the fire area in square feet or square meters.

Equivalent combustible weight is defined as the weight of ordinary combustibles having a heat of combustion of 8,000 Btu per lb (18 608 J/kg), that would release the same total heat as the combustibles in the space. For example, the equivalent weight of 10 lb per sq ft (48.8 kg/m^2) of a plastic with a heat of combustion of 12,000 Btu per lb (27 912 J/kg) would be:

10 lb per sq ft × 12,000 Btu per lb = 120,000 Btu per sq ft

120,000 Btu per sq ft ÷ 8,000 Btu per lb ordinary combustibles = 15 lb per sq ft

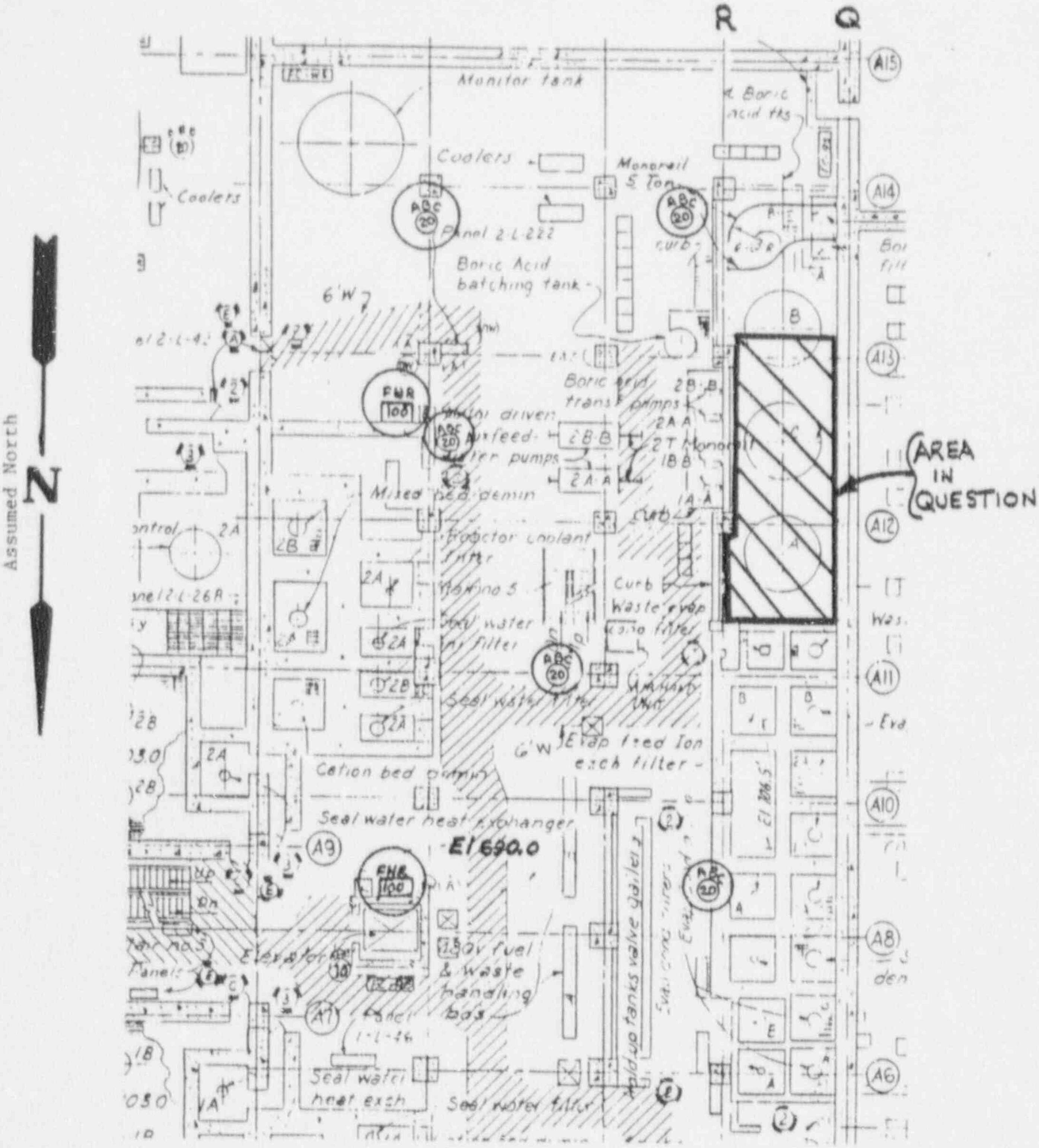
Technically accurate methods for relating fire severity, fire load, and fire resistance requirements are complex but can be advantageously used in important specific applications. Such methods require consideration of parameters other than the fuel load, such as ventilation, type of enclosure walls, and ceiling. These methods are complex and currently too difficult for general use in design or selection of barrier fire resistance.

ENCLOSURE 3

EQUIPMENT LAYOUT
MANUAL FIRE SUPPRESSION EQUIPMENT
AUXILIARY BUILDING, ELEVATION 690, COLUMN LINES A11 TO A13 AND Q TO R

47W200-5 REV. D
SAR FIGURE 1.2.3-5

ENCLOSURE 3



EQUIPMENT LAYOUT
47W200-5 Rev D
SAR Figure 1.2.3-5

FHR 100 .... 1½ fire hose rack. Number indicates length in feet.

ABC ⑳ .... Multipurpose type fire extinguisher. Number indicates capacity in pounds.