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225B ION EXCHANGE PIPING DESIGN DOCUMENTATION

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1	1	Cog.Eng. M. C. Prather	[signature]	2/26/96	G3-17	Inst/Cont. A. N. Joshi	[signature]	2/22/96	G3-17	1	1
1	1	Cog. Mgr. E. J. Renkey	[signature]	2/21/96	G3-17	Elec. C. E. Carlson	[signature]	2/22/96	G3-17	1	1
1	1	QA M. A. Hill	[signature]	2.26.96	S4-69	Inst/Cont. Review E. L. Vodopest	[signature]	2/23/96	G3-17	1	1
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1	1	Env. R. G. Hollenbeck	[signature]	2-23-96	G3-17	Kathleen A. Jennings-Mills	[signature]	2/26/96	S6-70	1	1
1	1	Customer W. W. Chen	[signature]	2-26-96	S7-57	J.H. RASMUSSEN			H6-70	3	3
1	1	Mech. Eng. Review B. E. Bielicki	[signature]	2/21/96	G3-17						

18.	19.	20.	21. DOE APPROVAL (if required)
[signature] M. C. Prather 2/26/96 Signature of EDT Originator Date	W. W. Chen [signature] for 2/26/96 Authorized Representative Date for Receiving Organization	E. J. Renkey [signature] 2/21/96 Cognizant Manager Date	Ctrl. No. N/A [] Approved [] Approved w/comments [] Disapproved w/comments

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225-B Ion Exchange Piping Design Documentation

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Abstract: This document describes the interface between the planned permanent ion exchange piping system and the planned portable ion exchange system.

225-B ION EXCHANGE PIPING DESIGN DOCUMENTATION

WHC-SD-WM-DA-217
Rev 0

M. C. Prather
ICF Kaiser Hanford Co.
for
Westinghouse Hanford Company

February 1996

TABLE OF CONTENTS

225-B ION EXCHANGE PIPING DESIGN DOCUMENTATION

1.0 NOMENCLATURE

A = cross sectional area of pipe or orifice, in square feet

a = cross sectional area of pipe or orifice, or flow area in valve, in square inches

C = flow coefficient for orifices and nozzles = discharge coefficient corrected for velocity of approach = $C_d / \sqrt{1-\beta^4}$

C_d = discharge coefficient for orifices and nozzles

C_V = flow coefficient for valves, expresses flow rate in gallons per minute of 60° F water with 1.0 lbf/in^2 pressure drop across valve

D = internal diameter of pipe, in feet

d = internal diameter of pipe, in inches

f = friction factor in formula $h_L = fLv^2/D2g$

f_T = friction factor in zone of complete turbulence

g = acceleration of gravity = 32.2 feet per second per second

H = total head, in feet of fluid

h_L = loss of static pressure head due to fluid flow, in feet of fluid

K = resistance coefficient or velocity head loss in the formula $h_L = Kv^2/2g$

K' = $\Delta P/Q^2$

L = length of pipe, in feet

ℓ = length of pipe, in inches

P = pressure, in pounds per square inch gauge

Q = rate of flow, in gallons per minute

q = rate of flow, in cubic feet per second at flowing conditions

R_e = Reynolds number

r = elbow centerline radius, in inches

S = specific gravity of liquids at specified temperature relative to water at standard temperature (60° F)

T = absolute temperature, in degrees Rankine (460 + t)

t = temperature, in degrees Fahrenheit, or time, in minutes, depending on context

V = mean velocity of flow, in feet per minute

v = mean velocity of flow, in feet per second

$\forall$ = volume, gallons

Z = potential head or elevation above reference level, in feet

Greek Letters

β = ratio of small to large diameter in orifices and nozzles, and contractions or enlargements in pipes

Δ = differential between two points

ε = absolute roughness

μ = absolute (dynamic) viscosity, in centipoise

ν = kinematic viscosity, in centistokes

ρ = weight density of fluid, pounds per cubic foot

θ = angle of convergence or divergence in enlargements or contractions in pipes

Subscripts for Diameter

(1)...defines smaller diameter

(2)...defines larger diameter

Subscripts for Fluid Property

(1)...defines inlet (upstream) condition

(2)...defines outlet (downstream) condition

2.0 INTRODUCTION

For a background of the Waste Encapsulation and Storage Facility (WESF) see the WESF Safety Analysis Report (Ref. 1). Page 6-46 of the Safety Analysis Report describes the current method of recovery from a cesium or strontium capsule leak in a storage pool cell. Contaminated pool cell water is pumped with a steam jet to B-Plant. This is initiated by a worker in the operating gallery.

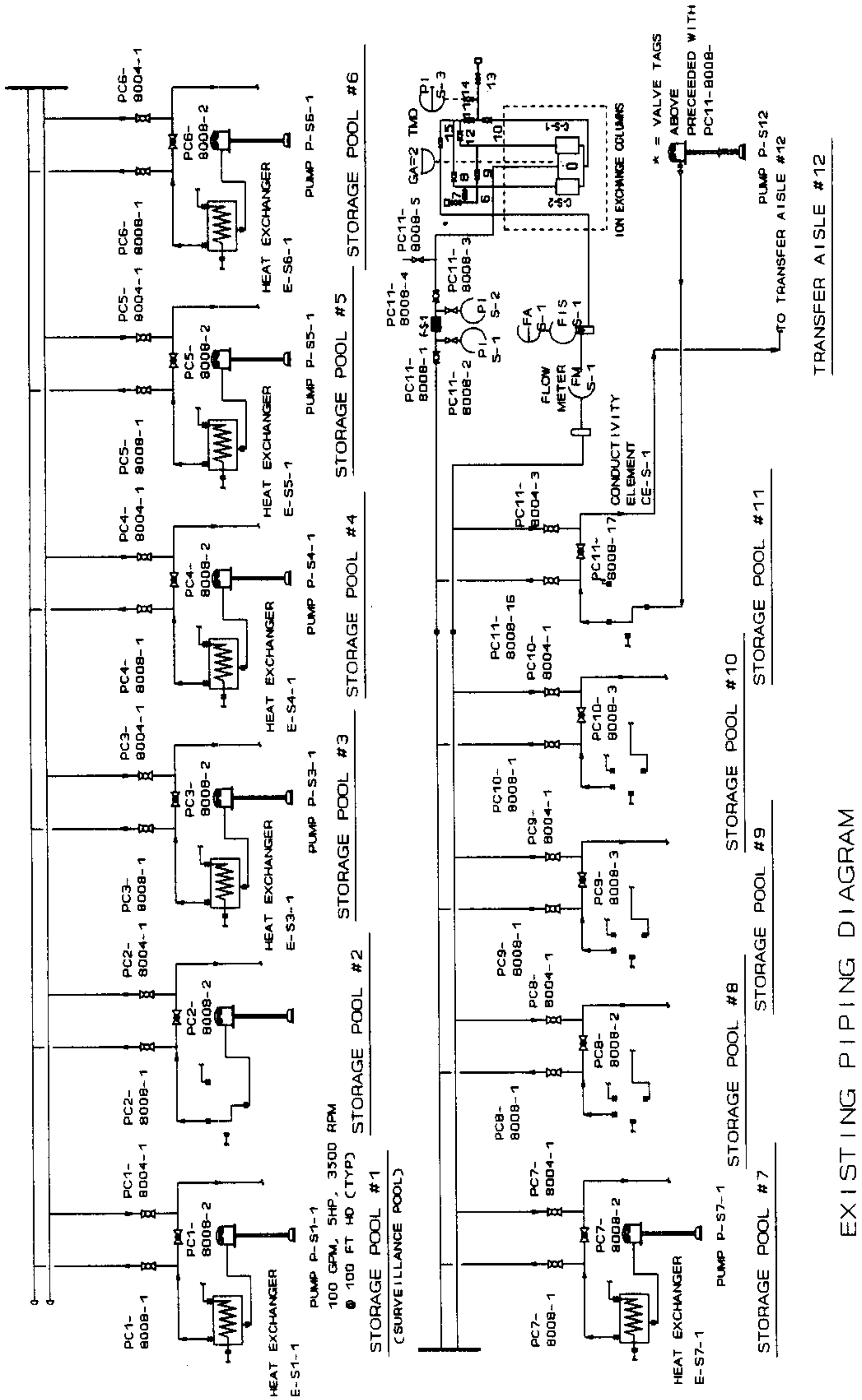
In order to decouple this WESF system from B-Plant and to improve the method of recovery from a capsule leak, contaminated pool cell water is planned to be recirculated through a portable ion exchange resin system. Alternatives to a portable system are not evaluated by ICF KH, since this is not in the work scope (Ref 2, Ref 3). The method for disposing of the contaminated resin has not yet been determined.

ICF Kaiser Hanford Company (ICF KH) is designing the permanent piping and controls portion of the system (Ref. 2, Ref. 3). A request for proposal (RFP) is being prepared by Westinghouse Hanford Company (WHC) WESF engineering for the design, construction, and operation of the portable system. The purpose of this analysis is to provide input to WESF engineering to be used in the RFP. This is limited to items related to the permanent system that are needed for the design of the portable system.

3.0 EXISTING ION EXCHANGE SYSTEM DESCRIPTION

In the existing system, each of the cells 1, 3, 4, 5, 6, and 7, has its own pump, which continuously recirculates 100 gal/min or more of cell water through its heat exchanger. Pool cell 12 is a transfer aisle, which also has a pump that recirculates water, but does not use a heat exchanger. No capsules are stored in cells 2, 8, 9, 10, and 11. Currently, 3-5 gal/min (Ref 7, P. 1) from each heat exchanger exit stream is periodically diverted for 24 hours using manually operated valves (operated from the pool cell area) through existing ion exchange columns and back to the pool. The purpose is to remove minerals from the water to prevent corrosion of the capsules.

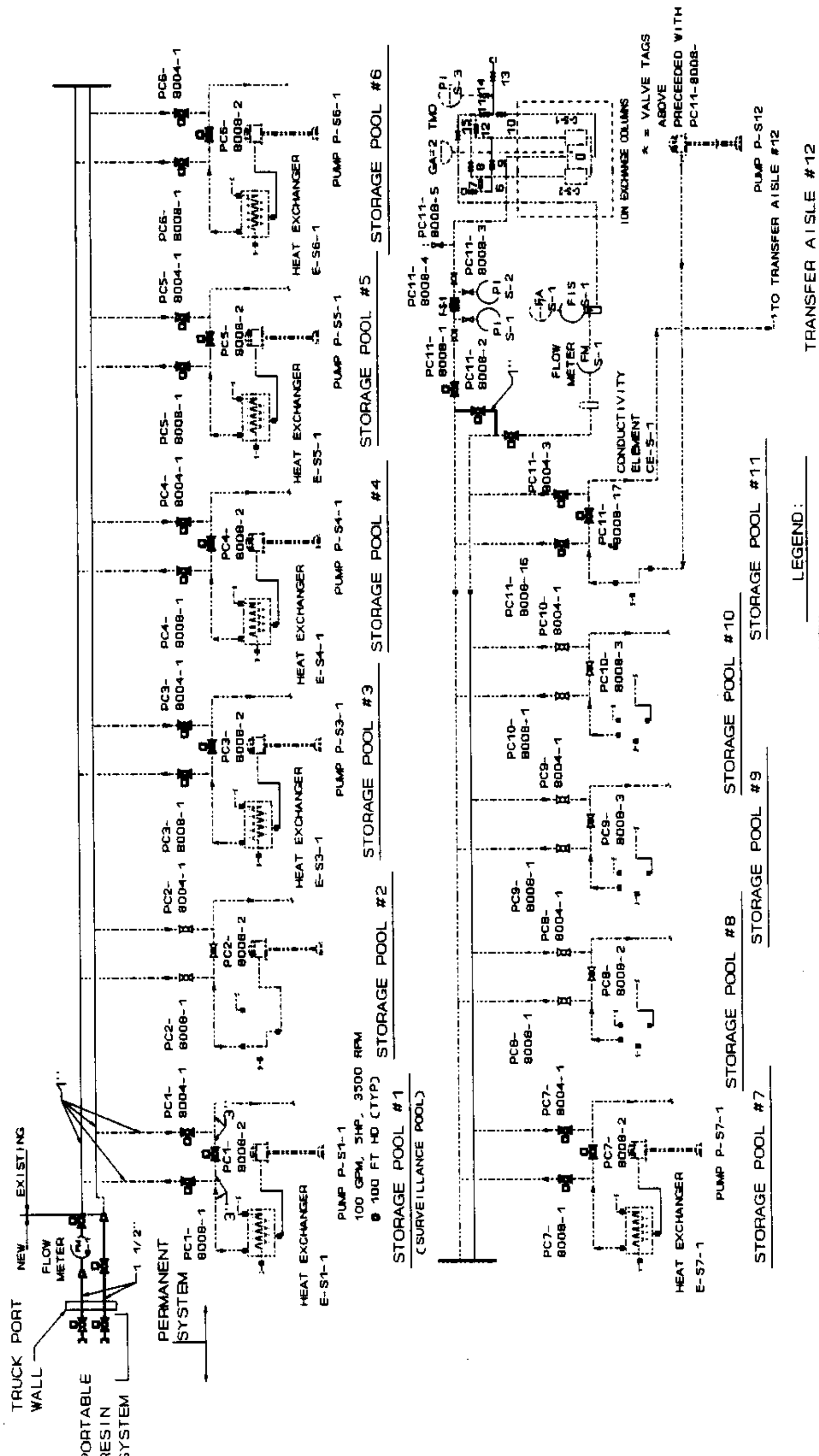
The following is a rough composite piping diagram of the existing ion exchange system. A legend has not been provided. For details and an up-to-date system diagram, see the current revisions of drawings H-2-66986, H-2-66987, H-2-67010, and H-2-67011. For a plan and sections, see H-2-67018, H-2-67019, and H-2-67008.


STORAGE POOL #1
(SURVEILLANCE POOL)
PUMP P-S1-1
100 GPM, 5HP, 3500 RPM
@ 100 FT HD (TYP)
HEAT EXCHANGER
E-S1-1
PC1-8008-1
PC1-8004-1
PC1-8008-2
STORAGE POOL #2
PC2-8008-1
PC2-8004-1
PC2-8008-2
STORAGE POOL #3
PUMP P-S3-1
HEAT EXCHANGER
E-S3-1
PC3-8008-1
PC3-8004-1
PC3-8008-2
STORAGE POOL #4
PUMP P-S4-1
HEAT EXCHANGER
E-S4-1
PC4-8008-1
PC4-8004-1
PC4-8008-2
STORAGE POOL #5
PUMP P-S5-1
HEAT EXCHANGER
E-S5-1
PC5-8008-1
PC5-8004-1
PC5-8008-2
STORAGE POOL #6
PUMP P-S6-1
HEAT EXCHANGER
E-S6-1
PC6-8008-1
PC6-8004-1
PC6-8008-2
STORAGE POOL #7
PUMP P-S7-1
HEAT EXCHANGER
E-S7-1
PC7-8008-1
PC7-8004-1
PC7-8008-2
STORAGE POOL #8
PC8-8008-1
PC8-8004-1
PC8-8008-2
STORAGE POOL #9
PC9-8008-1
PC9-8004-1
PC9-8008-3
STORAGE POOL #10
PC10-8008-1
PC10-8004-1
PC10-8008-3
STORAGE POOL #11
PC11-8008-16
PC11-8004-3
PC11-8008-17
CONDUCTIVITY
ELEMENT
CE-S-1
FLOW
METER
FM S-1
FA S-1
FIS S-1
PI S-1
PI S-2
PI S-3
PC11-8008-1
PC11-8008-2
PC11-8008-3
PC11-8008-4
PC11-8008-5
GA=2 TMO
ION EXCHANGE COLUMNS
* = VALVE TAGS
ABOVE
PRECEEDED WITH
PC11-8008-
PUMP P-S12
PUMP TRANSFER AISLE #12
TO TRANSFER AISLE #12
TRANSFER AISLE #12
EXISTING PIPING DIAGRAM

4.0 NEW EMERGENCY ION EXCHANGE SYSTEM DESCRIPTION

The general design concept is to replace the manual valves on pool cells 1, 3, 4, 5, 6, 7, and 12 with remotely controlled valves, and to extend the resin system piping through the truck port wall, stubbing them with connectors compatible with the portable system. See the following preliminary piping diagram. The design of the permanent system is the ICF-KH scope (Ref. 3). The portable system will fall in the scope of the RFP. The connectors in the truck port, where the portable system will connect to the permanent piping, will be located in a sump. Motor operated isolation valves are also permanently located in the sump.

Recirculation of pool cell water through the existing ion exchange columns will be automatic, using the new control system. Upon determining which pool has the leaking capsule, an operator remotely discontinues recirculation through the existing ion exchange columns (if the columns have not been automatically isolated by the control system, based on a signal from the radiation monitor located between the columns). The portable system is moved into the truck port and connected to the permanent piping, controls, and power system. The operator then diverts water exiting the heat exchanger of the contaminated pool cell (1, 3, 4, 5, 6, or 7) through the new portable system (located in the truck port) and back to the pool. Pool cell 12 is not designed to use the portable system (Ref. 3).



PRELIMINARY PIPING DIAGRAM

5.0 REQUEST FOR PROPOSAL INFORMATION

These items need to be considered for the RFP:

- Flow rate
- Available pressure drop
- Pipe coupler type
- Available power
- Controls interface
- Location of interface
- Miscellaneous

5.1 FLOW RATE

The estimated required flow rate through the resin system in the work plan (Ref. 3) was 20 gal/min. The flow rate calculation (Section 6.0) shows that 16 gal/min is required. This is achievable, given that pipe and components are sized as shown in the table in the pressure drop calculation (Section 7.0).

5.2 AVAILABLE PRESSURE DROP

Available pressure drop from the supply coupler to the return coupler (i.e., the pressure across the portable system) was estimated in the work plan at 8 lbf/in^2. The pressure drop calculation shows that available pressure is approximately 15 lbf/in^2. To be conservative, a safety factor should be used when estimating the actual pressure achievable in the field. We should be able to achieve 8 lbf/in^2.

5.3 PIPE COUPLER TYPE

The pipe couplers will be Hansen Two-Way Shut-Off Coupling, Bulletin No. 70-2, Hanson Series No. 12-HK, LL12-H46 Socket, No. LL12-K46 Plug, No. SDC-12-HK Socket Dust Cap, and No. PDC-12-HK Plug Dust Cap, C_v = 24 gal/min, standard seal.

The permanent system will include the socket. The socket will be mounted horizontally at less than 3 feet from the truck port floor. It will be located in a catch basin with leak detection. The catch basin cover will have cutouts for the incoming piping and plug (provided with the portable system), with splash-guards flush against the piping. Details will be available when the Engineering Change Notice (ECN) is complete.

5.4 AVAILABLE POWER

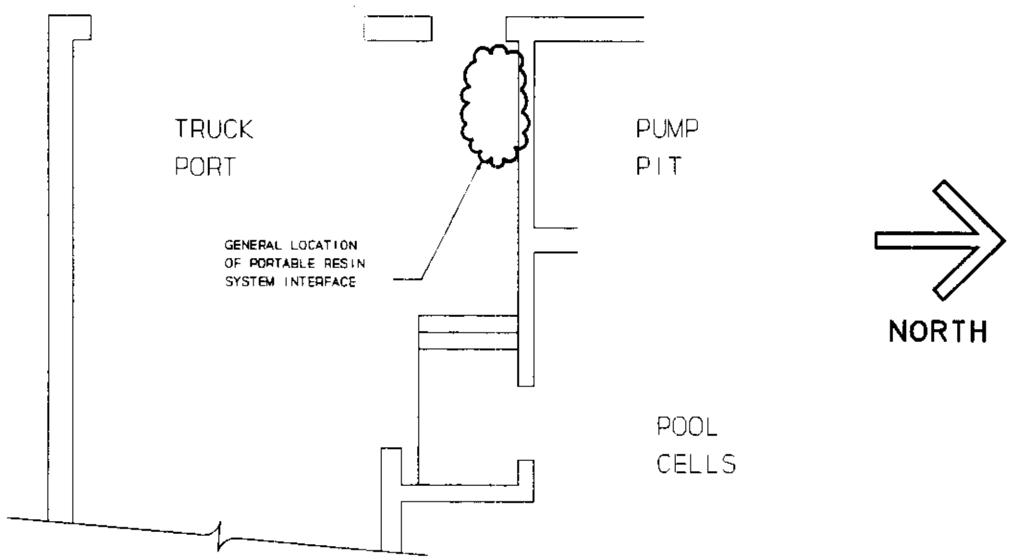
120 Vac power will be provided in the location shown in Section 5.6. A standard duplex receptacle mounted on the wall. This assumes that the portable system uses standard small equipment, such as leak detectors, radiation detectors, and small electrical valves.

5.5 CONTROLS INTERFACE

The portable system shall be connected by encased piping to the facility at the motor operated isolation valve interface. Encased piping shall be arranged to slope towards the sump for collection of leakage in piping. If this cannot be achieved, then the portable system shall provide leak detection system for encased piping. Portable system leak detection shall provide two DPDT (failsafe) contacts with a rating of 120Vac 10Amp for permanent system use. Leak detection contacts will be used to stop the emergency ion exchange system by closure of motor operated isolation valves. Emergency ion exchange system shall trip on the presence of leakage in sump, encased piping, and/or any leakage in the emergency ion exchange system or electrical power failure. Portable system shall provide sump leak detection contact (failsafe type) for interface to permanent system. Portable system shall ensure proper interface connection between systems (terminal block or connector type system).

5.6 LOCATION OF INTERFACE

The piping, controls, and power interface will be located in the general area shown:



5.7 MISCELLANEOUS

The efficiency of the resin system is assumed to be near 100% (Ref. 3). If this is not achievable, then a longer recirculation time will be necessary.

ANALYTICAL CALCULATIONS

Subject MECHANICAL CALCULATIONS
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Checker B. E. Bielicki [signature] Date 2/23/96

6.0 FLOW RATE CALCULATION

6.1 FLUID PROPERTIES

The fluid is water.

- Design temperature is: t = 20 °C (68 °F). Pool cell recirculation temperature is nominal 20 °C (68 °F) (Ref. 10, P. 18).

  The expected temperature range is: 13 °C (55 °F) $\leq t \leq$ 45 °C (113 °F). The water temperature should be within this range. The lower limit is based on a ground water temperature of approximately 13 °C (55 °F) (Ref. 9, P. 29.9). Since pool cell water is cooled by running raw water directly through the heat exchanger, the lower limit should not drop below this temperature (as an estimate). The upper limit is based on the surveillance procedure (Ref. 10, P. 12) upper pool cell temperature limit of 45 °C (113 °F). For the calculations here, the effect of this temperature differential on pressure and flow (due to density and viscosity changes) is small, so the nominal temperature listed in the surveillance procedure, 20 °C (68 °F), is used.

- Design density is: ρ = 62.32 lbm/ft^3

  Since:

  ρ = 0.99823 gm/ml at 20 °C (68 °F) (Ref. 4, P. F-11)

  and:

  1 gm/ml = 62.42621 lbm/ft^3 (Ref. 4, P. F-316)

- Design specific gravity is: S = 1.00 (water)

- Design viscosity is: μ = 1.0 centipoise (cp). (Ref. 5, P. A-3)

  This is based on 20 °C (68 °F).

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather — Date 2/23/96
Checker B. E. Bielicki — Date 2/23/96

6.2 FLOW RATE

Cesium or strontium is deposited on the resin in the portable system with the goal of reducing dose rates approximately one meter above the storage pool to about 100 mR/hr within a reasonable period of portable system operation after a capsule is completely dissolved in a pool (Ref. 11). This governs the flow rate through the resin bed.

Assuming that the resin bed has a 100% efficiency (Ref. 8, P. 9-21), the time rate of change of total curies (y) dissolved in the pool given a flow (Q) through the resin bed is:

- $dy/dt = -y*Q/\forall$

The solution is:

- $y = y_0*e^{-Q*t/\forall}$

Neglecting equipment in the cell, the volume of water in a storage cell (3, 4, 5, 6 and 7) of dimensions 13 ft deep x 4.42 ft wide x 21.75 ft long (Ref. 1, P. 6-45, Section 6.8.1.6) is approximately:

- $\forall = 13*4.42*21.75 = 1250 \text{ ft}^3$

Since:

1 gallon = 231 in^3

This corresponds to a water volume in each pool cell of:

$\forall = 1250*12^3/231$
$= 9351$ gallons

Pool cell 1 is a surveillance pool, and has double this volume, since it is double the width.

One capsule of cesium is 50k Ci, which is the limiting case. Note that, although Ref. 1, Page 6-46, lists the content of a cesium capsule as 50 Ci, the calculation on Page 9-103 is based on a 50k Ci content, so 50k Ci is used as the quantity here, because it is the correct value.

So:

- $y_0 = 50k$ Ci

It is anticipated that an achievable flow rate is 16 gal/min through the portable system. This will be shown in the following pressure drop calculation, but here it will be shown that this gives a reasonable resolution time.

ANALYTICAL CALCULATIONS

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather Date 2/23/96
Checker B. E. Bielicki Date 2/23/96

- Q = 16 gal/min

The dose at one meter above the center of a pool is 8.8 mR/hr per curie of cesium dissolved in a pool (Ref. 6). A dose rate of 100 mR/hr here corresponds to 11.36 Ci in the pool (8.8*11.36 = 100).

- t = -9351/16*ln(11.36/50,000)

  = 4,900 minutes (or 81.7 hours)

Resolution time is approximately double (164 hours) for pool cell 1, since it has twice the volume. These times are reasonable (Ref. 11).

7.0 PRESSURE DROP CALCULATION

Available pressure drop from the supply coupler to the return coupler (i.e., the pressure across the portable system) is calculated as follows.

The flow path through the portable system with the highest ΔP is shown in the following isometric diagram. The available pressure for the resin system is minimum for this path (by inspection). In the isometric, each piping element is numbered, from the outlet of the pump to the supply coupler, and from the return coupler to the last discharge nozzle in the pool. The loss of static pressure due to fluid flow is calculated for each element in the table following the isometric diagram.

The calculation is based on a flow rate through the resin bed of 16 gal/min, calculated above (Section 6.0). The flow rate through the heat exchanger is 100 gal/min, which is the minimum flow rate (Ref. 3). At this minimum flow rate, pump pressure is maximum, giving the achievable pressure drop for the portable system.

The pressure drop between two points in a piping system is governed by Bernoulli's equation:

- $z_1 + 144*P_1/\rho_1 + v_1^2/(2*g) = z_2 + 144*P_2/\rho_2 + v_2^2/(2*g) + h_l$ (Ref. 5, P. 3-2)

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather Date 2/23/96
Checker B. E. Bielicki Date 2/23/96

Between the supply coupler and return coupler:

$\rho_1 = \rho_2$

$v_1 = v_2$

$z_1 = z_2$

then:

- $P_1 - P_2 = \Delta P_{pump} - h_l * \rho/144$

From the table:

- $h_l * \rho/144 = \Delta P_{piping} = 28.6\ \text{lbf/in}^2$

Now, the pump specification sheet (Peabody Floway Order No. 84-03826-1, Form D-1093) shows that the pumps were designed for 100 gal/min at 100 ft of fluid.

- $\Delta P_{pump} = 100 * \rho/144 = 100 * 62.32/144$

  $= 43.3\ \text{lbf/in}^2$

Thus, the available pressure drop for the portable system is:

- $P_1 - P_2 = 43.3 - 28.6$

  $= 14.7\ \text{lbf/in}^2 \doteq 15\ \text{lbf/in}^2$

This, of course, does not include a safety factor. There may be error in the calculation due to approximations used, construction irregularities, unaccounted for increase in piping roughness over time, field changes adding piping and elbows, etc. A 7 lbf/in^2 safety factor is about 15% of the pump design pressure, which leaves 8 lbf/in^2 for the portable system.

Regarding the table, please refer to the element notes following the table for an explanation of each table entry. The first of each type of element in the table is described in detail in the notes. Thereafter, notes are only included where additional clarification is needed. Note that the table was developed using a spreadsheet program. However, code verification is not required, since the table and equations are printed in their entirety and checked by inspection.

The isometric diagram is shown on the next three pages. After the isometric diagram is the table. After the table are element notes.

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather *MCPrather* Date 2/23/96
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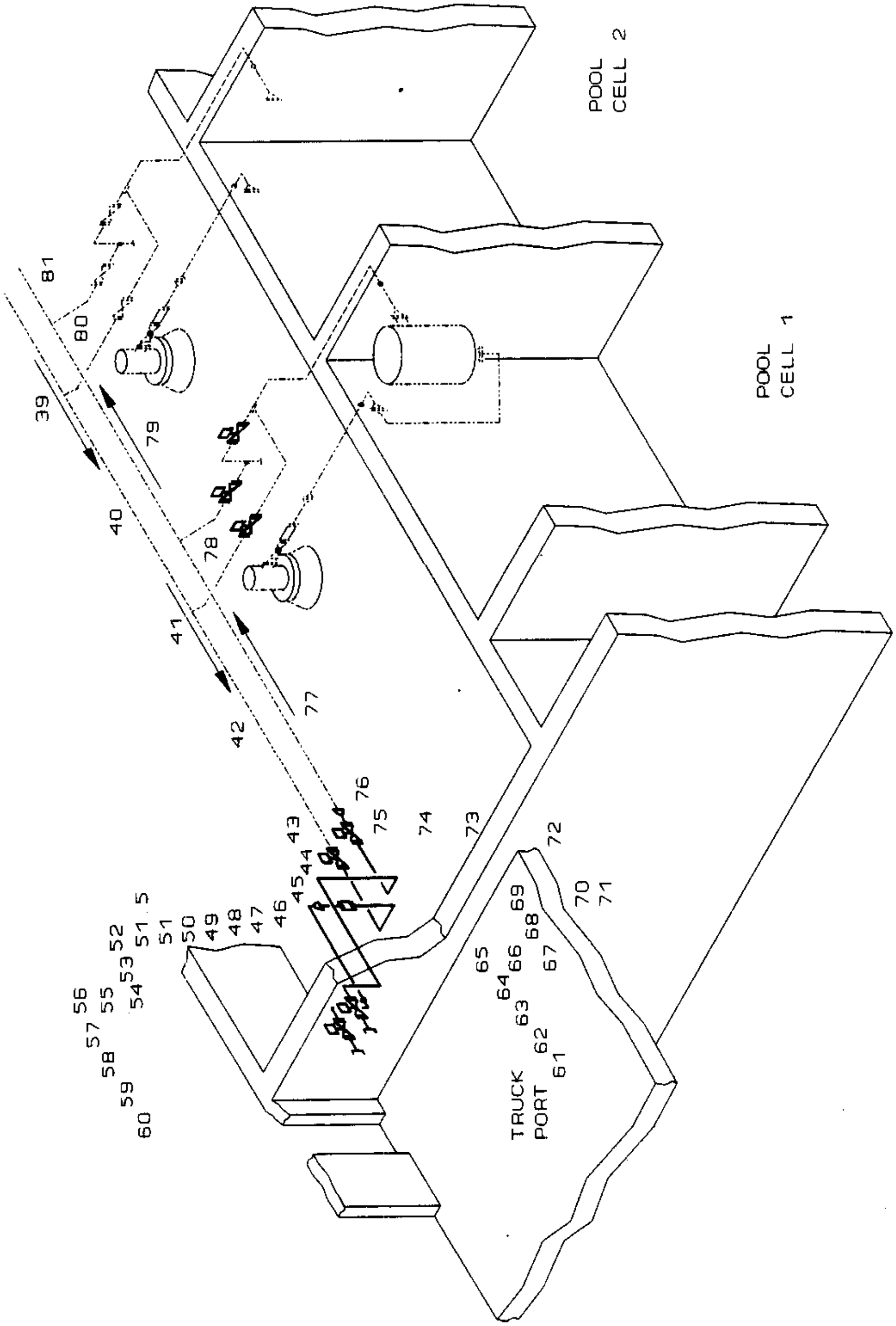

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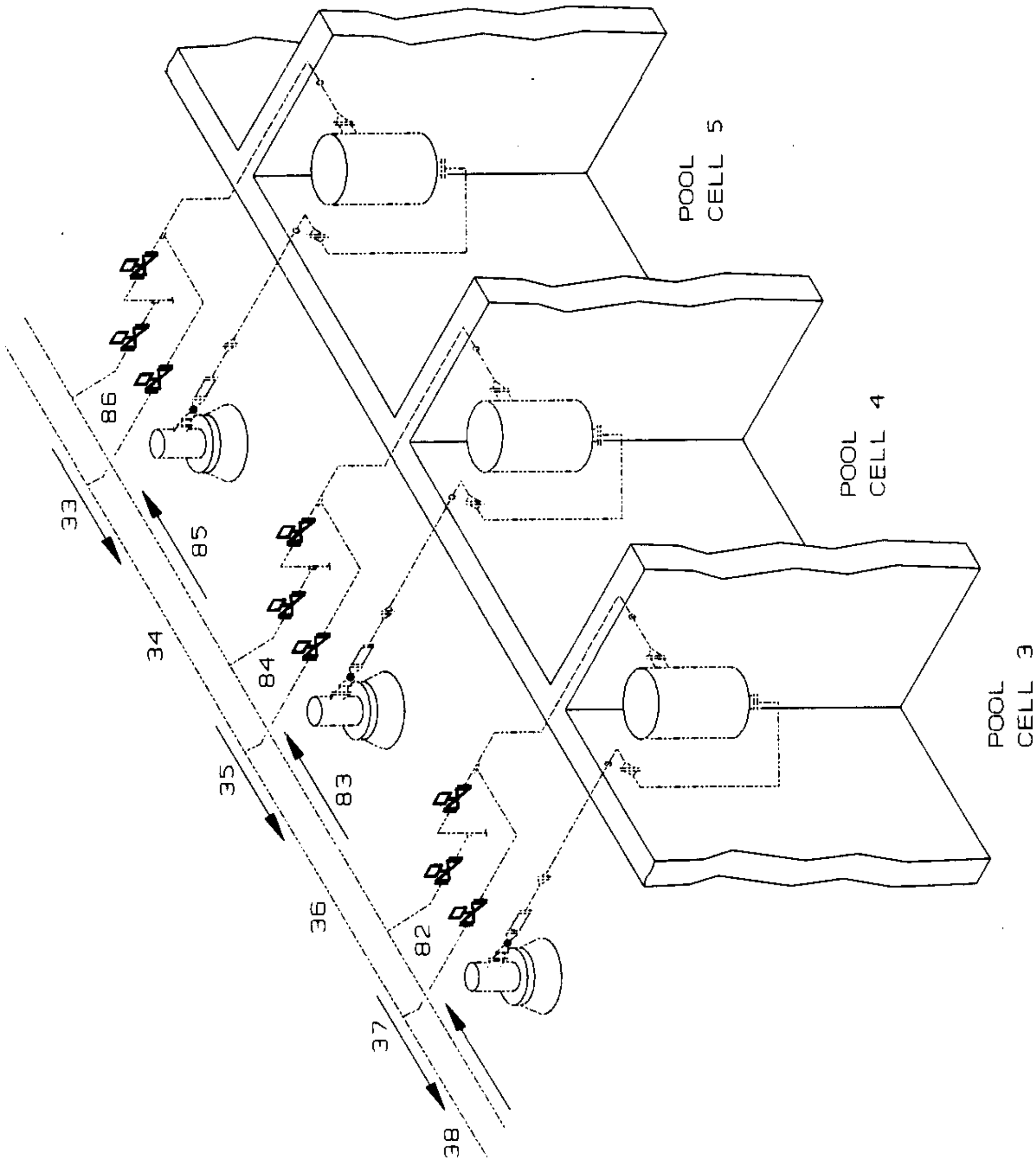

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject MECHANICAL CALCULATIONS
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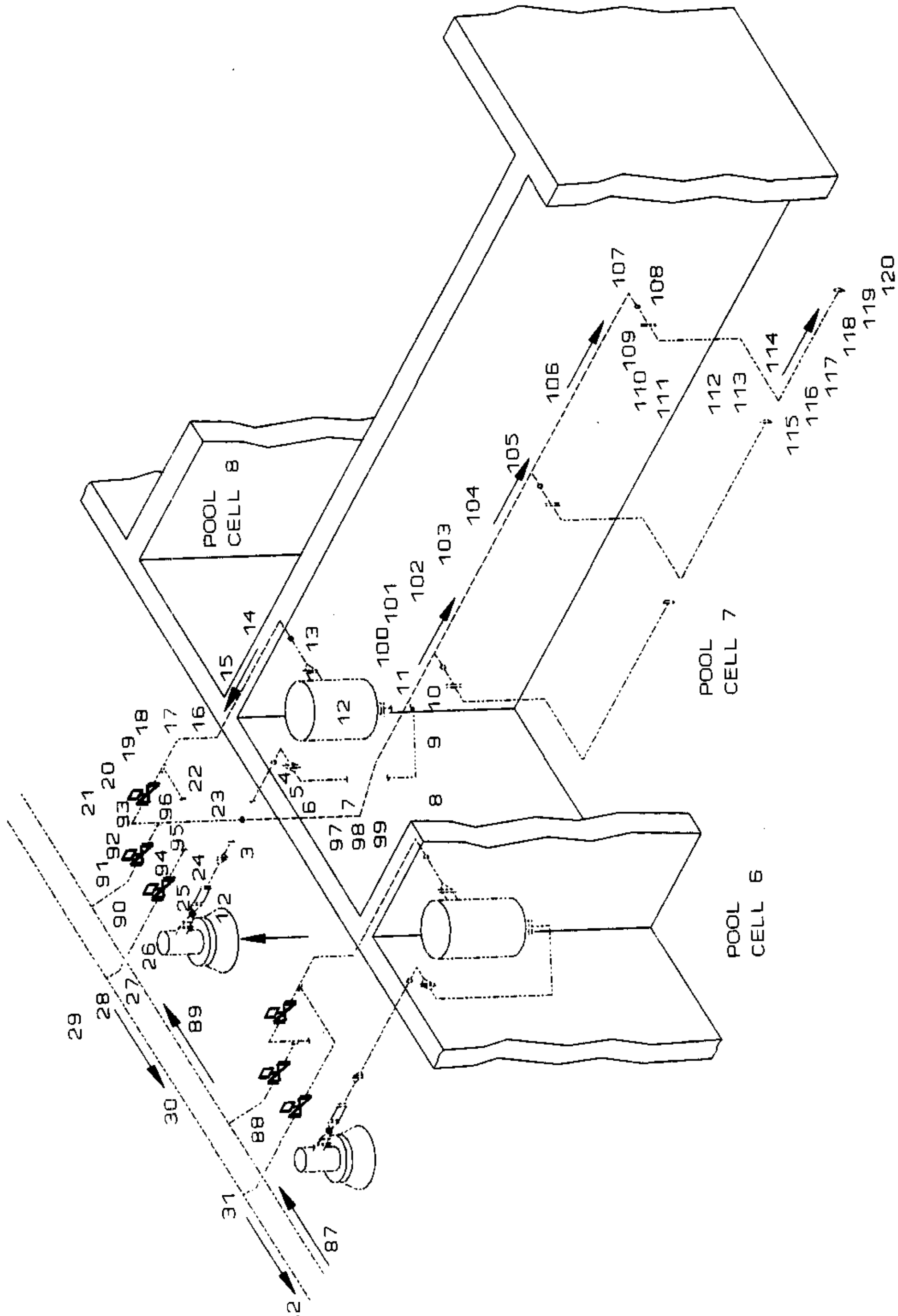

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather (signature) Date 2/23/96
Checker B. E. Bielicki (signature) Date 2/23/96

	ELEMENT DESCRIPTION	Q	L	d (IN)	d (OUT)	v (IN)	v (OUT)	Re (IN)	Re (OUT)	f	ft	K/f	K	Cv	K'	dP
1	PMP EXIT 4x3 RED	100		4.026	3.068	2.5	4.3	7.8E+04	1.0E+05				0.69		2.9E-06	0.029
2	FLEX CONN	100	0.5	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.054			0.11		1.3E-06	0.013
3	PIPE	100	3.8	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.39		4.9E-06	0.049
4	ELBOW	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	14	0.25		3.2E-06	0.032
5	PIPE	100	1.2	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.12		1.6E-06	0.016
6	ELBOW	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	14	0.25		3.2E-06	0.032
7	PIPE	100	4.0	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.41		5.2E-06	0.052
8	ELBOW	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	14	0.25		3.2E-06	0.032
9	PIPE	100	1.0	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.10		1.3E-06	0.013
10	ELBOW	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	14	0.25		3.2E-06	0.032
11	PIPE	100	0.5	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.05		6.5E-07	0.007
12	HEAT EXCHR	100														8
13	PIPE	100	1.0	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.10		1.3E-06	0.013
14	ELBOW	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	14	0.25		3.2E-06	0.032
15	PIPE	100	3.0	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.31		3.9E-06	0.039
16	ELBOW	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	14	0.25		3.2E-06	0.032
17	PIPE	100	1.0	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.10		1.3E-06	0.013
18	ELBOW	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	14	0.25		3.2E-06	0.032
19	PIPE	100	1.0	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.10		1.3E-06	0.013
20	TEE - STD BRNCH	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	60	1.08		1.4E-05	0.137
21	- REDUCER	16		3.068	1.049	0.7	5.9	1.6E+04	4.8E+04				36.00		4.6E-04	0.117
22	PIPE	16	0.6	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.21		1.9E-04	0.049
23	ELBOW	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	14	0.32		3.0E-04	0.076
24	PIPE	16	2.0	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.71		6.6E-04	0.169
25	VALVE	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04					32	9.8E-04	0.250
26	PIPE	16	3.0	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.07		9.9E-04	0.254
27	45 DEG ELBOW	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	14	0.32		3.0E-04	0.076
28	PIPE	16	0.5	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.19		1.8E-04	0.046
29	TEE BRANCH	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	60	1.38		1.3E-03	0.327
30	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
31	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
32	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
33	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
34	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
35	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
36	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
37	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
38	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
39	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
40	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
41	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
42	PIPE	16	11.0	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			3.93		3.6E-03	0.930
43	N/A	16														
44	VALVE	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04					32	9.8E-04	0.250
45	PIPE	16	2.0	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.71		6.6E-04	0.169
46	ELBOW	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	14	0.32		3.0E-04	0.076
47	PIPE	16	0.8	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.30		2.8E-04	0.070
48	ELBOW	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	14	0.32		3.0E-04	0.076
49	PIPE	16	2.0	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.71		6.6E-04	0.169

ANALYTICAL CALCULATIONS

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather Date 2/23/96
Checker B. E. Bielicki Date 2/23/96

	ELEMENT DESCRIPTION	Q	L	d (IN)	d (OUT)	v (IN)	v (OUT)	Re (IN)	Re (OUT)	f	ft	K/f	K	Cv	K'	dP
51.5	REDUCER	16		1.049	1.610	5.9	2.5	4.8E+04	3.1E+04				1.56		2.6E-04	0.067
52	ELBOW	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04		0.021	14	0.29		4.9E-05	0.013
53	PIPE	16	2.2	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.52		8.7E-05	0.022
54	ELBOW	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04		0.021	14	0.29		4.9E-05	0.013
55	PIPE	16	1.0	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.24		4.0E-05	0.010
56	ELBOW	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04		0.021	14	0.29		4.9E-05	0.013
57	PIPE	16	0.5	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.12		2.0E-05	0.005
58	VALVE	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04					82	1.5E-04	0.038
59	PIPE	16	0.5	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.12		2.0E-05	0.005
60	DISCONN	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04					24	1.7E-03	0.444
61	DISCONN	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04					24	1.7E-03	0.444
62	PIPE	16	0.5	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.12		2.0E-05	0.005
63	VALVE	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04					82	1.5E-04	0.038
64	PIPE	16	0.5	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.12		2.0E-05	0.005
65	ELBOW	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04		0.021	14	0.29		4.9E-05	0.013
66	PIPE	16	1.0	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.24		4.0E-05	0.010
67	ELBOW	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04		0.021	14	0.29		4.9E-05	0.013
68	PIPE	16	2.0	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.48		8.1E-05	0.021
69	ELBOW	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04		0.021	14	0.29		4.9E-05	0.013
70	PIPE	16	3.3	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.78		1.3E-04	0.033
71	ELBOW	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04		0.021	14	0.29		4.9E-05	0.013
72	PIPE	16	1.6	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.38		6.4E-05	0.016
73	ELBOW	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04		0.021	14	0.29		4.9E-05	0.013
74	PIPE	16	2.0	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.027			0.48		8.1E-05	0.021
75	VALVE	16		1.610	1.610	2.5	2.5	3.1E+04	3.1E+04					82	1.5E-04	0.038
76	REDUCER	16		1.610	1.049	2.5	5.9	3.1E+04	4.8E+04				1.41		2.4E-04	0.060
77	PIPE	16	11.0	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			3.93		3.6E-03	0.930
78	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
79	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
80	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
81	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
82	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
83	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
84	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
85	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
86	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
87	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
88	TEE THRU	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	20	0.46		4.3E-04	0.109
89	PIPE	16	5.4	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			1.92		1.8E-03	0.454
90	TEE BRANCH	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	60	1.38		1.3E-03	0.327
91	PIPE	16	1.6	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.57		5.2E-04	0.134
92	45 DEG ELBOW	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04		0.023	14	0.32		3.0E-04	0.076
93	PIPE	16	1.0	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.36		3.3E-04	0.085
94	VALVE	16		1.049	1.049	5.9	5.9	4.8E+04	4.8E+04					32	9.8E-04	0.250
95	PIPE	16	1.0	1.049	1.049	5.9	5.9	4.8E+04	4.8E+04	0.026			0.36		3.3E-04	0.085
96	TEE - STD BRNCH	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	60	1.08		1.4E-05	0.137
97	- REDUCER	16		1.049	3.068	5.9	0.7	4.8E+04	1.6E+04				64.00		8.1E-04	0.207
98	PIPE	100	10.3	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			1.07		1.3E-05	0.135
99	ELBOW	100		3.068	3.068	4.3	4.3	1.0E+05	1.0E+05		0.018	14	0.25		3.2E-06	0.032

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather   Date 2/23/96
Checker B. E. Bielicki   Date 2/23/96

	ELEMENT DESCRIPTION	Q	L	d (IN)	d (OUT)	v (IN)	v (OUT)	Re (IN)	Re (OUT)	f	ft	K/f	K	Cv	K'	dP
102	PIPE	100	4.5	3.068	3.068	4.3	4.3	1.0E+05	1.0E+05	0.022			0.46		5.9E-06	0.059
103	TEE THRU	63.1		3.068	3.068	2.7	2.7	6.5E+04	6.5E+04		0.018	20	0.36		4.6E-06	0.018
104	PIPE	63.1	8.0	3.068	3.068	2.7	2.7	6.5E+04	6.5E+04	0.023			0.86		1.1E-05	0.043
105	TEE THRU	26.3		3.068	3.068	1.1	1.1	2.7E+04	2.7E+04		0.018	20	0.36		4.6E-06	0.003
106	PIPE	26.3	8.0	3.068	3.068	1.1	1.1	2.7E+04	2.7E+04	0.027			1.01		1.3E-05	0.009
107	ELBOW	26.3		3.068	3.068	1.1	1.1	2.7E+04	2.7E+04		0.018	14	0.25		3.2E-06	0.002
108	PIPE	26.3	1.0	3.068	3.068	1.1	1.1	2.7E+04	2.7E+04	0.027			0.13		1.6E-06	0.001
109	ABRUPT REDCR	26.3		3.068	1.610	1.1	4.1	2.7E+04	5.1E+04				6.00		7.6E-05	0.052
110	PIPE	26.3	0.5	1.610	1.610	4.1	4.1	5.1E+04	5.1E+04	0.026			0.12		1.9E-05	0.013
111	ELBOW	26.3		1.610	1.610	4.1	4.1	5.1E+04	5.1E+04		0.021	14	0.29		4.9E-05	0.034
112	PIPE	26.3	2.8	1.610	1.610	4.1	4.1	5.1E+04	5.1E+04	0.026			0.66		1.1E-04	0.076
113	ELBOW	26.3		1.610	1.610	4.1	4.1	5.1E+04	5.1E+04		0.021	14	0.29		4.9E-05	0.034
114	PIPE	26.3	1.5	1.610	1.610	4.1	4.1	5.1E+04	5.1E+04	0.026			0.35		5.8E-05	0.040
115	ELBOW	26.3		1.610	1.610	4.1	4.1	5.1E+04	5.1E+04		0.021	14	0.29		4.9E-05	0.034
116	PIPE	21	1.0	1.610	1.610	3.3	3.3	4.1E+04	4.1E+04	0.027			0.24		4.0E-05	0.018
117	PIPE	15.8	1.0	1.610	1.610	2.5	2.5	3.1E+04	3.1E+04	0.028			0.25		4.2E-05	0.010
118	PIPE	10.5	1.0	1.610	1.610	1.7	1.7	2.1E+04	2.1E+04	0.029			0.26		4.3E-05	0.005
119	PIPE	5.26	1.0	1.610	1.610	0.8	0.8	1.0E+04	1.0E+04	0.033			0.30		4.9E-05	0.001
120	NOZZLE	2.63														5.7
															TOTAL:	28.59

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather [signature] Date 2/23/96
Checker B. E. Bielicki [signature] Date 2/23/96

Element Comments:

1 This is a 4x3 reducer (shown on H-2-67019, Sheet 1, Section B-B). Table entries are:

Q is a given

d (in) and d (out) are givens

v (in) and v (out) are calculated using:

$$v = 0.408*Q/d^2 \quad \text{(Ref. 5, P. 3-2)}$$

R_e (in) and R_e (out) are calculated using:

$$R_e = 50.6*Q*\rho/(d*\mu) \quad \text{(Ref. 5, P. 3-2)}$$

Or, since:

and: $\rho = 62.3\ \text{lbm/ft}^3$ (see Fluid Properties in Section 6.0)

and: $\mu = 1.0$ cp

$$\Rightarrow \quad R_e = 50.6*Q*62.3/(d*1.0)$$

$$= 3152*Q/d$$

Conservatively, assume that the reducer is abrupt.

$K_2 = 0.5*(1-\beta^2)*(\sin(\theta/2))^{1/2}/\beta^4$ (Ref. 5, P. A-26)

Where $\beta \doteq 3/4$ and $\theta = 180°$ (assumed θ)

then

$K_2 = 0.69$

Note that $K_2 = K$, where ΔP is based on properties at the outlet (Ref. 5, Nomenclature).

Since the pressure drop is proportional to the square of the flow for the turbulent regime, let (last column):

$$\Delta P = K'Q^2$$

where:

$$\Delta P = 0.00001799*K*\rho*Q^2/d^4 \quad \text{(Ref 5, Page 3-4)}$$

ANALYTICAL CALCULATIONS

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather [signature] Date 2/23/96
Checker B. E. Bielicki [signature] Date 2/23/96

We have:

$$K' = 0.00001799\ K\rho/d^4 \quad \text{(Ref 5, Page 3-4)}$$

Since:

$$\rho = 62.3\ \text{lbm/ft}^3$$

$$\Rightarrow \quad K' = 1.12*10^{-3}\ K/d^4$$

2 The pressure drop of the flex connection can be approximated as if the element is a pipe, using a conservative friction factor, neglecting bends and any misalignment of the inside surface of the flex material with the inside surface of the pipe. As an approximation, use a friction factor three times greater than the friction factor for clean steel pipe. Equations used to calculate table entries are identical to element 1 (4x3 transition) except for:

l is approximately 6 in.

K is calculated based on the equation:

$$K = f*L/D \quad \text{(Ref. 5, p. 3-4)}$$

Or, since:

$$D = d/12$$

$$\Rightarrow \quad K = 12*f*L/d$$

Where $f = 3*f_T = 3*0.018 = 0.054$ (Ref. 5, P. A-26)

3 For a pipe:

l is the length of the pipe, in inches.

As for the flex connection, K is calculated based on the equation:

$$K = f*L/D$$

However, in anticipation of error in the friction factor (f) due to construction practices and corrosion on the inside of the piping, we will use 1.2 times the friction factor for clean steel pipes from Ref. 5, p. A-23 and A-24. Ref. 5, page 1-7, points out one instance where the friction factor of a 4 in. galvanized steel pipe increased by 20% after three years of moderate use. Our system is stainless steel, with de-ionized water, so it should be conservative to use a friction factor 20% higher than that for clean steel pipe.

ANALYTICAL CALCULATIONS

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather [signature] Date 2/23/96
Checker B. E. Bielicki [signature] Date 2/23/96

Using 1.2 times the friction factor for clean steel pipes (f from Ref. 5, p. A-23 and A-24, ε = 0.00015), we have:

$$K = 1.2*f*L/D$$

As above, since:

$$D = d/12$$

$$\Rightarrow \quad K = 14.4fL/d$$

4 This is an elbow. K values for fittings are found in Ref. 5, Page A-26 ff. To be conservative, all elbows are assumed to be standard radius elbows (r/d = 1.5). Fittings use a friction factor, f_T, which is based on full turbulence (Ref 5, Page A-26). For elements that are fittings, table entries are similar to those for pipe elements, except that K values are found in the Ref. 5 tables.

12 The heat exchanger performance data, Ambassador Standard Division of Space Dynamics Corporation, Cincinnati Ohio, Drawing Number SDC-P98-03, 7/15/79, lists 100 gal/min at 8 lbf/in^2.

20/21 This is a 1 inch tap in a 3 inch line. To approximate the pressure drop of flow through the branch, model this with a standard tee (Ref. 5, p. A-29) followed by a sudden contraction.

For a standard tee, K/f_T = 60 through the branch.

For an abrupt contraction (Ref. 5, p. A-26):

$$K_2 = 0.5*(1-\beta^2)*(\sin(\theta/2))^{1/2}/\beta^4$$

Where β = 1/3 and θ = 180°

then

$$K_2 = 36$$

25 For estimating purposes, use a Worcester Controls 1" Series 44 ball valve, which has the Cv given (Worcester Controls Bulletin PB-401-29).

$$\Delta P = (Q/C_v)^2*\rho/62.4 \qquad \text{(Ref 5, Page 3-4)}$$

Since,

$$\rho = 62.3\ lbm/ft^3$$

$$K' = (1/C_v)^2$$

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather Date 2/23/96
Checker B. E. Bielicki Date 2/23/96

27 This is a 45 degree elbow. To be conservative, use K/f_t for a full 90 degree elbow.

43 Anticipated reducer was not used.

50 Mag flow meter 1" has the same ΔP as the equivalent length of pipe.

51.5 Expansion:

$K_2 = (1-\beta^2)^2/\beta^4$

where $\beta = 2/3$

K2 = 1.56

60/61 Disconnect Cv is 24.

76 Reducer, $\beta = 2/3$ and $\theta = 180°$, then:

$K_2 = 1.41$

96/97 Tap, treat as tee branch with reducer (expansion):

For a standard tee, $K/f_T = 60$ through the branch

$K_2 = (1-\beta^2)^2/\beta^4$

where $\beta = 1/3$

$K_2 = 64$

109 3" to 1-1/2" abrupt reducer

$K_2 = 0.5*(1-\beta^2)*(\sin(\theta/2))^{1/2}/\beta^4$

where $\beta = 1/2$ and $\theta = 180°$

then

$K_2 = 6$

120 Orifices in the distribution header are spaced roughly evenly along the length of the pool. See H-2-67018 for spacing. Assume that the flow is also distributed evenly among the orifices, which is the case since the pressure drop through an orifice is large compared to the pressure drop in the distribution header. There are 38 orifices.

Q = 100 gal/min/38 orifices = 2.63 gal/min per orifice

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject MECHANICAL CALCULATIONS
Originator M. C. Prather Date 2/23/96
Checker B. E. Bielicki Date 2/23/96

In order to use the method in Ref. 5 to calculate the pressure drop across an orifice, the Reynolds Number in the upstream pipe is needed. Since the flow varies along the header (due to loss of flow through the orifices), the Reynolds Number varies. Along the 1-1/2" header R_e is from 10000 to 51000 (see table). The smallest R_e is at the end of the 3" header:

R_e = 3152*Q/d = 3152*6.26/3.068 = 6400

Noting that d1 = 0.25", d1/d2 is less than 0.20 for the entire header (0.16 for 1.5" pipe, and smaller for the 2.5" and 3" pipes). The chart (Ref. 5, Page A-20) shows the flow coefficient (C) is constant at 0.59 for R_e from 6400 to 51000. We have:

$$Q = 236 * d_1^2 * C * (\Delta P/\rho)^{1/2}$$ (Ref. 5, p. 3-5)

or,

$$\Delta P = (2.63/236/0.25^2/0.59)^2 * 62.3$$

$$= 5.7 \text{ lbf/in}^2$$

8.0 REFERENCES

1 WHC-SD-M-SAR-005, Rev. 11a, "Waste Encapsulation and Storage Facility (WESF) Safety Analysis Report (SAR)."

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3 External Memo E30293-001, M. C. Prather (ICF KH) to K. A. Jennings-Mills (WHC), "Work Plan - Waste Encapsulation Storage Facility Pool Cell Ion Exchange Piping," W.O. #E30293, dated January 19, 1996.

4 Chemical Rubber Company, Handbook of Chemistry and Physics, 60th Edition, CRC Press, Inc., Boca Raton, Florida.

5 Crane Co., 1988, "Flow of Fluids Through Valves, Fittings, and Pipe," Crane Co., 104 N. Chicago St., Joliet, Illinois.

6 RHO-CD-1548, R. M. Orme, A Storage Basin Recovery System for the Waste Encapsulation and Storage Facility," Rockwell Hanford Operations, October 1, 1981

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8 Mechanical Engineering Reference Manual, Eighth Edition, Michael R. Lindeburg, Professional Publications, Inc., Belmont CA, Copyright 1990

9 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), Heating, Ventilating and Air-Conditioning Applications, 1995 ASHRAE Handbook

10 Plant Operating Procedure EO-040-001, Conduct Pool Cell Surveillance, Rev/Mod D-6

11 Engineering/Construction Change E30293-ECC-1, M. C. Prather, February 20, 1996