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WIPP Conceptual Design Report, #3

Addendum A: Design Calculations for Waste Isolation
Pilot Plant (WIPP) Conceptual Design Report,
Edited By Nuclear Waste Engineering Division 1142

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General/Nuclear Calculations

WIPP SITE POPULATION

BUILDING OR AREA

	Shift 1	Shift 2	Shift 3
Administration	80	2	2
Control/Computer	10	3	3
Security - Gate House (Site Entrance)	2	1	1
- Security Office & Gate House (into B area)	6	2	2
- Fire Protection	1	1	1
- Security Control Center	2	2	2
- First Aid	1		
Warehouse	4	-	-
Sewage Treatment	2	-	-
Water Treatment	1	-	-
Truck Drivers	4	-	-
Railroad Personnel	3	-	-
Motor Pool	3	-	-
Waste Treatment Area (Site Generated)			
- Liquid }	2	-	-
- Solid }			
- Laundry	3	-	-
TRU Waste Building			
- Administrative/Supervision	6	-	-
- Inventory/Inspection	3/6		
- Waste Handling Personnel			
- Health Physics	2	-	-
- Forklift/Equip. Operators	14	-	-
- Waste Handlers/Repair	4	-	-
TOTAL	159	11	11

WIPP SITE POPULATION

BUILDING OR AREA (Contd)

	Shift <u>1</u>	Shift <u>2</u>	Shift <u>3</u>
-Container/Vehicle Preparation	4	-	-
- Floaters	3	-	-
- Hoist Operator(s)	2	-	-
- Health Physics Lab	3	-	-
RH Waste Building			
- Administrative	6	-	-
- Inventory	2	-	-
- Waste Handling Personnel			
- Health Physics	3	-	-
- Cask Handlers	6	-	-
- Cask Preparation & Decon	4	-	-
- Waste Handlers-Remote	4	-	-
- Hoist Operator(s)/Crane Op	1/1	-	-
Cafeteria (Mgr. - cashier - food prep. - dishwash)	8		-
Grounds - Landscape	2		-
Area clean. (roads - tracks - tailing area)	4		-
Janitorial (Office - labs - shops)	2	5	-
Power Plant (not coal)	6	2	2
General Maint. (total 8)			
Plumber	2	-	-
Carpenter-painter	2	-	-
Electrician	2	1	1
Air-Cond. & refrig.	2	1	1
Lube & P.M.	2	2	-
Helpers	2	2	-
TOTAL	73	13	4

WIPP SITE POPULATION

BUILDING OR AREA (Contd)

	Shift <u>1</u>	Shift <u>2</u>	Shift <u>3</u>
Vehicle Maint. - (Motor pool - forklifts) (Mechanics, lube, hydraulics)	3	1	-
Machinery Maint. (above ground machinists and millwrights)	3	1	-
Mine Mach. Maint. (below ground)	6		-
Man/Materials Building			
- Administrative	2	-	-
- Health Physics	1	-	-
- Salt Disposal	4	-	-
- Hoist Operator(s)	2	-	-
Mine Personnel			
TRU Level			
- Supervision	5	-	-
- Miners	25	-	-
- Waste Handlers	10	-	-
- Maintenance	5	-	-
- Health Physics	3	-	-
RH Level			
- Supervision	5	-	-
- Miners	25	-	-
- Waste Handlers	10	-	-
- Maintenance	5	-	-
- Health Physics	<u>3</u>	<u>-</u>	<u>-</u>
TOTAL THIS SHEET	117	2	0
" SHEET 1	159	11	11
" " 2	<u>73</u>	<u>13</u>	<u>4</u>
TOTAL SITE POPULATION	349	26	15
GRAND TOTAL		<u>390</u>	

5.6

INTERIM REPORT

Remote Handling Facility Shielding Calculations - WIPP Conceptual Design

PURPOSE: The layout of the remote handling facility is in progress. Preliminary shielding calculations were performed in order to assess the adequacy of hot cell shielding in the current design.

SIGNIFICANT RESULTS, CONCLUSIONS AND RECOMMENDATIONS:

Current plant capacity requirements will probably require the transportation of three high level waste canister at a time to the mine. It is, therefore, conceivable that three canisters could be in the hot cell at one time placed next to the control room or catwalk shield wall. For calculational purposes it was also assumed that a canister was located at the viewing window being inspected. An open, loaded shipping cask was assumed to be open to the hot cell.

The dose rates received from these three sources are tabulated below:

<u>CONDITION</u>	<u>DOSE RATE (mR/hr)</u>		
	<u>4 ft - ordinary concrete</u>	<u>5/6 ft - ordinary concrete</u>	<u>4 ft - Barytes concrete</u>
(1) Three canisters stored along shield wall awaiting transport			
Primary gamma	750.0	21.0/0.09	0.0705
Secondary gamma	6.5	-	-
Neutrons	0.645	-	-
(2) Single canister being handled in front of viewing window			
Primary gamma	162.0	-	0.02
Secondary gamma	1.43	-	-
Neutrons	0.143	-	-

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<u>CONDITION</u>	<u>DOSE RATE (mR/hr)</u>		
	<u>4 ft - ordinary concrete</u>	<u>5/6 ft - ordinary concrete</u>	<u>4 ft - Barytes concrete</u>
(3) Dose from open loaded shipping cask			
Primary gamma	0.21	-	-
Secondary gamma	-	-	-
Neutrons	-	-	-
Approximate Totals	1000 mR/hr		0.1 mR/hr

These calculations show that four feet of ordinary concrete is not sufficient to reduce dose rates below the design level of 0.5 mr/hr. Increasing the shield thickness to between 5 and 6 feet of ordinary concrete would reduce radiation levels to within allowable limits but would tend to increase the cost of the viewing windows. Four feet seems to be a practical shield thickness.

For planning purposes it is recommended that four feet of Barytes (or equivalent heavy) concrete be used for the shield walls of the hot cell.

As expected, designing the shield for attenuation of primary gamma radiation was the most important aspect of the problem. Contributions due to neutrons and secondary gamma radiation was negligible.

Again as expected, dose rate from fuel stored in the hot cell storage ports calculated at the side of the storage monolith was negligible. A shield thickness of eight feet was assumed for these calculations.

ADDITIONAL WORK: Additional shielding calculations will be performed at a later date to determine the dose rates in the cask preparation and decontamination areas due to streaming through the shield plug when the plug design is completed. These calculations will determine the design of the isolation doors on the transfer passage. If the floor of the hot cell over the transfer facility is constructed of ordinary concrete, there will be an additional contribution to dose rate which will be included in the calculation.

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Streaming up the mine shaft as well as calculation of dose rate in the hoist control room will also have to be considered in the near future when this location of the control area is fixed.

DISCUSSION:

- (1) BUILDUP FACTORS: Dose buildup factors were calculated using two formulas; one from Glasstone and Sesonske (paragraph 10.70 and also in the Handbook, Vol. III-B, page 115) and the second taken from Reference (b).

Although 0.8 MEV monoenergetic gamma radiation was assumed since no gamma energy spectrum was specified for the high level waste, for 0.5 MEV gamma was assumed to add a degree of conservatism.

Dose buildup factors for a four foot thick ordinary concrete shield were calculated as follows:

G&S	43
H&N 8200.1	89.5

Although the G&S formula supposedly calculated dose buildup factors to within 5% accuracy, the H&N 8200.1 formula was used in all dose calculations in order to be conservative.

- (2) VERIFICATION OF SANDIA SUPPLIED DATA: Sandia supplied data is shown on Attachment 1. The accuracy of this data was checked in the following manner:

- (a) Line source geometry was assumed.
- (b) Average gamma energy of 0.8 MEV was assumed.
- (c) An energy flux (MEV/cm²/sec) was calculated from the dose rate data given and Table 9.2, Glasstone & Sesonske.
- (d) An equivalent line source flux (MEV/cm/sec) was calculated, using the geometry of a cylindrical 16 in. diameter X 10 foot long H. L. waste cask. The area of the cylinder ends was included to produce as high a line source flux as possible.

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- (e) The equivalent dose rate was at a distance of 10 feet in air.

The results are listed as follows:

<u>Source</u>	<u>Base Rate (mR/hr) @ 10 ft</u>
Sandia Data	6.5×10^3
Line Source Calculations	3.72×10^3

These results showed good correlation with Sandia data and verified the use of simple line geometry source terms. Most of the calculations used a line source. Calculated results were multiplied by two to initialize them to Sandia data.

- (3) ASSUMPTIONS: The assumptions made in the calculations had some conservatism included in their selection. These factors are summarized as follows:

- (a) Monoenergetic 0.8 MEV gamma. According to H&N 8200.1, most of the gamma energy in one year old HTGR spent fuel is 0.8 MEV gamma.
- (b) Buildup factors were conservatively calculated. See previous discussion.
- (c) Attenuation coefficients for both neutron and gamma radiation were conservatively selected. Values for ordinary concrete which were used:

$$\begin{array}{ll} \text{Neutrons} & = .083 \text{ cm}^{-1} \\ \text{Gamma} & = .126 \text{ cm}^{-1} \end{array}$$

- (d) Line source geometry calculations were modified by:

- (1) Multiplying calculated result by 2.
- (2) For three canister calculations, line sources were superimposed to maximize dose rate.
- (3) For calculational purposes, line sources were assumed to be on the "edge" of the cylinder rather than on the center line in order to maximize dose rate.

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- (4) COMPARISON WITH PREVIOUS HOLMES & NARVER WORK: The methods and level of detail used in these calculations is similar to that used in previous company work (Reference b). In that study, a gamma energy spectrum and multi-material shield was used. Self-absorption in HTGR fuel assemblies was also used in 8200.1 but was not needed in this study.

(5) PRINCIPAL REFERENCES:

- (a) Nuclear Reactor Engineering, S. Glasstone, A. Sesonske.
- (b) HTGR Reactor Service Building Alternate Fuel Handling and Storage Study 3000 MW(t) Reference Plant NSS - 8200.1- August 1974, Holmes & Narver, Inc.
- (c) Procedures for Shielding Calculations - Technical Report No. 1 AECU - 3510, January 1957, R. Dennis, S. N. Purohit, L. E. Brownell.

HIGH LEVEL/INT. LEVEL SOURCES

CASK	WT (lbs)	WATT	DIMENS.	✓ SURF R/hr	✓ 10' Q R/hr	n SURFACE R/hr	n 10' Q R/hr.	NO PER CASK
ERDA HI (TRUCK)	7000	230	2' X 10'	5000	400	1.5	0.1	
ERDA HI (RAIL)	7000	230	2' X 10'	5000	400	1.5	0.1	
NFS (INTER) (TRUCK)	7500	110	4' X 4'	700	30	-	-	
AGNS INTER (TRUCK)	15000	220	4' X 8'	700	60	-	-	
AGNS IL (RAIL)	15000	220	4' X 8'	700	60	-	-	
HL (TRUCK)	3000	3500	16" X 10'	1.3×10^5	6.5×10^3	33	1.6	
HL (RAIL)	3000	3500	16" X 10'	1.3×10^5	6.5×10^3	33	1.6	8

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Radwaste Calculations

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SHEET 1 OF 13TITLE LIQUID WASTE VOLUME - DAILYBY RMB DATE 2/4/77

Generation of waste volumes can be divided into three major areas:

- Daily
- Intermittent / Infrequent
- Accident or abnormal conditions

DAILY

Sources that input daily to the liquid rad waste system are tabulated as follows:

RH Bldg

- (1) Cask decontamination
- (2) Lcl decontamination
- (3) Laboratory samples
- (4) Cask cooling and draining
- (5) Canister cleaning
- (6) Contaminated showers

TRU Bldg

- (7) Lab samples
- (8) Contaminated showers

Radwaste / Laundry Bldg

- (9) Laundry
- (10) Contaminated showers

Miscellaneous

- (11) Routine Washdown

DAILY - RH BLDG(1) Cask Decontamination

A total of 50 canisters per week, on the average, will be handled in the RH bldg. It is assumed that these canisters come in single canister casks.

San Onofre N.G.S. ships single element spent fuel casks. They decontaminate these casks prior to shipping and use about 40 gallons per cask for decon. For unfilled casks.

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SHEET 2 OF 13TITLE LIQUID WASTE VOLUME - DAILYBY RMB DATE 2/4/77

Frimed casks require much more water for decontamination. ¹

Spent fuel ^{casks} shipped from nuclear power plants ^{are} generally "hotter" than the canisters expected at WIPP. The casks that we receive will have been decontaminated at the sending location and should be fairly clean.

For design purposes, we will assume 40 gal/cask, 10 casks/day, or 400 gallons ^{estimate} per day. Since the casks will be clean, detergent will probably not be needed.

(2) Lid Decontamination

Lids will be removed wrapped in plastic and placed in the hot cell when unloading the casks. After unloading, lids will be decontaminated and the casks washed for shipment.

Volume of water required for the lid is arbitrarily set at 1/2 that required for cask, i.e. 20 gal.

$$\text{Daily} = \frac{20 \text{ gal}}{\text{lid}} \times \frac{10 \text{ lid}}{\text{day}} = \boxed{200 \text{ gal/day}}$$

(3) Lab Drains

In accordance with Ref 2, 24 lab drains are established at $\boxed{90 \text{ gal/day}}$

(4) Cask Cooling and Draining

In establishing the cask cool/drain input, data for the GE-1F-300 spent fuel shipping cask was used. This cask can handle 7 PWR assemblies. ⁽²⁾

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SHEET 3 OF 13TITLE LIQUID WASTE VOLUME - DAILYBY RMB DATE 2/4/77

If all our shipments came in 7 canister casks, then we would receive 1.43 ($\frac{10}{7}$) casks per day.

Heat load - 7 PWR assys = 77 kw
7 ref canisters = 25 kw

Cooling water inventory = 4800 lbs for 7 PWR assys.

$$\frac{4800 \text{ lb} \times \frac{\text{gal}}{8.35 \text{ lb}}}{8.35 \text{ lb}} = 575 \text{ gal/cask}$$

Although the heat load is less, it will be assumed for design purposes that 575 gal of water will be drained for each 7 canisters (1 large cask)

$$\text{Total gal/day} = 1.43 (575) \approx \boxed{820 \text{ gal/day}}$$

(5) Canister Cleaning.

10 canisters per day will be decontaminated. Marv Reib, Aerojet, says decon system input will be 50 gal/day. Assume filter backflush included. Aerojet would not hazard a guess on contamination levels.

(6) Contaminated Showers

In accordance with Ref 2, 1 shower per day @ 50 gal is the total input.

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SHEET 4 OF 13TITLE LIQUID WASTE VOLUME - DAILYBY RMB DATE 2/4/77TRU BLDG

(7) Lab Samples In accordance with Ref (2), 180 gal/day is allocated for lab samples.

(8) Contaminated Shower - 50 gal/day - see Ref 2.

Radwaste / Laundry(9) Laundry

Review of the final site population estimate⁽⁵⁾ shows that about 107 sets of contaminated clothing per day will be laundered. This compares favorably with previous laundry evaluations.⁽⁶⁾ Information developed in Ref 6 will be used.

865 gal/day

(10) Contaminated Shower - Assume arbitrarily 1 @ 50 gal per day

MISCELLANEOUS

(11) Railcar / Truck Washdown - 1000 gal/day

Note that, per Sandia, there will be no contaminated shower from the Mpm / Materials Bldg. Decontamination that is necessary will be done below ground.

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		400 E. ORANGETHORPE AVE.	DATE 2/4/77
		ANAHEIM, CALIF. 92801	
TITLE INTERMITTENT / INFREQUENT LIQUID WASTE VOL.			BY RMB

General note - In order to simplify decontamination gals, water used for decon was allocated on a ft² basis. Based on building leak tests, Jim Robbins felt that a sufficient volume for cleaning was 38 gal / 100 ft².

A reasonable amount of water seems to be 1/2" (RMB). 100 ft²
@ 1/2" = 100 ft² × $\frac{0.5 \text{ ft}}{12}$ × $\frac{7.48 \text{ gal}}{\text{ft}^3}$ = 32 gal / 100 ft²

For purposes of this analysis 35 gal / 100 ft² will be assumed for decon.

Washdown Frequency = 4 week intervals

DECONTAMINATION VOLUMES

AREA	APPROX DIMENSION	FT ² (× 35 gal / 100 ft ²) =	GALLONS
TRU RECEIVING		12000	4200
TRU I+P		27000	9450
TRU O+R	65 × 65	4225	1479
RH RECEIVING		6720	2352
RH Cask Service		4800	1680
RH Hot Cell	(28 × 60)	1680	588

In all probability, the I+P will not be decontaminated all at once. $\frac{9450}{2} = \text{span style="border: 1px solid black; padding: 2px;">4725$ = design basis decon.

Radwaste / Laundry

Building has not yet been designed - assume 2500 ft².

$2500 \text{ ft}^2 \times \frac{35 \text{ gal}}{100 \text{ ft}^2} = \text{span style="border: 1px solid black; padding: 2px;">875 \text{ gal / decon}$

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APPROVED _____ DATE _____

TITLE LIQUID WASTE VOLUME - INTERMITTENT / INFREQ. RMB DATE 2/4/77**FILTER WASHING / EQUIPMENT DECON**

Prefilter washing will be infrequent, we think, possibly every six months. Equipment decon requirements are not known. Four buildings are affected - TRU, RW, storage vent and exhausts. For purposes of this study, 20 gal/mo. per bldg will be assumed.

3/8/77
Note that no quantity has been generated for cleanup of the ducts after filter replacement. This will require cleanup also.

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SHEET 7 OF 13TITLE ACCIDENT CONDITIONS - LIQUID RADWASTE VOLUME RMBDATE 2/7/75

Above ground accident conditions will be considered. For the TRU Facility, a fire in the hot cell will be assumed. For the TRU facility a fire in the RF box storage area will be assumed.

Fires will generate three sources of liquid radwaste -

- (1) Fire spray water
- (2) Cleanup following the fire.
- (3) NEPA fire-fighting sprays.

→ Fire spray water amounts should be determined based on NFP Handbook hazard categories.
TRU FACILITY

- Assumptions: (1) Duration of fire = 1/2 hour.
(2) Location - RF box storage
(3) Spray volume = $0.3 \text{ gpm}/\text{ft}^2$ ①

$$\text{Area} = (4 \times 7) \frac{\text{ft}^2}{\text{box}} \times 24 \text{ box} = 672 \text{ ft}^2$$

$$\text{Fire spray Volume} = 0.3 \frac{\text{gal}}{\text{min} \cdot \text{ft}^2} \times 672 \text{ ft}^2 \times 30 \text{ min} = \boxed{6048 \text{ gal.}}$$

$$\text{Cleanup} = \frac{35 \text{ gal}}{100 \text{ ft}^2} \times 27000 \text{ ft}^2 = 9450 \text{ gal}$$

Pre/Post sprays
Expected FOE spray is ~ $0.1 \text{ gpm}/1000 \text{ cfu}$. For TRU - flow rate = $\boxed{17 \text{ gpm}}$

$$\frac{17 \text{ gal}}{\text{min}} \times 30 \text{ min} = 510 \text{ gal}$$

$$\boxed{\text{Grand total for TRU} \approx 16,000 \text{ gal}}$$

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SHEET 8 OF 13TITLE ACCIDENT CONDITIONS - LIQUID RADWASTEBY RMB DATE 3/4/77RH FACILITY

A fire in the RH Facility is not too likely, however, for purposes of generating radwaste volume, a fire in the prep and v area will be assumed.

(1) Light hazard = 0.08 gpm/ft² ④

(2) Prefilter sprays = 1/2 TRU

(3) Cleanup required after the fire

$$4800 \text{ ft}^2 \times \frac{0.08 \text{ gal}}{\text{min} \cdot \text{ft}^2} \times 30 \text{ min} = 11520 \text{ gal}$$

$$\text{Cleanup} = \frac{6720}{100} \times \frac{35}{100} = 2352$$

$$\text{Prefilter sprays} = 255$$

$$\text{Total} = 14127$$

STORAGE VENT BLDG

A fire in this bldg is also unlikely. For purposes of the analysis a fire in the filter storage area will be postulated and the quantity generated by a spray system calculated.

$$\text{Area} = (28 \times 65) - 120 - (8 \times 26) = 1476 \text{ ft}^2$$

$$t = 30 \text{ min}$$

$$\text{Group I hazard} = 0.05 \text{ gpm/ft}^2 \text{ ④}$$

$$1476 \text{ ft}^2 \times \frac{0.05 \text{ gal}}{\text{min} \cdot \text{ft}^2} \times 30 \text{ min} = 2214$$

$$\text{Cleanup} = 1476 \times 0.35 = 517$$

$$\text{Prefilter spray} = 510$$

$$3241 \rightarrow 3500 \text{ GAL}$$

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SHEET 9 OF 13TITLE ACCIDENT CONDITIONS - LIQUID RADWASTEBY RMB DATE 2/14/77

RADWASTE BLDG - For our purposes, the building will be the only fire hazard area assumed.

Light hazard = .08 gal/min/ft²
Area = 25 x 40 = 1000 ft²

1000 x .08 x 30 = 2400 gal.

Cleanup = 1000 x .35 = 350

Pre-filt spray = 255
3005 gal

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SHEET 10 OF 13TITLE SOLID WASTE VOLUMES - "PROCESS"BY RMB DATE 2/9/77

Solid wastes from "process" operations will come from the following sources:

Spent ion exchange resins
Cartridge filters
Backflushable filter sludges

BACKFLUSHABLE FILTER SLUDGE

A total of 2600 canisters will be handled per year

Assumed surface area (at 2' x 15') = $2\pi + \pi dh = 32\pi = 100.5 \text{ ft}^2$

From Fig 6⁹ assume a corrosion rate of $60 \text{ g/ft}^2/\text{yr}$ or

$$60 (100.5) = 6030 \text{ g/yr/canister}$$

Assume canisters are 1 month old.

$$\frac{6030 \text{ g}}{\text{yr/canister}} \times \frac{2600 \text{ canisters}}{\text{yr}} \times \frac{1 \text{ yr}}{12} \times \frac{2.2 (10^{-3}) \text{ lb}}{\text{g}} \times \frac{\text{in}^3}{0.3 \text{ lb}} \times \frac{\text{ft}^3}{1728 \text{ in}^3} =$$

$$\frac{6030 (2600) (1) (2.2) (10^{-3})}{0.3 (1728) (12)} = 5.54 \text{ ft}^3/\text{yr}$$

→ 10 ft^3 if we assume some water present

CARTRIDGE FILTERS

From Ref 10, 3 μm data:

3.2 ft^2 = 5 gpm slightly turbid

3.2 ft^2 = 1 gpm turbid with algae

diameter = 3"

length = 10"

$$\text{compressed volume} = 3.2 \text{ ft}^2 \times 0.5 \text{ in} \times \frac{\text{ft}}{12 \text{ in}} = .13 \text{ ft}^3$$

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SHEET 11 OF 13TITLE SOLID WASTE VOLUMES - "PROCESS"BY RMB DATE 2/9/77

Laundry Filter - assume that it is sized on the basis of
.13 ft³ effective volume for 3 gpm

Flow is 10 gpm; Effective volume = $.13 \left(\frac{10}{3} \right) = .43 \text{ ft}^3/\text{week}$

It is assumed that this filter will be changed out once per week based on San Onofre 1 experience with the radwaste process filter⁽¹¹⁾.

Yearly volume = $.43 \frac{\text{ft}^3}{\text{week}} \times 52 \frac{\text{weeks}}{\text{yr}} = 22.5 \text{ ft}^3/\text{yr}.$

Miscellaneous Waste Filters

Assume that these will be changed out monthly.
Size for 40 gpm Flow.

$$22.5 \frac{\text{ft}^3}{\text{yr}} \times \frac{40}{10} \times \frac{12}{52} = 20.8 \text{ ft}^3/\text{yr}$$

Total Filter volumes = $20.8 + 22.5 = 43.3 \rightarrow \boxed{50 \text{ ft}^3/\text{yr}.}$

SPENT ION EXCHANGE RESINS

San Onofre Unit 1 mixed bed is non regenerable and ~ 25 ft³. It is changed out once per year.⁽¹¹⁾

Flow through the demineralizer will be based on an assumed normal process time of six hours.

Misc waste tank capacity = 8000 gal.

Time = $6 \times 60 = 360 \text{ min}.$

Flow = $8000/360 = 22.2 \text{ gpm}$

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SHEET 12 OF 13TITLE SOLID WASTE VOLUMES - "PROCESS"BY RMB DATE 2/6/77

Assume that 1 Ft³ is needed for each 2 gpm Flow.^{12,13}

Bed is assumed to be $\frac{22.2}{2} = 11.1 \rightarrow \boxed{12 \text{ Ft}^3}$

Even though conditions should be far less severe than San Onofre Unit 1, assume 12 Ft³/year spent resin volume

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SHEET 13 OF 13TITLE REFERENCESBY RMB DATE 2/9/77

- (1) Phone Conversation, R.M. Banister, H&N, to P.H. Penseyres, Southern California Edison of 1/28/77.
- (2) Radwaste Calculations, K.R. Brown, H&N, dated 10/26/76
- (3) General Electric IF-300 Shipping Cask Analysis, NEDO 10084-1
- (4) Phone Conversation, R.M. Banister, H&N, to Marv Reib, AMCO, of 1/28/77
- (5) Letter H&N 069, K.R. Brown to J.L. Ash, of January 21, 1977.
- (6) Memo 8251-M-35, R.M. Banister to K.R. Brown of October 21, 1976
- (7) Fire Protection Handbook (Fig 5-1B) 14th Edition, 1976
- (8) Fire Protection Handbook, Table 14-4B, 14th Edition, 1976
- (9) Metals Handbook Vol 1, Fig 6, pg 27
- (10) Pull Western Corporation Bulletin E256
- (11) Phone Conversation, R.M. Banister, H&N, to A.W. Beetz, SCE, of 2/9/77
- (12) SCE Coolwater Station Water Treatment Calculation Sheets
- (13) "Selecting Basic Ion Exchange Resins", C.H. Dallman, A.A. Askew, Power Engineering, October, 1971

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STRUCTURAL CONSTRUCTORS

4001 ORANGE GROVE AVE.

ANN ARBOR, CALIF. 96001

SHEET _____

OF _____

TITLE **WIPP FACILITY - SANOM**

BY _____

DATE _____

INDEX**PRELIMINARY STRUCTURAL CALCULATIONS**

<u>ITEM</u>	<u>SHEET NO'S</u>
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Design Basis Tornado Missile Characteristics	TL-2
Tornado Missile Impact Design Approach	TL-3
Typical Wall Sections for Missile Impact	TL-4 to TL-6
Typical Roof Sections for Missile Impact	TL-4 to TL-6
 <u>Tru-Waste Building</u>	
Preliminary Design Assumptions	TRB-1
Tornado Wind Loading Assumptions	TRB-2
Design Loading Combinations	TRB-3
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Tornado Wind Shears on Walls	TRB-7
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TITLE WIPP FACILITY - SANDIA

HOLMES & NARVER, INC.

ENGINEERS-CONSTRUCTORS
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ANAHEIM, CALIF. 92801

ISS NO.

120-00

SHEET

TL-1

OF

BY

WPS

DATE

4/14/77

TORNADO LOADING ASSUMPTIONS

Tornado characteristics

Rotational speed (mph)	Translational speeds (mph)	Radius of Maximum Rotational speed (feet)	Pressure Drop (psf)	Pressure Drop Rate (psi/sec)
	Maximum	Minimum		
240	60	5	150	7.25
				12

Assumed Profile of Tornado Translational Wind speeds

Note: Different scales are used

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7L-2

OF

BY

WPS

DATE

4/18/77DESIGN BASIS TORNADO MISSILE CHARACTERISTICS

The following missiles are summarized in Reference (1), and represent those which are currently accepted by the USNRC for the design of Nuclear Power Plants. This summary is included for information only.

Missile	Size	Length (feet)	Weight (pounds)	Horizontal Velocity (ft./sec.)		
				I	II	III
A. Wood plank	4x12	12.0	115	272	230	190
B. 6" Sch. 40 pipe	6.625" O.D.	15.0	287	171	138	33
C. 1" Sch. 40 Steel Rod	1.315" O.D.	9.0	9	167	131	26
D. Wood Utility Pole	13.5" O.D.	35.0	1125	180	157	85
E. 12" Sch. 40 pipe	12.75" O.D.	15.0	750	154	92	23
F. Automobile	6.56' x 4.27'	18.4	4000	194	171	134

Recommended Design Basis Missiles for WIPP Facilities (See Reference 2)

Missile	Size	Length (feet)	Weight (pounds)	Horizontal Velocity (ft./sec.)
Structural Shape	W 14x34	30.0	1020	120
6" Sch. 40 pipe	6.625" O.D.	21.0	400	138
Wood Utility Pole	14" O.D.	35.0	1500	157
Automobile	(20 ft ² frontal area)		4000	171

Note: Vertical velocity assumed as 0.80 x horizontal velocity.

References

1. Preliminary Draft of USNRC Publication NUREG-0121, "An Assessment of the Bases for Selecting Criteria for Protection Against Tornado-Entrained Debris", by J.B.J. Read and L.W. Bell, dated November 1976.
2. H.S.N. Letter to Fenix and Scisson, Inc. dated January 21, 1977 and transmitting "Recommendations for the Tornado Generated Design Basis Missile for WIPP."

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SHEET TL-3 OF _____TITLE WIPP FACILITY - SANDIABY HPS DATE 4/11/77TYPICAL WALL-ROOF THICKNESSES - CATEGORY I STRUCTURES - EXPOSED TO MISSILE IMPACT.General Design Approach

1. Establish concrete thickness required to prevent interior face scabbing.
2. Review capacity of member to absorb total energy due to missile impact.
3. Assess shear capacity of member.

TYPICAL WALLGeneral penetration and perforation equations (Reference)

d = projectile diameter (in)

D = caliber density = W/d^3 (lbs/in³)

e = perforation thickness (in)

f'c = concrete ultimate compressive strength (lbs/in²) = 4000 psiK = penetrability factor = $\frac{180}{\sqrt{f'c}} = \frac{180}{\sqrt{4000}} = 2.85$

N = projectile shape factor.

S = scabbing thickness (in)

t = target thickness (in)

V = striking velocity (ft/sec)

Vi = instantaneous velocity @ time ti

W = projectile weight (lbs)

x = total penetration depth

xi = penetration depth at ti

$$G\left(\frac{x}{d}\right) = K N d^{0.20} D \left(\frac{V}{1000}\right)^{1.80} \quad \text{where } G\left(\frac{x}{d}\right) = \begin{cases} (x/2d)^2 & \text{for } x/d \leq 2.0 \\ \frac{x}{d} - 1 & \text{for } x/d > 2.0 \end{cases}$$

$$\frac{e}{d} = 1.32 + 1.24 \frac{x}{d} \quad \text{where } (3 \leq \frac{e}{d} \leq 18)$$

$$\frac{S}{d} = 2.12 + 1.36 \frac{x}{d} \quad \text{where } (3 \leq \frac{S}{d} \leq 18)$$

Reference Document

Modified NDRC Formula from "A Review of Procedures for Analysis and Design of Concrete Structures to Resist Missile Effects".
by R.P. Kennedy, Holmes & Narver, Inc., September 1975.

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SHEET TL 4 OF _____TITLE WIPP FACILITY - SANDIA

BY _____ DATE _____

TYPICAL WALL SECTIONCritical Missile for Wall penetration - W14x54, W = 1020", V = 120 ft/sec.a) Penetration thickness, xAssume $t = 18"$

$$N = 0.72; A = 10.0 \text{ m}^2 = \pi d^2/4, d = 3.57; D = \frac{W}{d^2} = \frac{1020}{(3.57)^2} = 22.45$$

$$t/d = 18/3.57 = 5.04 > 3.0$$

$$G\left(\frac{x}{d}\right) = (2.85)(0.72)(3.57)^{0.20} \left(22.45\right) \left(\frac{120}{1000}\right)^{1.8} = 1.308$$

$$\left(\frac{x}{2d}\right)^2 = 1.308, \frac{x}{2d} = 1.144, \frac{x}{d} = 2.29 > 2.0$$

$$\therefore G\left(\frac{x}{d}\right) = \frac{x}{d} - 1 = 1.308; \frac{x}{d} = 2.308, x = (2.308)(3.57) = \underline{8.24 \text{ in}}$$

b) Perforation thickness, e

$$\frac{e}{d} = 1.32 + 1.24(2.308) = 4.18$$

$$e/d > 3$$

$$e = (4.18)(3.57) = \underline{14.92 \text{ in}}$$

c) Scabbing thickness, S

$$\frac{S}{d} = 2.12 + 1.36(2.308) = 5.26$$

$$S/d > 3$$

$$S = (5.26)(3.57) = \underline{18.78 \text{ in}}$$

Use 18"	Typical Exposed Wall Thickness
---------	-----------------------------------

TYPICAL ROOF SECTION

Missile design parameters assumed same as for Wall section, except for V

$$G\left(\frac{x}{d}\right) = (2.85)(0.72)(3.57)^{0.20} (22.45) \left(\frac{0.80 \times 120}{1000}\right)^{1.8} = 0.875$$

$$\frac{x}{d} - 1 = 0.875, x = (1.875)(3.57) = 6.69, \frac{x}{d} = \frac{6.69}{3.57} = 1.87 < 2.0$$

$$\left(\frac{x}{2d}\right)^2 = 0.875; \frac{x}{2d} = 0.935; \frac{x}{d} = 1.870, x = (1.870)(3.57) = 6.68$$

$$\frac{e}{d} = 1.32 + 1.24(1.87) = 3.64, e = (3.64)(3.57) = 12.99"$$

$$\frac{S}{d} = 2.12 + 1.36(1.87) = 4.66, S = (4.66)(3.57) = \underline{16.64 \text{ in}}$$

Use 17"	Typical Exposed Roof Slab Thickness
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SHEET TL-5 OF _____TITLE WIPP FACILITY - SANDIABY HPS DATE 4/11/77TYPICAL WALL SECTIONWall Response for Impact from Missile with greatest energy input4000# Automobile @ $V = 171$ ft./sec.

$$\text{Total KE} = \frac{WV^2}{2g} = \frac{4000 \times 171^2}{2 \times 32.2} = 1,816,200 \text{ ft. lbs.} = 1816 \text{ ft. kips}$$

$$\frac{\pi d^2}{4} = 20.0 \text{ ft}^2, \quad d = 5.05 \text{ ft. (dia. of equivalent circular contact area)}$$

$$\text{Assume } E \text{ (effective wall width)} = 0.45 + 3.75 = 15.75' \text{ (Use 15')}$$

$$W = 0.150 \times 1.5 \times 30 \times 15 = 101 \text{ k}$$

$$W_e = 0.33 \times 101 = 33 \text{ k (Effective Mass)}$$

Period of Vibration T

$$T \approx \left(\frac{L}{d}\right) \frac{L}{3600 \sqrt{\phi}} = \frac{30 \times 12}{16} \times \frac{30}{3600} = 0.188 \text{ sec}$$

$$\phi = 1.0$$

Equivalent Static Load

$$\textcircled{1} q_g = \frac{2\pi m V}{T} \sqrt{\frac{1}{2\mu - 1}} = \frac{2\pi \times 4 \times 171}{32.2 \times 0.188} \sqrt{\frac{1}{(2 \times 10) - 1}} = 163 \text{ k}$$

Wall Response

$$W_H = \frac{163}{15} = 11 \text{ k}$$

$$1.1 q = 1.1 \times 0.00256 \times 300^2 = 253 \text{ psf}$$

$$W_W = 253 \times 20 = 7.6 \text{ k}$$

Factored Loads per ft. of Wall widthAssume $1.2 W_W + 1.2 W_H$

$$P = 1.2 \times 11 = 13.2 \text{ k} \quad W = 1.2 \times 7.6 = 9.1 \text{ k}$$

$$M_{\text{Max}} = 13.2 \times \frac{30}{4} + 9.1 \times \frac{30}{8} = 133 \text{ kft}$$

$$\text{For } p_o = 0.01, \quad a_u = 4.10$$

$$q = 0.00256 (300)^2$$

$$\text{Des } M = \frac{133}{0.9} = 148 \text{ kft}$$

$$A_s = \frac{133}{4.1 \times 16} = 2.03 \text{ in}^2 / \text{ft} \left\{ \begin{array}{l} \text{Reinf. is} \\ \text{a reasonable} \\ \text{quantity} \end{array} \right.$$

Maximum Wall Displ. (Missile only)

$$\textcircled{1} x_m = \frac{mV^2}{q_g \left(\frac{2\mu - 1}{\mu} \right) - 2mg \left(1 + \frac{m_e}{m} \right)} = \frac{4 \times (171 \times 12)^2}{163 \left(\frac{2 \times 10 - 1}{10} \right) - \left(\frac{2 \times 4 \times 384}{384} \right) \left(1 + \frac{33}{4} \right)} = 15.7''$$

Reference Document ①

"Impact Effect of Fragments Striking Structural Elements"

By R.A. Williamson and R.R. Alvey, Holmes & Narver, Inc., Revised Nov. 1973

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SHEET

TL-6

OF

TITLE WIPP FACILITY - SANDIA

BY

WTS

DATE 4/11/77

TYPICAL WALL SECTION18" Wall - Punching Shear $d = 16"$ W 14 x 34 Missile $x = 8.24"$ $V = 120 \text{ ft/sec}$

$$T_s = \frac{2x}{V} = \frac{2 \times 8.24}{120 \times 12} = 0.0114 \text{ sec}$$

$$F_A = \frac{WV}{gT_s} = \frac{1020 \times 120}{32.2 \times 0.0114} = 332,000 \text{ lb} = 332 \text{ k}$$

$$T_a = \frac{332}{10.0} = 33.2 \text{ ksi} < 60.0$$

$$\text{Shear Perimeter } \approx 2(14" + 6.75") = 41.5"$$

 $\therefore$ Missile crushing likely

$$\text{Ave } J = \frac{332}{41.5 \times 16} = 0.50 \text{ ksi} < 0.2 f_c = 0.80 \text{ ksi}$$

 $\therefore$ Punching shear < Allowable punching shearOther Missiles

4000* Automobile - Energy absorption due to crushable elements make punching shear failure unlikely.

1500* Wood Utility Pole - Wood crushing will occur and a punching shear failure is not possible.

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SHEET TRB-1 OF _____TITLE WIPP FACILITY - SANDIABY HPS DATE 4/11/77TRU-WASTE BUILDINGPreliminary Design Assumptions

Roof - Reinforced concrete poured in place solid slab, flat plate or flat slab construction with beam and girder construction in areas requiring special framing.
Minimum slab thickness = 17" governed by tornado missile.

Floors - Upper levels - Same construction as roof except for minimum slab thickness.

Ground level - Concrete slab on compacted fill.

Walls - Reinforced concrete poured in place -
Minimum wall thickness = 18" governed by tornado missile.

Foundations - Spread footings. Continuous wall type or individual type under columns.

Assumed allowable bearing values

Load combinations not including wind, tornado or seismic loads _____ 6.0 KSF

Load combinations including wind, tornado or seismic loads _____ 8.0 KSF

Bottoms of footings at least 4.0 feet below existing ground level.

Materials : Concrete $f'_c = 4000$
Reinf. Steel ASTM A615, Gr 60
Struct. Steel ASTM A36

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OF _____

BY HPSDATE 4/11/77TITLE WIPP FACILITY - SANDIATORNADO LOADING ASSUMPTIONSTRU WASTE BUILDING ASSUMED BUILDING LOADING

- Note (A) Entry tunnels are assumed to act independently and are not considered to participate in transmitting loads to the building. Entry tunnels are to be capable of resisting the maximum tornado wind forces.

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SHEET T12A-3 OF _____TITLE WIPP FACILITY - SANDIABY WPS DATE 4/11/77TRU-WASTE BUILDINGWIND LOADING SUMMARYDesign Loading Combinations W_t = Total Tornado load W_w = Tornado wind load W_p = Tornado differential pressure load W_m = Tornado missile load

$$W_t = W_w$$

$$= W_p$$

$$= W_m$$

$$= W_w + 0.5 W_p$$

$$W_p = 2.25 \text{ psi} = 324 \text{ psf}$$

$$= W_w + W_m$$

$$= W_w + 0.5 W_p + W_m$$

Critical Tornado Wind Loadings - Not including Missile LoadsLocal Wall Loading (psf)

<u>W_w</u>	<u>$.5W_p$</u>	<u>W_t</u>
- 230	- 162	- 392
+ 253	-	+ 253

Building Translation Loading (psf)

<u>Longit. Direction</u>	<u>Transverse Direction</u>
146	127

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 SHEET TRB-4 OF _____
 BY WPS DATE 4/11/77

TRU-WASTE BUILDING

HIGH BAY WALL W/ 25 T. CRANE SUPPORT

Crane Wheel Load = 20^k @ $25'$ from Wall

Wind Loads

$$W_t = W_H + 0.5 W_p$$

$$= (0.00256 \times 300^2) + (0.5 \times \frac{2.25}{2} \times 144)$$

$$= 230 + 162 = 392 \text{ psf}$$

$$M_{\text{crane Ld}} = 20^k \times \frac{25}{12} = 42^k\text{ft}$$

$$R_{\text{Top}} = 42 / 53 = 0.79^k$$

$$M_{\text{above}} = 0.79 \times 11 = 8.7^k\text{ft}, M_{\text{below}} = 33.3^k\text{ft}$$

$$M_d = 21^k\text{ft}, \text{ Assume } 3.0' \text{ Strip, } M/F_t = 7^k\text{ft}$$

$$W = 1.2 \times 0.392 \times 53 = 24.93^k$$

$$M_W = 24.93 \times 53 / 8 = 165^k\text{ft}$$

$$M_{\text{crane}} = 1.4 (\text{Load Factor}) \times 7 = 10^k\text{ft}$$

$$\Sigma M = 175^k\text{ft}$$

$$M_y = 175 + 10 / 12 = 146^k\text{ft} \quad (\text{For } 10' \text{ Wide Section, ACI Sp 17(73) Vol 1, p 130})$$

$$A_s = 1.55 \text{ in}^2 = 0.25 \text{ pb} \quad (10' \text{ Width})$$

$$A_s = 1.55 + 12 / 10 = 1.86 \text{ in}^2 / \text{ft} \quad \text{Say } 2 \# 10'$$

$$p = \frac{100 + 1.86}{12 \times 22} = 0.70$$

$\therefore$ Say 24" Wall o.k.

$$t \approx \frac{h}{25} = \frac{53}{25} = 2.12'$$

Use $t = 24"$ $d = 22"$

* ACI 318-71, Sec 14.2(d)

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SHEET T2B-5 OF _____TITLE WIPP FACILITY - SANDIABY HPS DATE 4/11/77TRU-WASTE BUILDINGHIGH-BAY WALL W/ 25T. CRANE SUPPORTWall Response - 4000^{lb} Automobile Missile

$$KE = \frac{WV^2}{2g} = \frac{4000 \times 171^2}{2 \times 32.2} = 1816 \text{ ft-kips}$$

$$\pi d^2/4 = 20 \text{ ft}^2, \quad d = 5.046 \text{ ft} = 60.56''$$

$$\text{Effective Width } E = 0.45 + 3.75 = (0.4 + 53) + 3.75 = 25 \text{ ft}$$

Assume $E = 20 \text{ ft}$

$$W = 0.150 \times 53 \times 20 \times 2.0 = 312^k$$

$$W_e = 0.33 \times 312 = 106^k$$

Period of Vibration

$$d = 22'' \quad \phi = 1.0\%$$

$$T = \left(\frac{L}{d}\right) \left(\frac{L}{3600\phi}\right) = \frac{53 \times 12}{22} \times \frac{53}{3600 \times 1.0} = 0.425 \text{ sec}$$

Equiv. Static Load

$$\mu = 10 \text{ (Assumed)}$$

$$q_y = \frac{2\pi m v}{T} \sqrt{\frac{1}{2\mu - 1}} = \frac{2\pi \times 4 \times 171}{32.2 \times 0.425} \sqrt{\frac{1}{(2+10)-1}} = 72.0^k$$

$$W_m = \frac{72}{30} = 3.6^k \text{ for } 1' \text{ strip}$$

$$1.1q = 1.1 \times 0.00256(300)^2 = 253 \text{ psf}$$

$$W_w = 0.253 \times 53 = 13.4^k$$

$$\text{Use } 1.2 W_w + 1.2 W_m$$

$$P = 1.2 \times 3.6 = 4.3 \quad W = 1.2 \times 13.4 = 16.1$$

$$M = 4.3 \times 53/4 + 16.1 \times 53/8 = 57 + 107 = 158^k$$

$$A_s = 1.4 + 12/10 = 1.68 \text{ in}^2/\text{ft.} \quad \text{(ACI SP-17(73) - Vol 1, P-30)}$$

$$\#11 @ 11$$

$$p = \frac{100 \times 1.68}{12 \times 22} = 0.64\%$$

24" Wall o.k.

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SHEET T2A-6 OF _____TITLE WIPP FACILITY - SANDIABY WPS DATE 4/11/77TRU-WASTE BUILDINGSURFACE WIND PRESSURES WIND
DIRECTION

$$C_{pe} = \pm 0.3$$

WIND
DIRECTION

$$C_{pe} = \pm 0.3$$

PRESSURE COEFFICIENTS C_p & C_{pe}

$$P = q_f C_p - q_m C_{pe}$$

Velocity Pressures $q = 0.00256 V^2$; $V_{max} = 300 \text{ mph}$; $q = 0.00256 \times 300^2 = 230 \text{ psf}$

WIND PRESSURES ON BUILDING SURFACES

Surface No.	C_p	$q_f C_p$	C_{pe}	$q_m C_{pe}$	P	C_p	$q_f C_p$	C_{pe}	$q_m C_{pe}$	P
1	-0.7	-161	+0.3	+69	-92	+0.8	+184	+0.3	+69	+253
			-0.3	-69	-230			-0.3	-69	+115
2	-0.7	-161	+0.3	+69	-92	-0.5	-115	+0.3	+69	-46
			-0.3	-69	-230			-0.3	-69	-184
3	+0.8	+184	+0.3	+69	+253	-0.7	-161	+0.3	+69	-92
			-0.3	-69	+115			-0.3	-69	-230
4	-0.5	-115	+0.3	+69	-46	-0.7	-161	+0.3	+69	-92
			-0.3	-69	-184			-0.3	-69	-230
5	-0.7	-161	+0.3	+69	-92	-0.7	-161	+0.3	+69	-92
			-0.3	-69	-230			-0.3	-69	-230

$q_f = q_m = 230 \text{ psf}$ in above table

CHECKED _____ DATE _____

APPROVED _____ DATE _____

TITLE WIPP FACILITY - SALOIA

HOLMES & NARVER, INC.

ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801

JOB NO. _____

SHEET TRB-7 OF _____

BY HPS

DATE 4/11/77

TRU-WASTE BUILDING

WIND SHEARS ON WALLS

$$151 \times 54 = 8154 \text{ ft}^2 \times 146 = 1190 \text{ k} \quad (792 \text{ F}, 458 \text{ R})$$

$$63 \times 35 = 2205 \times 146 = 392 \text{ k} \quad (241 \text{ F}, 151 \text{ R})$$

$$151 \times 297 = 44,847 \text{ ft}^2 \times 161 = 7220 \text{ k}$$

$$63 \times 297 = 18,711 \times 161 = 3012 \text{ k}$$

$$298 \times 63 = 18,774$$

$$196 \times 63 = 12,348$$

$$24,948 / 297 = 84 \text{ k}$$

ROOF DIAPHRAGM LOADS

BUILDING WALL LOADS

WALL R

WALL RF

WALL F

HORIZ. WIND SHEARS (kips)
ACTING ON SIDE WALLS

$$494 / 297 = 1.66 \text{ k/ft}$$

$$V_{\text{ave}} = 1660 / 12 + 18 = 8 \text{ psi}$$

(very low)

CHECKED _____ DATE _____

APPROVED _____ DATE _____

TITLE WIPP FACILITY - SANDIA

HOLMES & NARVER, INC.
ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801

JOB NO. _____

SHEET _____

100-2

OF _____

BY WPS

DATE 4/11/77

TRU. WASTE BUILDING

End Wall Loads

Tornado Horiz.

$$H = \frac{54}{2} \times \frac{297}{2} + 0.8 \times 127 = 407^k$$

$$M = \frac{297}{2} \times 0.5 \times 1127 = 90^k$$

$$\frac{35}{2} \times \frac{297}{2} \times 0.8 \times 1127 = 155^k$$

$$M = (497 \times 58) + (155 \times 39) = 38,771$$

$$A = 3 \times (151 + 63) = 642 \text{ ft}^2$$

$$S_x = 3 \times \frac{114^3}{6} = 27,898$$

$$f_p = 1.69$$

Dead Load

$$16 \times 22 = 3.4^k$$

$$P = 3.4 \times 151 = 513^k$$

$$3.4 \times 63 = 214^k$$

$$x = \frac{M}{P} = \frac{(513 \times 151) + (214 \times 182)}{3807}$$

$$x = 10.6 \quad e = 10.4$$

$$M = 10.4 \times 3807 = 39726$$

$$f_m = \frac{39726}{27,898} = 1.73$$

$$f_a = \frac{3807}{642} = 5.93$$

Tornado Vertical

$$16 \times 1161 \times 151 = 389^k$$

$$16 \times 1161 \times 63 = 162^k$$

$$x = \frac{M}{P} = \frac{(389 \times 151) + (162 \times 182)}{451^k}$$

$$x = 10.68 \quad e = 0.2$$

$$M \approx 0$$

$$f_a = \frac{551}{642} = 0.86^k \text{ ft}^2$$

Wall Footing Soil Pressures

DL + Tornado Horiz + Tornado Vertical

$$\begin{array}{rclclcl} f_p(\text{left}) & 5.93 - 1.73 & + & 1.69 & - & 0.86 & = & 5.0 \\ & 5.93 + 1.73 & - & 1.69 & - & 0.86 & = & 5.1 \end{array} \quad \left. \vphantom{\begin{array}{rclclcl} f_p(\text{left}) & 5.93 - 1.73 & + & 1.69 & - & 0.86 & = & 5.0 \\ & 5.93 + 1.73 & - & 1.69 & - & 0.86 & = & 5.1 \end{array}} \right\} < 6.0 \text{ KSF}$$

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801

JOB NO. _____

APPROVED _____ DATE _____

SHEET TRB-9 OF _____TITLE WIPP FACILITY - SANDIABY HPS DATE 4/11/77TRU-WASTE BUILDINGSide Wall loads

$$M = 494 \times 39 = 19,266 \text{ kF}$$

$$A = 3.0 \times 299 = 897 \text{ ft}^2$$

$$S = 3 \times 299^2 / 6 = 44,701$$

$$f_m = \pm \frac{19,266}{44,701} = 0.43 \text{ k/f}$$

Roof

$$16' \times .22 = 3.4 \text{ k/f}$$

Mezz

$$10' \times .20 = 2.0 \text{ k/f}$$

Wall

$$39' \times .225 = 8.78 \text{ k/f}$$

$$P = 1010 + 594 + 2608 = 4212 \text{ k}$$

$$f_p = 4212 / 897 = 4.70 \text{ k/ft}^2$$

$$16' \times .161 = 2.58 \text{ k/f}$$

$$2.58 \times 297 = 766 \text{ k}$$

$$f_p = 766 / 897 = -0.85 \text{ ksf}$$

Wall Footing Soil Pressures

	DL	+	Tornado Horiz	+	Tornado Uplift	
$f_p(\text{ksf})$	4.70	+	0.43	-	0.85	= 4.28
	4.70	-	0.43	-	0.85	= 3.42
						< 6.0 ksf

Typical Foundation Loads - D.L. + LLRoof Loads

LL =	20
Rtg + Ins =	10
17" slab =	213
	<u>243 psf</u>

LL =	150
Flr	100
	<u>250</u>

Wall Footings - Typical

Wall Ht	57'	38'
Wall Wt/ft	13.9	9.2
Roof Ld $16 \times .243$	3.9	3.9
Flr Ld $16 \times .25$	4.0	4.0
	<u>21.8</u>	<u>17.1</u>
Width w @ 6.0 ksf =	4.0'	3.0'

Column Footings - Typ

Trib Area = 32×32	1056'
Trib Load = $1056(.243 + .300)$	= 573 k
Col Wt (30×30 c. $94 \text{ k/f} \times 31$)	= 2960 k
	<u>10,098 x 2.1 c</u>

24" Wall

57' + Crane Load

$17.7 + 100 / 25$	21.1 k
Roof Ld = $27 \times .200$	8.1
	<u>29.2 k</u>
	<u>5.0'</u>

Mechanical Calculations

COST OF ELECTRICAL POWER
USED IN LIFCY1 RUNS
FOR HVAC ENERGY STUDY

TRU

Cost of Electricity

- Assume .016/KWH + 4.50 demand
- Actual demand = 410 KW
- Total usage = 1,970,442 KWH

$$\begin{array}{rcl} \text{Demand charge} & = & \frac{410 \times 4.5 \times 12}{1,970,442} = .01124 \\ & & + \frac{.016}{.02724} \\ & \text{total cost / KWH} & \end{array}$$

$$\text{Cost / MBTU} = \frac{1,000,000}{3,413} \times .02724 = \$7.98$$

Cost of Electricity (RH Bldg.)

Assume: .016/kwh + 4.50 demand charge

$$\text{Actual demand rate} = 187 \times 1.1 = 205.7$$

$$\text{Total usage} = 895,656 \times 1.1 = 985,221$$

$$\begin{array}{rcl} \text{Demand charge} & = & \frac{205.7 \times 4.5 \times 12}{985,221} = .01127 \\ & & + .016 \\ & & \hline & & .0273 \end{array}$$

total cost / kwh

$$\text{Cost / MBTU} = \frac{1,000,000}{3413} \times .0273 = \$7.999$$

Cost of Electricity (Admin. Bldg. only)

Assume: .016/kWH + 4.50 demand charge.

Actual demand rate = 176

Total usage Alt. 3 = 727,797 KWH
 Alt. 4 = 557,047 KWH
 average = 642,422

$$\text{Demand charge} = \frac{176 \times 4.50 \times 12}{642,422} = .0148$$

$$\text{total cost/KWH} = \frac{+.016}{.0308}$$

$$\text{Cost/MBTU} = \frac{1,000,000}{3413} \times .0308 = 9.0243$$

Solar Assist. —

200 panels @ $306 \times 2 = \$122,400$

(to supply 1.36×10^9 BTU/yr.)

Laundry

Laundry - H.W. Energy use

$$30 \text{ KW} \times 5 \text{ hr.} = 150 \text{ KWH/day}$$

@ 30 KW demand

Cost of electricity - .016 KWH + 4.50 demand

$$\text{demand} = 30 \text{ KW} \quad \text{total usage} = 37,500$$

$$\begin{array}{rcl} \text{Demand charge} & \frac{30 \times 4.5 \times 12}{37,500} & = .0432 \\ & & + .016 \\ \text{total cost/KWH} & & \underline{0.0592} \end{array}$$

$$\text{Cost/MBTU} = \frac{1,000,000}{3413} \times .0592 = 17.345$$

$$\text{Solar panels} - 30 @ 306 \times 2 = \$18,360 + \$700/\text{yr. maint.}$$

KRB
3/21/77
1

FUEL CONSUMPTION
DIESEL GENERATORS

2600 KW RATED MACHINE IS RATED AT
3600 HP. FROM PROPOSAL DATA SUPPLIED
BY STEWART & STEVENSON THE FUEL
CONSUMPTION WILL BE 0.404 LB/BHP-HR

$$\therefore \text{CONSUMPTION/HR} = 3600 \text{ BHP} (.404 \text{ LB/BHP-HR})$$
$$= 1454.4 \text{ LB/HR}$$

$$\text{CONSUMPTION/DAY} = 24 \frac{\text{HR}}{\text{DAY}} (1454.4 \frac{\text{LB}}{\text{HR}})$$
$$= 34,905.6 \frac{\text{LB}}{\text{DAY}}$$

$$2 \text{ GENERATORS} = 69,811.2 \frac{\text{LB}}{\text{DAY}}$$

CAPACITY IN GALLONS ASSUMING NO.2 FUEL OIL
API = 26 7.5 LB/GALLON

$$\text{GALLONS/DAY} = \frac{69,811.2}{7.5}$$
$$= \underline{\underline{9308 \text{ GALLONS/DAY}}}$$

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3/22/77

2

$$\begin{aligned} 7 \text{ DAY FUEL SUPPLY} &= 7(9308 \text{ GPD}) \\ &= \underline{\underline{65,156 \text{ GALLONS}}} \end{aligned}$$

Reg Guide 1.108

Houston, Texas (713) 923-2161

3/23/77

Based on conversation with Robert Evans - National Contract Managers of Stewart & Stevenson and review of Reg. Guides the following is used to size the fuel system:

NRC requires 7 days - 168 hours. This is the capacity which should always be present in the system. Standard system tests shall never take system below 168 hour capacity.

∴ to allow for condensation space and tests the system should be sized for 100,000 gallons. This will be in addition to the 500 gallon day tank provided for each generator.

3/23/77

3

MECHANICAL SYSTEMS

STANDBY GENERATOR RADIATOR AIR FLOW

FROM STEWART & STEVENS CATALOG, HEAT
GENERATION RATE IS 50 BTU/MIN/KW

$$\begin{aligned}\text{MACHINE RATING} &= 2600 \text{ KW} \\ \therefore Q &= (50 \text{ BTU/MIN/KW}) 2600 \text{ KW} \\ &= 130,000 \text{ BTU/MIN} \\ &= 7,800,000 \text{ BTU/HR/MACHINE}\end{aligned}$$

AIR FLOW BASED ON $30^{\circ}\text{F } \Delta T$
WILL BE 2,400,000 CFM

BUILDING OPENING SIZE BASED ON 2000 FPM
VELOCITY WILL BE 120 FT^2 / GENERATOR

ADDENDA

WIPP CONCEPTUAL DESIGN

HIGH LEVEL WASTE SHIPPING CASK
COOLING SYSTEM

DESIGN CALCULATIONS

HOLMES & NARVER, INC.

Pages 1-3 dated 1/28/77 are concerned with the calculation of heat loads from high level waste shipping casks which will be cooled by this system.

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1/28/76

ERDA HIGH LEVEL WASTE - MULTIPLE CANISTER CASK

INPUT (SLA 1140/30; 11-30-76)

CASK SIZE 10' DIA X 18' LONG

GW = 100 TONS

CANISTERS - 7 @ 10,000 LBS

THERMAL POWER/CANISTER = 300 W

TOTAL THERMAL POWER = 2100 W = 2.1 KW

* CASK SURFACE TEMPERATURE (AT RECEIPT) = 225°F

* " " " (DESIRED) = 150°F

50 CANISTERS/WK = 7 1/7 SAY 8 CASKS/WK ~ 5 HRS/CASK

ASSUMPTIONS

CASK COMPOSITION 75% LEAD
25% STEEL

	STEEL	LEAD
C _p BTU/LB°F	.11	.034
K BTU/FT-HR-°F	20	20
ρ LB/FT ³	488	708

WASTE COMPOSITION IS ASSUMED TO
BE THE SAME AS LEAD FOR THIS CALC.

* 10-14-76 - W. WOWAK

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1/28/77

DESIRED MINIMUM COOL DOWN TIME IS 4 HRS/CASK

CALCULATIONS

PER W. WOWAK

$$Q_{4\text{HRS}} = \overset{\textcircled{A}}{\Delta Q_{75^{\circ}\text{F}}} + \overset{\textcircled{B}}{\Delta Q_{\text{CANISTER GENERATION (IN 4 HRS)}}}$$

$$\begin{aligned} \textcircled{A} \Delta Q_{75^{\circ}\text{F}} &= \rho V c_p \Delta T \left(\frac{\text{LB}}{\text{FT}^3} \right) (\text{FT}^3) \left(\frac{\text{BTU}}{\text{LB}^{\circ}\text{F}} \right) ^{\circ}\text{F} \\ &= \left[75 \text{ TONS} \left(\frac{2000 \text{ LB}}{\text{TON}} \right) (.034) + 25(2000)(.11) \right] 75 \\ \Delta Q_{75} &= (5.1^{+3} + 5.5^{+3}) 75 \text{ BTU} = 7.95^{+5} = 795,000 \end{aligned}$$

$$\frac{\Delta Q_{75}}{\text{HR}} = 795,000 / 4 \text{ HRS}$$

$$\Delta Q_{75} \begin{cases} \approx 200,000 \text{ BTU/HR} \\ \approx 58.5 \text{ KW} \end{cases}$$

3
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1/28/77

$$\textcircled{B} \quad \Delta Q_{\text{CAN GEN}} = 7 \text{ CANS} \left(300 \frac{\text{W}}{\text{CAN}} \right) \\ = 2.1 \text{ KW}$$

$$Q = \textcircled{A} + \textcircled{B} \\ = 58.5 \text{ KW} + 2.1 \text{ KW}$$

$$\underline{\underline{Q = 60.6 \text{ KW}}} \quad \underline{\underline{\text{FOR ERDA HIGH WASTE}}}$$

COMMERCIAL HIGH WASTE

Q $\approx$ 100 KW FROM CALCS BY W. WOWAK
ON 10-14-76

1
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1/31/77

ASSUMPTIONS

1. DURING INITIAL COOLDOWN, FLOW FROM THE HOT WATER TANK TO THE CASKS WILL BE BY GRAVITY ONLY.
- 2.

2
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1/31/77

CALCULATIONS

DETERMINE WATER FLOW REQ'D TO INITIALLY
COOL THE CASK VIA ~~HEAT~~ VAPORIZATION
OF THE HOT WATER FEED TO STEAM

WATER IN THE TANK IS HEATED TO 400°F
BY AN ELECTRIC HEATER

$$T = 400^{\circ}\text{F}$$

$$P = 247.31 \text{ PSIA}$$

$$h_f = 374.97 \text{ BTU/LB}$$

$$h_{fg} = 826.0 \text{ "}$$

$$h_g = 1201.0 \text{ "}$$

SYSTEM SIZING WILL BE BASED ON COOL DOWN
OF COMMERCIAL HIGH LEVEL WASTE. IT IS
ASSUMED THAT COOLING TIME IS LIMITED TO
4 HOURS. THE ~~H~~ COOLDOWN RATE IS 100 KW
PER CASK, WHICH IS 341,000 BTU/HR
FOR PURPOSES OF THE CALCULATION IT IS
ASSUMED THAT THE COOLING IS LINEAR - I.E. - THE
HEAT REMOVAL RATE IS A CONSTANT 341,000 BTU/HR
OVER THE 4 HOUR PERIOD IN QUESTION

SINCE THE FIRST PHASE COOLING IS BASED
ON VAPORIZATION THE FLOW REQUIRED
IS :

$$F = \frac{341,000 \frac{\text{BTU}}{\text{HR}}}{826 \text{ BTU/LB}}$$

$$F = 413 \frac{\text{LB}}{\text{HR}}$$

$$= 49.5 \text{ GPH}$$

$$\sim \underline{\underline{.83 \text{ GPM / CASK}}}$$

ASSUMING THE COOLING TO BE 3x AVERAGE
DURING VAPORIZATION STILL REQUIRES ONLY
2.5 GPM FLOW PER CASK

PHASE TWO (BOILING UNDER REDUCED PRESSURE)
WILL REQUIRE APPROXIMATELY THE SAME FLOW
AS DOES THE FIRST PHASE COOLING.

PHASE THREE (FORCED CONVECTION COOLING)
WILL REQUIRE A FLOW BASED ON THE FOLLOWING

WATER INLET TEMP. = 100°F	$h_f = 67.97 \frac{\text{BTU}}{\text{LB}}$
WATER OUTLET TEMP. = 210°F	$h_f = 178.05 \frac{\text{BTU}}{\text{LB}}$
$Q = 341,000 \text{ BTU/HR}$	$\Delta h = 110 \text{ BTU/LB}$

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$$F = \frac{341,000 \text{ BTU/HR}}{110 \text{ BTU/LB}}$$

$$= 3,100 \text{ LB/HR}$$

$$= 370 \text{ GPH}$$

$$= \underline{\underline{6.2 \text{ GPM}}}$$

COMMENT

CASK COOLING IN REPROCESSING FACILITIES IS BASED ON REDUCING CASK TEMPERATURES TO THE LEVEL THAT WILL NOT RESULT IN BOILING WHEN THE CASK IS INSERTED IN THE FUEL STORAGE POOL. WIPP IS REQUIRED TO COOL THE CASKS FOR THE FOLLOWING REASONS

- TO REDUCE CASK SKIN TEMPERATURES TO THE POINT WHERE HANDLING IS SIMPLIFIED AND SAFER ($\sim 150^{\circ}\text{F}$).
- TO REDUCE THE HEAT LOAD AND RESULTANT TEMPERATURES TO WHICH THE THE HOT CELL AND EQUIPMENT WILL BE EXPOSED.

FOR PURPOSES OF FURTHER ANALYSIS IT IS ASSUMED THAT ^{CASK} SKIN TEMPERATURE IS THE LIMITING

5
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1/31/77

FACTOR - THEREFORE THE ANALYSIS - AS IT IS
BASED ON SKIN TEMPERATURE REDUCTION
FROM 225 TO 150°F IS ACCEPTABLE.
THE FLOWS ARE ALSO ACCEPTABLE -
ASSUME A MAXIMUM OF 5 COOLING STATIONS
FOR HIGH LEVEL WASTE CASKS.

∴ THE MAXIMUM FLOWS FOR THE VARIOUS
COOLING PHASES WILL BE

PHASE	FLOW (GPM)
I	12.5
II	12.5
III	31

ASSUMING DIVERSITY WILL ALLOW REDUCTION
OF THE PHASE III FLOW - THIS FLOW WILL
BE SET AT 25 GPM BASED ON THE THOUGHT
THAT OVER WEEKENDS, HOLIDAYS, ETC. WHEN
CASKS MAY BE COOLED FOR LONG PERIODS
OF TIME THE ONLY HEAT TO BE REMOVED
WILL BE THAT GENERATED BY THE WASTE,
THE CASK HAVING BEEN PREVIOUSLY COOLED
TO ITS DESIRED 150°F SKIN TEMPERATURE.

THE FLOW UNDER THIS CONDITION WILL
THEN BE BASED ON A Q OF 28 KW

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$$\begin{aligned}\text{Flow} &= \frac{28 \text{ KW} \left(\frac{3415 \text{ BTU/HR}}{\text{KW}} \right)}{100 \text{ BTU/LB}} \\ &= 955 \frac{\text{LB}}{\text{HR}} \\ &= 114 \text{ GPH} \\ &= \underline{\underline{1.9 \text{ GPM}}}\end{aligned}$$

$$5 \text{ CASKS} = 9.5 \text{ GPM}$$

∴ SYSTEM COULD HANDLE 3 CASKS AT
MAX FLOW = 18.6 GPM, TWO AT
MAINTENANCE FLOW = 3.8 GPM WITH A 2.6 GPM
MARGIN —

$$\begin{array}{rcl} 18.6 & \text{MAX.} & \\ 3.8 & \text{MAINT.} & \\ \underline{2.6} & \text{MARGIN} & \\ \underline{\underline{25.0 \text{ GPM}}} & & \end{array}$$

∴ 25 GPM WILL BE UTILIZED

SYSTEM DESIGN

FLOW FROM THE HOT WATER TANK TO THE CASKS WILL BE BY GRAVITY ONLY - THE TANK IS ASSUMED TO BE LOCATED IN THE HVAC AREA - AVAILABLE PRESSURE HEAD = 32'

THIS IS APPROXIMATELY 14 PSI - THE ΔP WILL BE SPLIT $\frac{1}{2}$ FOR LINE LOSSES $\frac{1}{2}$ FOR CONTROL - $\therefore \Delta P_{\text{LINE}} = 7 \text{ PSI}$

FOR 2" PIPE $V = 1.3 \text{ FEET/SECOND}$

$\Delta P_{\text{FRICTION}} \sim 0.2 \text{ PSI/100'}$

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FOR THE PURPOSES OF CONCEPTUAL
DESIGN 2" PIPE WILL BE USED FOR MAJOR
SYSTEM ^{SECTIONS} ~~BRANCHES~~ WITH 1" PIPE USED
FOR BRANCHES.

PUMP SIZE = 25 GPM

OUTLET PRESSURE = 300 PSIA

INLET PRESSURE = 14.7 PSIA

HOT WATER TANK (Now A PRESSURE TANK)

ASSUMING 5 CASKS BEING COOLED IN
PARALLEL WITH A MAX FLOW TO EACH OF
2.5 GPM TOTAL FLOW = 12.5 GPM.

ASSUME ALSO THAT THE MAXIMUM ^{VOLUME} ~~LEVEL~~
VARIATION IN A 1 HR PERIOD SHOULD NOT
BE MORE THAN 20% OF THE VOLUME

$$\therefore \text{TANK SIZE} = \frac{(12.5 \frac{\text{GAL}}{\text{MIN}})(60 \frac{\text{MIN}}{\text{HR}})}{20\%/\text{HR}}$$
$$= \underline{3750 \text{ GAL}}$$

THIS IS A LARGE VOLUME OF WATER TO
MAINTAIN AT A HIGH TEMPERATURE $\therefore 40\%/\text{HR}$

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1/31/77

WILL BE ASSUMED GIVING A VOLUME OF 1775 GAL
THE TANK WILL BE SIZED AT 2000 GAL

CATCH TANK

LOW TEMP RECEIVER

THE RECEIVER WILL BE SIZED AT
500 GALLONS CAPACITY

- TO BE CALCULATED
SYSTEM CONDENSER AFTER SYSTEM BALANCE
COMPLETED -
SIZED ON THE BASIS OF 5 CASKS IN

PHASE I COOLING -

$$Q = 5(341,000 \frac{\text{BTU}}{\text{HR}})$$

$$= 1,705,000 \frac{\text{BTU}}{\text{HR}}$$

SAY 2,000,000 BTU/HR FOR DESIGN
PURPOSES

CATCH TANK

THE TANK HAS A 3000 GAL CAPACITY

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KPB
2/3/77

PARTIAL HEAT BALANCE AND COMPONENT SIZING

ASSUMPTIONS: $T_1 = 150^\circ\text{F}$
 $P_1 \approx 250 \text{ PSIA}$ } WATER

$T_3 = 400^\circ\text{F}$
 $P_3 \approx 250 \text{ PSIA}$ } WATER

$$\left. \begin{array}{l} T_4 = 400^\circ\text{F} \\ P_4 \approx 250 \text{ PSIA} \end{array} \right\} \text{STEAM}$$
$$T_5 = T_4 \quad P_4 = P_5$$
$$Q_c = 341,000 \text{ BTU/HR}$$

VAPORIZATION

F = FLOW

COMPONENT DESIGN BASIS

$$T_2 = 380^\circ\text{F} \quad T_6 = 370^\circ\text{F}$$
$$P_2 = P_1 \quad F_8 = F_1 = F_2 = F_3 = F_4 = F_5 = F_6$$

$$\therefore Q_{20} = 413 \frac{\text{LB}}{\text{HR}} (h_{880} - h_{150})$$

$$= 413(353.45 - 117.89)$$

$$= 413(235.56)$$

$$Q_{12} = 97,000 \text{ BTU/HR RECOVERY}$$

$$\left. \begin{aligned} Q_{23} &= 413 \text{ LB/HR } (h_{400} - h_{380}) \\ &= 413 (374.97 - 353.45) \\ &= 413 (21.52) \end{aligned} \right\} \begin{array}{l} \text{ELECTRIC} \\ \text{HEAT} \\ \text{ADDITION} \end{array}$$

$$Q_{23} = 9,100 \text{ BTU/HR}$$

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KPB
2/3/77

$$\begin{aligned} F_5 = F_6 &= Q_{12} / [h_{fg}(400) + \Delta h_{f400-300}] \\ &= \frac{97,000 \frac{\text{BTU}}{\text{HR}}}{\frac{1201.0 \frac{\text{BTU}}{\text{LB}}}{826} + (374.97 - 269.59) \frac{\text{BTU}}{\text{LB}}} \\ &= \frac{97000}{931.4} \text{ LB/HR} \end{aligned}$$

$$F_5 = F_6 = 104 \text{ LB/HR}$$

$$F_7 = 413 - 104 \text{ LB/HR}$$

$$F_7 = 309 \text{ LB/HR}$$

$$F_8 = 413 \text{ LB/HR}$$

$$\begin{aligned} \Delta Q \text{ FOR SYSTEM} &= 341,000 - 97,000 + 9,100 \\ &= 244,000 \text{ BTU/HR REJECTED} \\ &\text{IN PHASE I TO AN EXTERNAL} \end{aligned}$$

$$\begin{aligned} \therefore Q_{\text{CONDENSER}} &= \frac{\overset{\text{SYSTEM}}{253,000} \text{ BTU/HR}}{\text{CASK}} \text{ (5 CASKS)} \\ &= \frac{1,265,000 \text{ BTU/HR}}{\text{CASK}} \\ &\sim \underline{\underline{1,300,000 \text{ BTU/HR MAXIMUM}}} \end{aligned}$$

THIS IS THE PEAK SYSTEM HEAT LOAD TO BE
CONSIDERED FOR REJECTION TO ATMOSPHERE
AND TO BE CONSIDERED FOR CONSERVATION.

SYSTEM CONFIGURATION

COMPONENT DATA

HEAD TANK

CAPACITY = 2000 GAL

DESIGN PRESSURE = 300 PSIA

" TEMPERATURE = 180°F

SYSTEM PUMP - 2 INSTALLED - 1 AS SPARE

FLOW = 25 GPM

INLET TEMPERATURE = 150°F

" PRESSURE = ATMOSPHERIC

DISCHARGE PRESSURE = 300 PSIA (MAX RUNOUT)

" 250 PSIA NORMAL

HOT WATER HEATER (STEAM)

MAXIMUM FLOW = 6.2 GPM

" " $\Delta P = 5 \text{ PSI}$

NORMAL FLOW = 0.83 GPM

INLET PRESSURE $\approx 260 \text{ PSIA}$

INLET TEMPERATURE = 150°F

OUTLET TEMPERATURE = 380°F

$Q = 97,000 \text{ BTU/HR}$

ELECTRIC HEATER (SUPPLEMENTAL)

MAXIMUM FLOW = 6.2 GPM

" " $\Delta P = 5 \text{ PSI}$

NORMAL FLOW = 0.83 GPM

INLET PRESSURE $\approx 255 \text{ PSIA}$

INLET TEMPERATURE = 380°F

OUTLET TEMPERATURE = 400°F

$Q = 9,100 \text{ BTU/HR}$

SHELL & TUBE
STEAM IN SHELL

SHORT TERM DUTY

$Q = 107,000 \text{ BTU/HR}$

$T_{\text{IN}} = 150^\circ\text{F}$

$T_{\text{OUT}} = 400^\circ\text{F}$

FLOW = 0.83 GPM

-THIS IS THE
STARTUP MODE

KNOCK-OUT POT

CAPACITY = 150 GALLONS

DESIGN PRESSURE = 300 PSIA

" TEMPERATURE = ~~400~~⁴⁵⁰ $^\circ\text{F}$

~~TOO~~ LIQUID RECEIVER

CAPACITY = 500 GAL. PER PAGE 9

DESIGN PRESSURE = 300 PSIA

" TEMPERATURE = 400°F

VENT CONDENSER

CAPACITY = 24,000 BTU/HR (10% OF MAIN UNIT)

KNOCKOUT DRUM = 10 GALLON CAPACITY

OPERATING NOTES

1. RELIEF VALVES DISCHARGE TO THE BUILDING SUMP
2. SYSTEM MAKE-UP WATER COMES FROM THE RADWASTE RECYCLE TANK. IF WATER IN THIS SYSTEM BECOMES EXCESSIVELY CONTAMINATED IT IS ROUTED TO THE RAD WASTE SYSTEM FOR PROCESSING - NO PROCESSING WILL BE PERFORMED IN THIS SYSTEM. THE SYSTEM WILL RELY UPON THE CAPACITY OF THE RAD WASTE SYSTEM. EXCESS LIQUIDS WILL ALSO BE DRAINED TO THE LIQUID WASTE SYSTEM.

ENERGY CONSERVATION

HEAT FROM THE SYSTEM WILL BE DUMPED VIA AIR-WATER HEAT EXCHANGERS - TO BE LOCATED IN EITHER THE INLET OR DISCHARGE AIR STREAMS - ELIMINATING THE NEED FOR ADDITIONAL FANS - ONLY PENALTY ASSOCIATED WITH SYSTEM IS NEED TO INSTALL TWO H_x'S AND ASSOCIATED PIPING - TWO REQ'D BECAUSE BLDG WON'T ALWAYS BE ABLE TO USE, OR NEED INLET AIR PREHEATING - IN ADDITION INLET FANS AREN'T ON VITAL BUS AND A MEANS OF ASSURED HEAT REJECTION VIA THE EXHAUST SYSTEM (UTILIZES VITAL POWER) IS REQUIRED -

$$\begin{aligned} \text{MAXIMUM ENERGY AVAILABLE/YEAR} &= \frac{253,000}{1,012,000} \text{ BTU/HR (4 HRS)} \\ \text{ENERGY/CASK} &= \frac{253,000}{1,012,000} \text{ BTU/HR (4 HRS)} \\ &= 1,364,000 \text{ BTU} \end{aligned}$$

$$\begin{aligned} \text{CASKS/YR} &= \frac{50 \text{ CANS}}{\text{WK}} = 7 \text{ CASKS/WK} = 364 \frac{\text{CASKS}}{\text{YR}} \\ &\quad \frac{7 \text{ CANS/CASK}}{} \end{aligned}$$

$$\begin{aligned} \text{MAX ENERGY/YR} &= 364 (1,012,000) \\ &= 3.79 \times 10^8 \text{ BTU/YR} \end{aligned}$$

$$\text{ASSUME SYSTEM RECOVERS 80\%} \therefore Q_R = \underline{\underline{3.01 \times 10^8 \text{ BTU/YR}}}$$

APPROXIMATE COST OF SYSTEM = \$

COST COVERS ONE H_x, VALVES AND 200' OF 1" PIPE. (4-2 CONTROL)

16
KRB
2-9-77

ENERGY CONSERVATION PAYOFF WILL HAVE TO
OFFSET THE OPERATING AND SAFETY AND MAINTENANCE
PROBLEMS ASSOCIATED WITH A DUAL HEAT REJECTION
SYSTEM.

CASK COOLING SYSTEM

HEAT RECOVERY MODE

Systems

1. Baseline - heat recovery is utilized for the RH building to preheat inlet air ~~with~~ via a water loop from the building discharge.

2. Heat Recovery - the cask cooling system would supplement the above recovery system by providing heat to the water system.

Assumptions

1. The cooling system is a highly variable source of heat with complete dependence upon the rate of waste removal.

2. Building heating (RH bldg) is expected to occur over only a 4 month period per year, further the occurrence of waste heat need and availability is assumed to be only 50% of the time. Therefore the

2-7-77

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Z

waste heat recovery will represent only $\frac{1}{6}$ th of the annual energy available from the system.

Calculations

From 2-3-77 Calculations, page 15,

$$\text{Max Energy / year} = 3.79 \times 10^8 \text{ BTU}$$

$$\text{Recoverable} = \frac{1}{6} (\text{Max})$$

$$= \frac{3.79 \times 10^8}{6}$$

$$= .63 \times 10^8$$

$$= \underline{\underline{6.3 \times 10^7 \text{ BTU/YR}}}$$

For analysis the baseline system is assumed to be in at \$0 capital cost but it uses energy in the above amount.

The alternative system has a capital cost but utilizes only minimal energy.

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3

The data sheet is attached.

System would look like

SYSTEM WOULD REQUIRE 200' OF 2" PIPE AND
TWO VALVES, HEAT EXCHANGER AND INSTRUMENTS
AND SPACE -

PIPE	4,000
4x	3,000
VALVES	500

BLDG SPACES 5,000

SAY \$15,000 TOTAL COST

See Page 10

2-7-77

KPB

4

$$\text{ELECTRICAL ENERGY USED} = 1 \text{ HP FOR} \\ \text{2 MONTHS} = 8 \text{ wks} \left(\frac{168 \text{ HRS}}{\text{WK}} \right) 1 \text{ HP} \left(\frac{.7457 \text{ KW}}{\text{HP}} \right)$$

$$= 1008 \text{ KWHR / YEAR} \\ \text{CONSUMPTION} = \left(\frac{1008 \text{ KWHR}}{\text{YEAR}} \right) \frac{3415 \text{ BTU}}{\text{KWHR}} \\ = 3.69 \times 10^6 \text{ BTU/YR}$$

COST OF ENERGY

$$\text{FUEL OIL FOR STEAM} = \$.35 / \text{GALLON}$$

$$\text{ELECTRICITY} = \$ 0.016 / \text{KW} + 4.25 \text{ DEMAND}$$

STEAM COST

$$\text{STEAM } 1390 \text{ BTU/LB}$$

$$\text{LBS STEAM} = \frac{6.3 \times 10^7 \text{ BTU}}{\text{YR}} \\ \frac{1.39 \times 10^3 \text{ BTU/LB}}{=} \\ = \underline{\underline{4.5 \times 10^4 \text{ LB/YR}}}$$

FUEL OIL BURNED TO CREATE STEAM

$$\text{GALLONS OIL} = \frac{6.3 \times 10^7 \text{ BTU/YR}}{1.39 \times 10^3 \text{ BTU/GAL}}$$

$$\text{COST OF OIL} = \$ 0.35 / \text{GAL} \\ = 4.5 \times 10^2 \\ = 450 \text{ GAL/YR} \\ = \underline{\underline{\$ 157.50 / YR}}$$

2-7-77
KRB
5

COST OF STEAM / 10^6 BTU

OIL = \$0.35 / GALLON

1 GALLON = 138,700 BTU

$$10^6 \text{ BTU} = \frac{10^6}{1.39^{+5}} (.35)$$
$$= 2.52$$

ASSUME COST = \$5.00 TO TAKE INTO
ACCOUNT O&M, ETC ON STEAM PLANT

COST OF ELECTRICITY / 10^6 BTU

~~10.35~~

COST OF ELECTRICITY IS BASED ON HEAT
AVAILABLE FROM 1 KWHR 1 KWHR = 3415 BTU

COST OF 1 KWHR = \$0.016

$$10^6 \text{ BTU} = \frac{10^6}{3.415^{+3}} (.016) = \underline{\underline{293 \text{ KWTS}}}$$
$$= .293^{+3} (.016)$$
$$= \$4.68 \text{ PER } 10^6$$

$$\text{TOTAL} = 4.68 + 4.25 = \underline{\underline{\$8.93}}$$

2-7-77

KPB

6

COSTS

HEAT EXCHANGER \$ 25 / FT²
PIPE \$ 5.00 / FT
VALVES \$ 55.00 EACH

H _x = 100 FT ² (\$25)	2500
PIPE = 200' (\$5)	1000
VALVES = \$55 (6)	<u>330</u>
	3830
CONTINGENCY	<u>1200</u>
TOTAL	= 5030

DEMAND = \$1.75 / KW / MONTH
BASED ON PEAK DEMAND

Life cycle cost calculations run on LIFCY 1 for various assumptions on energy saved and cost of energy are attached. In all cases the payoff period is > 25 years. Therefore the heat recovery systems considered for this system over and above those utilized in the basic design are uneconomic and will not be utilized in the WIPP design.

77/02/08. 10.11.32.
PROGRAM LIFCY1

\$\$\$ LIFE-CYCLE COST COMPARISONS \$\$\$

♦♦INPUT DATA♦♦

BLDG: RH
PROJ. DIR. NO.: WIPP CONCEPTUAL DESIGN

LOCATION: CASK COOLING
DESIGNER: K. BROWN #4

COST OF ELECTRICAL ENERGY USED, PER MILLION BTU = \$8.9300
COST OF STEAM, GAS OR OTHER ENERGY USED, PER MBTU = \$7.2000
YEARLY ESCALATION RATE FOR ELECTRICITY IS 5.7 %
YEARLY ESCALATION RATE FOR STEAM, GAS OR OIL IS 8.0 %
YEARLY DISCOUNT RATE IS 8.0 %
NUMBER OF ALTERNATIVES BEING CONSIDERED ARE 2 ALTERNATES

♦♦♦RESULTS OF ECONOMIC STUDY♦♦♦

ALTERNATE NO. 1 DATA (BASELINE)

INSTALLATION FIRST COST..... \$.00
ANNUAL O & M COST (LESS ENERGY).... \$.00
ELECTRICAL ENERGY USED..... 0 MILLION BTU
STEAM, GAS AND/OR OIL USED..... 63 MILLION BTU
ECONOMIC LIFE..... 25 YEARS

RESULTS

TOTAL FIRST YEAR ENERGY COST IS \$453.60
TOTAL ANNUALIZED COST IS \$1,062.32
TOTAL PRESENT WORTH IS \$11,340.00

ALTERNATE NO. 2 DATA (HEAT RECOVERY)

INSTALLATION FIRST COST..... \$10,000.00
ANNUAL O & M COST (LESS ENERGY).... \$200.00
ELECTRICAL ENERGY USED..... 3.7 MILLION BTU
STEAM, GAS AND/OR OIL USED..... 0 MILLION BTU
ECONOMIC LIFE..... 25 YEARS

RESULTS

TOTAL FIRST YEAR ENERGY COST IS \$33.04
TOTAL ANNUALIZED COST IS \$1,195.99
TOTAL PRESENT WORTH IS \$12,766.90

♦♦♦DISCOUNTED PAYBACK PERIODS♦♦♦

TO GO FROM ALT 1♦ TO ALT 2 PAYOFF PERIOD IS GREATER THAN 25 YEARS!!!!
SAVINGS/INVESTMENT RATIO IS .857
ENERGY SAVINGS IS 148,249 BTU PER ANNUAL DISCOUNTED INVESTMENT DOLLAR.

♦ - LOWEST INCREMENTAL INSTALLATION FIRST COST ALTERNATE

SRU 1.230 UNITS.

RUN COMPLETE.

\$\$\$\$ LIFE-CYCLE COST COMPARISONS \$\$\$\$

◆◆INPUT DATA◆◆

BLDG: RH
PROJ. DIR. NO.: WIPP CONCEPTUAL DESIGN

LOCATION: CASK COOLING
DESIGNER: K. BROWN #3

COST OF ELECTRICAL ENERGY USED, PER MILLION BTU = \$4.6800
COST OF STEAM, GAS OR OTHER ENERGY USED, PER MBTU = \$7.2000
YEARLY ESCALATION RATE FOR ELECTRICITY IS 5.7 %
YEARLY ESCALATION RATE FOR STEAM, GAS OR OIL IS 8.0 %
YEARLY DISCOUNT RATE IS 8.0 %
NUMBER OF ALTERNATIVES BEING CONSIDERED ARE 2 ALTERNATES

◆◆◆RESULTS OF ECONOMIC STUDY◆◆◆

ALTERNATE NO. 1 DATA (BASELINE)

INSTALLATION FIRST COST.....	\$.00
ANNUAL O & M COST (LESS ENERGY)....	\$.00
ELECTRICAL ENERGY USED.....	0 MILLION BTU
STEAM, GAS AND/OR OIL USED.....	63 MILLION BTU
ECONOMIC LIFE.....	25 YEARS

RESULTS

TOTAL FIRST YEAR ENERGY COST IS	\$453.60
TOTAL ANNUALIZED COST IS	\$1,062.32
TOTAL PRESENT WORTH IS	\$11,340.00

ALTERNATE NO. 2 DATA (HEAT RECOVERY)

INSTALLATION FIRST COST.....	\$10,000.00
ANNUAL O & M COST (LESS ENERGY)....	\$200.00
ELECTRICAL ENERGY USED.....	3.7 MILLION BTU
STEAM, GAS AND/OR OIL USED.....	0 MILLION BTU
ECONOMIC LIFE.....	25 YEARS

RESULTS

TOTAL FIRST YEAR ENERGY COST IS	\$17.32
TOTAL ANNUALIZED COST IS	\$1,167.81
TOTAL PRESENT WORTH IS	\$12,466.14

◆◆◆DISCOUNTED PAYBACK PERIODS◆◆◆

TO GO FROM ALT 1◆ TO ALT 2 PAYOFF PERIOD IS GREATER THAN 25 YEARS!!!!
SAVINGS/INVESTMENT RATIO IS .887
ENERGY SAVINGS IS 148,249 BTU PER ANNUAL DISCOUNTED INVESTMENT DOLLAR.

◆ - LOWEST INCREMENTAL INSTALLATION FIRST COST ALTERNATE

SRU 1.228 UNITS.

RUN COMPLETE.

\$\$\$ LIFE-CYCLE COST COMPARISONS \$\$\$

◆◆ INPUT DATA ◆◆

BLDG: RH
PROJ. DIR. NO.: WIPP CONCEPTUAL DESIGN

LOCATION: CASK COOLING
DESIGNER: K. BROWN #2

COST OF ELECTRICAL ENERGY USED, PER MILLION BTU = \$4.6800
COST OF STEAM, GAS OR OTHER ENERGY USED, PER MBTU = \$5.0000
YEARLY ESCALATION RATE FOR ELECTRICITY IS 5.7 %
YEARLY ESCALATION RATE FOR STEAM, GAS OR OIL IS 8.0 %
YEARLY DISCOUNT RATE IS 8.0 %
NUMBER OF ALTERNATIVES BEING CONSIDERED ARE 2 ALTERNATES

◆◆◆RESULTS OF ECONOMIC STUDY◆◆◆

ALTERNATE NO. 1 DATA (BASELINE)

INSTALLATION FIRST COST.....	\$.00
ANNUAL O & M COST (LESS ENERGY)....	\$.00
ELECTRICAL ENERGY USED.....	0 MILLION BTU
STEAM, GAS AND/OR OIL USED.....	63 MILLION BTU
ECONOMIC LIFE.....	25 YEARS

RESULTS

TOTAL FIRST YEAR ENERGY COST IS	\$315.00
TOTAL ANNUALIZED COST IS	\$737.72
TOTAL PRESENT WORTH IS	\$7,875.00

ALTERNATE NO. 2 DATA (HEAT RECOVERY)

INSTALLATION FIRST COST.....	\$10,000.00
ANNUAL O & M COST (LESS ENERGY)....	\$200.00
ELECTRICAL ENERGY USED.....	3.7 MILLION BTU
STEAM, GAS AND/OR OIL USED.....	0 MILLION BTU
ECONOMIC LIFE.....	25 YEARS

RESULTS

TOTAL FIRST YEAR ENERGY COST IS	\$17.32
TOTAL ANNUALIZED COST IS	\$1,167.81
TOTAL PRESENT WORTH IS	\$12,466.14

◆◆◆DISCOUNTED PAYBACK PERIODS◆◆◆

TO GO FROM ALT 1 TO ALT 2 PAYOFF PERIOD IS GREATER THAN 25 YEARS!!!!
SAVINGS/INVESTMENT RATIO IS .541
ENERGY SAVINGS IS 148,249 BTU PER ANNUAL DISCOUNTED INVESTMENT DOLLAR.

♦ - LOWEST INCREMENTAL INSTALLATION FIRST COST ALTERNATE

SRU 1.206 UNTS.

RUN COMPLETE.

RUN

77/02/08, 10.08.07.
PROGRAM LIFCY1

\$\$\$\$ LIFE-CYCLE COST COMPARISONS \$\$\$\$

◆◆INPUT DATA◆◆

BLDG: RH
PROJ. DIR. NO.: WIPP CONCEPTUAL DESIGN

LOCATION: CASK COOLING
DESIGNER: K. BROWN #1

COST OF ELECTRICAL ENERGY USED, PER MILLION BTU = \$8.9300
COST OF STEAM, GAS OR OTHER ENERGY USED, PER MBTU = \$5.0000
YEARLY ESCALATION RATE FOR ELECTRICITY IS 5.7 %
YEARLY ESCALATION RATE FOR STEAM, GAS OR OIL IS 8.0 %
YEARLY DISCOUNT RATE IS 8.0 %
NUMBER OF ALTERNATIVES BEING CONSIDERED ARE 2 ALTERNATES

◆◆RESULTS OF ECONOMIC STUDY◆◆

ALTERNATE NO. 1 DATA (BASELINE)

INSTALLATION FIRST COST..... \$0.00
ANNUAL O & M COST (LESS ENERGY).... \$0.00
ELECTRICAL ENERGY USED..... 0 MILLION BTU
STEAM, GAS AND/OR OIL USED..... 63 MILLION BTU
ECONOMIC LIFE..... 25 YEARS

RESULTS

TOTAL FIRST YEAR ENERGY COST IS \$315.00
TOTAL ANNUALIZED COST IS \$737.72
TOTAL PRESENT WORTH IS \$7,875.00

ALTERNATE NO. 2 DATA (HEAT RECOVERY)

INSTALLATION FIRST COST..... \$10,000.00
ANNUAL O & M COST (LESS ENERGY).... \$200.00
ELECTRICAL ENERGY USED..... 3.7 MILLION BTU
STEAM, GAS AND/OR OIL USED..... 0 MILLION BTU
ECONOMIC LIFE..... 25 YEARS

RESULTS

TOTAL FIRST YEAR ENERGY COST IS \$33.04
TOTAL ANNUALIZED COST IS \$1,195.99
TOTAL PRESENT WORTH IS \$12,766.90

◆◆DISCOUNTED PAYBACK PERIODS◆◆

TO GO FROM ALT 1◆ TO ALT 2 PAYOFF PERIOD IS GREATER THAN 25 YEARS!!!!
SAVINGS/INVESTMENT RATIO IS .511
ENERGY SAVINGS IS 148,249 BTU PER ANNUAL DISCOUNTED INVESTMENT DOLLAR.

◆ - LOWEST INCREMENTAL INSTALLATION FIRST COST ALTERNATE

SRU 1.200 UNTS.

RUN COMPLETE.

HOLMES & HARVER, INC.
ENGINEERS - CONSTRUCTORS

PHONE-TALK

TO: K. R. Brown

Date: September 3, 1976

FROM: B. Steinbaugh, Sandia Labs. *VRB*

Page 1 of 1

SUBJECT: WIPP - ENERGY COSTS AND WATER SUPPLY

Bob called with the following energy costs:

	Cost/1,000,000 BTU	Use
Natural Gas	\$ 0.40	<i>Pres</i> .85 — 1.50/10 ⁶ BTU
Fuel Oil	2.14	.33 — .35 gal
Electricity	6.74	.0134 — .016/ (4-25 demand charge) (3.90)

Sandia currently favors the Double Eagle water system but would like to carry both Double Eagle and Carlsbad through the cost estimate phase of the project.

I requested that Bob investigate for any available rainfall data in the vicinity of the site for use in hydrology studies.

Drawings of the Super Tiger and 600 series ATMX cars are being sent in the mail to F&S and H&N.

KRB/bl

cc: L. Scully, Sandia Labs.
B. Steinbaugh, Sandia Labs.
J. Ash, Fenix & Scisson
M. Klatskin
A. Dunham

Coal
19.00/ton at mine

ERDA STANDARDS BTU CONVERSION FACTOR
FOR ENERGY CONSERVATION REPORTING (1)

Form of Energy	Btu Content	Btu x 10 ⁹ per Reporting Unit
Electricity (2)	11,600 Btu/KWH	0.0116 per MWH (Megawatt hour)
Fuel Oil	138,700 Btu/Gal.	0.1387 per 1000 Gallon
Natural Gas	1,031 Btu/C.F.	0.001031 per 1000 C.F.
LPG (3)	95,500 Btu/Gal.	0.0955 per 1000 Gal.
Coal	24,580,000 Btu/Short ton	0.2458 per short ton
Other (Examples) - Steam (4)	1,390 Btu/Lb.	0.00139 per 1000 Lbs.
- Chilled Water (5)	24,000 Btu/Ton-hour	0.024 per 1000 ton-hours
- Methanol	63,500 Btu/Gal.	0.0635 per 1000 Gal.
Automotive Gasoline	125,000 Btu/Gal.	0.125 per 1000 Gal.
Diesel	138,700 Btu/Gal.	0.1387 per 1000 Gal.
Aviation Gasoline	125,000 Btu/Gal.	0.125 per 1000 Gal.
Jet Fuel	130,000 Btu/Gal.	0.130 per 1000 Gal.

- (1) The use of different conversion factors is permitted only where such factors are identified and justified, and is subject to FCM approval.
- (2) Electricity - Assumes 10,536 Btu per KWH generated at station and 9% line loss.
- (3) Includes Propane and Butane.
- (4) Assumes 1000 Btu per pound of steam generated at boiler plant, 80% boiler efficiency at 11% line loss.
- (5) Assumes 12,000 Btu per ton-hour, and overall efficiency and 11% line loss.

HVAC CALCULATIONS

These calculations are supplemented
by the HVAC Energy Study

2-7-77

LIFCYL

INPUT DATA

4030 DATA "	TRU Waste Facility	"	Bldg. Name - K\$
4040 DATA "	Carlsbad	"	Location - J\$
4050 DATA "	Brown	"	Proj. Dir. No. - P\$
4060 DATA "	Klatzkin BROWN	"	Designer - D\$
4070 DATA	\$8.93 4.68		Cost of Electricity, Per MBTU - C2 10
4080 DATA	\$5.00 (7.20)		Cost of Steam, gas and/or oil, per MBTU-C3
4090 DATA	5.7%		Annual Electricity Escalation Rate, % - R1
4100 DATA	Oil - 8%		Annual Steam, Gas or Oil Escalation Rate, % - R2
4110 DATA	8%		Annual Cost of Money (discount rate), % - I
4120 DATA	2		Number of Alternates being considered - H

ALTERNATE NO. 1

4130 DATA "	Baseline	"	Alternate Name - A\$
4140 DATA	0		Installation First Cost - C
4150 DATA	0		Annual O&M Cost (less energy) - M
4160 DATA	—		Electrical Energy Used, MBTU - E
4170 DATA	63		Steam, Gas and/or Oil used, MBTU - S 63 ⁺⁶
4180 DATA	25		Economic Life, Years - N

ALTERNATE NO. 2

4190 DATA "	Heat Recovery	"	Alternate Name - A\$
4200 DATA	15,000 16,000		Installation First Cost - C
4210 DATA	200 200		Annual O&M Cost (less energy) - M
4220 DATA	3.69 ⁺⁶		Electrical Energy Used, MBTU - E
4230 DATA	0		Steam, Gas and/or Oil used, MBTU - S
4240 DATA	25		Economic Life, Years - N

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 1 OF 3TITLE WIPP-HVAC (High & Low Level Facilities)BY MK DATE 1-20-77Design Criteria (Work Areas)

Summer	Outside	99°F	
	Inside	82°F	$\Delta T = 17^{\circ}F$
Winter	Outside	21°F	
	Inside	65°F	$\Delta T = 44^{\circ}F$
	(Offices)		
Winter	Inside	72°	$\Delta T = 51^{\circ}F$

"U" Factors

Walls	0.097
Roof	0.08
Slab	0.16

Total Equiv. Temp Dif. Correction

Inside $75 - 82 = -7^{\circ}$ outside $99 - 85 = 14^{\circ}$
 total correction = $14 - 7 = 7^{\circ}F$

High Level Fac. (High Bay only)

Summer Inside = $\frac{T_o + T_i}{2} = \frac{99 + 82}{2} = 90.5$ $\Delta T = 8.5^{\circ}F$

Winter Inside = $\frac{T_o + T_i}{2} = \frac{21 + 65}{2} = 43$ $\Delta T = 22.0^{\circ}F$

"U" Factor

Wall	0.5025
------	--------

TETD Correction

Inside $75 - 90.5 = -15.5$ outside $99 - 85 = 14$

total correction = $14 - 15.5 = -1.5^{\circ}F$

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 2 OF 3TITLE WIPP - HVACBY MK DATE 1-20-77

Construction Data - "U" Factors

Exterior Wall

	f_o	0.17
Concrete (24")		2.28
	f_i (2)	1.36
Block (12" L.W. w/ filled voids)		5.82
	f_i	0.68
		<u>10.31</u>

$$U = \frac{1}{10.31} = 0.9699$$

Roof

	f_o	0.25
Roofing		0.33
Insulation (Rigid-3 1/2")		9.68
Slab (Concrete-12")		1.32
	f_i	0.92
		<u>12.50</u>

$$U = \frac{1}{12.50} = 0.08$$

Exterior Wall (High Level - High Bay)

	f_o	0.17
Concrete (12")		1.14
	f_i	0.68
		<u>1.99</u>

$$U = \frac{1}{1.99} = 0.5025$$

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS—CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 3 OF 3TITLE WIPP - HVACBY MK DATE 1-20-77*Multiplying Factors @ 4:00 P.M. Sun Time*

NE Wall	0.09699 (14+7)	2.037
NW Wall	0.09699 (13+7)	1.94
SE Wall	0.09699 (15+7)	2.134
SW Wall	0.09699 (15+7)	2.134
SW Door	0.65 (27+7)	22.1
Roof	0.08 (23+7)	2.4

Winter

Wall	0.09699 (44)	4.267
Roof	0.08 (44)	3.52

High Level (High Bay) @ 4:00 P.M. Sun Time

NE Wall	0.5025 (14-1.5)	6.28
NW wall	0.5025 (13-1.5)	5.779
NW Door	1.0 (21-1.5)	19.5
SE Wall	0.5025 (15-1.5)	6.784
SE Door	1.0 (21-1.5)	19.5
SW Wall	0.5025 (15-1.5)	6.784
Roof	0.08 (23-1.5)	1.72

Winter

Wall	0.5025 (22)	11.055
Roof	0.08 (22)	1.76

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 1 OF 6TITLE TRU Waste FacilityBY MK DATE 1-20-77Internal Heat Gain AssumptionsUnloading/Loading Area

Lighting	4 watts/sq.ft.	= 13.65 BTU/#
Drums	320 @ 10 w	= 10,052
Hoists (50% use.)	2 @ 40 HP = $\frac{40 \times 750 \times 3.413}{2}$	= 102,390
People	10 @ 300 BTU (sens.)	= 3,000

Inventory/Prep Area

Lighting	4 watts/sq.ft.	= 13.65 BTU/#
Drums	1300 + 320 = 1620 @ 10 w	= 50,890
Forklifts (75% use.)	2 @ 20 ton = $\frac{40 \times 3 \times 750 \times 3.413}{1.254}$	= 230,262
People	25 @ 300 BTU (sens.)	= 7,500

Overpack/Repair/Lab

Lighting	4 watts/sq.ft.	= 13.65 BTU/#
Drums	60 @ 10 w	= 1885
Hoist (50% use.)	40 HP = $\frac{40 \times 750 \times 3.413}{2}$	= 51,195
People	5 @ 300 BTU (sens.)	= 1,500

Office Area

Lighting	3 watts/sq.ft.	= 10.24
People	10 @ 250 BTU (sens.)	= 2,500

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS—CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 2 OF 6TITLE TRU Waste FacilityBY MK DATE 1-20-77Unloading / Loading Area

	Area	Factor	Cooling	Factor	Heating
NE Wall	$297 \times 40 = 11,880$	2.037	24,200	4.267	50,692
NW Wall	$(54 \times 40) - 324 = 1836$	1.94	3,562	4.267	7,834
NW Door	$18 \times 18 = 324$	$\frac{17}{2} = 8.5$	2,754	$4\frac{1}{2} = 22$	7,128
SE Wall	$(54 \times 40) - 972 = 1,188$	2.134	2,535	4.267	5,069
SE Door	$3 @ 18 \times 18 = 972$	8.5	7,880	22	20,394
Roof	$297 \times 54 = 16,038$	2.4	38,491	3.52	56,454
Lights @ 4 w/ft	16,038	13.65	218,919		
Motors	2 @ 40 HP		102,390		
Drums	320 @ 10 W		10,052		
People	10 @ 300 BTU (Sens.)		3,000		
OSA (w/recov.)	21,333 \$	6 x 1.08	138,237	15.4 x 1.08	354,810
			552,020		502,351

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HOLMES & NARVER, INC.ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 3 OF 6TITLE TRU Waste FacilityBY MK DATE 1-20-77Inventory & Preparation

	Area	Factor	Cooling	Factor	Heating
NW Wall 64x24	1536	1.94	2980	4.267	6554
SW Wall 100x24	2400	2.134	5122	4.267	10241
SE Wall 160x24	3840	2.134	8195	4.267	16385
Roof 37,000 #	37,000	2.4	88800	3.52	130,240
Lights @ 4 w/#	37,000	13.65	505050		
Motors (2-20 ton diesel) @ 75% usage			230262		
Drums 1300+320 @ 10 w			50890		
People 25 @ 300 BTU (sens.)			7500		
OSA (w/recov.) 120,000 \$		6 x 1.08	777,600	15.4 x 108	1,995,840
			<u>1,676,400</u>		<u>2,159,240</u>

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS—CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 4 OF 6TITLE TRV Waste FacilityBY AK DATE 1-20-77Overpack & Repair & Lab

		Area	Factor	Cooling	Factor	Heating
NW Wall	96x40	3840	1.94	7,450	4.26	16,358
SW Wall	33x40	1320	2.134	2,817	4.26	5,623
SW Wall	33x25	825	2.134	1,760	4.26	3,515
SE Wall	64x15	960	2.134	2,044	4.26	4,090
Roof		5230	2.4	12,552	3.52	18,410
Lights	@ 4 w/#	5230	13.65	71,390		
Motors	40 HP (50% use)			51,195		
Drums	60 @ 10w			2,048		
People	5 @ 300 BTU (sens.)			1,500		
OSA (w/recov.)	10,460		6x1.08	67,780	15.4x1.08	173,970
				202,541		221,966

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HOLMES & NARVER, INC.ENGINEERS—CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251-00

APPROVED _____ DATE _____

SHEET 5 OF 6TITLE TRU Waste FacilityBY MK DATE 1-20-77Office Area

	Area	Factor	Cooling	Factor	Heating
SW Wall 130x24	3120	2.134	6,658	4.267	13,313
SW Doors 10x7=	70	17	1190	44	3,080
Lights 5290 ϕ @3w			54,164		
People 10 @ 250 BTU (sens)			2,500		
OSA - 10% of total air = 700 ϕ		17x1.08	12,852	44x1.08	32,264
			<u>77,364</u>		<u>48,657</u>

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801.JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 6 OF 6TITLE TRU Waste FacilityBY MK DATE 1-20-77*Summary of Heat/Cool Loads (w/ recovery)*

	Cooling	Heat(day)	Heat(night)
Loading Area	552,020	505,351	43,576
Inv./Prep. Area	1,676,400	2,159,240	665,698
Overpack/Lab	202,541	221,966	34,833
Office Area	77,364		8,007
	<div>2,430,961</div>	<div>2,886,557</div>	<div>736,100</div>

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 1 OF 6TITLE WIPP-HVAC-RH FacilityBY MK DATE 2-14-77Internal heat gain assumptionsPreparation & Decpn

Lighting	— 4 watts/sq. ft.	— 3888×13.652	=	53 079
Casks	— 48 cans @ 3.5 KW	— 48×11945.5	=	573 384
Hoists	— 160 HP @ 10% usage	— $160 \times 3072 \times .1$	=	49 152
Carts	— 2 @ 10 HP @ 100% usage	— $2 \times 3072 \times 1.0$	=	61 440
Turntable	— 5 HP @ 10% usage	— $5 \times 3072 \times .1$	=	1 536
Water Wash	— 20 HP @ 50% usage	— $20 \times 3072 \times .5$	=	30 720
People	— 4 working @ 300 BTU sensible		=	1 200
	— 2 mod. act. @ 250 BTU sensible		=	500
				<u>771 011</u>

Hot Cell

Lighting	— 4 watts/sq. ft.	— 1680×13.652	=	22 935
Casks	— 8 cans @ 100% + 10 @ 50%	— $13 \times 3.5 \text{ KW}$	=	155 291
Hoist	— 40 HP @ 100% usage	— $40 \times 3072 \times 1.0$	=	122 880
Elevator	— 25 HP @ 10% usage	— $25 \times 3072 \times .1$	=	7 680
Misc. Motors	— 10 HP @ 50% usage	— $10 \times 3072 \times .5$	=	15 360
				<u>324 146</u>

Decpn

Lighting	— 4 watts/sq. ft.	— 352×13.652	=	4 805
Casks	— 2 cans @ 3.5 KW	— 2×11945.5	=	23 891
Pumps	— 2 @ 60 HP @ 100% usage	— $120 \times 3072 \times 1.0$	=	368 640
Brushes	— 2 @ 25 HP @ 100% usage	— $50 \times 3072 \times 1.0$	=	153 600
				<u>550 936</u>

total 1,646,093 BTU

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS—CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251-00

APPROVED _____ DATE _____

SHEET 2 OF 6TITLE WIPP-HVAC-RH FacilityBY MK DATE 2-14-77Preparation & Decon

	Area sq ft	Factor	Cooling BTU	Factor	Heating BTU
SE Wall	54x50=2700	2.134	5761	4.267	11520
Roof	54x72 3888	2.4	9331	3.52	13686
Lights	3888	13.652	53079		
Casks	48 x	11945.5	573384		
Hoists	160 x 3072 x .1		49152		
Carts	20 x 3072 x 1.0		61440		
Turntable	5 x 3072 x .1		1536		
Water Wash	20 x 3072 x .5		30720		
People	1200 + 500		1700		
OSA (w/recovery)	19,440 sq ft	6 x 1.08	125971	15.4 x 1.08	323326
			<u>912074</u>		<u>348532</u>

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HOLMES & NARVER, INC.ENGINEERS—CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 3 OF 6TITLE WIPP-HVAC-RH FacilityBY MK DATE 2-14-77Hot Cell

		Area sq ft	Factor	Cooling BTU	Factor	Heating BTU
SE Wall	28x48 =	1344	2.134	2868	4.267	5735
Roof	28x60 =	1680	2.4	4032	3.52	5914
Lights		1680	13.652	22935		
Casks	13x	11945.5		155291		
Hoist	40x 3072 x	1.0		122880		
Elevator	25x 3072 x	.1		7680		
Misc. Motors	10x 3072 x	.5		15360		
OSA	8,064 sq ft		6x1.08	52254	15.4x1.08	134120
				383300		145769

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS-CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 4 OF 6TITLE WIPP-HVAC-RH FacilityBY MS DATE 2-14-77Decon

	Area	Factor	Cooling	Factor	Heating
	sq		BTU		BTU
Lights	22 x 16 = 352	13.652	4805		
Casks	2 x 11945.5		23891		
Pumps	120 x 3072		368640		
Brushes	50 x 3072		153600		
OSA (w/recovery)	9,000 5	6 x 1.08	<u>58,320</u>	15.4 x 1.08	<u>149,688</u>
			609,256		149,688

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HOLMES & NARVER, INC.

ENGINEERS-CONSTRUCTORS

400 E. ORANGETHORPE AVE.

ANAHEIM, CALIF. 92801

JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 5 OF 6TITLE WIPP-HVAC - RH FacilityBY MR DATE 2-14-77Shipping & Receiving

Area Factor Cooling Factor Heating

NW Wall

SW Wall

SW Door

NE Wall

NE Door

Roof

Lights

Hoist

People

OSA(w/recovery) 23,466 \$

(No Refrig.)

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS—CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.00

APPROVED _____ DATE _____

SHEET 6 OF 6TITLE WIPP-HVAC-RH FacilityBY MK DATE 2-14-77Offices & Control Room

		Area #	Factor	Cooling BTU	Factor	Heating BTU
NW Wall	167 x 15	2505	1.94	4860	4.267	10689
SW Wall	82 x 15	1230	2.134	2625	4.267	5248
SE Wall	39 x 15	585	2.134	1248	4.267	2496
Roof	82 x 39	3198	2.4	7675	3.52	11257
Lights	3198 @ 3 watts/#		10.239	32744		
Equipment	3198 @ 2 watts/#		6.826	21830		
People	10 @ 250 BTU sensible			2500		
OSA	7300\$ @ 10% = 730\$		17 x 1.08	13403	44 x 1.08	34690
				86885		64380

CHECKED _____ DATE _____

HOLMES & NARVER, INC.ENGINEERS—CONSTRUCTORS
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801JOB NO. 8251.10

APPROVED _____ DATE _____

SHEET 1 OF 1TITLE Use of Mine Exh. Air as Heat SinkBY MK DATE 11-12-76

Assume maximum mine exh. air = 500,000 cfm

Assume exhaust air at 85°F - 50% R.H.

(with sprayed coil) = 73°F - 90% R.H.)

Assume condenser water 75°F in - 95°F out = 20° Δt

Total sink available = $500,000 \times 20 \times 1.08 = 10,800,000$ BTUSink required per ton of absorption refrigeration
= $12,000 + 18,000 = 30,000$ BTU

$$\therefore \text{Total sink available} = \frac{10,800,000}{30,000} = 360 \text{ tons}$$

Note: Total facility load approx. 800-900 tons

Alternate I

Central Plant (Chillers - Boilers - Cooling Towers)

1. 3-300 ton chillers @ 37,000 (incl. starters & freight)	111,000
2. 3-300 ton cooling towers @ 5,800 (incl. freight & erection)	17,400
3. 6-40 HP circulating pumps @ 1450 (freight)	8,700
4. 2-5,000 # boilers @ 18,000
+ controls, cond. ret., blowoff, feedwater 8,250	44,250
5. 3 - converters @ 1500	4,500

Buried pipe (3'-6" depth)

6. 3,375' of 8" steel chilled water (insulated) @ 45°-55°F	
7. 1,688' of 6" steam (insulated) @ 100 psi	
8. 1,688' of 4" condensate return (insulated)	

Alternate II
(Separate cooling & heating each building)

TRU Bldg.

1.	2- 225 ton cent. heat pumps	@ 43,500	87,000
2.	2- 225 ton cooling towers	@ 4,300	8,600
3.	4- 25 HP pumps	@ 1,151	4,604
4.	1 heat exchanger	@ 1,000	1,000
			<hr/>
			101,204

RH Bldg.

1.	2- 150 ton cent. heat pumps	@ 38,400	76,800
2.	2- 150 ton cooling towers	@ 3,300	6,600
3.	4- 15 HP pumps	@ 955	3,820
4.	1 heat exchanger	@ 850	850
			<hr/>
			88,070

Administration Bldg.

1.	2- 75 ton recip. heat pumps	@ 20,000	40,000
2.	2- 75 ton cooling towers	@ 2,300	4,600
3.	4- 10 HP pumps	@ 755	3,020
4.	1 heat exchanger	@ 750	750
			<hr/>
			48,370

total 237,644

Alternate III

(Central cooling tower + separate cool. & heat. each bldg.)

1. 3- 300 ton cooling towers @ 5,800	17,400
2. 3 - 50 HP circ. pumps @ 1533	4,599
3. 3,375' of 10" steel buried pipe 80°-90°F
(wrapped w/minimum insulation)	

P/US

TRU Bldg.

1. 2-225 ton cent. heat pumps @ 43,500	87,000
2. 2- 25 HP pumps @ 1,151	2,302
3. 1-heat x-changer @ 1,000	1,000

PH Bldg.

1. 2- 150 ton cent. heat pumps @ 38,400	76,800
2. 2- 15 HP pumps @ 955	1,910
3. 1- heat x-changer @ 850	850

Admin. Bldg.

1. 2- 75 ton recip. heat pumps @ 20,000	40,000
2. 2- 10 HP pumps @ 755	1,510
3. 1- heat x-changer @ 750	750

123

ESTIMATE SHEET

HOLMES & HARVEY, INC.
ENGINEERS - CONSTRUCTORSACTION
ORDERED
EXPIRATION

BY

DATE

CHECKED

600
63-15-77
2

DESCRIPTION	MANHOURS	LABOR	MATERIAL	THE CONTRACT	
ALTERNATE 1	6468	226,380	338,500	150,000	714,880
ALTERNATE 2	700	24,500	217,900	23,800	266,200
ALTERNATE 3	3324	116,340	320,840	36,500	473,900
NOTE: ABOVE ARE DIRECT COST NO MARKUP IN DIRECTS					
TOTAL					

WASTE ISOLATION PILOT PLANT

LOCATION

COST STUDY

JOB NO. 3251.10

SHEET NO.

OF

BIG ITEM NO.

DETAILED ESTIMATE SHEET

HOLMES & HARVEY, INC.
ENGINEERS - CONSTRUCTORS

ACTION
PRICE
EXTENTIONS

BY
C

DATE
3-15-77

CHECKED

DATE

DESCRIPTION	QUANTITY	UNIT	LABOR UNIT	TOTAL UNITS	UNIT PR.	AMOUNT	COST UNIT	AMOUNT	COST UNIT	AMOUNT
<u>ALTERNATE I</u>										
300 TON CHILLER	3	EA		300				111 000		
300 " COOLING TOWER	3			0						17 500
40HP CIRC PUMPS	6			120				9 000		
5000#/HR BOILER	2			300				44 500		
CONVERTORS	3			60				4 500		
PIPE-VALUE FTGS. IN BUILDING	43			1500				15 000		
<u>DISTRIBUTION PIPE</u>										
8" 4 STL PIPE INSULATED	3 720	LF		2250				83 500		
6" 4	1 860			750				37 500		
4" 4	1 860			600				33 500		
TRENCH & BACKFILL 5'0"W X 3'0"D	2200	CY		—				—		19 500
BUILDING PREFAB CONCRETE	2400	SF		—				—		29 000
ELECTRICAL	150	CY		—				—		39 000
TEST & SUPV	43			588				—		50 000
				6463 35"		226 380		338 500		150 000
										714 880

WASTE ISOLATION PILOT PLANT

COST STUDY

JOB NO. 8251.10

SHEET NO. 01

PRINCIPAL SUB ACCT. NO. ALT I

DETAIL ESTIMATE SHEET

HOLMES & HARVEY, INC.
ENGINEERS - CONSTRUCTORSACTION
PRICED
BY

BY

DATE

CHECKED

DATE

BY
3-15-74

DESCRIPTION	QUANTITY	UNIT	BASE UNIT	TOTAL AMTS	DATE	AMOUNT	COST UNIT	AMOUNT	COST UNIT	AMOUNT	DATE
<u>ALTERNATE II</u>											
<u>TECH BLDG.</u>											
225 TON HEAT PUMPS	2	EA		160				87 000			
COOLING TWR	2									8 600	
25 HP PUMPS	4			64				4 600			
HEAT EXCHANGER	1			16				1 000			
<u>R H BLDG</u>											
150 TON HEAT PUMPS	2	EA		120				76 800			
COOLING TOWERS	2									6 600	
15 HP PUMPS	4			60				3 800			
HEAT EXCHANGER	1			16				900			
<u>ADM. BLDG</u>											
150 TON RECIP HEAT PUMP	2	EA		100				40 000			
COOLING TOWER	2									4 600	
10 HP PUMP	4			48				3 000			
HEAT EXCHANGER	1			16				800			
TEST / SUPV	43			100							
CONCRETE	18	CY		5						4 000	
				700	35	24 500		217 900		23 800	262 200

WASTE ISOLATION PILOT PLANT

TYPE OF ESTIMATE: COST STUDY

JOB NO. 8251.10

SHEET NO. OF

PRINCIPAL SUB ACCT. NO.

147.7

Detailed Estimate Sheet

HOLMES & HARNY, INC.
ENGINEERS - CONSTRUCTORS

ACTION
ORDERED
DATE

BY
(initials)

DATE
3-15-76

DESCRIPTION	QUANTITY	UNIT	ESTIM. UNIT	TOTAL AMT	RATE PER	AMOUNT	COST UNIT	AMOUNT	COST UNIT	AMOUNT
<u>ALTERNATE III</u>										
300 TON COOLING TWR	3	EA		0						17 900
50 HP PUMPS	3	Y		72				4 600		
10" PIPE INSULATED	3 720	LF		2604				109 160		
TRENCH BACKFILL	1800	CY								16 600
<u>TRU BLOC</u>										
225 TON HEAT PUMPS	2	EA		160				87 000		
25 HP PUMPS	2	Y		32				2 300		
HEAT EXCHANGER	1	Y		16				1 000		
<u>RH BLOC</u>										
150 TON HEAT PUMP	2	EA		120				76 800		
15 HP PUMP	2	Y		30				1 900		
HEAT EXCHANGER	1	Y		16				900		
<u>ADMI. BLOC</u>										
75 TON HEAT PUMP	2	EA		100				40 000		
10 HP PUMP	2	Y		24				1 500		
HEAT EXCHANGER	1	Y		16				700		
CONCRETE	11	CY		0						2 500
TEST & SURV	48			300						
				3324 35		116 590		320 860		36 500 472 900

PROJECT: WASTE ISOLATION PILOT PLANT

TYPE OF ESTIMATE: COST ESTIMATE JOB NO. B251-10

SHEET NO. OF

PRINCIPAL SUB ACCT. NO. 1427 III

RH Bldg.

RUN 1

Alt. 1 - Base System (no recovery - no evap. cool.)
energy use cool. = 914,499 KW = 3121 therms
(therms) heat. =

$$\frac{1336}{4457} @ 1.1 = 4903$$

Install cost =

Alt. 2 - Base System (w/recovery)

energy use cool = 895,656 KW = 3057
heat =

$$\frac{363}{3420} = 3762$$

Install cost =

RUN 2

Alt. 1 - Base System (w/recovery)

Alt. 2 - Base System (w/recov. + evap. cool.)

energy use cool = 808,165 KW = 2758
heat -

$$\frac{441}{3199} = 3519$$

Install cost =

These charts represent the average BTU's per day per month that can be collected on a Raypak solar panel. For locations shown, merely pick the amount of heat you need and the chart can tell you how many panels are needed.

Example - average home - family of four - 140° hot water usage - 15 gal. per person

Amount of water needed - 60 gal./140°

Incoming water temperature - 60°F

60 gal. X 8.33 wt. per gal. water = 499.80 lbs.

1 BTU will heat one lb. of water 1° per hr. Thus 1 gal. of water can be heated 1° by 8.5 BTU's

1 X 499.80 lbs. = 499.8 BTU's for 60 gal. at 1°

Thus, 499.8 X 80 = 39,984 BTU's needed to heat 60 gal. of water to 140°F.

EXAMPLE MAY NOT BE APPLICABLE IN ALL LOCATIONS

APPROXIMATE BTU PER DAY FOR ONE MODEL SG-18P SINGLE GLAZED COLLECTOR

MBTU
PER DAY
AVERAGE

30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9

APPROX. LATITUDE 32° N.
PANEL ANGLE 32°
MAKE-UP WATER, AVER. TEMP 60°F
CITY SUPPLY
FINAL WATER TEMP 140°F
PANEL FACING SOUTH
WIND VELOCITY LIGHT
AMOUNT OF SUN U.S.
PER DAY WEATHER BUREAU

----- PHOENIX
———— LOS ANGELES
..... SAN DIEGO
----- ALBUQUERQUE
———— CARLSBAD

J F M A M J J A S O N D
14 17.5 20 22 24 23.5 23 21.75 18.5 15 = 223.75 MBTU/12 =

Double Glazing - (100-200°F) \$300/17.5

Single Glazing - (100-200°F) \$300/17.5
not inc. storage tank

18.646 MBTU/day

= 18,646 BTU/day

3 = .000053/BTU (.795/kWh) = 6,805,790 BTU/yr. 128

Civil Calculations

ok
6/8/77

2-22-77

WIPP - WATER SUPPLY AND SEWAGE
TREATMENT
DESIGN BASIS

The WIPP facility includes a water supply and distribution system and a sewage treatment plant. The site population is approximately 400 on a 24 hour basis, and the systems are designed on the following basis:

	<u>Gallons/Day/Person</u>
Water Supply	50
Sewage Treatment	100

The capacity of the sewage treatment plant exceeds the water supply system capacity in order to account for system surges. If the two systems were designed for the same capacity the sewage treatment process would be unable to accept surges in flow. The effluent control would suffer as a result. Using a design philosophy which allows for surges results in a higher quantity sewage treatment plant.

The WIPP facility peak water demand will be based on a combination of fire control flows, personnel demand flows and process requirements. The peak 8 hour demand flows and process requirements. The peak 8 hour demand will therefore be:

	<u>Capacity Gallons</u>
Fire System Make-Up*	135,000
Domestic Demand - 400 x 50	20,000
Process Demand	<u>5,000</u>
Total Peak Demand	160,000

Peak System flow in the eight hour period will therefore be:

Peak Flow = 160,000 gallons/480 minutes
Peak Flow = 332 gpm during fire water make-up

* From Sandia Design Criteria

Average daily demand will be based on total site population per 24 hours day plus process requirements.

$$\begin{aligned}\text{Average Demand} &= 400 \text{ people } \left(\frac{50 \text{ gpd}}{\text{person}} \right) + 5000 \text{ gpd (Process)} \\ &= 20,000 \text{ gpd} + 5000 \text{ gpd}\end{aligned}$$

$$\text{Average Demand} = 25,000 \text{ gpd}$$

$$\text{Average Peak flow during 8 hour period} = \frac{25,000}{480} = 52 \text{ gpm Average}$$

Due to the small site approximately 1000 feet by 2000 feet and containing 11 buildings having 164 plumbing fixtures and a kitchen with a total of 902 fixture units, the 902 fixture units require a peak flow of 200 gpm.

A duplex constant pressure water system with 2 - 100 gpm pumps at 60 psig will distribute the domestic water to the buildings.

CHECKED _____ DATE _____

HOLMES & NARVER, INC.

TECHNOLOGY—CONSTRUCTION

400 E. ORANGETHORPE AVE.

ANAHEIM, CALIF. 92801

JOB No. 8251.00

APPROVED _____ DATE _____

SHEET 1 OF _____TITLE WIPP - WATER DEMANDSBY ERG DATE 2-22-77

No	BUILDING	PLUMBING FIXTURES						
		W.C	U.	LAV	SH.	D.F	J.S	FWASH
5	MAN/MATERIALS	10	6	10	23	2	2	2
2	ADMINISTRATION	15	6	13			3	
10	TRU WASTE	5	3	5	8		1	
3	WAREHOUSE/SHOPS	6	3	6	2		1	
11	HOIST HOUSE	2		2				
4	VEHICLE MAINTENANCE	1	1	1				
1	GATE HOUSE	1		1				
21	MINE FILTER	1		1	1	1		
16	EMERGENCY POWER	1		1				
6	RAD. WASTE LAUNDRY	1		1	1	1		
12	R.H. WASTE	7	5	7	5	2	1	
TOTAL		40	24	40	40	10	8	2

PEAK WATER DEMAND BY FIXTURE UNITS
TOTAL SITE

WATER CLOSET	40 x 10	= 400
URINAL	24 x 5	= 120
LAVATORY	40 x 2	= 80
SHOWER	40 x 4	= 160
DRINK FT.	10 x 1	= 10
JAN. SINK	8 x 3	= 24
FOOT WASH	2 x 4	= 8
KITCHEN		= 100

TOTAL FIXTURE UNITS = 902

TOTAL DEMAND 902 FU = 200 GPM.

USE DUPLEX CONSTANT PRESSURE SYSTEM
200 GPM AT 60 PSI FOR DISTRIBUTION.

CHECKED _____ DATE _____

APPROVED _____ DATE _____

TITLE WIPP - WATER DEMANDS

HOLMES & NARVER, INC.
TECHNOLOGY—CONSTRUCTION
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801

JOB No. 8251.00SHEET 2 OF _____BY ERG DATE 2-22-77

MAN-MATERIALS BUILDING
FIXTURE UNITS

WC - 10 x 10 = 100

U - 6 x 5 = 30

LAV - 10 x 2 = 20

SHOW - 23 x 4 = 92

D.F. - 2 x 1 = 2

J.S. - 2 x 3 = 6

FOOT WA - 2 x 4 = 8

TOTAL F.U. = 258 FIXTURE UNITS

TOTAL DEMAND = 258 FU = 100 GPM PEAK

ADMINISTRATION BLDG
FIXTURE UNITS

WC - 15 x 10 = 150

U - 6 x 5 = 30

LAV - 15 x 2 = 30

J.S. - 3 x 3 = 9

KITCHEN = 100

TOTAL = 319 FIX. UNITS

TOTAL DEMAND = 110 GPM PEAK

TRU WASTE

FIXTURE UNITS

WC - 5 x 10 = 50

U - 3 x 5 = 15

LAV - 5 x 2 = 10

SHOWER - 8 x 4 = 32

J. SINK - 1 x 3 = 3

TOTAL 110 FIXTURE UNITS

TOTAL DEMAND = 70 GPM PEAK

CHECKED _____ DATE _____

APPROVED _____ DATE _____

TITLE WIPP - WATER DEMAND

HOLMES & NARVER, INC.
TECHNOLOGY - CONSTRUCTION
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801

JOB No. 8251.00SHEET 3 OF _____BY ERQ DATE 2-22-72WAREHOUSE & SHOPS

FIXTURE UNITS

WC - 6 x 10 = 60

U - 3 x 5 = 15

LAV - 6 x 2 = 12

SHOWER - 2 x 4 = 8

J. SINK 1 x 3 = 3

TOTAL = 98 FIXTURE UNITS

TOTAL DEMAND = 67 GPM PEAK

HOIST HOUSE

FIXTURE UNITS

WC - 2 x 10 = 20

LAV - 2 x 2 = 4

TOTAL = 24 FIXTURE UNITS

TOTAL DEMAND = 40 GPM PEAK.

VEHICLE MAINTENANCE

FIXTURE UNITS

WC - 1 x 10 = 10

U - 1 x 5 = 5

LAV - 1 x 2 = 2

TOTAL = 17 FIXTURE UNITS

TOTAL DEMAND = 33 GPM PEAK.

GATE HOUSE

FIXTURE UNITS

WC - 1 x 10 = 10

LAV - 1 x 2 = 2

TOTAL = 12

TOTAL DEMAND 26 GPM PEAK

MINE FILTER

FIXTURE UNITS

WC - 1 x 10 = 10

LAV - 1 x 2 = 2

SHOWER 1 x 4 = 4

D.F. 1 x 1 = 1

TOTAL = 17

TOTAL DEMAND = 35 GPM PEAK.

CHECKED _____ DATE _____

APPROVED _____ DATE _____

TITLE WIPP - WATER DEMAND

HOLMES & NARVER, INC.
TECHNOLOGY - CONSTRUCTION
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801

JOB NO. 8251.00SHEET 4 OF _____BY ERQ DATE 2-22-77EMERGENCY POWERFIXTURE UNITSWC - $1 \times 10 = 10$ LAV - $1 \times 2 = 2$

TOTAL = 12 F.U.

TOTAL DEMAND = 26 GPM PEAK

RAD. WASTE LAUNDRYFIXTURE UNITSWC - $1 \times 10 = 10$ LAV - $1 \times 2 = 2$ SHOWER - $1 \times 4 = 4$ D.F. - $1 \times 1 = 1$

TOTAL = 17 F.U.

TOTAL DEMAND = 33 GPM PEAK

R. H. WASTEFIXTURE UNITSWC. - $7 \times 10 = 70$ U. - $5 \times 5 = 25$ LAV. - $7 \times 2 = 14$ SHOWER - $5 \times 4 = 20$ D.F. - $2 \times 1 = 2$ J. SINK - $1 \times 3 = 3$

TOTAL = 134 F.U.

TOTAL DEMAND = 76 GPM PEAK.

SUSPECT WATER POND

200,000 GAL = 26,737 CF USE 30,000 CF

⑤ AVE. DEPTH USE 70' x 70'

$$70 \times 70 = 4900 \text{ SF}$$

$$\frac{30,000}{4900} = 6.12'$$

MAKE DEPTH 7'

SIDE SLOPES 2:1

BOTTOM DIM 58' x 58'

INTERCEPTER DITCH & BERM

$$C = 17 \times 7 = 119 \text{ SF}$$

$$F = 20 \times 5 = 100 \text{ SF}$$

$$= 100 \times 119\% = 119 \text{ SF}$$

EFFLUENT POND

250,000 GAL STORAGE

3' LIQUID DEPTH

3' FREEBOARD

$$\frac{250,000}{7.48} = 33,422 \text{ CF}$$

$$\frac{33,422}{3} = 11,140 \text{ SF @ AVE DEPTH}$$

$$\sqrt{11,140} = 105.5'$$

USE 110'

$$464 \times 14 = 6496$$

$$104 \times 104 = 10816$$

$$4 \times 128 \times 2 = 1024$$

$$18336$$

$$1024$$

$$19360 \text{ SF 3110 LINER}$$

Electrical Calculations

CHECKED _____ DATE _____

HOLMES & NARVER, INC.
TECHNOLOGY — CONSTRUCTION
400 E. ORANGETHORPE AVE.
ANAHEIM, CALIF. 92801

JOB No. _____

APPROVED _____ DATE _____

SHEET _____ OF _____

TITLE REFERENCE ELECTRICAL LOAD CALCSBY KRB DATE 4/6/77

THE WIPP ELECTRICAL LOAD SUMMARY
HAS BEEN COMPILED UTILIZING ESTIMATED
MOTOR HORSEPOWER SIZES. THE CONNECTED,
NORMAL AND VITAL LOADS, IN KVA, HAVE
BEEN CALCULATED USING THE FOLLOWING
FORMULA.

$$\text{LOAD(KVA)} = \left(\begin{array}{l} \text{FULL LOAD} \\ \text{CURRENT-AMPS} \\ \text{FOR ONE PHASE} \end{array} \right) \sqrt{3} \left(\begin{array}{l} \text{POWER SUPPLY} \\ \text{IN KV} \end{array} \right)$$

RH WASTE FACILITY

NOTE: These calculations were originally performed for the dual preparation/decontamination room concept. Room sizes have changed. Lighting loads are conservative.

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H.H. BLDG

Area to be lighted..... LOCKER RM & SHOWERS

Design level of illumination..... 10 FC (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 53 Room Length
 35 Room Width
 7.5 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 0 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 7100
 No. & Type lamps 2 - F40 CW
 Lumens/Lamp 6200
 Light loss Factor (LLD x LDD)70

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.8 ; Ceiling Cavity Ratio = .1 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .67

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .67

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 1855}{6200 \times .67 \times .75} = \frac{18550}{3115.5} = 6$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H.L. BLOC
 Area to be lighted..... 7.4
 Design level of illumination..... 1 P.F.S. (initially maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 10 Room Length
 10 Room Width
 13.5 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 0 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. 3100
 No. & Type lamps 1 F40 CW
 Lumens/lamp 3100
 Light loss Factor 0.70
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 13.5 ; Ceiling Cavity Ratio = 5 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 64

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 20

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .26

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 100}{3100 \times .26 \times .75} = \frac{1000}{604.5} = 1.65 - 2 \text{ ea}$$

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ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address H. L. BLDG.

Area to be lighted Toilet = 2
14

Design level of illumination 10 FC (initial) (maintained)

Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 16 Room Length
..... 10 Room Width
..... 13.5 Height of room between luminaire & work plane (hrc)
..... 0.5 Distance from luminaire plane to ceiling (hcc)
..... 9 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
..... 50 Walls above luminaire plane
..... 50 Walls between luminaire & work plane
..... 20 Walls below work plane
..... 20 Floor

Luminaire

Manufacturer
Catalog No. Q100
No. & Type lamps 1 - F40 CW
Lumens/Lamp 3100
Light loss Factor70
(LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 11 ; Ceiling Cavity Ratio = .4 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; $\rho_{cc} = 65$

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; $\rho_{fc} = 20$

4. Find coefficient of utilization from published data (for $\rho_{cc} = 20\%$) C.U. = .26

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 160}{3100 \times .26 \times .75} = \frac{1600}{604.5} = 2.4 - 3_{\text{ea}}$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG.....

Area to be lighted..... OFFICE..... 1, 2, & 3.....

Design level of illumination..... 70 FC..... (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 12..... Room Length
 11..... Room Width
 11..... Height of room between luminaire & work plane (hrc)
 0.5..... Distance from luminaire plane to ceiling (hcc)
 2.5..... Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70..... Ceiling
 50..... Walls above luminaire plane
 50..... Walls between luminaire & work plane
 20..... Walls below work plane
 20..... Floor

Luminaire

Manufacturer.....
 Catalog No. 7100.....
 No. & Type lamps .. 2 - F40 CW.....
 Lumens/lamp 6200.....
 Light loss Factor75.....
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 10.3 ; Ceiling Cavity Ratio = .5 ; Floor Cavity Ratio = 2.3

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .64

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .26

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 132}{6200 \times .75 \times .26} = \frac{9240}{1209} = 7.6 - 8$$

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ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H.L. BLDG.....

Area to be lighted..... OFFICE 485.....

Design level of illumination..... 70 FC..... (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 14 Room Length
 9 Room Width
 11 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling

 50 Walls above luminaire plane

 Walls between luminaire & work plane

 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. 7100
 No. & Type lamps .. 2 - F40CW
 Lumens/lamp 6200
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 12 ; Ceiling Cavity Ratio = .45 ; Floor Cavity Ratio = 2.3

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .64

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .26

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 126}{6200 \times .26 \times .75} = \frac{8820}{1209} = 7$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG.....

Area to be lighted..... OFFICE.....

Design level of illumination..... 10 FC..... (Initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 58..... Room Length
 12..... Room Width
 11..... Height of room between luminaire & work plane (hrc)
 0.5..... Distance from luminaire plane to ceiling (hcc)
 2.5..... Height of work plane above floor (hfc)

Room Surface Reflectance in %
 70..... Ceiling
 50..... Walls above luminaire plane
 50..... Walls between luminaire & work plane
 20..... Walls below work plane
 20..... Floor

Luminaire
 Manufacturer.....
 Catalog No. 7200.....
 No. & Type lamps .. 2 - F40 CW.....
 Lumens/lamp 6200.....
 Light loss Factor75.....
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 5.5 ; Ceiling Cavity Ratio = .25 ; Floor Cavity Ratio = 1.25

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 67

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 20

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .38

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 696}{6200 \times .75 \times .38} = \frac{6960}{1767} = 4$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H.L. BLDG.

Area to be lighted..... CONTROL ROOM

Design level of illumination..... 70 FC (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 54 Room Length
 10 Room Width
 10 Height of room between luminaire & work plane (hrc)
 5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 7100
 No. & Type lamps .. 2 F40 CW
 Lumens/Lamp 3100
 Light loss Factor (LLD x LDD)75

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 5.9 ; Ceiling Cavity Ratio = 0.3 ; Floor Cavity Ratio = 1.5

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .66

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .39

$$\text{No. of} \\ \text{FIGURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 540}{6200 \times .75 \times .39} = \frac{37800}{1813.5} = 20$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG
 Area to be lighted..... SHIPPING & RECEIVING (DOCK)
 Design level of illumination..... 20 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 216..... Room Length
 36..... Room Width
 56.5..... Height of room between luminaire & work plane (hrc)
 25..... Distance from luminaire plane to ceiling (hcc)
 6..... Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer..... HOLOPHANE
 Catalog No..... #1047 EG-P1-277
 No. & Type lamps..... DNE
 Lumens/Lamp..... 50000
 Light loss Factor..... .9 x .9 = .81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 9.0 ; Ceiling Cavity Ratio = .4 ; Floor Cavity Ratio = .9

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 46

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = 0.36

$$\text{No. of FIXTURES} = \frac{\text{FOOT CANDLES X AREA}}{\text{LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF}}$$

$$= \frac{20 \times 7776}{50000 \times .36 \times .81} = \frac{153520}{14580} = 10.6 \rightarrow 12$$

2 rows of 6 ea

18' apart

36' apart

148

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG.

Area to be lighted..... MECH. / ELEC. ROOM (-16 LEVEL)

Design level of illumination..... 20 F.C. (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 53 Room Length
 35 Room Width
 9.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps 100 W
 Lumens/Lamp 9500
 Light loss Factor 0.81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.25 ; Ceiling Cavity Ratio = .5 ; Floor Cavity Ratio = .8

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 46

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .66

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{20 \times 1855}{9500 \times .66 \times .81} = \frac{37100}{5079} = 7.3$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG.
 Area to be lighted..... CASH ELEV. (-16 LEVEL)
 Design level of illumination..... 10 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 56 Room Length
 17 Room Width
 20.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer..... HOLLO
 Catalog No..... 1930
 No. & Type lamps..... 1-100 W. HPS
 Lumens/Lamp..... 9500
 Light loss Factor..... .81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 79 ; Ceiling Cavity Ratio = .95 ; Floor Cavity Ratio = 1.5

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .58

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .45

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 952}{9500 \times .45 \times .81} = \frac{9520}{3463} = 3$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG
 Area to be lighted..... CASK PREPARATION/DECON ROOM
 Design level of illumination..... 50 FC (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 90 Room Length
 62 Room Width
 39.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1047 EG-P1-277
 No. & Type lamps 2NFG 400 W. HPS
 Lumens/Lamp 50,000
 Light loss Factor 0.81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

- Determine cavity ratios using Table A or by formula
 Room Cavity Ratio = 4.3 ; Ceiling Cavity Ratio = 2.5 ; Floor Cavity Ratio = 4
- Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 66
- Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 20
- Find coefficient of utilization from published data (for ρ_{av} = 20%) C.U. = 0.55

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/PICTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{50 \times 5580}{50000 \times 0.81 \times 0.55} = 12.5$$

3 rows of 4 ea
 20 center
 22 center

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address H. L. BLDG.
 Area to be lighted UPPER TRANSFER (HOT CELL)
 Design level of illumination 50 FC (initial) (maintained)
 Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 48 Room Length
 44 Room Width
 33.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer HOLD PHANE
 Catalog No. 1P.47-ER-PI-277
 No. & Type lamps ONE - 40W WATT. HPS
 Lumens/Lamp 50000
 Light loss Factor81 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 7.3 ; Ceiling Cavity Ratio = .5 ; Floor Cavity Ratio = .8

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .64

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .46

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{50 \times 2112}{50000 \times .46 \times .81} = \frac{105600}{18630} = 5.6 \rightarrow 6$$

2 rows of 3

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H.L. BLDG......

Area to be lighted..... STORAGE ROOM..... 25A

Design level of illumination..... 10 FC..... (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 30..... Room Length
 16..... Room Width
 7.5..... Height of room between luminaire & work plane (hrc)
 2.5..... Distance from luminaire plane to ceiling (hcc)
 4..... Height of work plane above floor (hfc)

Room Surface Reflectance 17%

..... Ceiling
 Walls above luminaire plane
 50..... Walls between luminaire & work plane
 Walls below work plane
 20..... Floor

Luminaire

Manufacturer.....
 Catalog No. 1990.....
 No. & Type lamps 100W.....
 Lumens/Lamp 9500.....
 Light loss Factor 81.....
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 4.5 ; Ceiling Cavity Ratio = 1.1 ; Floor Cavity Ratio = 1.8

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 41

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 78

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = 54

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 480}{9500 \times .54 \times .81} = \frac{4800}{4155} = 1.15 \quad - \quad 2$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG.....
 Area to be lighted..... EQUIP. PASS TMBU.....
 Design level of illumination..... 10 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 57 Room Length
 12 Room Width
 17.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 50 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. 1930
 No. & Type lamps 100 W
 Lumens/Lamp 9500
 Light loss Factor 81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 8.8 ; Ceiling Cavity Ratio = 1.25 ; Floor Cavity Ratio = 2.0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 56

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .44

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 684}{9500 \times .44 \times .81} = \frac{6840}{3386} = 2.02$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address H.L. BLDG
 Area to be lighted MECH. / ELEC T18' LEVEL
 Design level of illumination 20 F.C. (Initial) (maintained)
 Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 7.3 Room Length
 6.4 Room Width
 14.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps 100W
 Lumens/Lamp 9500
 Light loss Factor85
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.45 ; Ceiling Cavity Ratio = .25 ; Floor Cavity Ratio = .4

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .48

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .29

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .69

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{20 \times 4672}{9500 \times .69 \times .81} = \frac{93440}{5309.5} = 17.6 - 18$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG
 Area to be lighted..... CORRIDOR #1
 Design level of illumination..... 10 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 53 Room Length
 6 Room Width
 9.5 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 0 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. 4100
 No. & Type lamps 1-F40 CW
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 8.8 ; Ceiling Cavity Ratio = .46 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .64

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .32

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 318}{3100 \times .32 \times .75} = \frac{3180}{744} = 4.3$$

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ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG.

Area to be lighted..... LAB. = 4

Design level of illumination..... 70 FC..... (Initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 17 Room Length
 11 Room Width
 7 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 7100
 No. & Type lamps 2 F40 CW
 Lumens/Lamp 6200
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 5.24 ; Ceiling Cavity Ratio = 0.4 ; Floor Cavity Ratio = 1.9

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .65

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .43

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 187}{6200 \times .43 \times .75} = \frac{13090}{1999.5} = 6.5 - 7$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BARR.....
 Area to be lighted..... LAB. NO. 1, 2 & 3.....
 Design level of illumination..... 70 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 18 Room Length
 15 Room Width
 7 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. 7120
 No. & Type lamps .. 2 F. 40 CW
 Lumens/Lamp..... 6200
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 4.3 ; Ceiling Cavity Ratio = .3 ; Floor Cavity Ratio = 1.5

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .66

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .48

$$\text{No. of Fixtures} = \frac{\text{FCOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 270}{6200 \times .48 \times .75} = \frac{18900}{2232} = 8.46 - 9$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG
 Area to be lighted..... OBSERVATION ROOM
 Design level of illumination..... 70 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 20..... Room Length
 10..... Room Width
 7..... Height of room between luminaire & work plane (hrc)
 0.5..... Distance from luminaire plane to ceiling (hcc)
 2.5..... Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70..... Ceiling
 50..... Walls above luminaire plane
 50..... Walls between luminaire & work plane
 20..... Walls below work plane
 20..... Floor

Luminaire

Manufacturer.....
 Catalog No. 7100
 No. & Type lamps .. 2 - F40 CW
 Lumens/lamp 6200
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 5.25 ; Ceiling Cavity Ratio = 0.4 ; Floor Cavity Ratio = 1.9

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .65

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .43

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 200}{6200 \times .43 \times .75} = \frac{14000}{1999.5} = 7$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG
 Area to be lighted..... CORRIDOR
 Design level of illumination..... 12 F.C...... (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 17..... Room Length
 5..... Room Width
 13.5..... Height of room between luminaire & work plane (hrc)
 0.5..... Distance from luminaire plane to ceiling (hcc)
 0..... Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70..... Ceiling
 50..... Walls above luminaire plane
 50..... Walls between luminaire & work plane
 20..... Walls below work plane
 20..... Floor

Luminaire

Manufacturer.....
 Catalog No. 6199.....
 No. & Type lamps ... 1-P40 CW.....
 Lumens/Lamp 3100.....
 Light loss Factor75.....
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 17.0 ; Ceiling Cavity Ratio = .6 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .63

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .25

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 95}{3100 \times .75 \times .25} = \frac{950}{581} = 1.6 - 2$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H.L. BLOC.....
 Area to be lighted..... CORRIDOR #3.....
 Design level of illumination..... 10 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 15 Room Length
 6 Room Width
 13.5 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. 6100
 No. & Type lamps 1-F40CW
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 15.7 ; Ceiling Cavity Ratio = .4 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .63

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .25

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 90}{3100 \times .25 \times .75} = \frac{900}{581} \quad 1.5 - 2$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. R. Co.

Area to be lighted..... CORRIDOR

Design level of illumination..... 10 fc (Initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 103 Room Length
 5 Room Width
 13.5 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 0 Height of work plane above floor (hfc)

Room Surface Reflectance 17%

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. A-100
 No. & Type lamps 1-F. 40. CW
 Lumens/Lamp 3100
 Light loss Factor 1.75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 14 ; Ceiling Cavity Ratio = .5 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 64

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 20

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .26

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 103 \times 5}{3100 \times .26 \times 1.75} = \frac{5150}{604.5} = 8.5 - 9 \text{ ea.}$$

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ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG
 Area to be lighted..... EQUIP. REPAIR ROOM (HOIST MAINT)
 Design level of illumination..... 20 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 44 Room Length
 12 Room Width
 16.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 3 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 50 Walls below work plane
 50 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps 1 - 100 W. HPS
 Lumens/Lamp 9500
 Light loss Factor81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 8.7 ; Ceiling Cavity Ratio = 1.3 ; Floor Cavity Ratio = 1.4

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .56

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .43

$$\text{No. of FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{20 \times 528}{9500 \times .43 \times .81} = \frac{10560}{3308.8} = 3$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... H. L. BLDG
 Area to be lighted..... CASK DECONTAMINATION
 Design level of illumination..... 50 FC..... (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 90 Room Length
 62 Room Width
 39.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer..... HOLOPHANE
 Catalog No. 1047 EG-P1-277
 No. & Type lamps..... ONE - 400W HPS
 Lumens/Lamp..... 50 000
 Light loss Factor..... .81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 4.3 ; Ceiling Cavity Ratio = .25 ; Floor Cavity Ratio = .4

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .66

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .55

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{50 \times 5580}{50000 \times .81 \times .55} = \frac{279000}{22275} = 12.5$$

3 rows of 4

20 1/2 center

22 1/2 center

12.5

TRU WASTE FACILITY

165-166

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... LL BLDG
 Area to be lighted..... LOBBY
 Design level of illumination..... 10 FC (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 44 Room Length
 25 Room Width
 7 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. 7100
 No. & Type lamps 2 - F40CV
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.2 ; Ceiling Cavity Ratio = .15 ; Floor Cavity Ratio = .75

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .68

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .61

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 44 \times 25}{1000 \times .61 \times .75} = \frac{11000}{2837} = 3.8$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG.....
 Area to be lighted..... CONFERENCE.....
 Design level of illumination..... 50 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 25 Room Length
 14 Room Width
 7 Height of room between luminaire & work plane (hrc)
 9.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 50 Floor

Luminaire

Manufacturer
 Catalog No. 7100
 No. & Type lamps 2 - F40CW
 Lumens/Lamp 3100
 Light loss Factor 75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 3.6 ; Ceiling Cavity Ratio = .25 ; Floor Cavity Ratio = 1.25

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 66

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 20

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .45

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 25 \times 14}{6200 \times .45 \times .75} = \frac{20000}{2093} = 9.5$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG
 Area to be lighted..... PV - LOCKER - R.R. AREA
 Design level of illumination..... 10 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 90 Room Length
 45 Room Width
 7.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 0 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 7100
 No. & Type lamps 2 - F40CW
 Lumens/Lamp 3100
 Light loss Factor 75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.2 ; Ceiling Cavity Ratio = .38 ; Floor Cavity Ratio = .6

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .65

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .60

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 90 \times 45}{6200 \times .75 \times .60} = \frac{40500}{2700} = 15.0$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L. L. BLDG.

Area to be lighted..... LABORATORY

Design level of illumination..... 70 FC (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 60 Room Length
 22 Room Width
 7 Height of room between luminaire & work plane (hrc)
 0.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 7100
 No. & Type lamps 2 - F40CW
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2 ; Ceiling Cavity Ratio = .15 ; Floor Cavity Ratio = .75

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .68

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .60

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 60 \times 22}{3100 \times 2 \times .60 \times .75} = \frac{92400}{2790} = 33$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG

Area to be lighted..... I & P AREA

Design level of illumination..... 30 F.C...... (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 200 Room Length
 50 Room Width
 11.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 6 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 50 Walls below work plane
 50 Floor

Luminaire

Manufacturer..... HOLOPHANE
 Catalog No..... 1930
 No. & Type lamps..... 1-100 W. HPS
 Lumens/Lamp..... 9500
 Light loss Factor..... .81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 0.9 ; Ceiling Cavity Ratio = .2 ; Floor Cavity Ratio = .48

2. Obtain effective ceiling cavity reflectances (p_{cc}) from Table B; p_{cc} = .67

3. Obtain effective floor cavity reflectance (p_{fc}) from Table B; p_{fc} = .19

4. Find coefficient of utilization from published data (for p_{fc} = 20%) C.U. = .74

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES X AREA}}{\text{LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF}}$$

$$= \frac{30 \times 200 \times 84}{9500 \times .81 \times .74} = \frac{504000}{5694} = 88$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG

Area to be lighted..... AIR LOCK #1 F2

Design level of illumination..... 10 FC (Initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 12.0 Room Length
 2.0 Room Width
 11.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 6 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps 100W
 Lumens/Lamp 9500
 Light loss Factor81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 5.5 ; Ceiling Cavity Ratio = .75 ; Floor Cavity Ratio = 1.8

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .44

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .53

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 20 \times 120}{9500 \times .53 \times .81} = \frac{24000}{4078} = 5.8 \rightarrow 6 \times 2 \text{ ft} \times 2 \text{ ft} = 12 \text{ fix}$$

20' centers

6/172

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG.....

Area to be lighted..... AIR LOCK # 3 & 4.....

Design level of illumination..... 10 FC..... (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 60..... Room Length
 20..... Room Width
 11.5..... Height of room between luminaire & work plane (hrc)
 2.5..... Distance from luminaire plane to ceiling (hcc)
 6..... Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50..... Walls between luminaire & work plane
 Walls below work plane
 20..... Floor

Luminaire

Manufacturer.....
 Catalog No. 1930.....
 No. & Type lamps 100 W.....
 Lumens/Lamp 9500.....
 Light loss Factor81.....
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 3.8 ; Ceiling Cavity Ratio = .8 ; Floor Cavity Ratio = 1.98

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .43

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .57

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 60 \times 20}{9500 \times .57 \times .81} = \frac{12000}{4386} = 2.7 \rightarrow 3 - 6 \text{ for } 2 \text{ A/Ls}$$

3 on 20' centers

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address L.L. BLDG
 Area to be lighted AIR LOCK #5
 Design level of illumination 10 F.C. (initial) (maintained)
 Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 36 Room Length
 22 Room Width
 11.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 6 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps 100W
 Lumens/Lamp 9500
 Light loss Factor 81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 4.2 ; Ceiling Cavity Ratio = .9 ; Floor Cavity Ratio = 2.1

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 43

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .54

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 36 \times 22}{9500 \times .54 \times .81} = \frac{7920}{4309} = 1.8 - 2 \text{ fix}$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG
 Area to be lighted..... AIR LOCK #6
 Design level of illumination..... 10..... (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 20 Room Length
 12 Room Width
 11.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 6 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps 100 W
 Lumens/Lamp 9500
 Light loss Factor81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 7.6 ; Ceiling Cavity Ratio = 1.6 ; Floor Cavity Ratio = 3.9

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 39

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 17

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .44

$$\text{No. of FIXTURES} = \frac{\text{FOOT CANDLES X AREA}}{\text{LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF}}$$

$$\frac{10 \times 20 \times 12}{9500 \times .81 \times .44} = \frac{2400}{3385} = 1$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG
 Area to be lighted..... SHAFT ROOM
 Design level of illumination..... 50 (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 60 Room Length
 32 Room Width
 13.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 6 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 50 Walls below work plane
 50 Floor

Luminaire

Manufacturer.....
 Catalog No. 1930
 No. & Type lamps 100 W
 Lumens/Lamp 9500
 Light loss Factor81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.8 ; Ceiling Cavity Ratio = .6 ; Floor Cavity Ratio = 1.4

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .62

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .64

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 60 \times 32}{9500 \times .64 \times .81} = \frac{96000}{4925} = 19.5$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG
 Area to be lighted..... OVER PACK AREA
 Design level of illumination..... 50 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 70..... Room Length
 40..... Room Width
 13.5..... Height of room between luminaire & work plane (hrc)
 3.5..... Distance from luminaire plane to ceiling (hcc)
 4..... Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70..... Ceiling
 52..... Walls above luminaire plane
 52..... Walls between luminaire & work plane
 20..... Walls below work plane
 20..... Floor

Luminaire

Manufacturer.....
 Catalog No. 1930.....
 No. & Type lamps 100 W.....
 Lumens/Lamp 9500.....
 Light loss Factor81.....
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.65 ; Ceiling Cavity Ratio = .49 ; Floor Cavity Ratio = .8

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .64

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .64

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 70 \times 40}{9500 \times .64 \times .81} = \frac{140000}{4925} = 28$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address L L BLDG

Area to be lighted DESK AREA

Design level of illumination 20 FC (Initial) (maintained)

Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 300' Room Length
 60' Room Width
 31.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 6' Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 50 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1908
 No. & Type lamps 150 W. HPS
 Lumens/Lamp 16000
 Light loss factor 81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 3 ; Ceiling Cavity Ratio = .25 ; Floor Cavity Ratio = .6

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 48

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .7

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{20 \times 300 \times 60}{16000 \times .7 \times .81} = \frac{360,000}{9072} = 40$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address L.L. BLDG
 Area to be lighted MECH. EQUIP. ROOM
 Design level of illumination 20 FC (initial) (maintained)
 Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 60 Room Length
 45 Room Width
 13.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 57 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps 100 W
 Lumens/Lamp 9500
 Light loss Factor81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.6 ; Ceiling Cavity Ratio = .49 ; Floor Cavity Ratio = .78

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .46

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .62

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{20 \times 60 \times 45}{9500 \times .62 \times .81} = \frac{54000}{4771} = 11.3$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... L.L. BLDG.
 Area to be lighted..... MISC. STORAGE
 Design level of illumination..... 10 FC (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 90 Room Length
 48 Room Width
 11.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 6 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 22 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps ... 122W
 Lumens/Lamp 9500
 Light loss Factor70
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.8 ; Ceiling Cavity Ratio = .37 ; Floor Cavity Ratio = .9

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 46

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .66

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 90 \times 48}{9500 \times .66 \times .81} = \frac{43200}{5078} = 8.5$$

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ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address

Area to be lighted MISC STORAGE #2

Design level of illumination 10 FC (initial) (maintained)

Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 56 Room Length
 56 Room Width
 11.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 6 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1930
 No. & Type lamps 100 W
 Lumens/Lamp 9500
 Light loss Factor (LLD x LDD) 81

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2 ; Ceiling Cavity Ratio = .4 ; Floor Cavity Ratio = /

2. Obtain effective ceiling cavity reflectances (ρ_{ce}) from Table B; ρ_{ce} = 46

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .66

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 56 \times 56}{9500 \times .66 \times .81} = \frac{31360}{5098.7} = 6$$

181-182-

5

ADMINISTRATION FACILITY

183-184

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address.....AD. BLDG.....

Area to be lighted.....LOBBY.....

Design level of illumination.....10 F.C.....(Initial) (maintained)

Calculated by.....Date.....Checked by.....Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

.....30..... Room Length
18..... Room Width
6..... Height of room between luminaire & work plane (hrc)
1.5..... Distance from luminaire plane to ceiling (hcc)
2.5..... Height of work plane above floor (hfc)

Room Surface Reflectance in %

.....80..... Ceiling
50..... Walls above luminaire plane
50..... Walls between luminaire & work plane
20..... Walls below work plane
20..... Floor

Luminaire

Manufacturer.....
 Catalog No.....
 No. & Type lamps.....2 - F40
 Lumens/Lamp.....3100
 Light loss Factor......75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.7 ; Ceiling Cavity Ratio = .7 ; Floor Cavity Ratio = 1.1

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 70

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 20

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .63

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 30 \times 18}{6200 \times .63 \times .75} = \frac{5400}{2929} = 2$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG
 Area to be lighted..... ERDA OFFICE
 Design level of illumination..... 70 FC (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 54 Room Length
 12 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling

 50 Walls above luminaire plane

 Walls between luminaire & work plane

 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2 F 40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 3 ; Ceiling Cavity Ratio = .75 ; Floor Cavity Ratio = 1.25

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 70

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = 60

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 648}{6200 \times .60 \times .75} = \frac{45360}{2790} = 16$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG.....
 Area to be lighted..... WIPP OFFICE.....
 Design level of illumination..... 70 F.C...... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 5.4 Room Length
 1.2 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No.
 No. & Type lamps 2 - F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 3 ; Ceiling Cavity Ratio = .75 ; Floor Cavity Ratio = 1.25

2. Obtain effective ceiling cavity reflectances (ρ_{rc}) from Table B; ρ_{rc} = 70

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .60

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 648}{6200 \times .60 \times .75} = \frac{45360}{2790} = 16$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address.....AD BLDG

Area to be lighted.....MANAGEMENT CONF

Design level of illumination.....50 FC (Initial) (maintained)

Calculated by.....Date.....Checked by.....Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

.....3.4.....Room Length
12.....Room Width
6.....Height of room between luminaire & work plane (hrc)
1.5.....Distance from luminaire plane to ceiling (hcc)
2.5.....Height of work plane above floor (hfc)

Room Surface Reflectance in %

.....80.....Ceiling
Walls above luminaire plane
50.....Walls between luminaire & work plane
Walls below work plane
20.....Floor

Luminaire

Manufacturer.....
 Catalog No.....
 No. & Type lamps.....2 F40
 Lumens/Lamp.....3100
 Light loss Factor (LLD x LDD)......75

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 3.7 ; Ceiling Cavity Ratio = .9 ; Floor Cavity Ratio = 1.6

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .68

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .55

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 12 \times 24}{6270 \times .55 \times .75} = \frac{14400}{2557} = 5.6$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address.....AD BLDG.....

Area to be lighted.....THEATER-CONFERENCE RM.....

Design level of illumination.....50 FC.....(Initial) (maintained)

Calculated by.....Date.....Checked by.....Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

.....48.....Room Length
24.....Room Width
6.....Height of room between luminaire & work plane (hrc)
1.5.....Distance from luminaire plane to ceiling (hcc)
2.5.....Height of work plane above floor (hfc)

Room Surface Reflectance in %

.....80.....Ceiling
50.....Walls above luminaire plane
50.....Walls between luminaire & work plane
20.....Walls below work plane
20.....Floor

Luminaire

Manufacturer.....
 Catalog No.....
 No. & Type lamps.....2 - F40
 Lumens/Lamp.....3100
 Light loss Factor (LLD x LDD)......75

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.8 ; Ceiling Cavity Ratio = .45 ; Floor Cavity Ratio = .75

2. Obtain effective ceiling cavity reflectances (ρ_{rc}) from Table B; ρ_{rc} = .73

3. Obtain effective floor cavity reflectance (ρ_{fr}) from Table B; ρ_{fr} = .19

4. Find coefficient of utilization from published data (for ρ_{rc} = 20%) C.U. = .70

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 1152}{6200 \times .70 \times .75} = \frac{57600}{3255} = 17.6$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG

Area to be lighted..... VIP SEATING

Design level of illumination..... 50 (initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 18 Room Length
 12 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2 - F-40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 4.16 ; Ceiling Cavity Ratio = 1.0 ; Floor Cavity Ratio = 1.7

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .67

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .18

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .54

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 12 \times 18}{4200 \times .54 \times .75} = \frac{10800}{2511} = 4.3$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method.

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address A.D. BLDG

Area to be lighted FOOD PREP

Design level of illumination 70 FC (Initial) (maintained) FROM IES

Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 36 Room Length
 18' Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer S.H.
 Catalog No. GP-24R-FAS
 No. & Type lamps 2 - F40
 Lumens/Lamp 3100
 Light loss Factor (LLD x LDD) 75

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.5 ; Ceiling Cavity Ratio = .6 ; Floor Cavity Ratio = 1.6

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 71

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 18

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .63

$$\text{No. of FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 36 \times 18}{6200 \times .63 \times .75} = \frac{45360}{2929} = 15.5$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address.....ADMIN. BLDG.....

Area to be lighted.....CAFETERIA.....

Design level of illumination.....50 FC.....(initial) (maintained) FROM IES

Calculated by.....Date.....Checked by.....Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

.....42..... Room Length
36..... Room Width
6..... Height of room between luminaire & work plane (hrc)
1.5..... Distance from luminaire plane to ceiling (hcc)
2.5..... Height of work plane above floor (hfc)

Room Surface Reflectance in %

.....80..... Ceiling
60..... Walls above luminaire plane
50..... Walls between luminaire & work plane
20..... Walls below work plane
20..... Floor

Luminaire

Manufacturer.....SMOOTH HOLMAN.....
 Catalog No.....GP-24R-FAS.....
 No. & Type lamps.....2 F40.....
 Lumens/Lamp.....3100.....
 Light loss Factor......75.....
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.45 ; Ceiling Cavity Ratio = .4 ; Floor Cavity Ratio = .6

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .74

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .71

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{50 \times (42 \times 36)}{2 \times 3100 \times .71 \times .75} = \frac{86400}{3301} = 26$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG
 Area to be lighted..... CORRIDOR
 Design level of illumination..... 10 FC (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 10.5 Room Length
 6 Room Width
 9.5 Height of room between luminaire & work plane (hrc)
 5 Distance from luminaire plane to ceiling (hcc)
 0 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 72 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer..... HOLOPHANE
 Catalog No..... # 6100
 No. & Type lamps..... 1 - F40
 Lumens/Lamp..... 3100
 Light loss Factor..... .75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 8 ; Ceiling Cavity Ratio = .45 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .72

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .31

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 648}{3100 \times .36 \times .75} = \frac{6480}{1721} = 3.76$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... A.P. BLPG.....
 Area to be lighted..... CORRIDOR 2 & 3.....
 Design level of illumination..... 10 FC..... (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 60 Room Length
 6 Room Width
 9.5 Height of room between luminaire & work plane (hrc)
5 Distance from luminaire plane to ceiling (hcc)
 0 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 73 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No. 6100
 No. & Type lamps 1-F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 8.7 ; Ceiling Cavity Ratio = .45 ; Floor Cavity Ratio = 0

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .73

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = .28

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 360}{3100 \times .28 \times .75} = \frac{3600}{651} = 5.5 \quad \text{6 in each corridor}$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG

Area to be lighted..... CORRIDOR #4

Design level of illumination..... 10 FC (Initial) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 192 Room Length
 6 Room Width
 9.5 Height of room between luminaire & work plane (hrc)
5 Distance from luminaire plane to ceiling (hcc)
 0 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 1 - F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula
 Room Cavity Ratio = 8 ; Ceiling Cavity Ratio = .4 ; Floor Cavity Ratio = 0
2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .74
3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .20
4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .31

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 192 \times 6}{3100 \times .31 \times .75} = \frac{11520}{721} = 16$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address AD BLDG

Area to be lighted GENERAL AREA

Design level of illumination 50 FC (Initial) (maintained)

Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 108 Room Length

..... 60 Room Width

..... 6 Height of room between luminaire & work plane (hrc)

..... 1.5 Distance from luminaire plane to ceiling (hcc)

..... 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling

..... 50 Walls above luminaire plane

..... 50 Walls between luminaire & work plane

..... 50 Walls below work plane

..... 20 Floor

Luminaire

Manufacturer

Catalog No.

No. & Type lamps 2 - F40

Lumens/Lamp 3100

Light loss Factor 75 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = .8 ; Ceiling Cavity Ratio = .18 : Floor Cavity Ratio = .3

2. Obtain effective ceiling cavity reflectances (ρ_{ce}) from Table B; ρ_{ce} = .77

3. Obtain effective floor cavity reflectance (ρ_{fe}) from Table B; ρ_{fe} = .20

4. Find coefficient of utilization from published data (for ρ_{ce} = 20%) C.U. = .80

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 108 \times 60}{6200 \times .80 \times .75} = \frac{324000}{3720} = 87$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... A.P. BLDG
 Area to be lighted..... SECURITY / SAFETY
 Design level of illumination..... 70 F.C. (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 48 Room Length
 24 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No.
 No. & Type lamps 2 - F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.8 ; Ceiling Cavity Ratio = .5 ; Floor Cavity Ratio = .8

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .72

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .67

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 24 \times 48}{6200 \times .67 \times .75} = \frac{80640}{3116} = 26$$

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG
 Area to be lighted..... INVENTORY & CONTROL
 Design level of illumination..... 70 FC (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 48 Room Length
 24 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2 - F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

- Determine cavity ratios using Table A or by formula
 Room Cavity Ratio = 1.8 ; Ceiling Cavity Ratio = .5 ; Floor Cavity Ratio = .8
- Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .72
- Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19
- Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .67

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 24 \times 48}{6200 \times .67 \times .75} = \frac{80640}{3116} = 26$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG
 Area to be lighted..... FILES
 Design level of illumination..... 50 FC (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 24 Room Length
 24 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.0 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer.....
 Catalog No.....
 No. & Type lamps..... 2 - F40
 Lumens/Lamp..... 3100
 Light loss Factor (LLD x LDD)..... 75

SELECTION OF COEFFICIENT OF UTILIZATION

- Determine cavity ratios using Table A or by formula
 Room Cavity Ratio = 2.5 ; Ceiling Cavity Ratio = .6 ; Floor Cavity Ratio = 1.0
- Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 71
- Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19
- Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = 63

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 24 \times 24}{4200 \times .63 \times .75} = \frac{28800}{2929} = 10$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address AD BLDG

Area to be lighted MHL RM

Design level of illumination 50 (Initial) (maintained)

Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 24 Room Length
 24 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance

..... 80 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 50 Walls below work plane
 80 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2 F-40
 Lumens/Lamp 3100
 Light loss Factor .75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.5 ; Ceiling Cavity Ratio = .6 ; Floor Cavity Ratio = 1

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; $\rho_{cc} = .71$

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; $\rho_{fc} = .19$

4. Find coefficient of utilization from published data (for $\rho_{fc} = 20\%$) C.U. = .63

$$\text{NO OF FIXTURES} = \frac{\text{FOOT CANDLES X AREA}}{\text{LAMPS/FIX. X LUMENS/LAMP X CU X LLF}}$$

$$\frac{50 \times 24 \times 24}{6200 \times .63 \times .75} = \frac{28800}{2929} = 10$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address A.D. B.L.P.C.
 Area to be lighted REPRODUCTION
 Design level of illumination 70 F.C. (Initial) (maintained)
 Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 48 Room Length
 24 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2 - F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.8 ; Ceiling Cavity Ratio = .5 ; Floor Cavity Ratio = .8

2. Obtain effective ceiling cavity reflectances (ρ_{ce}) from Table B; ρ_{ce} = .72

3. Obtain effective floor cavity reflectance (ρ_{fe}) from Table B; ρ_{fe} = .19

4. Find coefficient of utilization from published data (for ρ_{ce} = 20%) C.U. = .67

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 24 \times 48}{6200 \times .67 \times .75} = \frac{80640}{3116} = 26$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG
 Area to be lighted..... FIRST AID & TREATMENT
 Design level of illumination..... 100 (initial) (maintained) IES
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 22 Room Length
 12 Room Width
 5.5 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 3 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 Walls above luminaire plane
 80 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2 - F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 3.5 ; Ceiling Cavity Ratio = .97 ; Floor Cavity Ratio = 1.95

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .74

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .25

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .55

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{100 \times 12 \times 22}{6200 \times .55 \times .75} = \frac{26400}{2557} = 10$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address AD. BLDG.
 Area to be lighted MECH. RM.
 Design level of illumination 20 FC (initial) (maintained)
 Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 24 Room Length
 19 Room Width
 5.5 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 3 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2 - F40
 Lumens/Lamp 3100
 Light loss Factor (LLD x LDD) 65

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.6 ; Ceiling Cavity Ratio = .7 ; Floor Cavity Ratio = 1.4

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 70

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 18

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = 63

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{20 \times 24 \times 19}{6200 \times 63 \times 65} = \frac{9120}{2539} = 3.6 - 4$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG
 Area to be lighted..... MECH. / ELEC. / TEL ROOM
 Design level of illumination..... 20 FC (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 48 Room Length
 42 Room Width
 5.5 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 3 Height of work plane above floor (hle)

Room Surface Reflectance in %

..... 80 Ceiling
 { Walls above luminaire plane
 50 Walls between luminaire & work plane
 { Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2 F40
 Lumens/Lamp 3100
 Light loss Factor65
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.1 ; Ceiling Cavity Ratio = 0.3 ; Floor Cavity Ratio = 0.4

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 75

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = 19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = 76

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{20 \times 42 \times 48}{6200 \times .76 \times .65} = \frac{40320}{2063} = 13$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... A.D. BLDG.
 Area to be lighted..... SECURITY CAR (GARAGE)
 Design level of illumination..... 20 FC..... (initial) (maintained) IES
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 36 Room Length
 26 Room Width
 6.5 Height of room between luminaire & work plane (hrc)
 5 Distance from luminaire plane to ceiling (hcc)
 3 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 70 Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2-F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2 ; Ceiling Cavity Ratio = .15 ; Floor Cavity Ratio = .9

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .67

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .67

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{20 \times 936}{6200 \times .67 \times .75} = \frac{18720}{3115} = 6$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... AD BLDG
 Area to be lighted..... TRAILER INSPECTION
 Design level of illumination..... 20 FC (initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 76 Room Length
 44 Room Width
 13.5 Height of room between luminaire & work plane (hrc)
 2.5 Distance from luminaire plane to ceiling (hcc)
 4 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 50 Ceiling
 Walls above luminaire plane
 20 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 1908
 No. & Type lamps 150 W HPS
 Lumens/Lamp 16000
 Light loss Factor81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2.4 ; Ceiling Cavity Ratio = .45 ; Floor Cavity Ratio = .72

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .43

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .17

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .62

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{20 \times 44 \times 76}{16000 \times .81 \times .62} = \frac{66880}{8035} = 8$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address

Area to be lighted *Lab. (Security bldg.)*

Design level of illumination *70 Fc* (Initial) (maintained)

Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... *30* Room Length
 10 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... *80* Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps *2-F 40*
 Lumens/Lamp *3100*
 Light loss Factor *.75*
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = *2.6* ; Ceiling Cavity Ratio = *.7* ; Floor Cavity Ratio = *1.1*

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = *70*

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = *18*

4. Find coefficient of utilization from published data (for ρ_{cc} = 20%) C.U. = *.64*

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 540}{6200 \times .64 \times .75} = \frac{37800}{2976} = 12.7$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... Security BLDG
 Area to be lighted..... COMPUTER ROOM
 Design level of illumination..... 70 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 59 Room Length
 31 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling

 50 Walls above luminaire plane

 20 Floor

Luminaire

Manufacturer..... SMOOT HOLMAN
 Catalog No..... G.P. 24R-FAS
 No. & Type lamps..... 2 F40
 Lumens/Lamp..... 3100
 Light loss Factor..... .75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.5 ; Ceiling Cavity Ratio = .4 ; Floor Cavity Ratio = .6

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table G; ρ_{cc} = .74

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .71

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 59 \times 31}{6200 \times .71 \times .75} = \frac{128030}{3301} = 38.7$$

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address *Security BLDG*

Area to be lighted *Security # HVAC Monitor*

Design level of illumination *70* (initial) (maintained)

Calculated by Date Checked by Date

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... *32* Room Length
 31 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... *80* Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer *S.H.*
 Catalog No. *GP-24R-EAS*
 No. & Type lamps *2 P-40*
 Lumens/Lamp *3100*
 Light loss Factor *.75*
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = *2.0* ; Ceiling Cavity Ratio = *.5* ; Floor Cavity Ratio = *.8*

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = *.72*

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = *.19*

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = *.67*

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 32 \times 31}{6200 \times .75 \times .67} = \frac{69440}{3115} = 22$$

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address..... Security BLDG......
 Area to be lighted..... MAIN SECURITY OFFICE.....
 Design level of illumination..... 70 FC..... (Initial) (maintained)
 Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 74 Room Length
 36 Room Width
 6 Height of room between luminaire & work plane (hrc)
 1.5 Distance from luminaire plane to ceiling (hcc)
 2.5 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... 80 Ceiling
 50 Walls above luminaire plane
 50 Walls between luminaire & work plane
 20 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No.
 No. & Type lamps 2-F40
 Lumens/Lamp 3100
 Light loss Factor75
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 1.3 ; Ceiling Cavity Ratio = .3 ; Floor Cavity Ratio = .5

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .75

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .73

$$\text{No. of Fixtures} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 74 \times 36}{6200 \times .73 \times .75} = \frac{186480}{3394} = 55$$

211-212

WAREHOUSE / SHOPS

213-214

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utilization)

GENERAL INFORMATION

Company name and address.....

Area to be lighted..... WAREHOUSE

Design level of illumination..... 10 (~~maintained~~) (maintained)

Calculated by..... Date..... Checked by..... Date.....

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions

..... 270 Room Length
 75 Room Width
 23 Height of room between luminaire & work plane (hrc)
 1 Distance from luminaire plane to ceiling (hcc)
 6 Height of work plane above floor (hfc)

Room Surface Reflectance in %

..... Ceiling
 Walls above luminaire plane
 50 Walls between luminaire & work plane
 Walls below work plane
 20 Floor

Luminaire

Manufacturer
 Catalog No. 966
 No. & Type lamps 150 W HPS
 Lumens/Lamp 16000
 Light loss Factor81
 (LLD x LDD)

SELECTION OF COEFFICIENT OF UTILIZATION

1. Determine cavity ratios using Table A or by formula

Room Cavity Ratio = 2 ; Ceiling Cavity Ratio = .08 ; Floor Cavity Ratio = .5

2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = .49

3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; ρ_{fc} = .19

4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .55

$$\text{No. of FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 270 \times 75}{16000 \times .55 \times .81} = \frac{202500}{7128} = 28$$

28 x 14 = 392

25-216

TRU Waste Surface Facility Time and Motion Analysis

WIPP - TRU WASTE SURFACE FACILITY TIME AND MOTION ANALYSIS

The analysis of material handling in the TRU Waste Facility was conducted and discussed over an extended period of time stretching from July to December of 1976. During that period of time, a number of TRU facility configurations were developed and considered. The final design concept resulted from this extended evolutionary process. As a record of the evolution, attached are several pertinent documents relating to the time and motion study for the facility.

Item I is letter H&N-023 discussing utilization factors for work areas within the building. The results of this portion of the work were the decisions that both truck and railcars should be handled simultaneously, that two overhead cranes should be used, and that separate truck and railcar airlocks should be provided.

Item II is a draft discussion, with comments on laydown space utilization within the facility. Item III is a partial revision to Item II.

ITEM 1

**HOLMES &
NARVER, INC.**
ENGINEERS & ARCHITECTS

400 EAST ORANGETHORPE AVENUE

ANAHEIM, CALIFORNIA 92801

(714) 870-8700

August 20, 1976
H&N-023

bcc: ✓ J. Duncan
Distribution
K. R. Brown
File

Mr. James L. Ash
Fenix & Scisson, Inc.
P. O. Box 15609
Tulsa, Oklahoma 74115

Dear Jim:

Attached for review and comment is a Material Handling Time and Sequencing Analysis for the TRU Waste Handling Facility. The analysis is based on the most current material flow requirements and presents a matrix of results based on the various combinations of waste shipments which may be received at the site. Section I is a summary of the various package configurations to be handled. Section II is the basis for the process flow and Section III presents the analysis and results.

Based on the analysis results, as shown in the attached, a number of recommendations regarding facility design may be made. These are:

1. A minimum of three single railcar movers will probably be required for the facility. One of the three, or a separate vehicle, will have to be sized to handle multiple cars from site entrance to storage yard and back. Two movers will support movement of TRU wastes, one will support RH waste operations.
2. A minimum of two railcar unloading stations are required. A third station may be required, depending upon decisions on such things as a separate car lid removal area.
3. Two overhead cranes should be used in the TRU Waste building for car unloading.

Mr. James L. Ash
August 20, 1976
H&N-023
Page 2

4. Two truck stations are required. One may be a combination truck and railcar station. Further development of the site arrangement and building configuration will aid in the decision on final configuration.
5. Consideration should be given to a combination lid removal, container storage and sorting station in the facility yard area. Railcars and trucks which have been unloaded in the TRU building would be utilized to transport empty containers from the building rather than requiring their immediate removal (empty) and subsequent return to be loaded. Containers would be stockpiled in the storage area on pads until such time as a vehicle was available to transport them offsite to their point of origin.
- deleted*

Review of the analysis will show considerable reduction in station (and therefore equipment) utilization if containers could be returned to any sender. Based on current criteria requiring return of containers to point of origin these reductions will not be realized. Use of an outside station would minimize the utilization of building stations resulting in a more efficient facility. Use of such a station would also reduce the interior storage space required for empty containers which are waiting for a vehicle to transport them home.

Review of the attached will be appreciated and will aid in decisions regarding configuration of the site and TRU waste handling system. In order to be most effective the comments should be received by September 3. If questions arise, please let me know.

Very truly yours,

HOLMES & NARVER, INC.

Kent

Kent R. Brown

Attach.

cc: L. Scully, Sandia Labs. (w/2 attaches.)

WIPP PROJECT
TRU WASTE HANDLING FACILITY
MATERIAL HANDLING TIME
AND SEQUENCING ANALYSIS
AUGUST 20, 1976

HOLMES & NARVER, INC.

221-222

WIPP PROJECT
CONTACT HANDLING WASTE FACILITY
I. PACKAGE SPECIFICATIONS

Item	Symbol	Dimensions, Ft.			Maximum Weight, Lbs.	
		Length	Width	Height	Gross	Tare
Supertiger Container	ST	20	8	8	UP* 44,300	17,000
					P 46,700	17,000
Cargo Container	CC	20	8	8	UP 44,000	5,000
					P 43,700	5,000
Rocky Flats Fiberglassed Box	RF	7	4	4	10,000	
Overpack Fiberglassed Box	OB	8	5	5	11,000	1,000
Mark 3 Container	M3	5	4	6	UP 6,000	750
					P 8,000	750
					C 10,000	750
55 Gallon Drum, DOT-17C	55D				UP 650	<100
					P 900	<100
83 Gallon Overpack Drum, DOT-17C	83D				UP 750	100
					P 1,000	100

* UP = Unprocessed Waste

P = Processed Waste

C = Mark 3 Container Holding Undrummed Waste

II. BASIS FOR PROCESS FLOW

1. All quantities are alternative average maxima per 8-hour shift unless otherwise noted. That is, the quantity flows between or through stations for the different packages are not additive; they are alternative possibilities. The quantities are daily averages based on a stated annual throughput and do not represent the maxima which could occur due to nonuniform frequency of shipments during a week or longer period of time. These surges could be leveled by holding the arriving vehicles for unloading at a later time.
2. Work will be performed during only one 8-hour shift per day, 5 days per week.
3. Four 55D or 83D drums per pallet.
4. Truck shipments are by flatbed truck only. A flatbed truck carries only one ST. No other type of package is shipped by truck.
5. A Supertiger can contain up to 33 drums of processed waste (29,700 lbs. maximum payload) or up to 42 drums of unprocessed waste (27,300 lbs. maximum payload).
6. A rail flatcar can carry up to three STs. No other type of package is shipped by rail flatcar. Each ST can contain the same payloads as in Item 5.
7. An ATMX railcar can contain three types of packages in combination or as single-package type shipments. The maximum number of packages for single-package type shipments are:
 - 24 RF Boxes
 - 2 Cargo Containers
 - 20 Mark 3 Bins
8. RF boxes are never unpacked. However, they may be damaged. Minor damage requires repair and major damage or external contamination requires overpack.
9. Cargo containers hold up to 60 55D of unprocessed waste (39,000 lbs. maximum payload) or up to 43 55D of processed waste (38,700 lbs. maximum payload).

10. Mark 3 bins hold up to 8 55-gallon drums each. Maximum payloads are:

Unprocessed waste 5,200 lbs.

Processed waste 7,200 lbs.

11. Mark 3s containing undrummed waste or contaminated drums and soil are not unpacked. However, they may require minor repair or overpack.
12. On the average, 1,300 55D drums per week will be received. These could be received by any combination (or single type shipment) of the following possible shipment types:
- Flatbed truck [1-ST (33-55D-P, 42-55D-UP)]
 - Flatcar [3-ST (99-55D-P, 126-55D-UP)]
 - ATMX [2-CC (86-55D-P, 120-55D-UP)]
 - ATMX [20-M³ (160-55D-P or UP)]
13. Based on Item 12, the average number of drums per day is 260 (32.5 drums/hr.), and the average maximum number (assuming containers and vehicles are loaded to capacity) of containers and vehicles per day and per hour for each shipment type is as follows:

Container and Vehicle Flow Rates (Average)

Shipment Type			Vehicles Per		Containers Per	
Vehicle	Container	Waste	Day	Hour	Day	Hour
Flatbed	ST	UP	6.2	0.8	6.2	0.8
Flatbed	ST	P	7.9	1.0	7.9	1.0
Flatcar	ST	UP	2.1	0.3	6.3	0.8
Flatcar	ST	P	2.6	0.3	7.9	1.0
ATMX	CC	UP	2.2	0.3	4.4	0.6
ATMX	CC	P	3.0	0.4	6.0	0.7
ATMX	M3	P/UP	1.6	0.2	32	4

14. Since vehicles arrive as discrete units, the next higher whole number of vehicles is used as the flow basis. Thus, the daily and hourly flow rates for vehicles, containers, and drums is as follows:

Basic Flow Rates
(Maximum Average Alternatives)

Shipment Type			Vehicles Per		Containers Per		Drums Per	
Vehicle	Container	Waste	Day	Hour	Day	Hour	Day	Hour
Flatbed	ST	UP	7	0.9	7	0.9	294	37
Flatbed	ST	P	8	1	8	1	264	33
Flatcar	ST	UP	3	0.4	9	1.1	378	47
Flatcar	ST	P	3	0.4	9	1.1	297	37
ATMX	CC	UP	3	0.4	6	0.8	360	45
ATMX	CC	P	3	0.4	6	0.8	258	32
ATMX	M3	P/UP	2	0.3	40	5	320	40

III. TIME AND SEQUENCING ANALYSIS

1. SPOT AND REMOVE VEHICLES

1.1 Requirements

The maximum number of railcars appears to be 4 per day (3 for drums, 1 for RF boxes once per week; contaminated M3s are assumed to be included with drums or RFs). The railcar must be spotted, the containers removed from the car, and the car removed from its unloading station to wait for the containers to be unloaded. (Containers must be returned to the sender on the same car as received.)* When the containers are available, the car is respotted, the containers loaded on the car, and the car moved to the yard to await pickup by a Santa Fe engine. Thus, there could be 7 spotting cycles per day. (Cars carrying RF boxes or contaminated M3s will not need to be respotted since RFs or these M3s are not returned to the sender.)

If all drums are received in STs on flatbed trucks, a maximum of 8 trucks could be received in a day. Arriving trucks would go to the truck parking area to wait for an available truck unloading station. When a station is available, the truck moves to the station, the ST is removed, and the truck returns to the parking area to wait for the ST to be unloaded. (The same truck/ST combination as received must be returned to the sender.)* When the ST is available, the truck is respotted, the ST loaded on the flatbed, and the truck returns to the sender. (Truck/ST combinations should be given priority treatment since the truck and driver are unproductive during unloading of the ST and while waiting for a truck unloading station.) To handle the maximum daily truck arrivals will require 16 truck spotting cycles.

1.2 Time Estimates

- a. Move car from holding yard to unloading station and spot. Minimum distance approximately 2,100', maximum distance approximately 5,500', average distance approximately 3,800'.

* Requirement modified August 4, 1976 - Analysis retained for continuity and future reference. Assumption is now that all containers, etc., return to point of origin but may be shipped on a different vehicle.

Average travel time at 3 mph (260 ft/min)	14.5 min
Hookup and start moving	4 min
Slow, enter building, stop, unhook	<u>5.5 min</u>
Time Required	24 min

(These times assume that rail switches and building doors are controlled such that the railcar never waits for these actions.)

b. Remove ATMX car lids (3 per car)

Sandia estimate	25 min
-----------------	--------

c. Unload cargo containers from ATMX

Sandia estimate, 25 min each (Includes removal of braces and shoring)	50 min
--	--------

d. Unload M3s from ATMX

(Assume M3s unloaded in groups of four). There will be 5 lifts made. Braces and shoring will need to be removed only once. Assume 20 minutes per lift cycle.

Time Required	100 min
---------------	---------

e. Replace ATMX lids

Lid restraints and braces are not replaced on empty cars waiting for reloading with CCs or M3s. Restraints are replaced on cars ready for return to sender (those that carried RFs or contaminated M3s). Assume replacement of lids and lid restraints requires same time as removal (i.e., 25 min.). Assume 10 min. required for lid restraints. Assume 15 min. for braces.

Time Required:

Empty cars to be returned	40 min
Reloaded cars to be returned	25 min
Empty cars to hold area	15 min

f. Unload STs (3) from flatcar

Remove ST tiedowns (4 per ST)	10	min
Engage crane sling (4 points)	5	min
Lift and move to laydown area		
(80 ft ave. at 40 fpm)	2	min
disengage crane sling	5	min
Return crane for next ST	2	min
Repeat lift cycle for 2nd ST	14	min
Engage crane to 3rd ST	5	min
Lift 3rd ST free of flatcar	<u>1</u>	min
Time from spot car to car ready to move out	44	min

g. Unload RF boxes from ATMX (24 boxes per ATMX, lifted 4 at a time. Includes removal of braces and shoring).

Remove shoring (first 4; others removed while preceding boxes removed.)	20	min
Lift 4 boxes, move to laydown, and return to ATMX	16	min
Repeat lift cycle 5 times	<u>80</u>	min
	116	min

Use of crane only

h. Move car from unloading station to holding yard	24	min
i. Remove ATMX lid from reload	15	min
j. Reload cargo containers on ATMX and replace braces (same as unload)	50	min

k.	Reload M3s on ATMX		
	Load in groups of 4. Assume 20 minutes per lift cycle	100	min
l.	Reload STs on flatcar		
	Engage crane to ST, move to flatcar, disengage crane, and move to next ST (perform twice)	28	min
	Engage 3rd ST, load and disengage	12	min
	Replace tie downs	10	min
	Time to reload	40	min
m.	Move truck from parking area to unloading station and spot.		
	Travel distance, approximately 400' including turnaround and back in to station.		
	Travel time at 1 mph average (87 ft/min)	4.5	min
	Turning and spotting	<u>1.5</u>	min
		6.0	min
n.	Unload ST from flatbed		
	Remove ST tiedowns (4 per ST)	10	min
	Engage crane sling (4 points)	5	min
	Lift ST free of flatbed	<u>1</u>	min
		16	min
o.	Move truck out of unloading station	4	min
p.	Respot truck for loading	6	min
q.	Load ST on flatbed		
	Engage crane sling (4 points)	5	min

Move ST and place on flatbed	2 min
Disengage crane sling	5 min
Replace tie downs	<u>10 min</u>
	22 min

- 1.3 A summary for Vehicle Unloading/Reloading Cycle times is presented in Table 1.3.

1.4 Shipment Scenarios

The usage of the railcar unloading stations can be determined from Table 1.3 for various shipment scenarios. For example, (assuming use of only one railcar prime mover):

- a. If all drums are received in CCs in ATMX cars, 3 cars per day are required. In addition, the weekly ATMX containing RFs could arrive on the same day. The unloading station time required would be:

$$\begin{aligned}
 3 \text{ ATMX (CC)} &= 276 \times 3 &= & 828 \\
 1 \text{ ATMX (RF)} &= 229 \times 1 &= & \underline{229} \\
 &&& 1,057 \text{ min}
 \end{aligned}$$

Since, with two 10-minute rest periods, there are 460 minutes in an 8-hour day, this requires 2.3 station days. Thus, two stations would fall 2.4 hours short of handling this vehicle load. However, since the RF shipment arrives only once per week, the daily average station time required, if all drums received in cargo containers in ATMX cars is 874 minutes. This could be handled in 1.9 station days, or 2 stations each utilized 95 percent of the time.

- b. If all drums are received in returnable M3s, 2 ATMX cars per day are required. In addition the weekly RF shipment would arrive on one of the days. The unloading station time required would be:

$$\begin{aligned}
 2 \text{ ATMX (M3)} &= 376 \times 2 &= & 752 \\
 1 \text{ ATMX (RF)} &= 229 \times 1 &= & \underline{229} \\
 &&& 981
 \end{aligned}$$

TIME SUMMARY FOR VEHICLE UNLOADING/RELOADING

Vehicle/Container Combination Unload - Reload Cycle	ATMX With CC	ATMX With M3 (returnable)	ATMX With M3 (contaminated)	ATMX With RF	Flatcar With ST	Truck With ST
Unload Vehicle (min.)						
Spot vehicle (from hold yard)	24	24	24	24	24	6
<i>sample 15</i> Remove vehicle restraints and lids	25	25	25	25	--	--
Unload container(s)	50	100	100	116	44	16
Replace vehicle lids	15	15	40	40	--	--
Move vehicle to hold yard	<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	<u>4</u>
Unload Cycle Time (min.)	138	188	213	229	92	26
Unload Cycle Time (hrs.)	2.3	3.2	3.6	3.8	1.5	0.5
Reload Vehicle (min.)						
Spot empty vehicle	24	24	(Not	(Not	24	6
Remove vehicle lid	15	15	Reloaded)	Re-	--	--
Reload container(s)	50	100		loaded)	40	22
Replace vehicle lid and restraints	25	25			--	--
Move vehicle to hold yard	<u>24</u>	<u>24</u>			<u>24</u>	<u>4</u>
Reload Cycle Time (min.)	138	188			88	32
Reload Cycle Time (hrs.)	2.3	3.1			1.5	0.5
Unload/Reload Cycle (min.)	276	376	213	229	180	58
Unload/Reload Cycle (hrs.)	4.6	6.3	3.6	3.8	3.0	1.0

Thus, the maximum day would require 2.1 station days, and two stations would fall 48 minutes short of handling the vehicle load. The daily average station time required would be 798 minutes or 1.75 station days.

Thus 2 stations, each utilized 88 percent of the time, could handle this situation on the weekly average.

- c. If all drums are received in STs on flatcars, 3 flatcars per day is the maximum required. The weekly shipment of RFs would also arrive. The unloading station time required would be:

2 hr 55 min

$$3 \text{ Flatcars (ST)} = 180 \times 3 = 540$$

$$1 \text{ ATMX (RF)} = 229 \times 1 = 229$$

*6 hrs
total
360 min*

Thus, the maximum day would require 1.7 station days, and the weekly average would require 586 minutes or 1.3 station days. Two stations each utilized 65 percent of the time could handle this average day.

- d. If all drums are received in STs on flatbed trucks, 8 trucks per day will be required for processed waste. The weekly shipment of RFs would also arrive but would be unloaded at a rail station rather than a truck station. The maximum truck unloading station time required would be:

$$8 \text{ Flatbed trucks (ST)} = 8 \times 58 = 464 \text{ min}$$

Thus, one truck station utilized 100 percent of the time would handle the maximum unloading requirement, if this very tight schedule could be maintained. However, materials and supplies must also be received at the truck station. Therefore, a single truck station is inadequate. Placing two truck stations side-by-side appears to provide adequate unloading capacity, since only 4 hours of actual use of the crane is required. (Only one crane can service these two truck stations.) However, greater flexibility could be obtained by using a railcar station and the second crane for the second truck unloading station. Thus, only one truck-only station would be required.

- e. If drums are received by any mix of ATMX (CC), ATMX (M3), Flatcar (ST) and Truck (ST), the railcar unloading station weekly time utilization (2 stations) will fall between the maximum of 95 percent for both stations if all ATMX (CC) and 50 percent for one station if all Truck (ST) (assuming one truck station is a railcar station). Shipments of contaminated M3s reduce the utilization of the railcar stations since the ATMX is not reloaded in this case.

1.5 Observations

- 1.5.1 The high utilization (95% and 88%) of the railcar stations seems too high for sustained operation. However, if shipments are equally distributed between ATMX (CC), ATMX (M3) and Flatcar (ST), the average utilization would be about 83%. If truck shipments also are considered, the utilization is reduced to 75%.

- 1.5.2 The utilization factor for the railcar stations could be reduced by providing rail access to the truck unloading station. This would provide the capability to handle the worst day case (ATMX (CC) + ATMX (RF)) with an average utilization of 75 percent for each of the three stations. The average utilization of each station during the worst week would be 63%.

With three unloading stations the utilization factor for worst day shipments of ATMX (M3) would be 71 percent, and the average for the worst week would be 57 percent.

- 1.5.3 Utilization of the bridge cranes in the unload/load area is as follows:

	<u>% of cycle</u>	<u>% of time</u>
ATMX (CC) shipment	58	
ATMX (RF) shipment	64	
ATMX (M3) shipment	70	
Truck (ST) shipment	66	
ATMX (CC) + ATMX (RF) worst day		68

	<u>% of cycle</u>	<u>% of time</u>
ATMX (CC) + ATMX (RF) average day	--	55
ATMX (M3) + ATMX (RF) worst day	--	73
ATMX (M3) + ATMX (RF) average day	--	60

By comparison of the utilization factors for the stations and the cranes, it is evident that for three stations and two cranes, the capacity of the cranes rather than the number of stations becomes the limiting constraint on the receiving capacity of the facility.

The above crane utilization factors assume that the cranes are not used for any other functions such as removal of container cover restraints or bracing, or removal and replacement of bin covers if the bin air-lock concept is used.

- 1.5.4 The cycle time for a station could be reduced by having two prime movers for railcars. This would permit an incoming car to standby just beyond the switch closest to the station. Thus, the tieup of the station for car movements would be reduced to about 22 minutes per unload/reload cycle rather than 96 minutes. Under these conditions, the worst day station time required would be 800 minutes. With two stations, each would be utilized 87 percent of the time. Comparing the use of two prime movers to use of three stations indicates that three stations gives better utilization factors than two prime movers. With two prime movers, the station utilization rather than crane utilization is the controlling factor.

- 1.5.5 The utilization time required for the prime movers would be as follows:

	<u>Min</u>
Hookup and start moving	4
Travel from hold yard to wait station	15
Wait at wait station	15

Enter building and unhook	6
Return to hold yard	<u>15</u>
	55

This sequence (or the equivalent) would occur four times for each unload/reload cycle. Thus the time utilized for the worst case day would be 770 minutes. This would utilize two prime movers, each 84 percent of the time. Three prime movers total probably would be needed to provide for high level waste and material and supply shipments.

If the wait time were eliminated, the prime mover time utilized would be 560 minutes, or 61 percent utilization of two prime movers.

- 1.5.6 Since a minimum of two prime movers is required to handle the worst day traffic, the utilization of two stations can be reduced to 87 percent by having a prime mover with incoming car wait near the unload/reload station. If three stations and the wait concept are used, the utilization of each station would be 58 percent, and the utilization of the cranes would become the controlling factor. This would provide flexibility and some relief in the event of malfunction of station doors.
- 1.5.7 The utilization of the stations could be reduced if any of the functions performed at the station could be removed to another station outside the building. The candidate functions and their time requirements are:

	<u>Remove</u>	<u>Replace</u>
Vehicle restraint	10	10
Vehicle lids	15	15
Vehicle bracing	15	15

Lid removal at a remote station would also reduce the crane utilization.

If it is assumed that:

- Vehicle restraints, lids and bracing are removed outside the building
- Cars wait close to the building for an available station

then the cycle times would be:

<u>Unload</u>	(Minutes) <u>ATMX (CC)</u>	(Minutes) <u>ATMX (M3)</u>	(Minutes) <u>ATMX (RF)</u>
Spot vehicle	6	6	6
Unload container	50	100	116
Move out vehicle	<u>5</u>	<u>5</u>	<u>5</u>
	61	111	127
Reload	<u>61</u>	<u>111</u>	<u>0</u>
Total cycle	122	222	127

Utilization factors would be:

	<u>Station % Each</u>		<u>Cranes</u>
	2 Stations	3 Stations	% Each
ATMX (CC) + ATMX (RF), worst day	54	36	45
ATMX (CC) + ATMX (RF), average day	42	28	35
ATMX (M3) + ATMX (RF), worst day	62	41	56
ATMX (M3) + ATMX (RF), average day	51	34	46

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If the vehicle bracing remained in the car until it reached the unload station, approximately 30 minutes would be added to the cycle and the ATMX (CC) + ATMX (RF) worst day station utilization with 2 stations would be 76 percent, and 51 percent for 3 stations.

1.5.8 Another possibility for reduction of the station utilization factor could be achieved if different containers (of the same type) than those received could be returned to sender. The effect on station utilization would be significant if lid removal cannot be performed outside the building, but minor if lid removal is outside. The effect on crane utilization appears to be insignificant since the only crane time eliminated would be about 8 minutes of crane travel for unloading CCs per cycle. The major effect would be reduction of delay time for the railcar or truck. As noted under Item 1.1 a modification of criteria allows the return of containers by different vehicles but still requires that they be shipped to the point of origin.

1.5.9 On the worst railcar day there are 3.5 unload/reload cycles. For each cycle the prime mover enters and leaves the building four times as follows:

- Enter, spot loaded vehicle, leave
- Enter, attach empty, leave
- Enter, spot empty, leave
- Enter, attach vehicle, leave

Therefore, the door is opened 14 times during the day. If 15 minutes is assumed to open the door, 5 minutes to close the door, and 10 minutes for the prime mover to move in and out, 280 minutes per day will find the door unsealed. This represents 61 percent of the active work day. Entry of trucks delivering materials or supplies will increase the percentage of time that doors are unsealed.

For the worst truck day there are 8 truck unloads, 8 truck reloads, and one ATMX (RF) unload/reload cycle. Therefore a door is opened 32 times for trucks and 2 times for the ATMX (RF). Thus, if a door open/close cycle requires 13 minutes for a truck and 20 minutes for the ATMX (RF), the total time a door is unsealed during the day is 456 minutes or essentially 100 percent of the work day.

14
20
280

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The large portion of the time that a door to the loading area must be unsealed appears to cast doubt on the acceptability of a facility concept without an air lock between the loading area and the container unloading area.

It also is observed that with these large utilization factors for the doors, the doors could become the limiting factor on the receiving capacity of the facility, if they are interlocked to allow only one unsealed door at any time.

Utilization of air locks for trucks and railcars therefore appears to be the most reasonable means of providing building access while assuring maintenance of control of facility environment.

- 1.5.10 A possible concept for an air lock between the loading area and the container unloading area is a bin, top opening into the vehicle unloading/loading area and end opening into the container unloading area. This would permit a container to be loaded into the bin through the open top by the vehicle unloading crane. After the bin lid is in place, the end of the bin is opened and the container unloaded through its end door.

The utilization of the cranes will be increased by the time required to remove and replace bin lids. Two bin lid lifts are required for each ¹⁶8 M3s and each ¹⁰12 RFs. If it is assumed that five minutes is required to move a bin lid from the top of a bin to a storage platform at the same elevation as the top of the bin, the crane time required for bin lid lifting associated with unloading each type of shipment is:

ATMX (CC)	10 minutes
ATMX (M3)	25 minutes
ATMX (RF)	24 minutes
Flatcar (ST)	10 minutes

Thus the added crane time and crane utilization for the maximum days would be as follows. (No station utilization time is added if it is assumed that lids are moved while the vehicles are being moved into or out of the station.)

	<u>Time (min)</u>	<u>Utilization %</u>
3 ATMX (CC) + ATMX (RF)	54	6
2 ATMX (M3) + ATMX (RF)	74	8

During the August 4 - 5, 1976 review meeting this concept was judged to be less desirable than the addition of truck/railcar air locks. This data is therefore presented for completeness but the represented design approach is not being pursued.

- 1.5.11 Discussions during the August 4 - 5, 1976 review meeting centered on the utilization of air locks for truck/railcar access to the building. ~~Two air locks would be added to retain the ability to have access to any station without disrupting operations in other stations.~~ Addition of air locks will impact station utilization because of the additional door travel required. The additional time for a railcar will be 5 minutes to open and 5 minutes to close the door and for trucks a total of 6 minutes additional time. Tables 1.6 and 1.7 show the impact of air locks and changes in shipping criteria on cycle times.

The impact of this additional time on the various cycles analyzed to this point is summarized in Table 1.8, Sections 6 and 7, for the assumed operation without close wait and without a lid station.

Table 1.8, Section 8, shows the impact of the addition of air locks to operation with close wait and an external lid station for removal of lids and bracing.

1.6 Summary and Conclusions

- 1.6.1 Table 1.7 summarizes the utilization factors for railcar stations and cranes under various conditions. It also contains incremental utilization factors for cranes to be added to the crane factors if air lock bins are used and the bin lids are handled by the cranes.
- 1.6.2 Station and crane utilization factors should be kept low to provide for future increased rates of material inflow, to provide flexibility, and to partially accommodate malfunctions of equipment.

or 4
Three reg'd?
4 UTILIZED 4/14/77
+ start/stop
time for
vehicle in
the lock

**TIME SUMMARY FOR VEHICLE UNLOADING/RELOADING
UTILIZING AIR LOCKS FOR BUILDING ACCESS**

Vehicle/Container Combination Unload - Reload Cycle	ATMX With CC	ATMX With M3 (returnable)	ATMX With M3 (contaminated)	ATMX With RF	Flatcar With ST	Truck With ST
Unload Vehicle (min.)						
Spot vehicle (from hold yard)	24	24	24	24	24	6
Air lock operation	10	10	10	10	10	3
Remove vehicle restraints and lids	25	25	25	25	--	--
Unload container(s)	50	100	100	116	44	16
Replace vehicle lids	15	15	40	40	--	--
Air lock operation	10	10	10	10	10	3
Move vehicle to hold yard	<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	<u>4</u>
Unload Cycle Time (min.)	158	208	233	249	112	32
Unload Cycle Time (hrs.)	2.6	3.5	3.9	4.2	1.8	0.5

TIME SUMMARY FOR VEHICLE UNLOADING/RELOADING
UTILIZING AIR LOCKS FOR BUILDING ACCESS

Vehicle/Container Combination Unload - Reload Cycle	ATMX With CC	ATMX With M3 (returnable)	ATMX With M3 (contaminated)	ATMX With RF	Flatcar With ST	Truck With ST
Reload Vehicle (min.)						
Spot empty vehicle	24	24	(Not Reloaded)	(Not Re- loaded)	24	6
Air lock operation	10	10			10	3
Remove vehicle lid	15	15			--	--
Reload container(s)	50	100			40	22
Replace vehicle lid and restraints	25	25			--	--
Air lock operation	10	10			10	3
Move vehicle to hold yard	<u>24</u>	<u>24</u>			<u>24</u>	<u>4</u>
Reload Cycle Time (min.)	158	208			108	38
Reload Cycle Time (hrs.)	2.6	3.5			1.8	0.6
Unload/Reload Cycle (min.)	316	416	233	249	220	70
Unload/Reload Cycle (hrs.)	5.2	7.0	3.9	4.2	3.6	1.1

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TIME SUMMARY FOR VEHICLE UNLOADING/RELOADING
UTILIZING AIR LOCKS FOR BUILDING ACCESS
ASSUMING EMPTY CONTAINERS AVAILABLE FOR RETURN TO SENDER

Vehicle/Container Combination Unload - Reload Cycle	ATMX With CC	ATMX With M3 (returnable)	ATMX With M3 (contaminated)	ATMX With RF	Flatcar With ST	Truck With ST
Unload ^{Reload} Vehicle (min.)						
Spot vehicle (from hold yard)	24	24	24	24	24	6
Air lock operation	10	10	10	10	10	3
Remove vehicle restraints and lids	25	25	25	25	--	--
Unload container(s)	50	100	100	116	44	16
Reload container(s)	50	100	--	--	40	22
Replace vehicle lids	15	15	40	40	--	--
Air lock operation	10	10	10	10	10	3
Move vehicle to hold yard	<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	<u>24</u>	<u>4</u>
Cycle Time (min.)	208	308	233	249	152	54
Cycle Time (hrs.)	3.5	5.1	3.9	4.2	2.5	0.9

TABLE 1.8
UTILIZATION FACTOR (% EACH UNIT)
(Railcar Stations and Cranes)

Handling Conditions Shipment Scenario	Maximum Day			Average Day		
	2 Stations	3 Stations	2 Cranes	2 Stations	3 Stations	2 Cranes
1. <u>Without close wait, without lid station</u>						
3 ATMX (CC) + ATMX (RF)	115	75	68	95	63	55
2 ATMX (M3) + ATMX (RF)	105	71	73	88	57	60
3 Flatcar (ST) + ATMX (RF)	85			65		
1/3 each ATMX (CC), ATMX (M3), Flatcar (ST) + ATMX (RF)				83		
1/4 each ATMX (CC), ATMX (M3), Flatcar (ST), Truck (ST) + ATMX (RF)				75		
2. <u>Without close wait, without lid station</u>						
3 ATMX (CC) + ATMX (RF)	87	58	68			55
2 ATMX (M3) + ATMX (RF)			73			60
3 Flatcar (ST) + ATMX (RF)						
3. <u>With close wait, with lid station (lid only)</u>						
3 ATMX (CC) + ATMX (RF)	76	51	45			35
2 ATMX (M3) + ATMX (RF)			56			46
3 Flatcar (ST) + ATMX (RF)						

TABLE 1.8 - Cont.
UTILIZATION FACTOR (% EACH UNIT)
(Railcar Stations and Cranes)

Handling Conditions Shipment Scenario	Maximum Day			Average Day		
	2 Stations	3 Stations	2 Cranes	2 Stations	3 Stations	2 Cranes
4. <u>With close wait, with lid station (lid + bracing)</u>						
3 ATMX (CC) + ATMX (RF)	54	36	45	42	28	35
2 ATMX (M3) + ATMX (RF)	62	41	56	51	34	46
3 Flatcar (ST) + ATMX (RF)						
5. <u>Air lock lids (add for lids)</u>						
3 ATMX (CC) + ATMX (RF)			6			
2 ATMX (M3) + ATMX (RF)			8			
6. <u>Building air locks</u> (Without close wait, without lid station)						
3 ATMX (CC) + ATMX (RF)	130	87		105	70	
2 ATMX (M3) + ATMX (RF)	120	80		90	60	
3 Flatcar (ST) + ATMX (RF)	100	67		70	47	

TABLE 1.8 - Cont.
UTILIZATION FACTOR (% EACH UNIT)
(Railcar Stations and Cranes)

Handling Conditions Shipment Scenario	Maximum Day			Average Day		
	2 Stations	3 Stations	2 Cranes	2 Stations	3 Stations	2 Cranes
7. <u>Return of containers to sender on different vehicle plus addition for air locks</u> (Without close wait, without lid station)						
3 ATMX (CC) + ATMX (RF)	95	63		70	47	
2 ATMX (M3) + ATMX (RF)	95	63		65	43	
3 Flatcar (ST) + ATMX (RF)	75	50		50	33	
8. <u>Building air locks with close wait, with lid station (lid and bracing)</u>						
3 ATMX (CC) + ATMX (RF)	80	53		55	37	
2 ATMX (M3) + ATMX (RF)	80	53		55	37	
3 Flatcar (ST) + ATMX (RF)	125 ?	83		100	67	

- 1.6.3 Maximum day shipments of CCs and M3s cannot be accommodated by two stations unless the "close wait" concept is used. That is, a car is standing by as close as possible to the station to move in as soon as the station is available.
- 1.6.4 Even with the close wait concept, the utilization of two stations is 87 percent which is higher than comfortable. This can be reduced by either of two approaches; installing a third station, or installing a vehicle lid removal/replacement station external to the building.
- 1.6.5 A third station could be installed by extending the building at the truck station and providing a dead end spur track to accommodate a railcar. The door would also probably need to be enlarged. If this were done, the station utilization would decrease to 58 percent but the crane utilization could be as high as 81 percent for an M3 day if the crane is also used to lift air lock lids. Thus, the cranes would be controlling and there would be little, if any, flexibility or unused capacity in the system. The crane utilization could be reduced to 73 percent maximum by installing a separate crane or other mechanical device for air lock lid lifting.
- 1.6.6 The crane utilization can be reduced to 56 percent (64 percent if bin lids lifted) by using a remote station to remove the ATMX lids. If the car bracing also is removed at this remote station, the car unloading station utilization is reduced to 62 percent for two stations. Thus a good balance is achieved between station utilization and crane utilization. There would be no gain in potential throughput increase by installing a third station since the crane utilization is controlling and for three stations and two cranes the crane utilization increases faster than station utilization when the throughput is increased.
- 1.6.7 The preferred approach appears to be to use the "close wait" concept and a remote ATMX lid station, without providing railcar access to the truck station. This would provide the ability to accommodate equipment malfunctions without rapid buildup of backlog and to achieve maximum growth in throughput. It also presents the alternative of providing for the remote station but postponing its installation until the throughput proves to exceed the capacity.

- 1.6.8 To achieve the utilization factors indicated will require very precise scheduling and traffic control both inside the building and on the site rail system. Automatic display, complete communication, and possibly central control of yard traffic will be required.
- 1.6.9 Although the truck station maximum utilization factor is only 50 percent for two stations, the crane utilization would be 66 percent (without bin lids which would be lifted by the other crane) since only one crane services both stations. Providing truck access to the railcar stations would be a minor expense and is recommended since it would provide access to the other crane.
- 1.6.10 If the "close wait" concept is used and there are only two prime movers, each would be utilized 84 percent of the working day. If there are two prime movers but the "close wait" concept is not used, each prime mover is utilized 61 percent of the time. Thus, 2 prime movers might suffice initially, but a third would need to be added as the number of movements increased or when a remote lid station was installed.

2. LAYDOWN SPACE UTILIZATION

2.1 Basis and Requirements

Three types of containers (ST, CC, M3) holding 55 gallon drums (55D) are received at the unloading stations. In addition, RF boxes are received. All containers and boxes are unloaded from the vehicles and transported to a laydown area by bridge cranes. An alternative possibility would be to unload drums from an ST while the ST is on a flatbed truck. This method of unloading might also be applied to the last ST on a flatcar. The laydown area is an open floor space between the vehicle unloading area and the container unloading area. (The container air sampling location and procedure should be defined. If sampling can be performed before unloading the ST from the vehicle, this may not be a consideration in the time cycle since sampling could probably be performed while the tiedowns are being removed.)

The forklift will need to be modified to reduce the height of the uprights and of the safety guard.

The 55Ds are assumed to be unloaded three at a time from the containers (STs and CCs) through end-opening doors while the containers are in the laydown area. (A special design drum grabber will need to be developed to lift three drums from the side since there is inadequate headroom in an ST to lift from above?) The 55Ds are then moved to a 24-drum pallet. However, a small portion of the containers may be found to be contaminated on the inside. Internally contaminated containers are moved to the overpack area for unpacking. (If internal sampling is performed while containers are on the vehicle, contaminated containers would be moved directly from the vehicle to the overpack area.) This frees the space for other use. When containers are unloaded in the laydown space, the space is tied up until the proper type vehicle is available in a loading station to receive the container.

Twenty M3s are received in an ATMX car. They are lifted, four at a time, using a special spreader, and moved to a laydown space. Eight

*Comments by J. Pelt (markings on copy given
1/11/74) by L. W. W. on 12/2/72*

M3s can be placed in a 11' x 27' laydown space with space remaining for stacking of the M3 lids as they are removed. Since the M3s are top loading, empty laydown space must be left between groups of M3s to allow unloading. The air in each M3 is sampled for contamination prior to removing the lid from it. (The sampling method should be defined).

55Ds are removed from the M3 using a ^{2.5T} forklift equipped with a special design drum grabber based on the Lift-O-Matic concept. The drum lifting device will need to extend below the truck forks far enough to reach the bottom layer of drums in the M3. This can be done by a fixed extension of at least 3 feet or by a movable extension which can travel vertically to reach the drums. The fixed extension would be less costly but it would increase the lift height required for the forklift by about 3 feet to a clear lift height of at least 12 feet under the forks.

The present design of the M3 prevents unloading drums 4 at a time. However, the design may be modified to permit unloading 4 at a time. If this design modification is not made it will be necessary to unload drums one or possibly two at a time. This would require modification of the lifting device to permit rotation so that a drum in any quadrant could be gripped at the point on a radius of the four drum cluster.

After the M3s are emptied, and the lids replaced on them, they are lifted, four at a time, into an ATMX car for shipment back to the sender.

Twenty-four RFs are received in an ATMX. They are handled four at a time (stacked two high) using the slings which are left in place by the sender. A spreader will need to be designed to maintain a 6-inch spacing between the RF stacks to permit removal of the slings after the RFs are placed in the laydown area. It is visualized that slings would be removed by

unhooking the outboard side of the sling from the crane hook and then pulling the slings from around the RFs by raising the crane hook to pull the slings through the space between the RF stacks. The slings would be returned to the ATMx by the crane as it approached for the next load of RFs. About 38 ft. clear from floor to crane hook would be required for the slings to clear the top of the RF stack.

The air inside the RF is not sampled for contamination nor is any material removed from the RF. The RFs are removed from the laydown space, one at a time, using a 7.5 T forklift. They are transported to a 8.5' x 12.5' pallet which holds two RFs. Before being placed on the pallet they are inspected for damage and external contamination(?). If damaged or contaminated, they are moved to the minor repair or overpack areas as appropriate.

In summary, the quantity of items moving into and out of a laydown space for the various types of containers and waste received, are:

LAYDOWN SPACE MATERIAL FLOW

Item Received Container/Waste	<u>Vertical</u>		<u>Horizontal</u> Out
	In	Out	
Supertiger/Processed	1-ST	1-ST	33-55D
Supertiger/Unprocessed	1-ST	1-ST	42-55D
Cargo Container/Processed	1-CC	1-CC	43-55D
Cargo Container/Unprocessed	1-CC	1-CC	60-55D
Mark 3/Processed Unprocessed	8-M3	8-M3	64-55D
Mark 3/ Unprocessed Contaminated	8-M3	-	8-M3
Rocky Flats Box	12-RF	-	12-RF

The arrangement of items in the laydown space and in the containers is indicated in the following sketches. It can be observed that:

- If four M3s are carried in a single lift by the unloading crane, eight M3s (2 lifts) can be loaded into a laydown space with space inside the laydown to stack the M3 lids when they

are removed. 2.5 laydown spaces are required to hold the M3s from an ATMX car.

- Twelve RFs in a laydown space is one-half an ATMX carload.
- An ST with inside dimensions of 76" x 76" x 172" long will hold 42 55Ds in three columns of seven each. To unload two at a time by forklift would present difficulty. (When drums are three per row, it is difficult to pick up two per lift without having drums moved about between lifts. A man would have difficulty moving a 900 lb drum by hand.) Therefore, drums should be removed one at a time or three at a time.
- Above comments regarding unloading also apply to the CC. Inside dimensions of CCs are about 7' -9-3/4" (93-3/4") wide by 7'-4-1/8" (88-1/8") high.
- Portable ramps will need to be used with the ST and CC to allow the forklift to enter the container. These ramps will need to be stored when not in use. The ramp for the ST will be about 10" high; for the CC about 6-1/2" high.
- It appears that M3s (contaminated) can be removed one at a time from the end of the laydown area by means of a 7.5 T forklift. A boom attachment appears feasible for lifting the M3 with a 30" load center.
- It may not be possible to lift 55Ds from the M3 four at a time due to the lip on the M3 which reduces the minimum opening to 46-3/4". The Lift-O-Matic four drum device spaces the drums at 1" apart (i.e., 47" outside dimension). Redesign of the M3 will be required for four drum lifting.
- It should be possible to remove drums, two at a time, with two single drum grapples on a lifting beam. One at a time may be the most practical.
- With the arrangements shown, a single laydown space size (11' x 27') will accommodate all four containers.

- o One laydown space is equipped with a dolly (50,000 lbs. capacity) for transport of occasional STs or CCs (internally contaminated to the overpack area for unpacking.

2.2 Time Estimates

A container laydown station is "tied up" or utilized from the time it is designated to receive a container(s) until the container(s) is removed and the space is available to receive another shipment. Thus, the activities that determine the time cycle for laydown space utilization are:

- a) Move container(s) from vehicle to laydown
- b) Sample air inside container (ST or CC). (This should be done, while container is on the vehicle, rather than in the laydown space.)
- c) Open container door (for ST and CC only)
Remove Lids (for uncontaminated M3 only)
- d) Place ramp (ST and CC only)
- e) Empty container (if ST, CC or uncontaminated M3) or laydown space (if RF or contaminated M3)
- f) Close container door(s) (ST or CC)
Replace lids (uncontaminated M3)
- g) Wait for proper type vehicle to be spotted (if ST, CC or uncontaminated M3)
- h) Move ST, CC or uncontaminated M3s from laydown space to vehicle.

if feasible,

for availability of crane, if necessary.

Time cycle estimates for the four types of containers, two types of waste and three types of vehicles follow:

1. Supertiger, Processed Waste (ST-P), Flatcar or Truck,
Sample air at laydown, no wait for vehicle.
 - 1.1 Move ST-P from flatcar or truck to laydown and disengage sling
 - 1.2 Sample air in ST

Min.

8

15

	<u>Min.</u>
1.3 Open ST door (unbolt and swing back two doors in sequence)	47
Based on estimate provided by Sandia:	
1. Remove 10 bolts from outer door	15
2. Open outer door and secure	7
3. Remove inner door bolts and open	<u>25</u>
	47
1.4 Place ramp on floor	10
1.5 Remove 33 55Ds from ST (3 per lift)	55
Assume forklift used to enter ST, engage three drums, backout and down ramp, turn, travel 20 ft. go up ramp onto pallet, release drums on pallet, back-off pallet and down ramp, turn, return 20 ft to ST (5 min/cycle)	
1.6 Remove ramp from floor and store	10
1.7 Close ST doors	47
1.8 Engage sling and move ST from laydown to flatcar or truck	<u>8</u>
	200
2. <u>Supertiger</u> , Unprocessed Waste (ST-U), Flatcar or Truck	
Sample air at laydown, no wait for vehicle.	
1.1 Time elements from moving the ST through placing ramp on floor (1.1 - 1.4) are the same as Case 1	80
1.5 Remove 42 55Ds from ST (3 per lift). Assume 5 min/lift cycle.	70
1.6 Time elements from removing ramp through returning ST to vehicle (1.6 - 1.8) are the same as Case 1.	<u>65</u>
	215
3. <u>Supertiger</u> , Processed Waste (ST-P), ST remains on Flatbed truck	
3.1 Sample air in ST.	15
3.2 Isolate tiedown from door only	10
3.3 Open ST door (unbolt and swing back two doors in sequence).	47
<i>(ST must be shipped on shims to raise it off flatbed.)</i>	
3.4 Place ramp on floor	10
3.5 Remove 33 55Ds from ST (3 per lift). Assume there are sufficient forklifts operating so that a forklift approaches the truck bed as soon as the approach is cleared by the	

	<u>Min.</u>
previous forklift (assume 4 min/cycle).	44
3.6 Remove ramp from floor and store	10
3.7 Close ST doors	47
3.8 Replace tiedown on door	<u>10</u>
	193

4. Cargo Container

Cargo containers are shipped only in an ATMX. Therefore, they must be unloaded from the ATMX and moved to a laydown area for removal of the 55Ds. Internal air can be sampled only at laydown area.

	<u>Min.</u>
4.1 <u>CC, unprocessed waste (CC-U), sample air at laydown, no wait for vehicle.</u>	
4.1.1 Move CC-U from ATMX to laydown area, disengage sling	8
4.1.2 Sample air in CC	15
4.1.3 Open CC doors (CCs are equipped with two doors and quick opening latch devices, 2 per door).	4
4.1.4 Place ramp on floor	10
4.1.5 Remove 60 55Ds from CC (3 per lift, 5 min/cycle)	100
4.1.6 Remove ramp from floor and store	10
4.1.7 Close CC doors	4
4.1.8 Move CC from laydown to ATMX	<u>8</u>
	159
4.2 <u>CC, processed waste (CC-P) sample air at laydown, no wait for vehicle</u>	
4.2.1 Move CC-P from ATMX to laydown area	8
4.2.2 Sample air in CC	15
4.2.3 Open CC doors	4
4.2.4 Place ramp on floor	10
4.2.5 Remove 43 55Ds from CC (3 per lift, 5 min/cycle, 15 cycles)	75
4.2.6 Remove ramp from floor and store	10
4.2.7 Close CC doors	4
4.2.8 Move CC from laydown to ATMX	<u>8</u>
	134

5. Mark 3

Min.

Eight M3s are moved from an ATM~~X~~ (4 at a time) and placed in a laydown space. M3s with undrummed waste are removed from the laydown area, one at a time, and placed on pallets for transport down the mine shaft. Handling of processed and unprocessed waste (in drums) is identical through the laydown area. Drums are removed through the top of the M3, one at a time (or 4 at a time if the M3 is redesigned) and placed on a 24-drum pallet.

5.1 M3, contaminated M3 or undrummed waste, no air sampling, no return of M3s

5.1.1 Move eight M3s from ATM~~X~~ to laydown area (four at a time), ^{two} lift cycles at 20 minutes (assumed) per cycle)

40

5.1.2 Remove eight M3s from laydown space

40

(Attach forklift sling to M3, lift M3, back out, turn, move to pallet, move up ramp onto pallet, deposit M3, return to laydown area. Assume 8 min/cycle.)

80

As there are no barriers around the laydown space, the forklift can start moving M3s out of the space as soon as the crane deposits the first four. Thus, the cycle time added is only that required to remove the five M3s from the space after the last load is deposited.)

6. RF Box

Twenty-four (24) boxes are received in an AMTX car. The crane moves them four at a time, from the AMTX to the laydown space. Twelve boxes are placed in a laydown space, i.e., 3 lift cycles at 16 minutes per cycle. RF boxes contain undrummed waste and therefore are never returned to the sender and do not require sampling of air in the box. RF boxes are removed from the laydown space one at a time by forklift.

6.1 RF, undrummed waste, no air sampling, no wait for vehicle, assume only one forklift used.

6.1.1 Move 12 RFs from ATMX to laydown area (four at a time) 48

6.1.2 Remove 12 RFs one at a time, from laydown area to log-in area. (132 minutes elapsed time)

a. Enter space, pick up RF, back out 1

b. Scan RF for contamination or minor repair 5

c. Move to log-in area or to minor repair area, laydown RF and return 5

(As there are no barriers on the laydown area, the forklift can remove the first RF as soon as the crane removes the sling from the RFs, i.e., about 12 minutes after starting to remove RFs from the ATMX. Thus RFs are being removed from the space during 36 minutes of the time the space is being loaded with RFs. Therefore, the added cycle time will be 96 minutes)

96
144

2.3 Shipment Scenarios

2.3.1 If all drums are shipped in STs on flatcars, nine (9) STs could arrive on the worst day and the ATMX with RFs could arrive the same day. Thus, on the worst day the following laydown space times would be required.

a. The maximum time requirement occurs if the waste is unprocessed, and air sampling is done after unloading.

$$9 \text{ ST-UP} = 215 \times 9 = 2130$$

$$24 \text{ RF (2 spaces)} = 144 \times 2 = \frac{288}{2418 \text{ min.}}$$

Thus for a 460 minute day, 5.2 laydown spaces would be required. Thus six spaces would need to be provided and would be 88% utilized. To provide turning space for the forklift unloading the STs, an empty space must be provided adjacent to each ST space, or a total of 12 spaces is required.

- b. Since the RFs are received only once per week, the average day would require

$$9 \text{ ST-UP} = 215 \times 9 = 2130$$

$$24 \text{ RF} = 144 \times 2/5 = \frac{58}{2188}$$

Thus five spaces would be 95% utilized, but 378 drums would be processed rather than the 260 daily average.

- 2.3.2 If all drums are shipped in CCs, six (6) CCs could arrive on the worst day and the ATMx with RF's could arrive the same day. If the waste is unprocessed, air sampling is done in the laydown space and no wait period is required for a vehicle, the laydown space time required is:

$$6\text{CC-U} = 159 \times 6 = 954$$

$$24 \text{ RF (2 binloads)} = \frac{288}{1242}$$

Thus 2.7 spaces would be adequate or 3 spaces would be 90% utilized.

- 2.3.3 If all drums (processed waste) are received in STs on flatbed trucks (8 per day) and the STs remain on the flatbed during unloading of ST, the tieup time for the truck station will be:

a. Move flatbed from parking area, turn and spot inside building airlock	6
b. Close outer door, open inner door, move truck to unload station, decouple tractor.	6
c. Unload ST	193
d. Move truck out of unloading station through airlock	8
	<u>213</u>

$$8 \times 213 = 1704 \text{ min.}$$

Thus, 3.7 truck stations are required. Four (4) stations would need to be provided (93% utilized) for trucks and one (1) station to handle the RF boxes.

2.4 UNLOAD ATMX/M3

Basis and Assumptions

- o Maximum of two ATMXs (20 M3s each) arrive per day.
- o Each M3 contains 8 55Ds.
- o On worst day an ATMX with 24 RFs will also arrive.
- o Flow through (in one airlock, out the other) used for vehicles.
- o When a railcar is pushed into station No. 1 it advances the incumbent car to station No. 2 and pushes the car from station No. 3 into airlock No. 2 where it is picked up by a donkey.
- o M3s are lifted 4 at a time from the ATMX and placed in position for unloading by a forklift.
- o M3 lids (12 ga. steel) are secured by 20, 5/16 x 1, 18 UNC screws (hex head). Assume 10 minutes to remove using power tool.
- o M3 lids weigh 100 lbs. and have no pickup points. They will need to be removed by using a sling. Assume sling attached to different forklift than will unload the M3s. Assume 5 minutes to lift, move and laydown lid.
- o Two 25 T cranes may work simultaneously on a single ATMX, but with the ATMX in Station 1 or 3 they must work in unison. Greater flexibility is obtained if each crane operates to the maximum extent in its own half of the building.
- o After the 25 T has moved an ATMX lid(s), the lid sling must be removed and a special sling or stiffback must be attached for lifting the 4 M3s. This time is included (on the average) in the M3 lifting cycle of 20 min per lift.
- o Air inside M3 must be sampled before lid is removed. Assume 10 minutes per M3. Assume sampling crew precedes lid removal crew in perfect sync. (Location of sampling port and method should be defined.)

	<u>Min.</u>
- Move to laydown area and lower	1
- Disengage 4 lifting bars (man must get to top of M3s)	10
- Move 25 T back to ATMX	$\frac{1}{20}$

M3 UNLOAD, SPACE REQUIREMENTS

1. Assumptions

- 1.1 ATMX lids are 17' x 10' x 6.3" thick
- 1.2 Space occupied by ST with door open is 25' x 11'.
- 1.3 Space occupied by CC with doors open is 24' x 8'.
- 1.4 Space occupied by 8 M3s with lids removed and stacked in two stacks at the end of the M3s is 25' x 8' min. or allowing 6" clearance between items, 27' x 8'6". If lids are rotated 90 degrees and stacked in a single stack the overall dimensions including clearance would be 26' x 8'6"
- 1.5 Space occupied by 12 RFs stacked 2 high is 24' x 7'. If 6" clearance is provided between RFs, the space becomes 26'6" x 7'.
- 1.6, 6 Laydown space is needed for two spreaders for removal of CCs. Each spreader is 20' x 8'.
- 1.7 Unloading space module should be 27' x 11'.
- 1.8 When drums are unloaded from STs or CCs three at a time, the maximum payload is 2700 lbs. *When it is necessary to reach over one row of drums to reach second row on a sheet of plywood,* ~~Assuming that pallets are loaded from both sides, the center of the load is 36" from the fork face, when the load is laid down in the inner rows on the pallet.~~ The distance from axle centerline to fork face (4000 lb towmotor) is 12.5". Assuming the lifting device is equivalent to 800 lbs at 36", the total load is 3500 lbs. Thus the inch-pound rating is $(36 + 12.5)(3500) = 170,000$. A capacity of 5000 lbs at 24" is required to give this rating. The minimum aisle for 90 degree stacking is 94" + 48" load or 12'. Thus, a 2.5 T forklift has the ability to load pallets by either driving onto the pallet or reaching

- o Two 2.5 T forklifts work simultaneously to unload 55Ds one at a time from a group of M3s. Each forklift operates in a vacant laydown space; one on each side of the M3 group.
- o As soon as four M3s are emptied they can be reloaded on the ATMX (after lid replacement). Pickup and unhook time is included in the 20 minute M3 handling cycle.
- o As 55Ds are removed from the M3 they are carried by the forklift to a laydown area consisting of a pallet large enough to hold 24 55Ds in a 6 x 4 array. (6.67 pallets are needed to hold the 55Ds from an ATMX). 55Ds are placed on the pallet by driving the forklift up a ramp onto the pallet.
- o Assume the forklift is equipped with a single drum Lift-O-Matic mounted so it can be rotated 360 degrees and have two direction translation. It also has a vertical arm to provide lateral support at the lower portion of the drum.

	<u>Min.</u>
o 55D unload time estimate	
a. Obtain position at M3	.5
b. Lower, align gripper, engage and lift drum	2.0
c. Back, turn and start run	.5
d. Run to laydown and turn	.5
e. Inspect for repair and swipe representative sample	1.5
f. Laydown, back, turn and return to M3	1.0
g. Inventory taken on pallet, independent of handling process. (No cycle time involved.)	<u>0</u>
	6
o The lift cycle for removing M3s from an ATMX consists of:	
- Move 25 T crane with special sling into place	1
- Attach 4 lifting bars to 4 M3s (Crew on top of ATMX from lid removal)	6

and two pickup three drums from the
outboard side of a 4' plywood sheet.

from either side to place drums in the center rows. It also provides some margin of safety if drums are handled four at a time. (The minimum aisle for a 2T forklift is about 11'-4". Thus no significant gain is made by using the smaller lift and some flexibility is sacrificed.)

5.1 Calculation of Forklift size to handle loaded pallet.

12.5'			
24 drums overpacked @ 1000 lbs ea.	8.5'	<u>Load</u>	
		drums	24,000
		pallet	5,000
		forks	<u>1,000</u>
			30,000 lbs

Center of load is 51" from fork face. For trucks in 30K class, distance from fork face to centerline of drive axle is about 24". Thus, inch-pound rating required is $(51 + 24) 30,000 = 2,250,000$ inch-pounds. The truck capacity at 30" (towmotor load center distance for trucks above 20,000 lb class) would be $\frac{2,250,000}{(30 + 24)} = 42,000$ lbs

At 36" load center (Clark rating distance above 30,000 lbs), the truck capacity would be 38,000 lbs. For Clark trucks both the 35K and 40K trucks have 240" turning radius. Overall length to fork face is 242". Thus the machine with forks would be about 26 ft long by 11 ft wide. These trucks (Clark) have gas or diesel engines. The minimum aisle for 90 degree stacking is about 29 feet.

5.2 Calculation of forklift size to handle RF boxes.

This forklift should handle overpacked RFs as well as regular RFs. The overpacked RF is 5 x 5 x 8 and weighs up to 11,000 lbs with a 30" load center. In the 12,000 lb class, the drive axle to fork face distance is 16.13" Thus the inch-pound rating is $(30 + 16.13)(11,000) = 510,000$. The 12,000 lb capacity truck is rated at only 481,000 inch-pounds. Therefore, the next larger size, i.e., the 15,000 lb truck is required. This truck has about an 18" drive axle to fork face distance. Thus the inch-pound rating is $(30 + 18)(11,000) = 528,000$. This is well within the 628,125 inch-pound rating of the truck.

The minimum aisle for 90 degree stacking for the 15,000 lb truck is 128.25" plus load length (60"), or 188.25" (15.7'). An aisle width of 16' should be used.

5.3 Fork lift dimensions (approximate)

<u>Capacity</u>	<u>Dimensions (unloaded)</u>		Min. aisle for <u>90° stacking</u>
	<u>Length</u>	<u>Width</u>	
2000	8'	3'	10'
5000	10'	4'	12'
15,000	14'	5'	16'
40,000	26'	11'	30' 29'

5.4 Hoist

25T with 5T aux (Shaw-Box) requires 3'3" from hook to rail centerline and 10-1/8" from rail to column or wall face. That is, the main hook will reach within 50" of the column face.

The auxiliary hook, following behind the main hook, has a separation distance of 4'10". Thus, it will reach within 9' of the column face.

With the aux hook leading, the main hook will reach within 100" (8'4") of the column face and the aux within 43".

The closest approach of the hooks to the stops in the direction of bridge travel is 8' in one direction and 12' in the other.

2. UNLOAD LAYDOWN SPACE

2.1 Basis and Requirements

Three types of containers (ST, CC, M3) holding 55 gallon drums (55D) are received at the unloading stations. In addition, RF boxes are received. All containers and boxes are unloaded from the vehicles and transported to a laydown area by bridge cranes. The laydown area is an open floor space if no airlock is used between the vehicle unloading area and the container unloading area. If an airlock is used, the laydown area could be end-opening bins with removable lids. If bins are used, about 25 percent more floor space will be required to provide for bin walls and for air sampling of STs if the sampling ports are not on the hinge side of the container. (The sampling location and procedure should be defined. If sampling can be performed before unloading the ST from the vehicle, this is not a consideration.)

The 55Ds are normally unloaded, two or three at a time, from the containers (STs and CCs) through end-opening doors while the containers are in the laydown area. The 55Ds are then moved to a receiving/inspection area. However, a small portion of the containers may be found to be contaminated on the inside. Internally contaminated containers are moved to the overpack area for unpacking. (If internal sampling is performed while containers are on the vehicle, contaminated containers would be moved directly from the vehicle to the overpack area.) This frees the space for other use. When containers are unloaded in the laydown space, the space is tied up until the proper type vehicle is available in a loading station to receive the container.

Since the M3 is top loading, it must be removed from the airlock bin (if the bin is used) before unloading and to free the bin for other use. (If the airlock is not used, the M3s would still be moved from the laydown area to an unloading/receiving/inspection area before unloading, since

access is not available to all M3s while in the laydown area.) The M3s probably are removed one at a time from the bin or laydown area to an *unloading/receiving/inspection area.*

After the M3s are unloaded, they are moved back to a bin or laydown area to await loading onto an ATMX car.

RFs are removed from the bin (or laydown space), probably one at a time, to a receiving/inspection area. It may be desirable to equip the laydown area handling RFs with a movable dolly, so that the entire load (120,000 lbs) can be moved from the laydown area for forklife access to the long side of the RF.

In summary, the quantity of items moving into and out of the laydown space for the various types of containers and waste received, are:

Received		Bin Quantity-Item		
Item (waste)	In Top	Out Top	Out End	In End
Supertiger/Processed	1-ST	1-ST	33-55D	—
Supertiger/Unprocessed	1-ST	1-ST	42-55D	—
Cargo Container/Processed	1-CC	1-CC	43-55D	—
Cargo Container/Unprocessed ^{ed}	1-CC	1-CC	60-55D	—
Mark 3/Processed	10-M3	10-M3	10-M3	10-M3
Mark 3/Unprocessed	10-M3	10-M3	10-M3	10-M3
Mark 3/Undrummed	10-M3	—	10-M3	—
Rock Flats Box	12-RF	—	12-RF	—

The arrangement of items in the bin or laydown space and in the containers is indicated in the following sketch. It can be observed that:

- o If 4 M3s are carried in a single lift by the unloading crane, 10 M3s (2.5 lifts) can be loaded into an airlock bin by lowering to near the bin floor and moving two of the four M3s under the bin top deck. (The center of gravity remains about 2 feet clear of the deck.)
- o To load 10 M3s (4 per lift) into each bin, the loading sequence would be:
 1. Load 4 M3s into bin "a" near the door
 2. Lower 4 M3s at rear of bin "a", leaving two at wall
 3. Carry 2 M3s to bin "b" and deposit at rear wall
 4. Place 4 M3s at center of bin "a"
 5. Place 4 M3s in bin "b" near door
 6. Place 4 M3s in center of bin "b"
- o Ten M3s in a bin is one-half an ATMX carload (This is desirable).
- o Twelve RFs in a bin is also one-half an ATMX carload (This is also desirable).
- o With the arrangements shown, a single bin size and shape will accommodate all four containers.
- o The minimum dimensions for the bin appear to be:
 - Bin inside - 12' x 27'
 - Hatch opening - 9'6" x 22'
 - Door opening - 10' x 10'
- o An ST with inside dimensions of 76" x 76" x 72" long will hold 42 55Ds in 3 columns of 7 each. To unload 2 at a time by forklift would present difficulty. (When drums are 3 per row, it is difficult to

AIR LOCK BINS
PLAN VIEW

AIR LOCK BINS
END ELEVATION
(Unloading Door Open)

1.37 R

ITEM 8251 WIPP PROJECT
ARRANGEMENT IN BINS AND CONTAINERS

SSD Drum: 23" ad x 35 1/4" hi

NO SLIMS

2" square

55 Ds
in 113

56 $\frac{3}{4}$ " inside clear opening
61" outside

51" outside
46 $\frac{3}{4}$ " inside
clear opening

17C Drum
23" diam
35 $\frac{1}{2}$ " high

JD
9/13/76

pick up two per lift without having drums moved about between lifts.

A man would have difficulty moving a 900 lb drum by hand.) Therefore, drums should be removed one at a time or 3 at a time.

- o Above comments regarding unloading also apply to the CC.
 - o If magnetic coupling to drums can be used (this is being investigated), and there is sufficient head room inside the ST and the CC, the drums might be picked out three at a time by forklift. (Other means of drum removal, such as "Lift-O-Matic", are also being investigated.
 - o Portable ramps will need to be used with the ST and CC to allow the forklift to enter the container. These ramps will need to be stored when not in use.
 - o At least one laydown space will need to be equipped with a dolly (50,000 lbs capacity) for transport of occasional STs or CCs (internally contaminated) to the overpack area.
 - o A practical means of removal of the M3s and RFs from the laydown area will need to be determined. (More detail on the configuration of the M3 and RF is needed as a basis for this determination.) One possibility is to install a roller floor in some of the laydown spaces. The rollers would extend about 8 feet beyond the roll up doors (if bins used) allowing M3s and RFs to be pushed or pulled into the working aisle for access by a forklift. Undesirable features of this approach are that it adds the cost of rollers, makes some laydown spaces different from others and adds an activity (lateral rolling movement) to the unloading sequence.
 - o It appears that M3s can be removed one at a time from the laydown area by means of a forklift. There appears to be adequate head room, and a boom attachment appears feasible for lifting the M3.
-

- o Placing of RF boxes in the laydown space from above and removal from the end of the space can be visualized for two alternative configurations; one with the long dimension of the RF parallel to the long dimension of the bin; the other with the long RF dimension perpendicular to the long bin axis.
- o If the RF and bin major axes are parallel, the RFs can be loaded easily, four at a time, into the bin. However, unloading through the end of the bin may present a problem. The slings used to unload the RFs from the vehicle and transport to the bin will have been removed by the overhead crane for return to the sender in the ATMX. The only access under the RF is from the long dimension side. There are no other pickup points. Two approaches to removal from the bin are apparent: a special boom device with pendulous arms to grip an RF from above, or a means of sliding the RFs (on rollers or dollies) through the bin door to provide forklift access to the long dimension of the RFs. Both of these approaches would entail the cost of special equipment development for a low utilization activity. In addition, rollers would need to be covered or dollies removed for bin use with a CC or ST.
- o If the RF and bin major axes are perpendicular, the RFs cannot be loaded, four at a time, into the bin through the 22-foot long top opening indicated. This constraint could be removed by providing a removal section of top deck about 3 by 9 feet at the door end of the bin. (This constraint does not exist if the airlock concept is not used.) With the RF and bin major axes perpendicular, the RFs can be removed through the bin door, one at a time, by conventional forklift. This approach appears to be the simplest and least costly of the alternatives and is the preferred approach.

2.2 Time Estimates

A container laydown station or airlock bin is "tied up" or utilized from the time it is designated to receive a container(s) until the container(s) is removed and the space is available to receive another shipment. Thus, the activities that determine the time cycle for laydown space utilization are:

- a) move container(s) from vehicle to laydown
- b) close bin lid (if airlock used)
- c) open bin door (if air lock used)
- d) Sample air inside container (ST or CC). This should be done while container is on the vehicle, rather than in the laydown space.
- e) Open container door (for ST and CC only)
- f) Place ramp (ST and CC only)
- g) Empty container (if ST or CC) or laydown space (if RF or M3)
- h) Close container door(s) (ST or CC)
- i) Close bin door (if airlock used)
- j) Open bin lid (if airlock used)
- k) Wait for proper type vehicle to be spotted (if ST or CC).
- l) Move ST or CC from laydown space to vehicle.

Time cycle estimates for the four types of containers, two types of waste, and three types of vehicles, follow:

Min.

1. Supertiger, Processed Waste (ST-P), Flatcar or Truck, Bin Airlock, Sample air at laydown, wait for vehicle.
 - 1.1 Move ST-P from Flatcar to laydown, disengage sling and clear top of bin. 8
 - 1.2 Close bin lid 5
 - 1.3 Open bin door (door and lid are interlocked) 2
 - 1.4 Sample air in ST 15
 - 1.5 Open ST door (unbolt and swing back two doors in sequence) 15
 - 1.6 Place ramp on floor 10
 - 1.7 Remove 33 55Ds from ST (3 per lift) 44
 (Is there dunnage to remove?)
 Assume forklift used to enter ST, engage three drums, backout, turn, travel 20 ft., release drums on conveyor, turn, return 20 ft. to ST (4 min/cycle)
 - 1.8 Remove ramp from floor and store 10
 - 1.9 Close ST doors 15
 - 1.10 Close bin door 2
 - 1.11 Open bin lid 5
 - 1.12 Wait for available of proper flatcar or truck 30
 - 1.13 Move ST from laydown to flatcar or truck 8

2. Supertiger, Unprocessed Waste (ST-U), Flatcar or Truck, Bin Airlock, Sample air at laydown, wait for vehicle.	<u>Min.</u>
1. 1- Time elements from moving the ST through 1. 6 placing ramp on floor are the same as Case 1.	55
1. 7 Remove 42 55Ds from ST (3 per lift). Assume 4 min/lift cycle.	56
1. 8- Time elements from removing ramp through 1. 13 returning ST to vehicle are the same as Case 1.	<u>70</u>
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3. Supertiger, Processed Waste (ST-P), ST remains on Flatbed Truck, No airlock.

	<u>Min.</u>
3.1 Sample air in ST.	15
3.2 Open ST door (unbolt and swing back two doors in sequence).	15
3.3 Place ramp on floor	10
3.4 Remove 33 55Ds from ST (3 per lift). Assume there are sufficient forklifts operating so that a forklift approaches the truck bed as soon as the approach is cleared by the previous forklift (assume 4 min/cycle).	44
3.5 Remove ramp from floor and store	10
3.6 Close ST doors	<u>15</u>
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Shaft Sinking Procedures

WASTE ISOLATION PILOT PLANT

CONCEPTUAL DESIGN

SHAFT SINKING PROCEDURES

TRU SHAFT SINKING PROCEDURE

No development on the TRU Level except for 30 feet of the station on both sides of the shaft will be done off the TRU shaft. Therefore, as storage operations are not to begin until May 1, 1983, the sinking of this shaft can be done relatively late during construction of the WIPP facility. However, its sinking will interfere with construction of the TRU Building on surface so the sinking operations will have to be scheduled to be compatible with the surface construction.

The sinking and grouting methods developed in the conceptual design for the TRU Shaft are shown on sheet A7 of Drawing No. 94569. ERDA No. 9 and the 21 potash evaluation holes provided the majority of the information used as a basis to formulate this shaft sinking plan. Thus, it is based upon extremely limited information.

The TRU Shaft sinking program developed for the conceptual design can be described in a stepwise manner as follows:

1. Contractor sets up his temporary electrical system, hoist and compressors.
2. Excavate the shaft collar area to at least a 14-foot depth with either a clamshell bucket or backhoe equipment.
3. Form and install the necessary rebar for the shaft collar.
4. Pour the shaft collar.
5. Commence actual shaft sinking for a 20 foot diameter excavation and establish the drilling and blasting pattern, depth of round, etc. while mucking with a clamshell shovel. Concurrent with the sinking operation, install an 15-inch thick shaft concrete lining at pour intervals suitable for the ground conditions. If problem areas are encountered, the shaft walls are shotcreted as necessary prior to concreting to insure a safe and efficient sinking and lining operation.

through the salt. However, as sinking progresses, sections may be encountered where siltstone and shales present loose ground conditions. In the event that condition develops, roof bolts and cyclone screen are used to secure the shaft walls. Spray-mortar, i.e., gunite or shotcrete, is then applied to prevent further air slackening of the shale members.

Sinking is continued to the shaft bottom located 13 feet below the anticipated floor elevation of the TRU Level to minimize floor damage on the TRU Level and also to allow examination of the bedding to determine the final mining horizon. Excavation of that portion of the station done off the shaft is started using the work deck as a drilling platform. The station excavation (30 feet on either side of the shaft) proceeds with both sides advanced concurrently with a cycle of drilling on one side while mucking on the other.

As this station has a large cross-sectional area, it is mined by benching to facilitate a cycle of drilling, blasting, mucking and roof bolting. Removal of the salt excavated in the station is done using compressed air operated tugger hoists to slush material to the shaft for loading into the sinking skip.

10. Upon completion of the TRU Level Station excavation for the concrete station sill is completed, then formed and the concrete poured.
11. Complete the shaft bottom.
12. Remove shaft sinking equipment, all temporary utilities and ventilation equipment from shaft.
13. Install the shaft conveyances.
14. Remove all of the shaft contractor's shaft equipment from the job site.

When the clamshell becomes inefficient for muck removal, a sinking headframe, hoist and sinking bucket are installed and used. (This will probably occur in the depth range of 50 to 60 feet.)

Initial ventilation for the sinking operation is established utilizing tubing with a positive blowing system. Later, when sinking at a greater depth, it will be more efficient if an exhaust ventilation system is used because the blasting fumes will be cleared faster from the shaft bottom.

6. Install a multideck sinking stage with hoist. These are then used to complete the shaft sinking.
7. Commence installation of shaft sets and guides.
8. Resume shaft sinking and installation of the concrete lining, shaft sets and guides through the lined section of the shaft. The only potential fluid zones known at this time are the Magenta and Culebra Dolomites in the Rustler Formation and the contact between the Rustler and Solado Formations. If grouting of these zones becomes necessary, the suggested procedures are shown on sheet A4 of Drawing No. 94569.

The shaft lining is continued into the Salado Formation until a competent formation is reached that is suitable for effecting a water tight seal. There are several anhydrite beds near the top of the Solado Formation which, if present as expected, should be good candidates for this purpose. The bottom of the lining is then formed and keyed to provide a bearer set and water collecting ring.

9. Resume sinking, but at a 20.5-foot diameter. This will allow shaft closure, due to stress induced creep, to occur over the service life of the shaft without imposing the requirement for later enlargement. Severe ground problems are not expected while sinking

RH SHAFT SINKING PROCEDURE

No development on the RH Level except for the underground transfer cell will be done from the RH Shaft. Therefore, as storage operations are not to begin until May 1, 1983, the sinking of this shaft can be done relatively late during construction of the WIPP facility. However, its sinking will interfere with construction of the RH Building on surface so the sinking operations will have to be scheduled for compatibility with the surface construction.

ERDA No. 9 and the 21 potash evaluation holes provided the majority of the information used as a basis to formulate the shaft sinking plan. Thus, the shaft sinking plan is based upon extremely limited information. Sheet A3 of Drawing No. 94567 shows the sinking and grouting methods developed during the conceptual design for the RH Shaft.

The RH Shaft sinking program developed for the conceptual design is described in a stepwise manner as follows:

1. Contractor sets up his temporary electrical system, hoist and compressors.
2. Excavate the shaft collar area to a minimum depth of 14 feet using either a clamshell bucket or backhoe equipment.
3. Install the concrete forms and rebar for the shaft collar.
4. Pour the shaft collar.
5. Commence actual shaft sinking at a 11-foot diameter and establish the drilling and blasting pattern, depth of round, etc. while mucking with a clamshell shovel. The 18-inch thick shaft concrete lining is poured concurrently at suitable pour intervals dependent upon ground conditions. The shaft walls through problem areas are shotcreted as necessary prior to concreting to insure a safe and efficient sinking and lining operation.

Efficient use of the clamshell for muck removal is anticipated to be in the range of 50 to 60 feet. When this operation becomes inefficient, a sinking headframe, hoist and sinking bucket are installed and used until later replaced with the permanent hoist system.

Ventilation for the sinking operation is established using tubing and a positive blowing system. Later on, at a deeper depth, it will be more efficient to use an exhaust ventilation system for clearing the blasting fumes from the shaft bottom.

6. Install a multideck sinking stage with its hoist. The multideck stage enables several work tasks to proceed concurrently for maximum efficiency by allowing drilling and mucking in the bottom to be done at the same time as the lining operation (forming, placing concrete or removing forms) or while sets and guides are being installed. This multideck stage is used until completion of the shaft sinking.
7. Commence installation of the shaft sets and guides.
8. Resume shaft sinking and installation of the concrete lining, shaft sets and guides through the upper lined section of the shaft.

Continue the shaft lining through all the potential water bearing zones and into the Salado Formation until a competent formation is reached that can be used to effect a water tight seal. Several anhydrite beds are expected to be present near the top of the Salado Formation and one of these should be a good candidate for this purpose. The bottom of the lining is then formed and keyed so as to provide a bearer set and water collecting ring.

At this time, the only known potential fluid zones are the Magenta and Culebra Dolomites in the Rustler Formation and, possibly, a zone at or near the contact between the Rustler and Solado Formations. The suggested grouting procedures to be used, if required, are shown on sheet A3 of Drawing No. 94567.

9. Continue sinking of the shaft at a 9-foot diameter to an approximate depth of 2175 feet and then at a diameter of 10 feet to the shaft bottom. These increased shaft diameters provide an allowance for the closure resulting from stress induced creep.

Shaft sinking through the salt is not expected to present any ground problems. However, there may be sections where siltstone and shales present loose ground conditions as sinking progresses. Should this condition develop, roof bolts and cyclone screen are used for securing the shaft walls. If deemed advisable at the time, spray-mortar, i.e. gunite or shotcrete, is also applied to prevent further air slacking of the shale members.

10. At the depth of the RH Level, to improve ventilation, excavate a minimal sized temporary breakthrough to the shaft entry travelway mined previously by a continuous miner. The Underground Transfer Cell, because of its height, is best mined by benching to allow drilling and mucking simultaneously. Roof support is installed as dictated by the ground conditions. All excavation of the Underground Transfer Cell is completed via the RH Shaft. The shaft is completed when the sump below the floor of the Transfer Cell is completed.
11. Remove all shaft sinking equipment, temporary utilities and ventilation equipment from the shaft.
12. Install the shaft conveyances.
13. Remove all of the shaft contractor's shaft equipment from the job site.

MAN AND MATERIALS SHAFT PROCEDURE

As with all of the shafts, the majority of the information used as a basis to formulate this shaft sinking plan was obtained from the 21 potash evaluation holes and ERDA No. 9. By necessity, therefore, it is based upon extremely limited information. The conceptual shaft sinking program developed for the Man and Material Shaft, along with the suggested grouting procedures, are shown on sheet A5 of Drawing No. 94571 and can be described in a stepwise manner as follows:

1. Contractor sets up his temporary electrical system, hoist and compressors.
2. Excavate the shaft collar area to a depth of 14 feet using either a clamshell bucket or backhoe equipment. Also excavate the permanent headframe foundation concurrently with the shaft collar.
3. Form and install the necessary rebar for both the shaft collar and headframe foundation.
4. Pour the shaft collar and the headframe foundation utilizing a monolithic concrete pour.
5. Commence actual sinking for a 26-foot diameter excavation and establish a drilling and blasting pattern, depth of round, etc.

while mucking with the clamshell shovel. In conjunction with the sinking operation, Pour an 18-inch thick concrete lining at pour intervals suitable for the ground conditions encountered. In any problem areas encountered, shotcrete as necessary prior to concreting for a safer and more efficient sinking and lining operation.

It is anticipated that use of the clamshell for muck removal will be efficient only down to a depth of 50 or 60 feet. When use of the clamshell becomes inefficient, then a sinking headframe, hoist and sinking bucket are installed and used until replaced at a later time by the permanent hoist system.

Ventilation for the sinking operation is initially established with tubing and a positive blowing system. Later, at a greater depth, it is replaced by an exhaust ventilation system for greater efficiency in clearing the blasting fumes from the shaft bottom.

6. Install a multideck sinking stage and hoist. These are then used to complete the shaft sinking.
7. Commence installation of the shaft sets and guides.
8. Resume shaft sinking and installation of the concrete lining, shaft sets and guides through the lined portion of the shaft.

The Magenta and Culebra Dolomites in the Rustler Formation and the contact between the Rustler and Solado Formations are the only potential fluid zones known at this time that will be encountered in this shaft. If grouting of these zones is required, the procedure recommended is shown on sheet A5 of Drawing No. 94571.

The shaft lining extends into the Salado Formation to the first competent formation reached that can be used to effect a water tight seal. The information available at this time indicates that there are several anhydrite beds near the top of the Solado Formation which will be good candidates for this purpose. The bottom of the shaft lining is formed and keyed in the anhydrite bed selected to provide a bearer set and water collecting ring.

9. After the concrete lining is completed, the last stage of forms are removed and, if deemed more efficient, the staging is modified to a double deck stage for installation of shaft sets only.
10. Recommence sinking, only at a 25.5-foot diameter. This is done to allow for that shaft closure which will occur as a result of the stress induced creep. A small pump station is excavated at a reasonable distance below the water ring. The water collected in

the water ring is piped to this pump station where it is then pumped to surface for disposal.

Install the permanent headframe, bin, hoist and a surface salt conveyor disposal system. This can be done at any time during the shaft sinking, but the earlier it is done, the more it benefits the shaft contractor with his muck removal. The production hoist is brought into service for muck handling with balanced self-dumping sinking buckets as soon as it is ready following erection of the headframe.

It is not expected that any severe ground problems will be encountered while sinking through the salt. However, there may be sections of the shaft in which siltstone and shales present loose ground conditions. To prevent undue delay if this occurs, roof bolts and cyclone screen are used to secure the shaft walls. Spray-mortar, i.e., gunite or shotcrete can be applied to prevent further air slacking of the shale members.

Sinking is continued to 15 or 20 feet below the anticipated floor elevation of the TRU Level. This additional distance will then minimize floor damage at the station and also allow examination of the bedding to determine the final mining horizon. Further, it also reduces the possibility of blasting damage when sinking is resumed.

11. Excavation of the station on the TRU Level is started using the work deck as a drilling platform and allowing the blasted salt to fall into the vacated shaft opening. Station excavation proceeds with both sides being advanced concurrently with a cycle of drilling on one side while mucking on the other. Mining of the station, as it has a large cross-section, is done by benching to facilitate a cycle of drilling, blasting, mucking and roof bolting.

Because this shaft is the main access for all personnel and materials handling, development advantages are gained for future concurrent work if some development is accomplished prior to completion of the shaft. Therefore, in addition to excavation of the station, an entry is mined from the shaft station to the Construction Ventilation Shaft. An early breakthrough into the Construction Ventilation Shaft allows improved ventilation flows with one shaft downcast and the other upcast. In addition, a minimal sized opening is mined to the top of the muck transfer raise with sufficient room made to allow installation of a raise drill at a later time. The major advantage gained from this procedure is the time that will be saved later by allowing equipment to be lowered and assembled while still sinking the shaft or during installation of the skip loading equipment.

Upon completion of the TRU Level Station, excavation for the station concrete sill is completed, formed, and then the concrete poured. The hardware shown in the station design is installed concurrently with the station construction in order to facilitate equipment handling. This hardware will include such items as the bridge crane and monorails in addition to that equipment useful to the shaft sinking and development done in this phase.

12. Resume shaft sinking operations to the RH Level at a shaft excavation diameter of 28 feet.
13. The RH Level Station is excavated following the same procedure as that described in Step 11 for the TRU Level Station. This includes installation of the monorail and crane to facilitate handling of equipment and supplies.

14. Upon completion of the station, an entry connecting the Man and Material Shaft to the Construction Ventilation Shaft is mined to improve ventilation. In addition, a minimal sized entry is also driven from the Construction Ventilation Shaft around to the top of the skip loading pocket. This will allow an early breakthrough to be made when later excavating for the skip loading facilities. Due to the relatively inefficient muck handling facilities available at this time (as compared to the skip loading equipment available later), all entry development should be kept to minimal sizes and then enlarged later when more efficient facilities are installed.
15. Excavate, form and pour the RH Station sill.
16. Resume shaft sinking at a 28-foot excavation diameter. As the shaft is deepened, excavate the opening required for installation of the skip loading pocket.
17. Continue with the skip pocket excavation and complete the shaft excavation to a depth that allows installation of the skip pocket equipment.
18. Form and pour the concrete floor of the skip loading pocket and install the loading pocket steel and skip loaders.
19. Complete excavation to the shaft bottom, including concreting the floor and sump. Also mine a 10-foot long entrance to the ramp off the shaft bottom to provide a safe breakthrough for the ramp when it is driven later.
20. Remove the shaft sinking equipment.
21. Install the shaft conveyances and remove all temporary utilities and ventilation equipment from the shaft.
22. Install the permanent power, connections, etc. in the shaft.
The remainder of the shaft oriented work is done using the permanently installed shaft equipment (especially the skips) for improved efficiency.

23. Excavate the openings required for installation of the salt handling equipment below the RH Level. Until this facility is complete and operable, muck handling at the Man and Material Shaft is inefficient and no mine development can begin.

Start the excavation with a small sized (approximately 6 foot diameter) inclined raise to connect the skip loading pocket to the transfer gallery (about 35 feet in length). Then drive an opening (again of minimal dimensions for maximum advance rate) to the transfer storage location. This requires a sublevel 75 to 80 feet in length. At the end of this sublevel, drive a vertical breakthrough raise up to the RH Level. The purpose of this work is to provide ventilation with a minimal amount of muck handling. Upon making the connection, ventilation is established through the skip loading facility.

Starting at the top of the skip loading pocket and working upward, enlarge this breakthrough to its final dimensions by slashing. The excavated muck is fed through the skip loading pocket into the skips. All of the skip loading facility is mined from this shaft.

24. Install the equipment for the salt transfer facility, including the RH storage bin, the chute for the TRU salt transfer, the bin feeders and all conveyors. Concurrently, install the TRU transfer conveyor on the RH Level to the bottom of the proposed TRU-RH muck raise. At the same time this equipment is being installed, the TRU-RH muck raise pilot hole is drilled from the TRU Level.
25. The TRU-RH muck raise pilot hole is enlarged to its final 6-foot diameter by reaming upward. Since the cuttings fall by gravity to the RH Level, they are loaded onto the conveyor installed in

Step 24. As no facilities exist for handling muck from the TRU Level until this raise is completed, it is readily apparent that Steps 23, 24, and 25 must be carefully scheduled and until these facilities are complete and operable, full scale mining on both levels is delayed. Some equipment assembly and installation work can be performed, but the operation of the muck handling facility is the focal point for mining by continuous miners on the two underground levels and, therefore, the shaft salt handling capability must be operational before any significant development work can be started on either level.

26. Although it is not an integral part of the shaft, the incline from the RH Level to the shaft bottom is required for efficient full scale operation. Mining can commence prior to completion of this incline, however, it is required in order to provide an efficient method of cleaning the inevitable spill that will occur during skip loading.
27. Completion of Steps 25 and 26, and the removal from the site of the shaft sinking equipment constitutes completion of the shaft construction.

VENTILATION SHAFTS SINKING PROCEDURE

Both ventilation shafts are the same size and, therefore, will be sunk in the same manner. As with all of the other shaft sinking plans formulated for the conceptual design, ERDA No. 9 and the 21 potash evaluation holes provided the majority of the information used as a basis to formulate this shaft sinking plan. Sheet A3 of Drawings No. 94573 and No. 94574 shows the sinking and grouting procedures developed during the conceptual design for the TRU-RH and Construction Ventilation Shafts respectively.

The shaft sinking program developed during the conceptual design for the two ventilation shafts is described in a stepwise manner as follows:

1. Contractor sets up his temporary electrical system, hoist and compressors.
2. Excavate the shaft collar area to a minimum depth of 14 feet using either a clamshell bucket or backhoe equipment.
3. Install the concrete forms and rebar for the shaft collar.
4. Pour the shaft collar.
5. Commence the actual shaft sinking at a 16.5-foot diameter excavation size and establish a drilling and blasting pattern, depth of round, etc. while mucking with a clamshell shovel. The 15-inch shaft concrete lining is poured concurrently with the sinking operations and at pour heights suitable for the ground conditions encountered. The shaft walls through any problem areas are shotcreted as necessary prior to concreting to insure a safe and efficient sinking and lining operation.

Efficient use of the clamshell for muck removal will probably be in the range of 50 or 60 feet. When this operation becomes

inefficient, then a sinking headframe, hoist and sinking bucket are installed and used.

Ventilation for the sinking operation is established with tubing and a positive blowing system. Later on, when at a deeper depth, it will be more efficient if an exhaust ventilation system is used for clearing the blasting fumes from the shaft bottom.

6. Install a multideck sinking stage with its hoist. These are then used to complete the shaft sinking. Use of the multideck stage allows concurrent performance of several tasks such as drilling and mucking on the bottom while forming, pouring or stripping forms for the shaft lining or while installing shaft sets and guides.
7. Commence installation of the shaft sets and guides.
8. Resume shaft sinking and installation of the concrete lining, shaft sets and guides through the upper lined section of the shaft.

Continue installation of the shaft lining through all the potential water bearing zones and into the Salado Formation until a competent formation is reached that can be used to effect a water tight seal. Based on presently available information there will be several anhydrite beds near the top of the Salado Formation which should be good candidates for this purpose. The bottom of the lining is formed and keyed at the selected bed so as to provide a bearer set for the shaft lining.

At this time, the only known potential fluid zones are the Magenta and Culebra Dolomites in the Rustler Formation and, possibly a zone at or near the contact between the Rustler and Salado Formations. The suggested grouting procedures to be used, if required,

are shown on sheet A3 of Drawing No's. 94573 and 94574.

9. Continue sinking of the shaft at a 15.5-foot diameter to about 15 or 20 feet below the anticipated floor elevation of the TRU Level to minimize floor damage and also to allow examination of the bedding to determine the final mining horizon. Further, this also reduces the possibility of blasting damage when sinking is resumed.

Shaft sinking through the salt is not expected to present any ground problems. However, there may be sections where siltstone and shales present loose ground conditions as sinking progresses. Should this condition develop, roof bolts and cyclone screen are used for securing the shaft walls. If deemed advisable at the time, spray-mortar, i.e. gunite or shotcrete, is also applied to prevent further air slacking of the shale members.

Excavation of the station can be started by using the work deck as a drilling platform with the broken muck going into the vacated shaft opening. As this station is relatively small, both in cross-section and length, it can be mined rather easily off the shaft.

Connection between the station and the remainder of the TRU-Level is made from the level itself.

10. Upon completion of the TRU station, excavation of the concrete station sill is completed, then formed, and the concrete poured.
11. Resume shaft sinking operations to the RH Level at an excavation diameter of 16.5 feet.
12. The RH Level station is excavated following the same procedure as that in Step 9 for the TRU Level Station.
13. Excavate, form and pour the RH station bearer.

14. Complete the shaft bottom.
15. Remove shaft sinking equipment, temporary utilities and ventilation equipment from the shaft.
16. Install the shaft conveyances.
17. Remove all of the shaft contractors shaft equipment from the job site.

Hoist Time and Motion Studies

TRU SHAFT HOISTING TIME MOTION STUDY

A TRU Shaft hoisting cycle was developed for the conceptual design. A brief description of this hoisting time-motion study follows.

A one-shift-per-day operation of 8 hours that includes a 30-minute lunch period and two breaks of 10 minutes each was used. It was assumed that preventive maintenance would be performed at the start of the shift and during the lunch and rest breaks, with major maintenance done on the weekends or back shifts. A hoisting speed of 500 fpm with an acceleration of 2 fps^2 and a retardation of 2.5 fps^2 was assumed. Allowance was also made for a 2-s creep time during acceleration and a 4-s creep time during retardation.

A test run by an empty cage will be made through the shaft from the collar to the underground station and back each day before loading. This will be required after an extended lapse in hoisting (overnight or weekends) and after any repairs to either the cage or the shaft. Safety regulations do not require it, but because of the type material handled, such a test run is advisable.

At the start of the shift the cage will be in a released position just below the collar to prevent access to the cage without first notifying the hoistman. The cage is set on the collar landing chairs and the hoistmen and cage tenders then routinely check the equipment before beginning operations. This, unlike the cage test run, is required at the start of each operating shift, regardless of whether the operation is on a continuous or intermittent basis. Typical landing chairs as conceptually designed for the TRU Shaft are shown on Sheet M3 of Drawing No. 945__.

Moving the cage off the landing chairs initiates the test run cycle that ends when the cage is returned to the landing chairs on surface. During the check of the shaft equipment on surface and also during the test run cycle, the loading crew

performs routine equipment checks and then prepares the first load to have it ready for the first lowering cycle whenever the cage is ready. At the end of the shift, the cage is left in the released position. If the shaft operation is on a single-shift basis, the cage is then ready for an emergency situation. If the operation is on a continuous basis instead, no access to the cage is possible during the hoistmen's change of shift. Our analysis for the operation of the TRU shaft hoist over the period of one shift is summarized in Table II.2-2.

Morning and afternoon breaks, in addition to a lunch period, have been excluded from the time available to lower the TRU waste containers, as has the time needed for a shift wrap-up. These times, by proper planning and scheduling, can be used for minor equipment maintenance and repair with scheduled premaintenance and repairs on weekends. For maximum efficiency, the working hours for all personnel involved in the underground waste handling system must be carefully scheduled, both underground and on the surface. Scheduling the start of the underground work shift for later than those on the surface is recommended to allow an even flow of material into storage.

No additional time has been allowed for unforeseen delays in the cycle analysis. There is a small amount of conservatism in the estimated times allowed for the various tasks such as signaling and the opening and closing of doors, chairs, etc. Staggering breaks and rest periods for personnel can also provide additional time and an additional measurement of conservatism. For the purpose of the conceptual design, it is felt that this degree of conservatism is proper. Further definition of the tasks, especially the loading and unloading tasks, will allow further refinement of the time cycles.

TABLE II.2-2

SUMMARY OF ONE SHIFT'S OPERATION
FOR TRU SHAFT HOIST

<u>Function</u>	<u>Time Allotted (Minutes)</u>
Equipment Check.....	15
Shaft Test Run	12
Morning Break	15
Lunch Break	30
Afternoon Break	15
Shift Wrap-Up	15
Load Cycles (14 Trips @ 27 min. 00 sec. ea.).....	378

Total Time 480 min = 8 hrs

CYCLE BREAKDOWNS

Shaft Test Run			Load Cycles		
Action Item	Elapsed Time		Action Item	Elapsed Time	
	Min.	S		Min.	S
Signal, Hoist	0	- 05	Open Cage Doors	0	- 15
Hoist Cage off Chairs	0	- 03	Load Cage (incl. secur-		
Signal, Stop	0	- 02	ing load)	8	- 03
Release Chairs	0	- 05	Close Cage Doors	0	- 15
Signal, Lower	0	- 05	Signal, Hoist	0	- 05
Lower Cage to Station	4	- 36	Hoist Cage off Chairs	0	- 03
Signal, Stop	0	- 02	Signal, Stop	0	- 02
Inspect Cage	2	- 04	Release Chairs	0	- 05
Signal, Hoist	0	- 05	Signal, Lower	0	- 05
Hoist Cage to Collar	4	- 36	Lower Cage to Station	4	- 36
Signal, Stop	0	- 02	Open Cage Doors	0	- 15
Set Chairs	0	- 05	Unload Cage, Load Empty	8	- 03
Signal, Lower	0	- 05	Close Cage Doors	0	- 15
Lower Cage onto Chairs	0	- 05	Signal, Hoist	0	- 05
Total Elapsed Time	12 min.		Hoist Cage to Collar	4	- 36
			Signal, Stop	0	- 02
			Set Chairs	0	- 05
			Signal, Lower	0	- 05
			Lower Cage onto Chairs	0	- 05
			Total Elapsed Time	27 min.	

RH SHAFT HOIST TIME-MOTION STUDY

An RH shaft hoisting cycle was developed for the conceptual design. A brief description of this time and motion-study follows.

A single 8-hr daily shift was assumed, with a 30-minute lunch and two breaks of 15 minutes each (one in the morning and one in the afternoon). It was assumed that preventive maintenance would be performed at the start of the shift and during the lunch and rest breaks, with major maintenance on either the weekends or the back shifts. A hoisting speed of 500 fpm with an acceleration of 2 fps^2 and a retardation of 2.5 fps^2 was used. In addition, an allowance was made for a 2-s creep time during acceleration and a 4-s creep time during retardation.

A test run by an empty cage will be made through the shaft from the clean cell on surface down to the underground transfer cell and back each day before loading. This procedure will be required after an extended lapse in hoisting (overnight or weekends) and after any repairs are made to either the shaft or its conveyance. Safety regulations do not require this, but considering the nature of the material being handled, such a test run would be very advisable.

At the start of a shift, the cage will be on the landing chairs at the clean cell. A brief equipment check is then made before commencing operations. This, unlike the cage test run, will be required at the start of each operating shift irrespective of whether the operation is on a continuous or intermittent basis. Moving the cage off the clean cell landing chairs initiates the test run cycle that ends when the cage is returned to the clean cell. During both the surface check of the shaft equipment and the test run through the shaft, the loading crew will perform routine equipment checks and then prepare the first load so that it is ready for the first cycle when the shaft conveyance is ready. Our analysis for operating the RH shaft hoist over one shift is summarized in Table II.2-1.

In our analysis the morning and afternoon breaks, the lunch period and the time estimated to be necessary for a shift wrap-up

TABLE II.2-1

SUMMARY OF ONE SHIFT'S OPERATION
FOR THE RH SHAFT HOIST

<u>FUNCTION</u>	<u>TIME ALLOTTED (MINUTES)</u>
Equipment Check.....	15
Shaft Test Run	14
Morning Break	15
Lunch Break	30
Afternoon Break.....	15
Shift Wrap-Up	30
*Load Cycles(25 trips @ 14 min. 00 sec. ea.)..	<u>350</u>

Total Time 469 = 7.8 hrs

*25 trips of the cage per day is 15 more than required with the current surface hot cell design, but will allow for further expansion.

CYCLE BREAKDOWNS

Shaft Test Run			Load Cycles		
Action Item	Elapsed Time		Action Item	Elapsed Time	
	Min.	Sec.		Min.	Sec.
Signal Hoist	0	- 05	Load Cage (incl. securing load)	0	- 30
Hoist Cage off Chairs	0	- 03	Signal, Hoist	0	- 05
Signal, Stop	0	- 02	Hoist Cage off Chairs	0	- 03
Release Chairs	0	- 05	Signal, Stop	0	- 02
Signal, Lower	0	- 05	Release Chairs	0	- 05
Lower Cage to Station	5	- 00	Signal, Lower	0	- 05
Signal, Stop	0	- 02	Lower Cage to Station	5	- 00
Lower Cage into Transfer Cell	0	- 33	Signal, Stop	0	- 02
Check Cage	1	- 00	Signal, Lower	0	- 05
Check Turntable Operation	1	- 00	Lower Cage into Transfer Cell	0	- 30
Signal, Hoist	0	- 05	Unload Cage in Transfer Cell	0	- 26
Hoist Cage	5	- 00	Load Empty Cart onto Cage	0	- 30
Hoist Cage into Clean Cell	0	- 33	Signal, Hoist	0	- 05
Close Landing Chairs	0	- 15	Hoist Cage	5	- 00
Signal, Lower	0	- 05	Signal Stop	0	- 02
Lower Cage onto Chairs	0	- 07	Signal, Hoist	0	- 05
Total Elapsed Time 14 min.			Hoist Cage into Clean Cell	0	- 26
			Signal, Stop	0	- 02
			Close Chairs	0	- 15
			Signal, Lower	0	- 05
			Lower Cage onto Chairs	0	- 07
			Unload Empty Cart	0	- 30
			Total Elapsed Time 14 min.		

at the end of the shift were excluded in determining the number of waste canisters requiring movement per conveyance trip. These times, through proper planning and scheduling, could be used for minor equipment maintenance and repair with scheduled premainenance and repairs performed on the weekends. No additional time was allowed for unforeseen delays.

There is very little conservatism in estimated times allowed for tasks. Staggered breaks, lunch and rest periods for personnel could provide additional time and thus an additional measure of conservatism. For the purpose of the conceptual design, it is felt that the degree of conservatism utilized is proper and not overly estimated. Further definition of the tasks will allow further refinement of the hoisting cycles.

Mining System Analysis

MINING SYSTEM ANALYSIS AND EQUIPMENT DESCRIPTION

Within a hydrostatic stress field, mine openings having an aspect ratio other than one are more stable when they are of an ovaloidal shape. Underground openings mined by boring machines tend to be more stable than those mined by conventional drilling and blasting methods because the shock that results from blasting tends to fragment and fracture the ground surrounding the opening. For these reasons, boring machines were selected as the best method to mine the underground openings at the WIPP facility.

To have an opening with sufficient width but without excessive height, an elliptical, ovaloidal, or rectangularly shaped opening must be used. Of these three configurations, the ovaloidal shaped opening is the most practical selection because it allows a conventional roadway, which an elliptically shaped opening will not; and it will definitely be more stable than a rectangularly shaped opening.

A variable-height, three-bladed twin rotor, boring type of continuous miner was selected. For this analysis, 78 different room configurations and sizes were investigated. Taking into consideration the possible storage configurations that were practical for the TRU waste containers, these 78 opening configurations were reduced to 21 possibilities. Of these 21 possibilities, only 7 remained suitable after considering the requirements for closure resulting from stress-induced creep of the salt strata.

The final 7 candidate opening configurations were then compared on the basis of the areal extent required for the TRU-level mining horizon, mined tonnage required to obtain the volumes necessary to store the containers, storage room length, service life of the openings, number of cutting passes required to be made per opening, and the efficiencies of utilization for the spaced mined. From this comparison, a machine size was selected that

allowed cutting an opening 10 ft. high by 18 ft. wide with a 13.5-ft. roadway in a single pass. The actual opening sizes selected were a three-pass-wide, two-pass-high opening (16.5 ft. high by 45 ft. wide with a 40.5-ft. roadway) for the storage rooms on the TRU level. An average mining capacity of 450 tons per machine shift was used for the conceptual design.

All of the underground openings mined by the continuous miner are advanced in a stepwise procedure with the miner first advancing along the right-hand side of the opening, cutting as it moves forward. The miner advances for approximately its own length and then backs out, moves 13.5 ft. to the left, and advances the second pass of the opening to the same depth as the first. When necessary, such as for the storage rooms on the TRU level, the machine then backs out from the second pass and proceeds to cut a third pass. Upon advancing the final horizontal pass to the same depth as the first, the miner moves back to the right-hand side of the opening and repeats the advancing process.

In the TRU-level storage rooms, it is necessary also to cut a lower second vertical pass. This lower vertical pass is made in the floor of the first vertical pass and after the first vertical pass has been completed for the entire room length.

The continuous miner selected consists of two sections, the cutting and conveying mechanisms that are joined together and connected to the main frame, and the tractor frame tramming unit assembly. The main frame carries the rear thrust posts and serves as a mounting structure for both the rear trim cylinders and the conveyor lift cylinders. The front thrust posts are integral with the rotor-drive gearcase. The tractor frame supports the entire weight of the machine and transfers this weight to tractor treads through bogey wheels in the track assembly. The weight of the rotor drive gearcase, conveyor assembly and main frame is supported by the tractor frame through the front and rear trim cylinders

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that provide for complete control of the cutting mechanism position regardless of the seam orientation. The thrust of the tramming mechanism is transferred to the cutting elements through the thrust post on the rotor-drive gearcase. The miner uses three electric motors, one for each rotor, with the third driving the hydraulic system pump.

Each rotor contains three arms that are extended and retracted by a ball-screw mechanism. The two rotor assemblies, on which the tool holders and cutter bits are mounted, are driven through the rotor-drive gearcase. Trim-chains and cutter bars are used both on the top and bottom of the machine to trim the area between the rotor arm assemblies and also to extend the opening roadway width.

A conveyor passes through the machine and conveys the material excavated out to the back of the machine. This conveyor is loaded by gathering arms located on an apron at the front of the miner.

Mine Ventilation Calculations

VENTILATION

BASIC GENERAL EQUATIONS: The following equations have been used in designing the underground ventilation systems for the conceptual design of WIPP.

PRESSURE LOSS DUE TO FRICTION

$$H_f = \frac{f L V^2}{2g} = \frac{f L V^2}{2g} = 5.1918 \times 0.075 A = 0.389385 A$$

PRESSURE LOSS DUE TO SNACK

$$H_s = K \left(\frac{V}{V_0} \right)^2 = 2.32174 \times 3600 \times 5.1918 \times \frac{V^2}{V_0^2} = 1,202,695.00799 \times \frac{V^2}{V_0^2} = 0.31966 \rho V^2 \times 10^{-3}$$

SNACK FACTORS FOR BENDS (change in the airflow direction)

α = angle of airflow deflection

$\frac{R}{W} = r$ = radius ratio

$\frac{H}{W} = a$ = aspect ratio

For a Normal Bend

$$X_N = \frac{0.85}{r^2} \left(\frac{\alpha}{90} \right)^2$$

For a Square Bend, $X_S = \frac{0.60}{r^2} \left(\frac{\alpha}{90} \right)^2 = 0.90 X_N$

SNACK FACTORS FOR AREA CHANGES (change in the airflow velocity)

$A_c = C =$ coefficient of contraction

$A_0 = N_c =$ ratio of contraction (areas)

$A_0 = N_e =$ ratio of expansion (areas)

$$C = \left(\frac{1 - N_c^2}{1 + N_c^2} \right)^{1/2} \text{ where } \frac{1}{2} \text{ is the contraction factor}$$

$$X_c = \left(\frac{1 - C}{C} \right)^2$$

$$X_e = \left(\frac{1 - C N_e}{C N_e} \right)^2$$

$$X_e = \left(\frac{1 - C N_e}{C N_e} \right)^2$$

SNACK FACTORS FOR SPLITS AND JUNCTIONS (air streams leaving or entering the main stream)

Splits are comparable to bend losses except the velocity pressure of the air stream in the split is used.

Junctions can be approximated by using a shock factor that is 1.5 times that for a bend using the velocity pressure of the entering air

stream.

SHOCK FACTORS FOR OBSTRUCTIONS IN THE AIR STREAM ~ can be approximated by using the equations for determining the shock factor of an area change with an appropriate selection of the value used for ϵ .

Where the obstruction is sufficiently long, three pressure losses are involved: (1) an abrupt contraction, (2) an increase in friction loss over the constricted section of airway and (3) an abrupt expansion. The friction loss over the constricted section can be taken as equivalent to $\epsilon \cdot N$ times the normal loss for the same length of unobstructed airway, where N is the ratio of constricted area to normal area. An allowance must also be made to account for the velocity of the obstruction relative to that of the air stream for a moving obstruction.

SHOCK FACTORS FOR LOCAL ENLARGEMENTS OF AREA AND DEAD ENDS

These shock losses are normally negligible because the expansion in area occasioned by flow is small and over only a limited length. If the enlarged section is relatively long, the shock losses resulting from expansion and contraction are usually counteracted by the decreased friction loss occasioned by the lower flow velocity through the enlarged section of airway.

LENGTH OF AIRWAY REQUIRED TO GIVE A FRICTION LOSS EQUIVALENT TO A SHOCK LOSS.

$$\text{From } H_p = H_s, \quad L_{eq} = \frac{5.1918 \cdot 0.075 \cdot AX}{2.32179 \cdot 3600 + 5.1918 \cdot LP} = \frac{XA}{3.088789 LP} = \frac{32.3710 AX}{LP \cdot 10^6}$$

AIRFLOW LEAKAGE THROUGH STOPPINGS

$$Q = m(AH)^n A \quad \text{where } n = 355.0 \text{ and } n = 0.7 \text{ for Jute @ 14.33 per } \text{yd}^2$$

0.05	1.0	w/1-inch of foam
3.10	1.8	w/1/8-inch of latex
0.05	1.0	Nylon, 20 mil thickness

Use $Q = 0.054 \Delta H$ for both stoppings and ventilation overpasses.

Based upon the temperature logs run in the ERDA #9 Hole, the virgin rock temperature on the TEL and RH levels can be expected to be approximately 85.17° and 87.68° F. respectively. Use the values of 85.25° and 87.75° F. for the virgin rock temperature on the TEL and RH levels respectively.

From the available meteorology data, the mean temperatures on surface can be said to vary from about 40°F. in the winter to about 80°F. in the summer with the normal extremes expected over the year being 0° to 110°F. On the average, the surface air temperature can be expected to vary over the period of a day from a low of 67°F. to a high of 94°F. in the middle of summer and from a low of 26°F. to a high of 55°F. in the middle of winter. Over a yearly period, the average low and high temperatures will be about 47° and 75°F. For the underground ventilation design, use surface air temperature extremes of 0° and 110°F. with an average daily temperature mean of 61°F. For daily extremes of 44.5° and 75.5°F. and then on surface at

TEMPERATURE	DRY AIR DENSITY	DENSITY @ SATURATION	ABSOLUTE HUMIDITY @ SATURATION
	b	b - 0.0192320589	0.0233679916
0°F	396.52186	396.52186	b - 0.0376
	b	b - 0.1202692128	0.1977307872
44.5°F	381.57356	381.57356	b - 0.3180
	b	b - 0.2043986939	0.3363013066
61°F	392.50366	392.50366	b - 0.5907
	b	b - 0.3361530032	0.5536469978
75.5°F	403.43376	403.43376	b - 0.8898
	b	b - 0.9783479039	1.6176520961
110°F	422.93986	422.93986	b - 2.596

where "b" is the barometric pressure in inches of mercury, density is in lbs/ft³ and absolute humidity is in lbs of water vapor per lb of dry air.

MAN AND MATERIAL SHAFT

Using a diameter of 23 feet and $t = 20 \times 10^{-10}$ to a 965-foot depth and 60×10^{-10} below the 965-foot depth with $Z = 3.00$; the friction and shock factors and the equivalent lengths for the various shock factors are as follows:

SHAFT BETWEEN THE COLLAR AND TEL LEVEL; $t = 92.2120 \times 10^{-10}$ for $L = 2170$ feet
 from $t \times 10^{10} = \frac{20 \times 965}{2170} + \frac{60 \times 1205}{2170}$

SHAFT BETWEEN THE TEL AND EH LEVELS; $t = 58 \times 10^{-10}$ for $L = 573$ feet

SHAFT COLLAR; $X = 0.39$ and $l_y = 199.95$ feet for $Z = 2.50$

SHAFT DIVIDERS; $X = 0.3161$ per set and if assumed to be on 10-foot centers

then $X = 216 \times 0.3161 = 68.2776$ and $l_y = 30,111.60$ feet for
 between the collar and TEL level and $X = 57 \times 0.3161 = 18.0177$
 and $l_y = 5590.36$ feet for between the TEL and EH levels at $Z = 5.00$

EACH SET; $X = 0.01312 + 0.09315 + 0.00387 = 0.0601$ and $l_y = 26.52$ feet

CAGE MOVING UPWARD; $X = 0.39315 + 0.18827 + 0.20213 = 0.78355$ and $l_y = 323.55$ feet

TEL SHAFT

Using a diameter of 17.5 feet and $t = 20 \times 10^{-10}$ to a 965-foot depth and 60×10^{-10} below the 965-foot depth with $Z = 3.00$; the friction and shock factors and the equivalent lengths for the various shock factors are as follows:

SHAFT; $t = 92.2120 \times 10^{-10}$ for $L = 2170$ feet

SHAFT DIVIDERS; $X = 0.1117$ per set and if assumed to be on 10-foot centers

then $X = 216 \times 0.1117 = 24.1272$ and $l_y = 8096.09$ feet at $Z = 5.00$

CAGE MOVING DOWNWARD; $X = 1.69036 + 0.69965 + 1.93629 = 3.7263$ and $l_y = 1250.38$ feet

RH SHAFT

Using a diameter of 8 feet and $t = 20 \times 10^{-10}$ to a 985-foot depth, $= 60 \times 10^{-10}$ between the 985-foot and 2720-foot depths and $= 20 \times 10^{-10}$ below the 2720-foot depth with $Z = 3.00$; the friction and shock factors and the equivalent lengths for the various shock factors are as follows:

SHAFT; $t = 95.1906 \times 10^{-10}$ for $L = 2755$ feet from $t \times 10^{-10} = \frac{20 \times 985}{2755} + \frac{60 \times 1735}{2755} + \frac{20 \times 35}{2755}$

CAGE MOVING DOWNWARD; $X = 7.61781 + 31.32378 + 8.95708 = 47.7686$ and $l_{eq} = 6849.60$ feet

VENTILATION SHAFTS:

Using a diameter of 14 feet and $t = 20 \times 10^{-10}$ to a 965-foot depth and $= 60 \times 10^{-10}$ below the 965-foot depth with $Z = 3.00$; the friction and shock factors and the equivalent lengths for the various shock factors are as follows:

SHAFT BETWEEN THE COLLAR AND TEL LEVEL; $t = 42.2120 \times 10^{-10}$ for $L = 2170$ feet (42.2633) (2165)

SHAFT BETWEEN THE TEL AND RH LEVELS; $t = 60 \times 10^{-10}$ for $L = 570$ feet

SHAFT DIVIDERS; $X = 0.0329$ per sq ft and if assumed to be on 10-foot centers then $X = 216 \times 0.0329 = 7.1064$ and $l_{eq} = 1907.68$ feet for between (1905.36)

the collar and TEL level and $X = 57 \times 0.0329 = 1.8753$ and $l_{eq} = 354.17$ feet for between the TEL and RH levels at $Z = 5.00$

EMERGENCY CAGE; $X = 0.22939 + 0.21911 + 0.10374 = 0.5472$ and $l_{eq} = 146.90$ feet (0.21937) (0.5475) (146.80)

CONSTRICTION VENT. COLLAR; $X = 0.35 + 0.0010 + (0.25 + 0.12375) \left(\frac{5.17^2}{7^2} \right) = 0.3623$ and $l_{eq} = 97.29$ feet

TEL-RH VENT. COLLAR; $X = 0.60 + \frac{0.0764}{2} = 0.7692$ and $l_{eq} = 383.52$ feet

TEU LEVEL

Use a minimum airflow velocity of 100 fpm in the development headings, 75 fpm in the shops and fuel storage areas and 50 fpm in the warehouse and storage rooms.

In start-and development headings, use a brattice curtain wall to divide the heading into fresh and exhaust airways with the exhaust airway cross-sectional area being approximately a quarter of that used for the fresh air.

Based on the foregoing, for
 SYSTEM OPERATIONS, use 36,000 cfm of fresh air per room and assume two rooms at a time require ventilation.

DEVELOPMENT OPERATIONS, use 24,000 cfm of fresh air per room with the brattice curtain wall installed 9'-6" from the left wall while cutting the right side and use 24,000 cfm of fresh air per entry with the brattice curtain wall installed 7'-0" from the left wall.

Assume that there can be two rooms being driven simultaneously. For determining the quantities of air that are sent circulated through stoppages and ventilation overpasses, use $Q = 14.7962 \text{ AH}$ for those stoppages in entries, $Q = 21.473505 \text{ AH}$ for those stoppages in rooms and $Q = 29.6183 \text{ AH}$ for ventilation overpasses.

Using an air temperature of 65.35°F on the TEU level, the dry air density will be 0.00123 ⁶ 910.78331 ^{16.23}, the density @ constant will be $6-0.9617806879$ ^{16.23} and the absolute humidity & saturation will be 0.7612193421 ^{16.23} the water vapor/16.2 dry air. Taking the barometric pressures on surface and the TEU level to be 26.35 and 28.59 inches of mercury respectively and a temperature change of 11.75°F between surface and the TEU level, then the natural ventilation pressure can be expected to range from about 9.9337 inches of water, in the winter with the

downcast air stream remaining dry and the upcast air stream remaining saturated, to about -2.9565 inches of water, in the summer with the downcast air stream remaining saturated and the upcast air stream remaining dry.

Using $\epsilon = 25 \cdot 10^{-4}$, $\epsilon = 1.50$ and Square Bends with $r = 0.5$, the shock factors and equivalent lengths for the various shock losses are as follows:

ENTRY BENDS AND ELBOWS; $X = 2.13$ and $l_{eq} = 1066.88$ feet for $\alpha = 90^\circ$

$X = 0.53$ and $l_{eq} = 266.72$ feet for $\alpha = 45^\circ$

ENTRY JUNCTIONS; $X = 3.19$ and $l_{eq} = 1600.31$ feet for $\alpha = 90^\circ$

$X = 0.80$ and $l_{eq} = 400.08$ feet for $\alpha = 45^\circ$

ROOM ENTRANCE; $X = \{0.75(0.2037) + 2.5956 + 0.92(0.1625)\} \left(\frac{719,9933}{429,9701} \right)^2 = \frac{(2.7666)}{(2.6282)} = 1.488(0.1)$

ROOM EXIT when not joining; $X = \{0.1229 + 0.1280 + 2.5956 + 0.1322\} \left(\frac{719,9933}{429,9701} \right)^2 = \frac{(3.9610)}{(2.6282)} = 1.488(0.1)$
and $l_{eq} = 5818.31$ feet

ROOM EXIT when joining; $X = \{0.0229 + 0.0280 + 1.5(2.5956) + 0.0322\} \left(\frac{719,9933}{429,9701} \right)^2 = \frac{(3.9610)}{(2.6282)} = 1.488(0.1)$
and $l_{eq} = 8635.93$ feet

RESTRICTED OVERPASS; $X = \{0.0169 + 0.1107 + 0.1018\} \left(\frac{295,9290}{201,9998} \right)^2 = 0.9927$ and $l_{eq} = 296.81$ feet

HAZ & MATERIALS SHAFT STATION; $X = \{0.60 + 0.0888\} \left(\frac{295,9290}{201,9998} \right)^2 = 1.3977$ and $l_{eq} = 700.15$ feet

for $r = 1.0$

TEU SHAFT STATION; $X = 0.60$ and $l_{eq} = 339.95$ feet for $r = 1.0$ and using the shaft A and P.

CONSTRUCTION VENT. SHAFT AND TEU-BA VENT. SHAFT STATIONS; $X = \{0.9318 + 0.90\} \left(\frac{295,9290}{153,9380} \right)^2 = 5.9216$ and $l_{eq} = 2965.38$ feet for $r = 1.0$ and a 14-foot shaft diameter.

The quantity of fresh air required on the TEU level under what appears to be the worst conditions will be 215,000 cfm plus the amount required through the TEU shaft. If 9,500 cfm is taken as the airflow quantity upcast through the TEU shaft, then the total quantity of fresh air required on the TEU level will be 229,500 cfm and the efficiency factor thus resulting is $\frac{72,000 + 86,000 + 9,500}{229,500} = 0.7961 = 79.6\%$

VENTILATION OF A PANEL DURING STORAGE OPERATIONS:

$$AB = BC = CD = DE = EF = FG = GH = IJ = JK = KL = LM = MN = NO = OP =$$

$$156.00 \text{ feet}$$

$$GJ = HI = 511.50 \text{ feet}$$

$$\text{Using } \epsilon = 25 \times 10^{-10} \text{ and } \rho = 0.0690 \text{ lb/ft}^3,$$

$$H_p = 0.727356 (L + L_{eq}) V^2 \times 10^{-10} \text{ for GJ and HI}$$

$$= 1.145291 (L + L_{eq}) V^2 \times 10^{-10} \text{ for all the other airways}$$

$$\text{At } 36,333 \text{ cfm per room, } V^2 = 0.250352 \times 10^9 \text{ fpm for GJ and HI}$$

$$= 1.979992 \times 10^8 \text{ fpm for GH and IJ}$$

$$= 5.919767 \times 10^8 \text{ fpm for FG and JK}$$

$$H_{GHIJ} = 1.145291 (156.00 + 156.00) (1.979992 \times 10^8 + 0.727356 (6125 + 511.50 + 5818) 0.250352 \times 10^{-6})$$

$$= 0.000529 + 0.002268 = 0.002797 \text{ inches of water}$$

$$H_{GJ} = 0.727356 (6125 + 511.50 + 8636) 0.250352 \times 10^{-6} = 0.002781 \text{ inches of water}$$

Thus, a resistance of $0.002797 - 0.002781 = 0.000016$ inches of water must be added to the GJ circuit. This difference can be ignored for all practical purposes through and then

$$H_{total} = \frac{0.002797 + 0.002781}{2} + 1.145291 (156.00 + 156.00) 5.919767 \times 10^{-6}$$

$$= 0.002789 + 0.002115 = 0.004905 \text{ inches of water}$$

As an approximation, the pressure difference between A and P can be said to be $0.004905 + 5 \times 1.145291 (156.00 + 156.00) 5.919767 \times 10^{-6} =$

0.015982 inches of water and if we assume a nylon stopping between A and P, the leakage through that stopping will only be 13 cfm.

If a jute stopping is assumed, the leakage will be 8,292 cfm.

The actual quantity of airflow leakage through each stopping will actually be somewhere between these two extremes so, as an approximation the quantity of airflow leakage is taken to be 1300 cfm through an entry stopping, 1500 cfm through a room stopping

and 3500 cfm through a ventilation outpass.

Based on the above discussion, $V^c = 0.250352 \times 10^6$ fpm for HI and GI

1.979942×10^6 fpm for GH and IJ

5.919767×10^6 fpm for FG and JK

6.168993×10^6 fpm for EF and KL

6.423358×10^6 fpm for DE and LM

6.682862×10^6 fpm for CD and MN

6.997504×10^6 fpm for BC and NO

7.217286×10^6 fpm for AB and OP

7.992205×10^6 fpm for A and P.

and in the fan during storage operations,

$$\begin{aligned}
 H = H_p &= 1.145291 \left(156.00 + 156.00 \right) \left(1.979942 + 5.919767 + 6.168993 + 6.423358 + \right. \\
 &\quad \left. 6.682862 + 6.997504 + 7.217286 \right) \times 10^{-6} + 1.145291 \left(1067 + 156.00 + \right. \\
 &\quad \left. 156.00 \right) 7.992205 \times 10^{-6} + 0.727356 \left(6125 + 511.50 + 5818 \right) 0.250352 \times 10^{-6} \\
 &= 0.014593 + 0.011833 + 0.002268 = 0.028694 \text{ inches of water}
 \end{aligned}$$

VENTILATION OF A PANEL DURING CONSTRUCTION:

Using the same conditions as for a Panel during Storage Operations except for the air flow quantity that is required per room which is taken to be 25.00 cfm, then $V^2 = 1.002969 \times 10^{-6}$ fpm for HI and GJ

$$2.111929 \times 10^{-6} \text{ fpm for GH and IJ}$$

$$8.445717 \times 10^{-6} \text{ fpm for FG and JK}$$

$$8.742902 \times 10^{-6} \text{ fpm for EF and KL}$$

$$9.045230 \times 10^{-6} \text{ fpm for DE and LM}$$

$$9.357695 \times 10^{-6} \text{ fpm for CD and MN}$$

$$9.665299 \times 10^{-6} \text{ fpm for BC and NO}$$

$$9.983091 \times 10^{-6} \text{ fpm for AB and OP}$$

$$10.305922 \times 10^{-6} \text{ fpm for A and P}$$

In addition, $H_p = 1.071005 (L + L_p) V^2 \times 10^{-10}$ for JV and HZ

$$= 1.145291 (L + L_p) V^2 \times 10^{-10} \text{ for all the other airways}$$

$$\text{Then, } H_{\text{panel}} = 1.145291 (156.00 + 156.00) 2.111929 \times 10^{-6} + 1.071005 (1982 + 511.50 + 1408) 1.002969 \times 10^{-6}$$

$$= 2.111929 + 0.003652 = 0.369505 \text{ inches of water}$$

$$H_{\text{air}} = 1.071005 (1982 + 511.50 + 1408) 1.002969 \times 10^{-6} = 0.004389 \text{ inches of water}$$

This difference of 0.004389 inches of water can be ignored for all practical purposes and so for a Panel during construction;

$$H = H_p = 1.145291 (156.00 + 156.00) (2.111929 + 8.445717 + 8.742902 + 9.045230 +$$

$$9.357695 + 9.665299 + 9.983091) \times 10^{-6} + 1.145291 (1067 + 156.00 +$$

$$156.00) 10.305922 \times 10^{-6} + 1.071005 (1982 + 511.50 + 1408) 1.002969 \times 10^{-6}$$

$$= 2.000490 + 2.111929 + 0.003652 = 0.340421 \text{ inches of water}$$

EH LEVEL

Use the same minimum airflow velocities and procedure for ventilating dead-end headings as on the TEL level.

Based on the foregoing, for

STORAGE OPERATIONS, use 15,000 cfm of fresh air per room and assume two rooms at a time require ventilation

DEVELOPMENT OPERATIONS, use 25,000 cfm of fresh air per entry and/or room with the brotice curtain wall installed 7'-0" from the left wall. Assume that there can be three headings being driven simultaneously.

For determining the quantities of airflow that are short circuited through stoppings and ventilation overpasses, use $Q = 21.473505$ cfm for the stoppings and $Q = 49.6125$ cfm for ventilation overpasses.

Using an air temperature of 87.75 °F on the EH level; the dry air density will be $412.66781 \frac{\text{lb}}{\text{ft}^3}$, the density @ saturation will be $412.66781 \frac{\text{lb}}{\text{ft}^3}$ and the absolute humidity @ saturation will be $0.8299729992 \frac{\text{lb water vapor}}{\text{lb of dry air}}$.

Taking the barometric pressure on surface and the EH level to be 26.35 and 29.17 inches of mercury respectively and a temperature change of 19.80 °F between surface and the EH level, then the natural ventilation pressure can be expected to vary from about 6.8056 inches of water, in the winter with the downcast air stream remaining dry and the upcast air stream remaining saturated, to about -3.8376 inches of water, in the summer with the downcast air stream remaining saturated and the upcast air stream remaining dry.

Using $t = 25 \times 10^{-6}$, $Z = 1.50$ and Square Bends with $r = 0.5$; the shape factors and equivalent lengths for the various short losses are as follows:

ENTRY BENDS AND STOPS: $X = 2.13$ and $l_{eq} = 1066.88 \text{ feet}$ for $\alpha = 90^\circ$

$X = 0.53$ and $l_{eq} = 268.72 \text{ feet}$ for $\alpha = 45^\circ$

ENTRY JUNCTIONS; $X = 3.19$ and $L_y = 1500.31$ feet for $\alpha = 90^\circ$

$X = 0.80$ and $L_y = 200.08$ feet for $\alpha = 45^\circ$

ROOM ENTRANCES; $X = 2.13$ and $L_y = 1066.88$ feet

ROOM EXIT when not joining; $X = 2.13$ and $L_y = 1066.88$ feet

ROOM EXIT when joining; $X = 3.19$ and $L_y = 1500.31$ feet 0.3732

CONSTRICTED OVERPASS; $X = \{0.0159 + 0.1107 + 0.1018\} \left(\frac{295.9240}{201.2998} \right)^2 = 0.2727$ and $L_y = 246.81$ ft

MAN & MATERIALS SHAFT STATION; $X = \{0.60 + 0.0000\} \left(\frac{295.9240}{207.2578} \right)^2 = 1.3977$ and $L_y = 780.15$ feet

for $r = 1.0$

RH SHAFT JUNCTION; $X = \{0.0497 + 0.60\} \left(\frac{295.9240}{60.26598} \right)^2 = 22.5182$ and $L_y = 3226.56$ feet for

$r = 1.0$ and a diameter of 8 feet for the RH shaft.

CONSTRAINED VENT SHAFT AND TELL-RH VENT SHAFT STATIONS; $X = \{0.9318 + \dots\} \left(\frac{295.9240}{153.9380} \right)^2 = 3.8130$ and $L_y = 1910.09$ feet for $r = 1.0$ and a 14-foot shaft diameter

The quantity of fresh air required on the RH level, assuming an airflow volume of 15,000 cfm for storage operations and use of 25,000 cfm for construction operations in the experimental area, will be 200,500 cfm under which appears to be a very low value. This value of 200,500 cfm volume for an RH level of 24,000 cfm of the RH shaft.

The efficiency factor thus resulting is $\frac{30,000 + 72,000 + 20,000}{200,500} = 0.6085 = 60.8\%$

VENTILATION OF A PANEL DURING STORAGE OPERATIONS:

$$AB = BC = CD = DE = EF = FG = GH = IJ = JK = KL = LM = MN = NO = OP = 115 \text{ ft.}$$

$$HI = 59.9 \text{ ft.}$$

Using $t = 25 \times 10^{-10}$ and $\rho = 0.0701 \text{ lb/ft}^3$

$$H_p = 1.163550 (L + L_y) V^2 \times 10^{-10} \text{ for all the airways}$$

At 15,000 cfm per 1500 ft, $V^2 = 0.256939 \times 10^{-4} \text{ fpm}^2$ for HI and taking the quantity of air flow through a stopping to be 1000 cfm, then $V^2 = 0.223818 \times 10^{-4} \text{ fpm}^2$ for GH

$$0.256939 \times 10^{-4} \text{ fpm}^2 \text{ for FG and HI}$$

$$0.292334 \times 10^{-4} \text{ fpm}^2 \text{ for EF}$$

$$0.330018 \times 10^{-4} \text{ fpm}^2 \text{ for DE and IJ}$$

$$0.369985 \times 10^{-4} \text{ fpm}^2 \text{ for CD and JK}$$

$$0.412237 \times 10^{-4} \text{ fpm}^2 \text{ for BC and KL}$$

$$0.456772 \times 10^{-4} \text{ fpm}^2 \text{ for AB and LM}$$

$$0.503591 \times 10^{-4} \text{ fpm}^2 \text{ for A and MN}$$

$$0.552694 \times 10^{-4} \text{ fpm}^2 \text{ for NO}$$

$$0.609081 \times 10^{-4} \text{ fpm}^2 \text{ for OP}$$

$$0.657752 \times 10^{-4} \text{ fpm}^2 \text{ for P-}$$

So for a panel during storage operations,

$$H_p = 1.163550 (115) (0.223818 + 0.256939 + 0.292334 + 0.503591 + 0.552694 +$$

$$0.609081 + 0.657752) \times 10^{-6} + 1.163550 (115) (0.330018 + 0.369985 +$$

$$0.412237 + 0.456772) \times 10^{-6} + 1.163550 (1067 + 115) (0.503591) \times 10^{-6} +$$

$$1.163550 (1067 + 599 + 1500) (0.256939) \times 10^{-6}$$

$$= 0.000914 + 0.000920 + 0.000693 + 0.000975 = 0.002502 \text{ inches of water}$$

VENTILATION OF A PANEL DURING CONSTRUCTION

$$AB = BC = CD = DE = EF = FG = GH = IJ = JK = KL = LM = MN = NO = OP = 115 \text{ ft}$$

$$AI = PI = 500 \text{ feet}$$

$$\text{Using } L = 25 \times 10^{-3} \text{ and } \rho = 0.0701 \frac{\text{lb}}{\text{ft}^3}$$

$$H_p = 1.163550 (L + L_p) V^2 \times 10^{-3} \text{ for all the airways}$$

$$\text{At } 23,000 \text{ cfm per room, } V^2 = 0.657752 \times 10^4 \text{ fpm for GI and HI}$$

and using the quantity of air flowing through a ductway is 23,000 cfm, then

$$V^2 = 3.609081 \times 10^4 \text{ fpm for IJ}$$

$$0.657752 \times 10^4 \text{ fpm for GI and HI}$$

$$1.712736 \times 10^4 \text{ fpm for JH}$$

$$2.201594 \times 10^4 \text{ fpm for JK}$$

$$3.631008 \times 10^4 \text{ fpm for KL}$$

$$3.741775 \times 10^4 \text{ fpm for FG and LM}$$

$$3.304873 \times 10^4 \text{ fpm for EF and MN}$$

$$3.470107 \times 10^4 \text{ fpm for DE and NO}$$

$$3.087780 \times 10^4 \text{ fpm for CD and JI}$$

$$3.467582 \times 10^4 \text{ fpm for BC and PI}$$

$$3.325869 \times 10^4 \text{ fpm for AB}$$

$$3.454339 \times 10^4 \text{ fpm for AI}$$

$$\text{Then } H_{p1} = 1.163550 (1067 + 594 + 1000) 0.657752 \times 10^4 = 0.002496 \text{ inches of water}$$

$$H_{p21} = 1.163550 (115) 3.750021 \times 10^4 + 1.163550 (1067 + 594) 0.657752 \times 10^4 +$$

$$1.163550 (1067 + 115) 0.300000 \times 10^4$$

$$= 0.000941 + 0.001871 + 0.001631 = 0.003443 \text{ inches of water}$$

This minimum of 0.003443 inches of water can be ignored for all practical purposes during construction

$$\text{At } H_p = 1.163550 (115 + 594 + 1000) 0.657752 \times 10^4 = 0.002496 (115) (3.750000 +$$

15

$$2.631008 + 3.207602 + 3.329869) \times 10^{-6} + 1.163550(115)^2(2.741775 +$$

$$2.859826 + 2.970161 + 3.087780) \times 10^{-6} + 1.163550(115 + 1600) \times$$

$$3.207682 \times 10^{-6} + 1.163550 (1067 + 115) 3.459339 \times 10^{-6}$$

000462

$$= 0.002996 + 0.001564 + 0.003119 + 0.006901 + 0.009751$$

6214042

$$= 0.014042 \cdot$$

$$= 0.018331 \text{ inches of water.}$$

①

TRU/RH VENT SHAFT

DECON. STA.

RADSAFE
CHECK STA.

16,450

24,400

TRU SHAFT

CONST. VENT SHAFT

23,000

71,200

SHOP AREA

MAN/MAT'L. SHAFT

5280.0' RADIUS
(RADIUS POINT @ N - 1980 E - 1980)

○ RH SHAFT

②

Architectural floor plan of a building with a grid system. The plan shows multiple rooms and corridors. Key dimensions include 115.0' (MP) for a large room, 12.000 for a corridor, and 12.000 for a room. The plan is labeled with "D-" in the top right and "C-" in the bottom right. A small "337" is visible in the bottom left corner.

-E

-F

EXPERIMENTAL AREA
AND PILLAR SIZES UNDEFINED

ALL DRIFTS AND ROOMS
X 31.5' WIDE AND ALL
83.5' WIDE EXCEPT II
(ON LEVEL PLAN-SHAFT)

31.5' (TYP.)

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

MINE AIRWAY AIRFLOW PRESSURE LOSSES

SHEET 18 OF _____

PROJECT NO. 888

DATE: _____

AIRWAY	SIZE	GROSS-SECTION AREA Sq. Ft.	PERI-METER FT.	ACTUAL LENGTH Ft.	PERCENTAGE FACTOR %	SMALL FACTOR	EQUAL LENGTH Ft.	TOTAL LENGTH Ft.	AIRFLOW VOLUME CFM	PRESSURE LOSS AIRWAY INCHES OF WATER	REMARKS
0-1	23-4/8"	915.98	78.26	2170	42.212	19.97	30438	32,908	925,000	9.5370	Used $\rho = 0.0701$ pcf
1-2	10-3/15	225.92	76.50	250.75	25.0	3.53	1767	2018	83,950	0.0184	Used $\rho = 0.0690$ pcf
1-34				106.5		1.90	780	887	191,050	0.0210	9.5580
2-58									1000	0.1595	
2-3				358.5		2.13	1067	1423	82,950	0.0127	9.5681
3-5				714.50		9.79	2900	3117	26,900	0.0028	9.5709
3-9	10-2/5	225.92	76.50	106.5	25.0			106.5	56,050	0.0008	9.5885
4-0	17.5-1/8"	290.53	59.98	2170	42.212	28.95	9686	11,856	9500	0.0031	9.5716 Used $\rho = 0.0671$ pcf
4-5	10-2/5	225.92	76.50	447.36	25.0	0.80	400	897.5	96,550	0.0029	9.5709 Used $\rho = 0.0690$ pcf
5-6				199.15				193	72,950	0.0013	9.5722
34-37				547.81		1.86	933	1481	68,950	0.0092	9.5672
34-35				53.39		0.53	267	320	72,200	0.0022	9.5682
35-58									1000	0.1597	
35-36				919.19		1.06	382	243	71,200	0.0063	9.5665
36-56									1000	0.1120	
36-37				106.5				106.5	70,200	0.0007	9.5672
37-38				742.59				742.5	101,000	0.0099	9.5771
37-55				106.5		2.13	1067	1173	38,050	0.0022	9.5894
55-54									3500	0.1052	
55-6				213.0		3.19	1600	1813	59,550	0.0028	9.5722
6-32									1000	0.2276	
6-7				213.0				213	106,500	0.0032	9.5754
7-8									3500	0.1942	
7-9				530.59				530.5	113,000	0.0074	9.5828
9-31									1000	0.0892	
9-11									1000	0.1443	
9-10				511.5				511.5	101,000	0.0068	9.5896
10-11									3500	0.1375	
10-12				189.5				189.5	97,500	0.0015	9.5911
12-28									1000	0.0692	
12-14									1000	0.1234	
12-13				511.5				511.5	95,500	0.0061	9.5972
13-14									3500	0.1173	
13-15				189.5				189.5	92,400	0.0014	9.5986
15-25									1000	0.0597	

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

DESIGN SHEET

MINI AIRWAY AIRFLOW PRESSURE LOSSES

SHEET 19 OF _____

PROJECT NO. 200

DATE: _____

AIRWAY	SIZE	CROSS-SECTIONAL AREA Sq. Ft.	PER-METER ACTUAL LENGTH FT.	FRICTION FACTOR	SMALL FACTOR	EQUIV. LENGTH FT.	TOTAL LENGTH FT.	AIRFLOW VOLUME CFM	PRESSURE LOSS AIRWAY INCHES OF WATER	COMMENTS
15-17								1000	0.1052	
15-16			54.5				54.5	90,000	0.1059	9.6090
16-17								3500	0.1000	
16-18			129.5				129.5	86,500	0.0012	9.0052
18-22			106.5		2.13	1067	1173	84,500	0.0110	9.6162
18-19								1000	0.0903	
18-19								1000	0.0903	
19-20			106.5		3.19	1000	1707	2000	0.0800	9.6835
38-53								1000	0.0899	
38-39			54.5				54.5	100,000	0.0067	9.5838
39-52								1000	0.0778	
39-40			129.5				129.5	99,000	0.0016	9.5859
40-51								1000	0.0799	
40-41			54.5				54.5	98,000	0.0069	9.5918
41-50								1000	0.0629	
41-42			129.5				129.5	97,000	0.0015	9.5933
42-49								1000	0.0600	
42-43								95,000	0.0009	9.6337
42-43			54.5				1000	0.0009		
43-48			106.5		2.13	1067	1173	95,000	0.0138	9.6471
43-44								1000	0.0168	
47-49			106.5				106.5	81,000	0.0009	9.6505
44-45								81,000	0.0287	9.6792
44-45								1000	0.0287	
45-46			106.5				106.5	82,000	0.0009	9.6801
46-20			106.5		3.19	1000	1707	83,000	0.0159	9.6955
47-46								1000	0.0630	
48-47								1000	0.0021	
22-47			106.5				106.5	81,000	0.0009	9.6171
20-21			54.5				54.5	85,000	0.0098	9.7003
22-21								3500	0.0891	
21-23			129.5		0.99	297	371	88,500	0.0038	9.7091
17-23			106.5		3.68	1097	1259	4500	0.0001	9.7091
98-23								1000	0.0566	
48-49			54.5				54.5	93,000	0.0058	9.6533

ADD 0.0325 INCHES OF WATER RESISTANCE

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

MINE AIRWAY AIRFLOW PRESSURE LOSSES

SHEET 20 OF _____

PROJECT NO. 288

DATE: _____

AIRWAY	SIZE	CROSS-SECTION AREA SQ. FT.	PER-METER FACTOR	ACTUAL LENGTH FT.	FRICTION FACTOR	SHAPE FACTOR	EQUIV. LENGTH FT.	TOTAL LENGTH FT.	AIRFLOW VOLUME CFM	PRESSURE LOSS AIRWAY INCHES OF WATER	COEFF. CORR.	REMARKS
49-50				129.5				129.5	91,500	0.0019	9.6597	
49-25				106.5				106.5	2500	0.0000	9.6533	
23-29				541.5				541.5	99,000	0.0059	9.7100	
25-29									3500	0.0567		
29-26				129.5		0.99	297	371	97,500	0.0096	9.7196	
19-26				106.5		3.68	1897	1969	4500	0.1001	9.7196	
50-26									1000	0.0599		
50-51				541.5				541.5	91,500	0.0056	9.6603	
51-52				129.5				129.5	90,000	0.0013	9.6616	
51-28				106.5				106.5	2500	0.0000	9.6603	
26-27				541.5				541.5	103,000	0.0071	9.7217	
28-27									3500	0.0619		
27-29				129.5		0.99	297	371	106,500	0.0055	9.7272	
11-29				106.5		3.68	1897	1969	4500	0.0001	9.7272	
52-29									1000	0.0656		
52-53				541.5				541.5	90,000	0.0059	9.6870	
53-59				743.59				743.5	88,500	0.0076	9.6796	
53-31				106.5				106.5	2500	0.0000	9.6670	
29-30				541.5				541.5	112,000	0.0089	9.7356	
31-30									3500	0.0686		
30-8				637.09		2.42	1319	1951	115,500	0.0390	9.7696	
8-32				319.5		2.42	1319	1633	119,000	0.0302	9.7998	
32-33				279.61		5.95	2732	3007	120,000	0.0566	9.8569	ADD 0.2953 INCHES OF WATER RESISTANCE
59-56				106.5		0.99	297	353	93,000	0.0039	9.6785	
56-57				204.67		5.95	2732	3219	93,000	0.0369	9.7199	ADD 0.3188 INCHES OF WATER RESISTANCE
58-57	10 x 31.5	295.92	76.50	25.75	25.0	4.92	2965	2991	2000	0.0000	9.7199	
1-59	23 x 44	415.98	72.26	570	60.0	18.02	5390	6160	200,500	0.2787	9.8157	Used P = 0.0745 P ₁
59-60	10 x 31.5	295.92	76.50	670	25.0	1.90	700	767	89,500	0.0082	9.8239	Used P = 0.0701 P ₁
59-113				498.5		1.90	700	899.5	111,000	0.0139	9.8296	
60-61									3500	0.1208		
60-62				115.0				115	86,000	0.0011	9.8250	
62-63									3500	0.1320		
62-69				115.0				115	82,500	0.0010	9.8260	
69-72				1335.08		2.46	1334	2669	96,500	0.0077	9.8337	ADD 0.0825 INCHES OF WATER RESISTANCE
69-65				185.12		2.43	1067	1252	96,000	0.0022	9.8402	

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: MINE AIRWAY AIRFLOW PRESSURE LOSSES

SHEET 21 OF _____

PROJECT NO: 288

DATE: _____

AIRWAY	SIZE	CROSS-SECTION AREA Sq. Ft.	PERIMETER FT.	ACTUAL LENGTH FT.	FRICTION FACTOR	SMALL FACTOR	EQUIV. LENGTH FT.	TOTAL LENGTH FT.	AIRFLOW VOLUME CFM	PRESSURE LOSS AIRWAY INCHES OF WATER	REMARKS
65-111									1000	0.1312	
65-67				3950		795	3739	4079	12,425	0.0009	9.0291
65-66	10 x 31.5	295.92	76.50	230.0	25.0	2.13	1067	1297	22,375	0.0009	9.0291
66-0	8 x 40	50.27	25.13	2765	45.191	47.77	1895	2000	20,000	0.5971	5.9262 USED $R = 0.0677 \text{ pcf}$
66-67	10 x 31.5	295.92	76.50	115.0	25.0			115	2375	0.0000	9.0291 USED $R = 0.0781 \text{ pcf}$
67-68				1929.79		0.53	267	1696.5	15,000	0.0005	9.0296
72-73									3500	0.0323	
72-74				395.0				395	43,000	0.0008	9.9171
75-79									3500	0.0901	
79-76				575.0				575	46,500	0.0017	9.9187
76-107									1000	0.0091	
76-78									1000	0.0229	
76-77				115.0				115	44,500	0.0003	9.9190
77-78									3500	0.0226	
77-79				1035.0				1035	41,000	0.0023	9.9213
79-78									1000	0.0203	
79-109									1000	0.0163	
79-80				115.0		2.13	1067	1182	39,000	0.0029	9.9237
80-81									3500	0.0142	
80-82				115.0				115	35,500	0.0002	9.9239
82-103									1000	0.0109	
82-83				115.0				115	35,500	0.0002	9.9241
83-102									1000	0.0109	
83-84				115.0				115	35,500	0.0002	9.9243
84-101									1000	0.0099	
84-85				599.0				599	34,500	0.0009	9.9252
85-86									3500	0.0078	
85-87				115.0				115	31,000	0.0001	9.9253
87-89									1000	0.0075	
87-88				599.0				599	30,000	0.0007	9.9260
88-89									3500	0.0058	
88-90				115.0				115	26,500	0.0001	9.9261
90-91									1000	0.0055	
90-91				599.0				599	24,500	0.0006	9.9267
91-92									3500	0.0041	

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

MINE AIRWAY AIRFLOW PRESSURE LOSSES

SHEET 22 OF _____

PROJECT NO: 280

DATE: _____

AIRWAY	SIZE	CROSS-SECTIONAL AREA SQ. FT.	PERI-METER FT.	ACTUAL LENGTH FT.	FRICTION FACTOR	SMALL FACTOR	EQUIV. LENGTH FT.	TOTAL LENGTH FT.	AIRFLOW VOLUME CUM.	PRESSURE LOSS AIRWAY INCHES OF WATER	PRESSURE LOSS CURVE INCHES OF WATER	REMARKS
91-92				15.0				15	23,000	0.0001	9.9268	
92-93									21,000	0.0025	9.9293	
93-94									1000	0.0025		✓
93-95									1000	0.0090		✓
94-95				709.0		2.13	1067	1776	25,000	0.0015	9.9308	
95-96				115.0				115	26,000	0.0001	9.9309	
96-97				115.0		3.68	1897	1962	5500	0.0001	9.9309	
96-97				599.0				599	30,500	0.0007	9.9316	
97-98				115.0				115	31,500	0.0002	9.9318	
98-98				115.0		3.68	1897	1962	3600	0.0000	9.9318	
98-99				599.0				599	35,000	0.0010	9.9328	
99-100				115.0				115	36,000	0.0002	9.9330	
100-100				115.0		3.68	1897	1962	3500	0.0000	9.9330	
100-101				599.0				599	39,500	0.0012	9.9392	
101-102				115.0				115	40,500	0.0003	9.9395	
102-103				115.0				115	41,500	0.0003	9.9398	
103-104				115.0		2.13	1067	1192	42,500	0.0028	9.9376	
104-81				115.0				115	43,500	0.0003	9.9379	
81-105				1035.0		0.89	847	1282	47,000	0.0038	9.9417	
78-105				115.0		3.68	1897	1962	5300	0.0001	9.9417	
113-145									1000	0.1268		✓
113-114				230.0		2.13	1067	1297	110,000	0.0209	9.8505	
114-116				621.37		1.59	800	1921.5	55,625	0.0059	9.8564	
114-115				282.10		1.46	533	987.5	54,375	0.0039	9.8544	
115-149									1000	0.0862		✓
115-116				119.63		0.80	480	580	53,375	0.0020	9.8569	
116-117				628.77				629	119,000	0.0099	9.8663	
117-118									3500	0.0488		✓
117-119				525.0				575	105,500	0.0085	9.8748	
119-120				115.0		2.13	1067	1182	34,500	0.0019	9.8767	
120-121									3500	0.0539		✓
120-119				115.0				115	31,000	0.0001	9.8768	
119-108									3600	0.0488		✓
109-15				115.0				115	37,500	0.0001	9.8769	
75-70				522.15				547	29,000	0.0004	9.8773	

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

NINE AIRWAY AIRFLOW PRESSURE LOSSES

SHEET 23 OF _____

PROJECT NO: 288

DATE: _____

AIRWAY	SIZE	CROSS-SECTION AREA Sq. Ft.	PERI-METER FT.	ACTUAL LENGTH FT.	FRIC-TION FACTOR	SMALL FACTOR	EQUIV LENGTH FT.	TOTAL LENGTH FT.	AIRFLOW VOLUME CFM	PRESSURE LOSS AIRWAY INCHES OF WATER	PRESSURE LOSS CURV INCHES OF WATER	REMARKS
119-122				525.0				575	71,000	0.0839	9.8787	
122-142									1000	0.0991		✓
122-140									1000	0.0925		✓
122-123				145.0		2.13	1067	1182	69,000	0.0875	9.8862	
123-139									1000	0.0899		✓
123-129				599.0				599	68,000	0.0836	9.8898	
129-125									3500	0.0277		✓
129-126				145.0				115	69,500	0.0806	9.8904	
126-137									1000	0.0266		✓
126-127				599.0				599	63,500	0.0832	9.8936	
127-128									3500	0.0207		✓
127-129				145.0				115	60,000	0.0806	9.8992	
129-135									1000	0.0196		✓
129-130				599.0				599	59,000	0.0827	9.8969	
130-131				115.0		4.26	2139	2299	30,175	0.0827	9.8996	
130-132				115.0				115	28,825	0.0802	9.8971	
132-99									1000	0.0322		✓
132-133				145.0		2.13	1067	1182	27,825	0.0812	9.8983	
133-99									3000	0.0310		✓
133-134				145.0		3.19	1600	1715	25,825	0.0815	9.8998	
131-134				145.0				115	30,175	0.0802	9.8998	
134-92									1000	0.0310		✓
134-90									1000	0.0263		✓
134-135									53,000	0.0190	9.9138	
134-135									1000	0.0190		✓
135-136				145.0				115	55,000	0.0805	9.9143	
128-136				145.0		3.68	1897	1942	3500	0.0800	9.9143	
136-137				599.0				599	58,500	0.0827	9.9170	
137-138				145.0				115	59,500	0.0805	9.9175	
125-138				145.0		3.68	1897	1942	3500	0.0800	9.9175	
138-139				599.0				599	63,000	0.0831	9.9206	
139-140				115.0				115	69,000	0.0806	9.9212	
140-83									1000	0.0029		✓
140-141				115.0				115	69,000	0.0806	9.9218	
141-82									1000	0.0021		✓

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

MINE AIRWAY AIRFLOW PRESSURE LOSSES

SHEET 29 OF _____

PROJECT NO: 288

DATE: _____

AIRWAY	SIZE	CROSS-SECTION AREA Sq. Ft.	PER-METER WATER FT.	ACTUAL LENGTH FT.	FEISTMAN FACTOR	SMALL FACTOR	EQUV. LENGTH FT.	TOTAL LENGTH FT.	AIRFLOW VOLUME CFM	PRESSURE LOSS AIRWAY CUMUL. INCHES OF WATER	REMARKS
191-105									1000	0.0199	
191-142				165.0		2.13	1067	1192	62,000	0.0860	9.9275
142-107				115.0				115	2500	0.0000	9.9275
142-121				525.0				575	60,500	0.0028	9.9906
121-143				575.0		0.99	297	822	69,000	0.0095	9.9351
143-106				115.0				115	33,500	0.0009	9.9421
107-106									2500	0.0193	
106-108				575.0		0.99	297	822	57,000	0.0835	9.9456
108-110				345.0		0.99	297	592	60,500	0.0829	9.9485
73-110				115.0		0.37	187	382	1000	0.0000	9.9485
73-69				525.08		0.37	187	712	8500	0.0000	9.9485
110-63				1930.35		0.53	287	1697	61,500	0.0085	9.9570
63-111				185.12		0.99	297	492	65,000	0.0029	9.9599
111-112				230.0		3.19	1600	1830	66,000	0.0106	9.9700
71-112				2097.99		0.53	287	2365	41,500	0.0059	9.9700
112-33	10 x 31.5	295.92	76.50	932.0	25.0	3.81	1910	2892	107,500	0.0936	5.0136
	14 x 49	153.94	43.98	570	60.0	1.88	354	924	107,500	0.1381	5.1517 Used R = 0.0696 pcf
33-150	14 x 49	153.94	43.98	2165	42.213			2165	227,500	0.9839	6.1856 Used R = 0.0671 pcf
118-143	10 x 31.5	295.92	76.50	145.0	25.0	3.68	1807	1942	3500	0.0000	9.9851 Used R = 0.0701 pcf
143-149				635.33		0.53	287	902	67,500	0.0055	9.9906
149-61				468.29				660	68,500	0.0091	9.9947
61-148				379.5		2.42	1344	1493	72,000	0.0117	9.9964
148-57	10 x 31.5	295.92	76.50	41.5	25.0	3.81	1910	1922	73,000	0.0136	9.9700
	14 x 49	153.94	43.98	570	60.0	1.88	354	924	73,000	0.0637	5.0337 Used R = 0.0696 pcf
57-0	14 x 49	153.94	43.98	2170	42.212	7.97	2005	4175	168,000	1.0335	6.0672 Used R = 0.0671 pcf
150-0	11 x 14	154.0	50.0	230	20.0	0.77	382	619	227,500	0.1502	6.2858 Used R = 0.0672 pcf
68-71										0.1350	
69-71										0.0161	
70-71										0.0873

JOY MANUFACTURING COMPANY

air moving products • NEW PHILADELPHIA, OHIO

DIMENSIONS (Inches) JOY AXIVANE FANS

A HUB DIA	B CAS- ING DIA	FAN UNIT PROPER							FAN UNIT WEIGHT— LESS MOTOR	FAN SUPPORTS										INLET BELL		RECOMMENDED OUTLET CONE, (1.5/1.0 AREA RATIO)					
		C	D	E	F	G	H	J		L	M	N	P	Q	R	S	T	U	V	W	AA	BB	CC	DD	FF	GG	
14	18	19 1/2	21 1/2	28	10 GA	1/4	1/8	12	165	25 1/2	1 1/4	13	19 1/2	2 1/2				1/8	23 1/2	4	23 1/2	25 1/2	26 1/2	15	1 1/8	14	
	21 1/4	23 1/4	24 1/4	31	10 GA	1/4	1/8	12	195	28 1/2	1 1/4	15	22 1/2	9 1/4				1/8	27 1/4	4 1/2	27 1/4	29 1/4	30 1/4	17	1 1/8	16	
	23 1/4	25 1/4	26 1/4	33	10 GA	1/4	1/8	14	215	30 1/2	1 1/4	16 1/2	26 1/2	11 1/4				1/8	30 1/4	5	29 1/4	31 1/4	32 1/4	17	1 1/8	16	
	25 1/4	27 1/4	28 1/4	33	10 GA	1/4	1/8	14	230	30 1/2	1 1/4	17 1/2	28 1/2	12 1/4				1/8	33	5 1/2	32	33 1/2	35 1/2	15 1/2	1 1/8	18	
	27 1/4	29 1/4	30 1/4	33	10 GA	1/4	1/8	16	250	30 1/2	1 1/4	19	29	13				1/8	35 1/2	6	34	35 1/2	37 1/2	19 1/2	1 1/8	18	
	29 1/4	31 1/4	32 1/4	33	10 GA	1/4	1/8	16	260	30 1/2	1 1/4	20	31	14				1/8	38	6 1/4	36	38	39 1/2	19 1/2	1 1/8	20	
	32	33 1/2	35 1/2	33	10 GA	1/4	1/8	18	295	30 1/2	1 1/4	22	31 1/2	14 1/4				1/8	41 1/4	6 1/2	42 1/4	44 1/4	45 1/4	29 1/2	1 1/8	24	
	34	35 1/2	37 1/2	36	10 GA	1/4	1/8	18	320	33 1/2	1 1/4	23 1/2	33 1/2	15 1/4				1/8	44 1/4	7 1/4	42 1/4	44 1/4	45 1/4	23 1/2	1 1/8	24	
	36	38	39 1/2	36	10 GA	1/4	1/8	20	400	33 1/2	1 1/4	24 1/2	38	17 1/2				1/8	47	7 1/2	45	47	48 1/2	25 1/2	1 1/8	24	
17 1/2	21 1/4	23 1/4	24 1/4	31	10 GA	1/4	1/8	12	215	28 1/2	1 1/4	15	22 1/2	9 1/4				1/8	27 1/4	4 1/2	27 1/4	29 1/4	30 1/4	17	1 1/8	16	
	23 1/4	25 1/4	26 1/4	33	10 GA	1/4	1/8	14	235	30 1/2	1 1/4	16 1/2	26 1/2	11 1/4				1/8	30 1/4	5	29 1/4	31 1/4	32 1/4	17	1 1/8	16	
	25 1/4	27 1/4	28 1/4	33	10 GA	1/4	1/8	14	250	30 1/2	1 1/4	17 1/2	28 1/2	12 1/4				1/8	33	5 1/2	32	33 1/2	35 1/2	19 1/2	1 1/8	18	
	27 1/4	29 1/4	30 1/4	33	10 GA	1/4	1/8	16	270	30 1/2	1 1/4	19	29	13				1/8	35 1/2	6	34	35 1/2	37 1/2	19 1/2	1 1/8	18	
	29 1/4	31 1/4	32 1/4	33	10 GA	1/4	1/8	16	285	30 1/2	1 1/4	20	31	14				1/8	38	6 1/4	36	38	39 1/2	19 1/2	1 1/8	20	
	32	33 1/2	35 1/2	33	10 GA	1/4	1/8	18	315	30 1/2	1 1/4	22	31 1/2	14 1/4				1/8	41 1/4	6 1/2	42 1/4	44 1/4	45 1/4	29 1/2	1 1/8	24	
	34	35 1/2	37 1/2	36	10 GA	1/4	1/8	18	345	33 1/2	1 1/4	23 1/2	33 1/2	15 1/4				1/8	44 1/4	7 1/4	42 1/4	44 1/4	45 1/4	23 1/2	1 1/8	24	
	36	38	39 1/2	36	10 GA	1/4	1/8	20	425	33 1/2	1 1/4	24 1/2	38	17 1/2				1/8	47	7 1/2	45	47	48 1/2	25 1/2	1 1/8	24	
	38	40	41 1/2	40	10 GA	1/4	1/8	20	470	37 1/2	1 1/4	26	40	18 1/2				1/8	49 1/2	8	48	50	51 1/2	28 1/2	1 1/8	30	
21	42 1/4	44 1/4	45 1/4	42	10 GA	1/4	1/8	24	530	39 1/2	1 1/4	28 1/2	40 1/2	18 1/2				1/8	55	9	54	56 1/2	58 1/2	33 1/2	1 1/8	30	
	45	47	48 1/2	44	10 GA	1/4	1/8	24	575	41 1/2	1 1/4	30 1/2	42 1/2	19 1/2				1/8	58 1/2	9 1/2	60	62 1/2	64 1/2	43	1 1/8	30	
	25 1/4	27 1/4	28 1/4	33	10 GA	1/4	1/8	14	320	30 1/2	1 1/4	17 1/2	28 1/2	12 1/4				1/8	33	5 1/2	32	33 1/2	35 1/2	19 1/2	1 1/8	18	
	27 1/4	29 1/4	30 1/4	33	10 GA	1/4	1/8	16	335	30 1/2	1 1/4	19	29	13				1/8	35 1/2	6	34	35 1/2	37 1/2	19 1/2	1 1/8	18	
	29 1/4	31 1/4	32 1/4	33	10 GA	1/4	1/8	16	355	30 1/2	1 1/4	20	31	14				1/8	38	6 1/4	36	38	39 1/2	19 1/2	1 1/8	20	
	32	33 1/2	35 1/2	33	10 GA	1/4	1/8	18	395	30 1/2	1 1/4	22	31 1/2	14 1/4				1/8	41 1/4	6 1/2	42 1/4	44 1/4	45 1/4	29 1/2	1 1/8	24	
	34	35 1/2	37 1/2	36	10 GA	1/4	1/8	18	425	33 1/2	1 1/4	23 1/2	33 1/2	15 1/4				1/8	44 1/4	7 1/4	42 1/4	44 1/4	45 1/4	23 1/2	1 1/8	24	
	36	38	39 1/2	36	10 GA	1/4	1/8	20	505	33 1/2	1 1/4	24 1/2	38	17 1/2				1/8	47	7 1/2	45	47	48 1/2	25 1/2	1 1/8	24	
	38	40	41 1/2	40	10 GA	1/4	1/8	20	555	37 1/2	1 1/4	26	40	18 1/2				1/8	49 1/2	8	48	50	51 1/2	28 1/2	1 1/8	30	
26 1/2	42 1/4	44 1/4	45 1/4	42	10 GA	1/4	1/8	24	620	39 1/2	1 1/4	28 1/2	40 1/2	18 1/2				1/8	55	9	54	56 1/2	58 1/2	33 1/2	1 1/8	30	
	45	47	48 1/2	44	10 GA	1/4	1/8	24	670	41 1/2	1 1/4	30 1/2	42 1/2	19 1/2				1/8	58 1/2	9 1/2	60	62 1/2	64 1/2	43	1 1/8	30	
	48	50	51 1/2	48	10 GA	1/4	1/8	30	745	45 1/2	1 1/4	32 1/2	45 1/2	21 1/2				1/8	62 1/2	10	60	62 1/2	64 1/2	43	1 1/8	30	
	34	35 1/2	37 1/2	36	10 GA	1/4	1/8	18	490	33 1/2	1 1/4	23 1/2	33 1/2	15 1/4				1/8	44 1/4	7 1/4	42 1/4	44 1/4	45 1/4	23 1/2	1 1/8	24	
	36	38	39 1/2	36	10 GA	1/4	1/8	20	550	37 1/2	1 1/4	26 1/2	38	17 1/2				1/8	47	7 1/2	45	47	48 1/2	25 1/2	1 1/8	24	
	38	40	41 1/2	40	10 GA	1/4	1/8	20	630	37 1/2	1 1/4	26	40	18 1/2				1/8	49 1/2	8	48	50	51 1/2	28 1/2	1 1/8	30	
	42 1/4	44 1/4	45 1/4	42	10 GA	1/4	1/8	24	705	39 1/2	1 1/4	28 1/2	40 1/2	18 1/2				1/8	55	9	54	56 1/2	58 1/2	33 1/2	1 1/8	30	
	45	47	48 1/2	44	10 GA	1/4	1/8	24	760	41 1/2	1 1/4	30 1/2	42 1/2	19 1/2				1/8	58 1/2	9 1/2	60	62 1/2	64 1/2	43	1 1/8	30	
	48	50	51 1/2	48	10 GA	1/4	1/8	30	840	45 1/2	1 1/4	32 1/2	45 1/2	21 1/2				1/8	62 1/2	10	60	62 1/2	64 1/2	43	1 1/8	30	
30	54	56 1/2	58 1/2	48	10 GA	1/4	1/8	30	960	49 1/2	1 1/4	36 1/2	50	26				1/8	70	10 1/2	66	67	71 1/2	34	1 1/8	32	
	60	62 1/2	64 1/2	48	10 GA	1/4	1/8	30	1055	49 1/2	1 1/4	40 1/2	54	29 1/2				1/8	78	11 1/2	73 1/2	75 1/2	78 1/2	38 1/2	1 1/8	32	
	66	69	71 1/2	48	10 GA	1/4	1/8	32	1350	49 1/2	1 1/4	45	60	32				1/8	86	12	81	83 1/2	87 1/2	43	1 1/8	32	
	72	75	77 1/2	48	10 GA	1/4	1/8	32	1465	49 1/2	1 1/4	48	66	35				1/8	92	12	88 1/2	91 1/2	94 1/2	46 1/2	1 1/8	32	
	78	81 1/2	84 1/2	48	10 GA	1/4	1/8	32	1605	49 1/2	1 1/4	51	70	38				1/8	95	12	91 1/2	94 1/2	97 1/2	49 1/2	1 1/8	32	
	84	87 1/2	90 1/2	48	10 GA	1/4	1/8	32	1720	49 1/2	1 1/4	54	74	41				1/8	104	12	100 1/2	103 1/2	106 1/2	52 1/2	1 1/8	32	
	66	21	10																								
	72	23	11																								
	78	25	12																								
84	27	13																									

* Indicates non-stock sizes

JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

MODEL 45-26 $\frac{1}{2}$ -1750
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

C-1336

JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

MODEL 45-26 $\frac{1}{2}$ -1750 2-STAGE
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

C-2446

JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

C-1339

MODEL 48-26½-1750
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

MODEL 48-26 $\frac{1}{2}$ -1750 2-STAGE
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

C-2509

OKC.

JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

MODEL 54-26 $\frac{1}{2}$ -1750
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

C-1342

JOY MANUFACTURING COMPANY
332 S. BROADWAY
NEW PHILADELPHIA, OHIO 44663
SEPTEMBER 14, 1955

MODEL 54-26 $\frac{1}{2}$ -1750 2-STAGE
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

C-2606

374

Mine Structural Analysis

Sept 16, 76

SHAFT PILLAR DESIGN - EVALUATION -

Depth = 2225 ft

Entry Height = 10 ft

Density = 150 lb/ft³

Pillar Radius = 1000 ft

$$\text{Arch Distance} = 0.154 (\text{Depth} - \text{ft}) + 70 = 408.8 \text{ ft}$$

SHAFT TRIBUTARY-AREA-LOAD-(TAL)

$$\text{TAL} = \frac{\pi (1000 + 408.8)^2 (150 (2225))}{2000} = 1,040,500,000 \text{ Tons}$$

LOAD CARRYING CAPABILITY (L)

I. Most Likely Physical Properties

$\Phi = 30^\circ$ (Metz (f)) σ_c (cohesion) = 450 psi (Boulby)

$\hat{\sigma}_v = 7399 \text{ psi}$ $\hat{\gamma} = 8.08 \text{ ft}$

$L = 1,660,000,000 \text{ Tons}$

$$\underline{FS} = L / \text{TAL} = \underline{1.60}$$

II. "Pure" Wilson, A. H. $\sigma_c = 1 \text{ psi}$

$\Phi = 30^\circ$ $\sigma_c = 1 \text{ psi}$

$\hat{\sigma}_v = 6950 \text{ psi}$ $\hat{\gamma} = 25.54 \text{ ft}$

$L = 1,532,000,000 \text{ Tons}$ $\underline{FS} = \underline{1.47}$

III Cohesion Equals Unconfined Compression Strength Divided by Two - SHORT-TERM COHESION

$\Phi = 30^\circ$ $\sigma_c = 1600 \text{ psi}$

$\hat{\sigma}_v = 8549 \text{ psi}$ $\hat{\gamma} = 4.84 \text{ ft}$

$L = 1,924,000,000 \text{ Tons}$ $\underline{FS} = \underline{1.85}$

13/1

IV Cohesion for Long-term (Infinite) Pillar Life Friction Angle of Repose

$$\Phi = 35^\circ \quad \sigma_o = 450 \text{ psi}$$

$$\hat{\sigma}_v = 8997 \text{ psi} \quad \hat{y} = 5.80 \text{ ft}$$

$$L = 2,023,000,000 \text{ Tons}$$

$$\underline{\underline{FS = 1.94}}$$

V Minimum Unconfined Compression Strength for 10-ft High Pillar Rib to Stand

$$\Phi = 30^\circ \quad \sigma_o = 10 \text{ psi}$$

$$\hat{\sigma}_v = 69.59 \text{ psi} \quad \hat{y} = 18.89 \text{ ft}$$

$$L = 1,544,500,000 \text{ Tons}$$

$$\underline{\underline{FS = 1.48}}$$

PILLAR RADIUS NEEDED FOR FACTOR OF SAFETY OF ONE

$$I_1 = \Phi = 30^\circ \quad \sigma_o = 450 \text{ psi} \quad \underline{\underline{R = 529 \text{ ft}}}$$

$$TAL = \pi (R + 408.8)^2 (150)(2225) = 524(R^2 + 817.6R + 167100)$$

$$TAL = 524(R^2 + 817.6R + 167100) = 524R^2 + 428600R + 87610000$$

$$L = 0.05655 \hat{\sigma}_v [4R^2 - 4R\hat{y} + \frac{4}{3}\hat{y}^3]$$

$$L = 418.4 [4R^2 - 32.32R + 87.05]$$

$$L = 1674R^2 - 13520R + 36422$$

$$-TAL = -524R^2 - 428600R - 87610000$$

$$L - TAL = 1149R^2 - 442200R - 87580000 = 0$$

$$R = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = 528.8 \text{ ft}$$

$$II \quad \Phi = 30^\circ \quad \sigma_o = 1 \text{ psi} \quad \underline{\underline{R = 580 \text{ ft}}}$$

$$L - TAL = 1048R^2 - 468800R - 87270000 = 0$$

$$R = 588.8 \text{ ft}$$

3

III. $\Phi = 30^\circ$ $\sigma_c = 1600 \text{ psi}$ $R = 449 \text{ ft}$
 $I - TAL = 1410 R^2 - 438,000 R - 87,600,000 = 0$
 $R = 449.1 \text{ ft}$

IV. $\Phi = 35^\circ$ $\sigma_c = 450 \text{ psi}$ $R = 427 \text{ ft}$
 $I - TAL = 1511 R^2 - 440,400 R - 87,590,000 = 0$
 $R = 427.2 \text{ ft}$

V. $\Phi = 30^\circ$ $\sigma_c = 10 \text{ psi}$ $R = 580 \text{ ft}$
 $I - TAL = 1050 R^2 - 458,400 R - 87,425,000 = 0$
 $R = 580.1 \text{ ft}$

STORAGE DRIFT PILLAR DESIGN FOR $FS = 1.5$

Depth = 2225 ft
 Density = 150 lb/ft³
 Pillar Length = 500 ft

Room Height = 16.5 ft
 Room Width (M_x) = 42 ft
 $R = ? \%$

$FS = 1.5 = I / TAL$ Design for 1-ft Slice

$I = 1.5 TAL$

I. Most Likely Physical Properties

$\Phi = 30^\circ$ $\sigma_c = 450 \text{ psi}$ $p = \text{pillar width}$
 $\hat{\sigma}_r = 7399 \text{ psi}$ $\hat{\gamma} = 13.34 \text{ ft}$

$TAL = \frac{(1)(p+42)(150)(2225)}{2000} = 166.9(p+42)$

$TAL = 166.9 p + 7009 \text{ Tons}$

$I = 0.072 \hat{\sigma}_r [p - \hat{\gamma}] = 0.072 (7399) [p - 13.34]$

$I = 532.7 p - 7104$

$$L = 1.5 T A L$$

$$532.7p - 7104 = 1.5(166.9p + 7009)$$

$$532.7p - 7104 = 250.4p + 10510$$

$$282.4p = 17620$$

$$p = \underline{62.4 \text{ ft}}$$

II "Pure" Wilson $\Phi = 30^\circ$ $\sigma_c = 1050$ $\hat{\sigma}_v = 6950$

$$L = 0.072(6950)[p - 42.14] = 500.4[p - 42.14]$$

$$L = 500.4p - 21085$$

$$\hat{\gamma} = 25.54 \text{ ft}$$

$$-1.5 T A L = -250.4p - 10510$$

$$+ 250.4p - 31595 = 0$$

$$p = \underline{126.4 \text{ ft}} \quad R = 24.9$$

III Cohesion Equals Unconfined Compression Strength
Divided by Two - SHORT-TERM COHESION

$$\Phi = 30^\circ; \sigma_c = 1600 \text{ psi}; \hat{\sigma}_v = 8549 \text{ psi}; \hat{\gamma} = 4.84 \text{ ft}$$

$$L = 0.072(8549)[p - 7.98]$$

$$L = 615.5p - 4973$$

$$-1.5 T A L = -250.4p - 10510 = 0$$

$$365.1p - 15482 = 0$$

$$p = \underline{42.2 \text{ ft}}$$

IV Friction Angle of Repose - Long-Term Cohesion

$$\Phi = 35^\circ; \sigma_c = 450 \text{ psi}; \hat{\sigma}_v = 8997 \text{ psi}; \hat{\gamma} = 9.56 \text{ ft}$$

$$L = 0.072(8997)[p - 9.56]$$

$$L = 647.8p - 6196$$

$$-1.5 T A L = -250.4p - 10510$$

$$397.4p - 16706 = 0$$

$$p = \underline{42.0 \text{ ft}}$$

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V. Minimum Unconfined Compression Strength
for 16.5-ft High Pillar Rib to Stand
 $\Phi = 30^\circ$; $\sigma_0 = 16.5 \text{ psi}$; $\hat{\sigma}_v = 6965 \text{ psi}$; $\hat{\gamma} = 28.79 \text{ ft}$
 $L = 0.072(6965)[p - 28.79]$
 $L = 501.5p - 14440$
 $-1.5 \text{ TAL} = -250.4p - 10510$
 $p = 99.4 \text{ ft}$

MAIN ENTRY PILLAR DESIGN FOR **FS = 1.5**

Depth = 2225 ft

Density = 150 lb/ft³

Pillar Lengths - 500 ft and "p" from Storage

Pillar Weight - 10 ft Draft Design

Room Width - 32 ft

I. $\Phi = 30^\circ$; $\sigma_0 = 450 \text{ psi}$

$\hat{\sigma}_v = 7399 \text{ psi}$; $\hat{\gamma} = 8.08 \text{ ft}$

$p = 43.6 \text{ ft}$ $R = 42.3\%$

II. $\Phi = 30^\circ$; $\sigma_0 = 1 \text{ psi}$

$\hat{\sigma}_v = 6950 \text{ psi}$; $\hat{\gamma} = 25.54 \text{ ft}$

$p = 83.1 \text{ ft}$ $R = 27.8\%$

III. $\Phi = 30^\circ$; $\sigma_0 = 1600 \text{ psi}$

$\hat{\sigma}_v = 8549 \text{ psi}$; $\hat{\gamma} = 4.84 \text{ ft}$

$p = 30.1 \text{ ft}$; $R = 51.5\%$

IV. $\Phi = 35^\circ$; $\sigma_0 = 450 \text{ psi}$

$\hat{\sigma}_v = 8997 \text{ psi}$; $\hat{\gamma} = 5.80 \text{ ft}$

$p = 29.6 \text{ ft}$; 51.9%

V. $\Phi = 30^\circ$; $\sigma_0 = 10 \text{ psi}$

$\hat{\sigma}_v = 6959 \text{ psi}$; $\hat{\gamma} = 18.89 \text{ ft}$; $p = 69.7 \text{ ft}$; $R = 31.5\%$

16.5-ft High
42-ft Wide
I.

Storage
II.

Drifts
III.

FS	p (ft)	R (%)	p (ft)	R (%)	p (ft)	R (%)
1.25	48.95	46.18	102.29	29.11	33.60	55.55
1.50	62.39	40.24	126.36	24.95	42.24	49.86
1.75	80.48	34.29	160.07	20.78	53.11	44.16
2.00	106.16	28.35	210.66	16.62	67.19	38.47
2.25	145.47	22.40	295.05	12.46	86.16	32.77
2.50	213.18	16.46	464.08	8.30	113.13	27.07

IV.

V.

FS	p (ft)	R (%)	p (ft)	R (%)
1.25	39.05	55.22	79.21	34.65
1.50	42.04	49.98	99.34	29.71
1.75	51.89	44.73	127.50	24.78
2.00	64.36	39.49	169.65	19.84
2.25	80.66	34.24	239.72	14.91
2.50	102.84	29.00	379.13	9.97

32 ft OVERALL ENTRY WIDTH

FS	p (ft)	% R
2.0	75.32	29.8
2.5	152.84	17.3
2.25	103.80	23.56
1.5	43.6	42.3
1.75	43.6 56.72	36.07
1.25	33.88	48.57

FS	p (ft)	R %
1.25	66.67	32.93
1.50	83.13	27.79
1.625	93.61	25.48
1.75	106.19	23.19
1.875	121.56	20.29
2.00	140.78	18.52
2.125	165.51	16.20
2.25	198.49	13.88
2.50	314.08	9.21

p (ft)	R %
82.23 72	57.43
30.09	51.59
38.09	45.65
48.47	39.76
62.46	33.88
82.33	27.99

p (ft)	A (%)
33.88	48.57
43.6	42.3
56.72	36.07
75.32	29.8
2.125 87.89	26.69
103.80	23.56
2.375 127.57	20.99
152.84	17.3

FS	p (ft)	R %
1.25	23.75	57.40
1.50	29.60	51.95
1.75	36.82	46.50
2.00	45.96	41.04
2.25	57.91	35.59
2.50	74.17	30.19
2.75	78.16	29.05

p (ft)	R (%)
55.20	36.70
69.71	31.42
90.01	26.23
1.875 120.44	20.99
2.125 142.16	18.37
171.09	15.76
272.15	10.52

Storage Drift Design — 42-ft Room Width

Entry Design — 32-ft Entry Width

Storage Drift Design - 42-ft Wide Room

32-ft Entry Width

TRU LEVEL ENTRY DESIGN— 31.50 FT. WIDTH
 10.00 FT. HEIGHT
 2,225.00 FT. DEPTH

TRU STORAGE ROOM DESIGN - 45.00 FT. WIDTH
 16.54 FT. HEIGHT
 2225 FT. DEPTH

HR Level
2800 ft Depth

ENTRY DESIGN - 31.5 FT. ROOM WIDTH
10.0 FT. ROOM HEIGHT

①

TRU Level Nov. 16, '76 Triaxial Test Quasi-static Results - Wawersik

②

TRU LEVEL DESIGNS CONT.

Depth - 2300 ft; Temperature - Start 305.2°K, at 10 yrs 373°K, then steady.
 Pillar Width - 83.5 ft; Room Width - 31.5 ft; Room Height - 10 ft.

FIGURE ____ HR Level Convergence Versus Elapsed Time for 83.5-ft Wide Pillars.

Depth 2800 ft ; Temperature - Start 305.2°K, at 10 yrs 373°K, then steady.
 Room Width - 31.5 ft ; Room Height - 10 ft

FIGURE ____ HR Level Convergence Versus Time Since Loading

1961

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Premises: Verbal - 500,000; P. Plan - 100; Room with - 3/500

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Pillar width 78.5 ft

Pillar width - 88.54

Pillar Width - 03.5 ft

[illegible]

FIGURE ____ TRU Level Convergence Versus Elapsed Time

FENIX & SCISSON, INC.

LAS VEGAS, NEVADA 89101

COMPUTED BY: J. L. AIN

CHECKED BY: _____

CALCULATIONS FOR: MINE STABILITY BASED ON HISTORICAL DATA

DESIGN SHEET

SHEET 1 OF 1PROJECT NO. 288DATE: SEPT. 17, 1975

THE FOLLOWING DATA POINTS WERE UTILIZED TO OBTAIN A
GENERALIZED EQUATION FOR AN ALLOWABLE EXTRACTION RATE IN MINES
OPERATING IN EVAPORITE DEPOSITS:

	DEPTH (feet)	EXTRACTION RATE (%)
	0	100
HUTCHINSON	895	75
WINNIFIELD	811	66
LYONS	1024	68
PETSON	1063	73.5
DETROIT	1100	65
BELLA ISLE	1250	52.8
COTE BLANCHE	1354	56
* GOODRICH	1760	32.2
WHISKEY ISLAND	1775	54
SONACA LAKE	2000	55
NRAB (AVG)	3200	38
ESTERNARY	3400	36.6

* GOODRICH ~ THIS DATA POINT NOT USED DUE TO UNSTABILITY

THE METHOD OF LEAST SQUARES WAS USED TO OBTAIN THE BEST FIT
OF THE DATA TO THE EQUATION.

FENIX & SCISSON, INC.

LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

SHEET 2 OF _____

PROJECT NO. 288

DATE: SEPT. 17, 1975

$n =$	12 (no Goderich)	13
$E_n =$	17,622	19,382
$E_n^2 =$	31,008,732	37,466,332
$E_n^3 =$	99,507,990,966	99,959,216,966
$E_n^4 =$	274,666,206,979,900	289,261,332,739,920
$E_n^5 =$	851,676,759,228,000,000	868,569,175,565,680,000
$E_n^6 =$	2,728,521,076,013,000 $\times 10^6$	2,758,242,937,567,000 $\times 10^6$
$E_n^7 =$	8,889,872,769,326,000 $\times 10^9$	8,942,183,245,661,000 $\times 10^9$
$E_n^8 =$	29,230,096,506,860,000 $\times 10^{12}$	29,322,412,949,410,000 $\times 10^{12}$
$E_y =$	739.90	772.10
$E_{ny} =$	919,877.50	971,549.50
$E_{ny}^2 =$	1,845,133,796.50	1,799,875,516.50
$E_{ny}^3 =$	3,970,977,029,239	9,196,529,216,929
$E_{ny}^4 =$	10,919,093,566,930,000	11,223,006,616,400,000

$y = q_0 + q_1 x + q_2 x^2 + q_3 x^3 + q_4 x^4$																			
$12 q_0 + 17,622 q_1 + 36,808,732 q_2 + 99,507,440,966 q_3 + 279,666,206,979,400 q_4 = 739,90$																			
$17,622 q_0 + 36,808,732 q_1 + 99,507,440,966 q_2 + 279,666,206,979,400 q_3 + 851,676,759,228,000,000 q_4 =$																			
																		914,877.50	
$36,808,732 q_0 + 99,507,440,966 q_1 + 279,666,206,979,400 q_2 + 851,676,759,228,000 q_3 \times 10^3 +$																			
																		$2,728,521,076,013,000 q_4 \times 10^6 = 1,695,132,796.50$	
$99,507,440,966 q_0 + 279,666,206,979,400 q_1 + 851,676,759,228,000 q_2 \times 10^3 + 2,728,521,076,013,000 q_3 \times 10^6 +$																			
																		$0,889,872,769,326,000 q_4 \times 10^9 = 3,970,977,629,239.$	
$279,666,206,979,400 q_0 + 851,676,759,228,000 q_1 \times 10^3 + 2,728,521,076,013,000 q_2 \times 10^6 +$																			
																		$0,889,872,769,326,000 q_3 \times 10^9 + 29,230,046,506,060,000 q_4 \times 10^{12} = 10,914,043,586,930,000.$	

COMPUTED BY: _____
 CHECKED BY: _____
 CALCULATIONS FOR: _____

FENIX & SCISSION, INC.
 LAS VEGAS, NEVADA 89101
DESIGN SHEET

SHEET 9 OF 91
 PROJECT NO. 448
 DATE SEP 17 1975

FENIX & SCSIGN, INC.
LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: _____
CHECKED BY: _____
CALCULATIONS FOR: _____

DATE: 1-20
PROJECT NO: 40
SHEET: 07/08

2-1	$10,930,825 q + 40,453,818,029 q + 135,882,029,920,800 q + 498,329,429,278,800,000 q = -171,665.65$
3-1	$40,453,818,029 q + 161,759,311,025,400 q + 561,785,165,351,100 q \times 10^3 + 1,886,011,589,167,000 q \times 10^6 =$ $-579,938,270.7830$
4-1	$135,882,029,920,800 q + 561,785,165,351,100 q \times 10^3 + 1,989,216,376,185,000 q \times 10^6 +$ $6,726,706,079,209,000 q \times 10^9 = -1,856,191,268,323$
5-1	$498,329,429,278,800 q \times 10^3 + 1,886,011,589,167,000 q \times 10^6 + 6,726,706,079,209,000 q \times 10^9 +$ $22,942,252,739,690,000 q \times 10^{12} = -6,021,416,978,910,000$

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FENIX & SCISSON, INC.
LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: _____
CHECKED BY: _____
CALCULATIONS FOR: _____

SHEET 5 OF 9
PROJECT NO. 588
DATE APR 17 1985

7-6	$12,099,043,173,900 q_2 + 58,900,258,571,600 q_3 \times 10^3 + 236,792,086,902,830 q_4 \times 10^6 = 60,883,999,18$
8-6	$58,900,258,571,700 q_2 \times 10^3 + 285,055,122,996,000 q_3 \times 10^6 + 1,153,989,206,355,000 q_4 \times 10^9 = 277,796,257,522$
9-6	$226,792,086,902,000 q_2 \times 10^6 + 1,153,989,206,356,000 q_3 \times 10^9 + 9,559,953,899,890,000 q_4 \times 10^{12} =$ $1,019,975,941,999,000$
11-10	$7,008,954,946,200 q_3 \times 10^6 + 49,378,871,968,000 q_4 \times 10^9 = -19,951,205,101,80$
12-10	$49,378,871,971,000 q_3 \times 10^9 + 289,907,014,870,000 q_4 \times 10^{12} = -126,984,181,560,000$
14-13	$-3,941,669,570,700 q_4 \times 10^{12} = -658,398,183,600$ $q_4 = 192.98415920890 \times 10^{-6}$

DESIGN SHEET

COMPUTED BY: _____
CHECKED BY: _____
CALCULATIONS FOR: _____

SHEET 6 OF 8
PROJECT NO. 400
DATE 5/27/1975

$$\text{at } q_1 = 192,984,152,2890 \times 10^{-15}$$

$$7,008,956,946,200 q_1 \times 10^6 = -28,515,424,395.18$$

$$99,378,871,971,000 q_1 \times 10^9 = -181,870,230,197,800$$

$$q_2 = -9,0684547806560 \times 10^{-9}$$

$$= -4,0981269759650 \times 10^{-9}$$

$$\text{at } q_2 = -4,0832906283110 \times 10^{-9}$$

$$18,084,043,173,380 q_2 = 237,623,592,9010$$

$$58,900,358,571,700 q_2 \times 10^3 = 1,259,987,896,363$$

$$236,792,086,408,000 q_2 \times 10^6 = 4,850,452,752,756,000$$

$$q_3 = 21,390125325370 \times 10^{-6}$$

$$= 21.391890747960 \times 10^{-6}$$

$$= 21.387222233840 \times 10^{-6}$$

$$\text{at } q_3 = 21.389746102220 \times 10^{-6}$$

$$10,930,825 q_3 = -568,637,20502580$$

$$90,453,808,029 q_3 = -2,109,461,112,6780$$

$$135,882,029,920,800 q_3 = -7,068,651,901,736,00$$

$$998,329,429,278,700 q_3 \times 10^{-3} = -23,323,312,771,680,000$$

$$q_4 = -52.021435255360 \times 10^{-3}$$

$$= -52.121322972690 \times 10^{-3}$$

$$= -52.020505624300 \times 10^{-3}$$

$$= -52.122711980350 \times 10^{-3}$$

COMPUTED BY: _____
 CHECKED BY: _____
 CALCULATION FOR: _____

FENIX & SCISSON, INC.
 LAS VEGAS, NEVADA 89101

DESIGN SHEET

WANT 1 OF 600
 PROJECT NO. 600
 DATE APR 17 1985

$$a_1 q_1 = -52.021993833130 \times 10^{-3}$$

$$12 q_0 = 1202.1884539880$$

$$17,622 q_0 = 1,765,419,384.252$$

$$36,808,782 q_0 = 3,687,592,986,903.0$$

$$94,507,440,966 q_0 = 9,468,113,809,657$$

$$274,646,206,979,400 q_0 = 27,516,45,751,640,000$$

$$q_0 = 100.1823711290$$

$$= 100.1864074595$$

$$= 100.1825595868$$

$$= 100.1837919426$$

$$= 100.1803827790$$

$$a_1 q_0 = 100.1823025824$$

$$y = 100.1823025824 - 52.021993833130 \times 10^{-3} + 21.38974610222 \times 10^{-6} - 9.083290628311 \times 10^{-9} +$$

$$192.9891592083 \times 10^{-15}$$

$$a_1 x = 0, y = 100.1823$$

$$200 \quad 90.6012$$

$$400 \quad 88.5397$$

$$600 \quad 75.8127$$

$$800 \quad 70.2929$$

$$1000 \quad 65.6602$$

$$1200 \quad 61.9020$$

$$a_1 x = 1400, y = 58.8129$$

$$1600 \quad 56.2952$$

$$1800 \quad 54.0585$$

$$2000 \quad 52.1197$$

$$2200 \quad 50.3033$$

$$2400 \quad 48.4910$$

$$2600 \quad 46.5721$$

$$a_1 x = 2800, y = 44.4432$$

$$3000 \quad 42.0089$$

$$3200 \quad 39.1791$$

$$3400 \quad 35.8742$$

$$3600 \quad 32.4200$$

$$3800 \quad 27.5501$$

$$4000 \quad 22.4056$$

$$4661.25 \quad 0.00039906195$$

FENIX & SCIBSON, INC.
LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: _____
CHECKED BY: _____
CALCULATIONS FOR: _____

SHEET 8 OF _____
PROJECT NO. 208
DATE SEP 10 1978

$y = 100.0980626787 - 50.5966809262x \cdot 10^{-3} + 16.57579925422x^2 \cdot 10^{-6} - 2.24653999477x^3 \cdot 10^{-9}$											
$\alpha/x = 0, y = 100.0981$			$\alpha/x = 1000, y = 58.7149$			$\alpha/x = 2000, y = 44.8506$					
200	90.7250		1000	56.1420		2000	42.3832				
400	82.7333		1800	53.9997		3200	39.3858				
600	75.9865		2000	52.1357		3400	35.7196				
800	70.3978		2200	50.9284		3600	31.8987				
1000	65.6806		2400	49.7362		3800	25.8364				
1200	61.8984		2600	46.9225		4000	19.3462				
						4451.85	0.000199				
$y = 96.688039422230 - 34.413163806520x \cdot 10^{-3} + 5.055112996052x^2 \cdot 10^{-6}$											
$\alpha/x = 0, y = 96.6880$			$\alpha/x = 1000, y = 58.9176$			$\alpha/x = 2000, y = 38.9633$					
200	90.0076		1000	54.5681		3000	38.9446				
400	83.7316		1800	51.1829		3200	38.3303				
600	77.8600		2000	48.0822		3400	38.1204				
800	72.3928		2200	45.9458		3600	38.3199				
1000	67.3300		2400	43.2139		3800	38.9438				
1200	62.6716		2600	41.3869		4000	39.9172				
$y = 89.72072062595 - 15.709729579530x \cdot 10^{-3}$											
$\alpha/x = 0, y = 89.7207$			$\alpha/x = 2000, y = 53.3113$			$\alpha/x = 4000, y = 21.9018$					

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K&E 10 X 10 TO 1/2 INCH 46 1322
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

SHEET 9 OF
PROJECT NO. 208
DATE: SEPT. 18 1975

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: J. G. Ash

CHECKED BY: _____

CALCULATIONS FOR: _____

SHEET _____ OF _____

PROJECT NO: 208

DATE: SEPT. 16, 1976

CRITICAL STRESS CONCENTRATIONS FOR OPENINGS
OF VARIOUS CROSS SECTIONS

Ratio of Stress Concentration to Vert. Applied Stress

- x = ELLIPTICAL OPENING
- = OVALOIDAL OPENING
- = RECTANGULAR OPENING w/ ROUNDED CORNERS
- = H/h VERT STRESS OF 1
- - - = " " " $1/3$

WIDTH TO HEIGHT RATIO FOR OPENING

CRITICAL STRESSES ON OPENING BOUNDARY

Ratio of
HORIZ. TO VERT.
APPLIED
STRESS ANGLE
FROM
HORIZONTAL WIDTH TO HEIGHT RATIO (W/H) FOR OPENING

ELLIPTICAL OPENING

		0.35	0.50	1.00	2.00	4.00
0	0°	1.5	2.0	3.0	5.0	9.0
	90°	-1.0	-1.0	-1.0	-1.0	-1.0
1/2	0°		1.67	2.67	4.33	8.33
	90°	2.3			-0.33	-0.5
1	0°			2.0	4.0	8.0
	90°	3.0	4.0	2.0		

QUADRANTAL OPENING

0	0°	1.9	2.0	3.0	3.9	9.85
	90°	-0.9	-0.9	-1.0	-0.9	-1.9
1/2	0°		2.05	2.67	3.15	4.5
	90°	2.1			-0.33	-0.5
1	0°			2.0	3.15	7.1
	90°	4.1	3.15			

RECTANGULAR OPENING WITH ROUNDED CORNERS HAVING A FILLET

FACTOR OF OPENING SHARP DIMENSION RATIO OF 1:6

0	CORNER	2.5	2.67	3.35	4.0	5.33
	90°	-1.0	-1.0	-1.0	-0.5	-0.5
1/2	CORNER	3.5	3.1	3.15	4.0	5.5
	90°		-0.2	-0.33	-0.5	-0.5
1	CORNER	6.15	4.67	3.75	4.67	6.15
	90°					

J. L. Ash
9/20/76

Creep Rates and Total Closure for Isolated Openings

Use $C_c = k \sigma^n t^{-0.85}$ for first year and then assume to be constant thereafter
 where C_c is the creep rate in inches per inch per day
 σ is the initial in situ rock stress in pounds per square inch
 t is the elapsed time in days
 k and n are octahedral strain constants
 Total Closure = $\int_0^t k \sigma^n t^{-0.85} dt = \frac{k \sigma^n t^{0.15}}{0.15}$ in inches per inch

At a density of 150 pounds per cubic foot for the overlying material,
 $\sigma = \text{height} \times \text{density} = \frac{150 \times 3230}{144} = 2325 \text{ psi for the TTH level}$
 $= \frac{150 \times 2800}{144} = 2920 \text{ psi for the ETL level}$

Taking $k = 4.75 \times 10^{-15}$ and $n = 3.55$; then for the
 TTH level, $C_c = 77.069914 \times 10^{-8} \times \sigma^{-0.85}$ and Total Closure = $503.7261 \times 10^{-5} t^{0.15}$
 for the first year plus $2.571663 \times 10^{-5} (t - 365)$ thereafter
 ETL level, $C_c = 169.59371 \times 10^{-8} \times \sigma^{-0.85}$ and Total Closure = $1097.3997 \times 10^{-5} t^{0.15}$
 for the first year plus $1.092621 \times 10^{-5} (t - 365)$ thereafter

t	For $\sigma = 2325$		For $\sigma = 2920$	
	C_c	Total Closure	C_c	Total Closure
1	7.7069×10^{-8}	5.1380×10^{-3}	1.6960×10^{-7}	1.0973×10^{-2}
10	1.0386×10^{-8}	7.2576×10^{-3}	2.3250×10^{-8}	1.5500×10^{-2}
100	1.5377×10^{-5}	1.0252×10^{-2}	3.5841×10^{-5}	2.1899×10^{-2}
365	5.1160×10^{-6}	1.2999×10^{-2}	1.0926×10^{-5}	3.6587×10^{-2}
	(2.1721×10^{-6})	(1.9981×10^{-2})	(4.6389×10^{-6})	(3.0926×10^{-2})
1000	5.1160×10^{-6}	1.5698×10^{-2}	1.0926×10^{-5}	3.9525×10^{-2}
		(2.0955×10^{-2})		(4.3684×10^{-2})
10 ⁴		6.1792×10^{-2}		1.3186×10^{-1}
		(2.8893×10^{-1})		(6.1706×10^{-1})
10 ⁵		5.2218×10^{-1}		1.1152×10^0
2,922,997 $\times 10^4$				1.0000×10^0
1,034,307 $\times 10^5$		1.0000×10^0		

J. L. Asch
9/23/76

CREEP RATES AND TOTAL CLOSURE FOR ISOLATED OPENINGS

Use $C_e = t^m \sigma^n$ during the first year and $C_e = t^m (365)^{-0.85}$ thereafter

where C_e is the creep rate in inches per inch per day

σ is the initial in situ rock stress in pounds per square inch

t is the elapsed time in days

t and n are octahedral strain constants

The total closure at any time during the first year will then be =

$$\int_0^t t^m \sigma^n dt = \frac{t^{m+1} \sigma^n}{m+1} = \frac{t^{0.15} \text{ inches per inch}}{0.15} \text{ and after the first year,}$$

$$\text{it will be} = \frac{t^{0.15} (365)^{0.15}}{0.15} + t^{0.15} (365)^{-0.85} (t-365) \text{ inches per inch}$$

Using a density of 150 pounds per cubic foot for the overlying material,

$$\sigma = 150 \times \text{depth} = \frac{150 \times 2330}{144} = 2325 \text{ psi for the TEL Level}$$

$$= \frac{150 \times 2900}{144} = 2920 \text{ psi for the EH Level}$$

Taking $t = 4.75 \times 10^{-15}$ and $n = 3.33$, then

$$t^m = 77.06941406 \times 10^{-5} \text{ for the TEL Level}$$

$$= 169.59570796 \times 10^{-5} \text{ for the EH Level}$$

Therefore:

t	For $\sigma = 2325$		For $\sigma = 2920$	
	C_e	TOTAL CLOSURE	C_e	TOTAL CLOSURE
1	7.7169×10^{-4}	5.1380×10^{-3}	1.6960×10^{-3}	1.0973×10^{-2}
10	1.0886×10^{-3}	7.2576×10^{-3}	2.3250×10^{-4}	1.5500×10^{-2}
100	1.5377×10^{-4}	1.0352×10^{-2}	3.2891×10^{-5}	2.1399×10^{-2}
365	5.1160×10^{-6}	1.3449×10^{-2}	1.0926×10^{-5}	2.6587×10^{-2}
1000	5.1160×10^{-6}	1.5698×10^{-2}	1.0926×10^{-5}	3.3535×10^{-2}
10^4	5.1160×10^{-6}	6.1742×10^{-2}	1.0926×10^{-5}	1.3186×10^{-1}
10^5	5.1160×10^{-6}	5.7218×10^{-1}	1.0926×10^{-5}	1.1552×10^0
1.93031×10^5		1.0000×10^0		
8.20897×10^5				1.0000×10^0

Creep Rate for Isolated Openings

TOTAL CLOSURE OF ISOLATED OPENINGS

	@ 2325 psi	@ 2920 psi
After 1 day, total closure will be 5.1380×10^{-3} and 1.0973×10^{-2} inches per inch		
3 days	6.0584	1.2939
1 week	6.8795	1.4692
2 weeks	7.6333	1.6302
3 weeks	8.1119	1.7324
1 month	8.5755	1.8319
3 months	9.5151×10^{-3}	2.0321
3 months	1.0112×10^{-2}	2.1595
4 months	1.0558	2.2528
6 months	1.1220	2.3962
9 months	1.1923	2.5464
1 year	1.2499	2.6587
2 years	1.4316	3.0575
3 years	1.6184	3.4563
4 years	1.8551	3.8551
5 years	1.9918	4.2539
6 years	2.1736	4.6527
7 years	2.3653	5.0516
8 years	2.5520	5.4504
9 years	2.7388	5.8492
10 years	2.9255	6.2480
15 years	3.8592	8.2930×10^{-2}
20 years	4.792.0	1.0236×10^{-1}
25 years	5.7265×10^{-2}	1.2230×10^{-1}

TOTAL CLOSURE OF ISOLATED OPENINGS

KE 10 X 10 TO THE INCH 46 0702
7 X 10 INCHES
MADE IN U.S.A.
KEUFFEL & ESSER CO

Miscellaneous Underground Calculations

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

SHEET _____ OF _____

PROJECT NO: _____

DATE: _____

ASSUMPTIONS:

$$\text{AREA OF LOADING INFLUENCE} = \frac{115(X + 186.5)}{43560} \text{ ACRES}$$

TOTAL WASTE STORAGE 1,970,000 CU FT

CANNISTER VOLUME 39 CU FT

TOTAL NO. CANS 50513 CANS

THERMAL POWER 300 WATTS

TOTAL POWER 15154 KILOWATTS

ALLOWABLE LOAD 75 KW/ACRE

AREA REQUIRED 202.05 ACRES PLUS BLOCK & PANEL ENTRIES

$X = 522.5$ = Length of Storage Space

562.5 = Pillar Length

59.4 = C-C Distance Between Entries

$$\text{Area of Influence} = 115'W \times 709'lg. = 81,535 \text{ Sq Ft} = 1.8718 \text{ Ac}$$

$$@ 75 \text{ KW/Ac} = 140.3840 \text{ KW/Rm}$$

$$@ 300 \text{ w/Can} = 468 \text{ Cans/Rm}$$

$$\text{or } 107.95, \text{ SAY } 108 \text{ Rms.}$$

$$\text{or } 18,250 \text{ Cu Ft/Rm}$$

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

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SHEET _____ OF _____

PROJECT NO. _____

DATE: _____

MINED SALT STORAGE

Assumptions: Salt density in place 135 lbs/cu ft
 " " mine run 90 "
 " " backfill 68 "

Storage Piles are developed using "mine run" salt assumed to have a density of 90 lbs/cu ft. To backfill, the stored salt would be excavated, crushed and dried, reducing this density to 68 lbs/cu ft. In the process of backfilling, no compaction is assumed, however it is assumed that 100% of the original mined volume requires backfilling. Salt creep will of course reduce this volume considerably.

	TRU LEVEL	RH LEVEL
MINED VOLUMES	2,290,218 TONS	2,965,841 TONS
(@ 135 #/CF)		
SPACE EXCAVATED	33,929,156 Cu Ft	43,938,385 Cu Ft
	6,500,136	2,337,611
RADWASTE STORED	5,835,020 Cu Ft	1,970,000 Cu Ft
VOLUME TO BACKFILL	28,094,136 Cu Ft	41,968,385 Cu Ft
	27,429,020	41,600,774
TOTAL SALT STORED (WGT.)	2,290,218 TONS	2,965,841 TONS
(@ 40 #/CF)		
" " " (VOL.)	50,893,733 Cu Ft	65,907,578 Cu Ft

7,245,560 55' x 70' square (29'0" x 29'0")
 15,650 83' " " 28'0" x 28'0"

$764,650 \times 2.57 = 1,532,729.7 \text{ ft}^3$
 $15,650 \times \frac{5437}{100} = 2,483,975.7 \text{ ft}^3$
 (1,979,406) 25,317,975.7 50' 2" DIAM

13,144 28' x 28' x 29' boxes
 266 28' x 28' x 26' "

$13,144 \times 112 = 1,472,128$
 $268 \times 200 = 53,600$
 1,525,728 3" 60x3

29,514 29'0" x 15' 20' x 15'
 1010 26'0" x 16' "

$29,514 \times 15.7 = 442,710.7$
 $1010 \times \frac{997}{36} = 27,777.7$
 470,488.4 36 4' 3" DIAM

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

SHEET _____ OF _____

PROJECT NO: _____

DATE: _____

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

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CALCULATIONS FOR: _____

SHEET _____ OF _____

PROJECT NO: _____

DATE: _____

$u_o = 0$ WHEN THE MINIMUM u IS AT A MAXIMUM AND AT THAT CONDITION

$$h_1 (\tan 37^\circ - 0.02) = h_2 (\tan 37^\circ + 0.02) + 9.9 \tan 37^\circ + 0.0008L$$

$$h_1 = 1.854529 h_2 + 9.519968 + 0.00109058L = 109.972868 + 0.00109058L$$

$$= 0.00109058(100838.88 + L)$$

Assuming RH Pile is Pile #1, TRU Pile is Pile #2, $h_2 = 100$

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: _____

CHECKED BY: _____

CALCULATIONS FOR: _____

SHEET _____ OF _____

PROJECT NO: _____

DATE: _____

TRU LEVEL - PILE #2 - $h = 100$	Assume $L = 1006.41$ ft	$\therefore H = h + 0.02L = 120.13$ ft
VOLUME RAMP = $\frac{1}{3}(A_1)M$	$= 3511,710.715$ SAY	$= 3,511,711$ Cu FT
$A_1 = 0.50(W_3 \tan 37^\circ + 0.04)W_3 + 230h + 0.50(W_4 \tan 37^\circ + 0.04)W_4$	$= 36,337.74579$ ft ²	
if, $W_3 = \frac{h + 2.30}{\tan 37^\circ + 0.02}$	$= 139.4580263$ say	139.46 ft
$W_4 = \frac{h - 2.30}{\tan 37^\circ + 0.02}$	$= 126.3001596$ "	126.30 ft
$\& M = \frac{h}{0.02 + \tan 18^\circ}$	$= 289.9225562$ "	289.92 ft
VOLUME CENTER = $\frac{1}{2}(A_1 + A_2)L$	$= 41,868,145.93$ SAY	$41,868,146$ Cu FT
$A_1 = 36,337.74579$		
$A_2 = 0.50(W_4 \tan 37^\circ + 0.04)W_4 + 230H + 0.50(W_3 \tan 37^\circ + 0.04)W_3$	$= 46,866.04182$	
if, $W_4 = \frac{H + 2.30}{\tan 37^\circ + 0.02}$	$= 166.8973131$ say	166.90 ft
$W_3 = \frac{H - 2.30}{\tan 37^\circ + 0.02}$	$= 152.320578$ say	152.32 ft
VOLUME END = $\frac{1}{3}(A_B + A_T + \sqrt{A_B \times A_T})H$	$= 5513877.712$ say	$5,513,878$ Cu FT
if $A_T = 140^2 \pi (\frac{11}{36}) - 115(80)$	$= 9614.649336$	
$A_B = (140^2 + 280m + \frac{16m^2}{11}) \pi (\frac{11}{36}) - 9200$	$= 97,472.11214$	
if $m = \frac{H + 1.60}{\tan 37^\circ + 0.02}$	$= 165.9427822$ say	165.94 ft
TOTAL TRU SALT STORED (when $L = 1006.41$ ft)		$50,893,735$ Cu FT
RH LEVEL - PILE #1 TOP ELEV. SAME AS PILE #2		
Also, $h_1 = 0.00109058(100838.88 + L)$	$= 111.0704364$ say	111.07 ft
Assume $L = 1128.90$ ft	$\therefore H = 133.65$ ft	
VOLUME RAMP	$= 4,507,709.313$ SAY	$= 4,507,709$ Cu FT
$A_1 = 41994.91181$ ft ²		
if $W_1 = 154.5495337$	SAY	$= 154.55$ ft
$W_2 = 140.6112946$	SAY	$= 140.61$ ft
$\& M = 322.0182483$	SAY	$= 322.02$ ft
VOLUME CENTER =		$54,491,076$ Cu FT
$A_1 = 41994 +$ ft ²		
$A_2 = 54543 +$ ft ²		
$W_1 = 185.53$ ft		
$W_2 = 169.80$ ft		
VOLUME END		$6,908,792$ Cu FT
if $A_T = 9614 +$ ft ²		
$A_B = 112568 +$ ft ²		
$\& m = 184.37$ ft		
TOTAL RH SALT STORED (when $L = 1128.90$ ft)		$65,907,577$ Cu FT

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: J. L. ASH

CHECKED BY: _____

CALCULATIONS FOR: _____

PRELIMINARY ENTRY AND ROOM DIMENSIONS

SHEET 1 OF _____

PROJECT NO: 208

DATE: SEPT. 15, 1976

TYPE										ONE PASS			TWO PASSES			THREE PASSES		
	A	C	E	G	I	K	M	O	Q	U	W	Y	A	C	E	A	C	E
5-0	17'-9"	2'-3"	3'-6"	9 1/16"	37 1/8"	37 1/4"	9 5/8"	4 7/8"	23 3/16"	29'-9"	7'-0"	22'-3"	47'-0"	10'-1 1/2"	44'-6"	69'-3"	13'-3 3/4"	66'-9"
			5'-9"	9"	46 5/16"	38 3/8"	15 5/16"	6 7/8"	21 1/8"	23'-3"	7'-6"		47'-6"	11'-9 1/4"		69'-9"	15'-2 1/2"	
			4'-0"	8 5/16"	39 7/8"	39 3/8"	20 7/8"	8 5/8"	20 1/4"	25'-9"	8'-0"		46'-0"	12'-4 3/4"		70'-3"	17'-1 3/4"	
6-0	7'-3 3/4"	2'-9"	4'-6"	11 1/4"	62 5/8"	49"	22 3/8"	10"	22 1/16"	16'-3 3/4"	9'-0"	12'-9 3/4"	28'-1 1/2"	14'-2 1/2"	25'-7 1/2"	41'-11 1/4"	19'-5 1/4"	38'-5 1/4"
			4'-9"	10 1/2"	70 1/16"	44 3/4"	27 1/16"	12 1/4"	21 1/16"	16'-9 3/4"	9'-6"		28'-7 1/2"	15'-9 1/2"		42'-5 1/4"	21'-9 3/4"	
			5'-0"	9 7/8"	78 1/16"	45 5/16"	32 7/8"	14 1/16"	20 1/16"	17'-3 3/4"	10'-0"		30'-1 1/2"	16'-4 1/2"		42'-11 1/4"	23'-1 1/4"	
7-0	5'-3"	9 5/16"	86 3/16"	45 3/4"	37 3/16"	17 1/4"	19 1/16"	17'-9 3/4"	10'-6"				30'-7 1/2"	17'-8 1/2"		42'-5 1/4"	24'-11"	
			5'-6"	8 3/16"	94 3/8"	46 1/8"	42 3/8"	19 7/8"	18 1/4"	18'-3 3/4"	11'-0"		31'-1 1/2"	18'-10 1/4"		42'-4 1/4"	26'-8 3/4"	
10-0	8'-0"	2'-9"	5'-0"	9 1/8"	78 1/16"	45 5/16"	32 1/16"	14 1/16"	20 1/16"	18'-0"	10'-0"	13'-6"	31'-6"	16'-6 1/2"	27'-0"	45'-0"	23'-1 1/4"	20'-6"
			5'-3"	9 5/16"	86 3/16"	45 3/4"	37 3/16"	17 1/4"	19 1/16"	18'-6"	10'-6"		32'-0"	17'-8 1/2"		45'-8"	24'-11"	
			5'-6"	8 3/16"	94 3/8"	46 1/8"	42 3/8"	19 7/8"	18 1/4"	19'-8"	11'-0"		32'-6"	18'-10 1/4"		46'-0"	26'-9 3/4"	
10-0	5'-9"	8 3/8"	102 1/16"	46 3/8"	47 1/8"	22 3/16"	17 5/16"	19'-6"	11'-6"				33'-0"	20'-0"		46'-6"	28'-6"	
			6'-0"	8"	109 1/16"	46 5/8"	51 1/8"	23 3/8"	17 1/8"	20'-0"	12'-0"		33'-6"	21'-1 1/2"		47'-0"	30'-3 1/4"	

COMPUTED BY: J C AAY
 CHECKED BY: _____
 CALCULATIONS FOR: _____

PRELIMINARY ENTRY AND ROW DIMENSIONS

FENIX & SCISSON, INC.
 TULSA, OKLAHOMA 74112
DESIGN SHEET

SHEET 2 OF 01
 PROJECT NO. 200
 DATE MAY 15 1976
 DRAWN BY JOE J. BRYAN

J. L. Allen

SHEET 3 OF

SEPT. 22, 1976

CORRECTED: Oct. 5, 1976

APPROXIMATE CONFIGURATIONS

TYPE MEASUREMENT	R	VERTICAL PASSES	HORIZONTAL PASSES
780.24W-4	4'-0"	3 for 17'-1 1/4" ~ 58,0526 yrs to 14'-6" 16'-5 1/2"	1 for 22'-3" ~ 78,5540 yrs to 19' 2 for 44'-6" ~ 12,3895 yrs to 43' 3 for 66'-9" ~ 29,9180 yrs to 63'
911.5	5'-3"	2 for 16'-6 1/2" ~ 36,1817 yrs to 14'-6" 15'-5 3/4"	2 for 25'-7 1/2" ~ 42,1909 yrs to 23' 3 for 38'-5 1/4" ~ 42,2250 yrs to 35'
	3'-3"	2 for 17'-8 1/2" ~ 8,16618 yrs to 16'-6" 16'-11 1/4"	2 for 25'-7 1/2" 3 for 38'-5 1/4"
	5'-6"	2 for 16'-10 1/4" ~ 27,5725 yrs to 17'-0" 13'-1 1/2"	2 for 25'-7 1/2" 3 for 38'-5 1/4"
	4'-0"	3 for 19'-5 1/4" ~ 37,7536 yrs to 17'-0" 12'-6"	2 for 25'-7 1/2" 3 for 38'-5 1/4"
	2'-9"	3 for 21'-3 1/2" ~ 17,8544 yrs to 19'-6" 21'-4 3/4"	2 for 25'-7 1/2" 3 for 38'-5 1/4"
1155.42U	5'-0"	2 for 16'-6 1/2" ~ 36,1817 yrs to 14'-6"	2 for 27'-0" ~ 72,6683 yrs to 23' 3 for 40'-6" ~ 19,1673 yrs to 20'
	3'-3"	2 for 17'-8 1/2" ~ 8,16618 yrs to 16'-6"	2 for 27'-0" 3 for 40'-6"
	5'-6"	2 for 16'-10 1/4" ~ 27,5725 yrs to 17'-0"	2 for 27'-0" 3 for 40'-6"
	6'-0"	2 for 21'-1 1/2" ~ 19,9185 yrs to 19'-6" 21'-2 1/2"	2 for 27'-0" 3 for 40'-6"

TYPE 7000-9 MACHINE

AT 5'-0" RADIUS

TYPE 911A MACHINE

AT 5'-0" RADIUS

TYPE 1012ACD MACHINE

AT 5'-0" RADIUS

AT 5'-3" RADIUS

AT 5'-3" RADIUS

AT 5'-6" RADIUS

AT 5'-6" RADIUS

AT 5'-9" RADIUS

AT 6'-0" RADIUS

AT 5'-9" RADIUS

J.L. ACH

NOT TO SCALE
46 1000

Let n be the number of vertical passes and N the number of horizontal passes, then

$$\text{X-SECTIONAL AREA} = \frac{\pi R^2}{2} + \frac{\pi R^2}{180} \text{Arcsin} \frac{d}{2R} + \frac{d^2}{2} + 2 \left(R - \frac{d}{2} \right) C + \left(R - \frac{d}{2} - 14 \right) (e - C) + \frac{997}{95} \left(90 + \right.$$

$$\text{Arcsin} \frac{2R - d - 28}{2R} \left. \right) + 2dR + \left(d^2 + dC + \frac{\pi R^2}{90} \text{Arcsin} \frac{d}{2R} \right) (n - 1) + \left[2(a + C)R + \frac{\pi R^2}{180} \text{Arcsin} \frac{C}{R} + \right.$$

$$\left. (e - b)C + (a + 2C)(n - 1)d \right] (N - 1)$$

$$\text{N-SECTIONAL AREA} = \frac{\pi R^2}{180} \left\{ 90 \left(1 + \frac{19}{R} \right) + \left(\frac{14}{R} \right)^2 \text{Arcsin} \left(\frac{2R - d - 28}{2R} \right) + (2n - 1) \text{Arcsin} \frac{d}{2R} + (N - 1) \text{Arcsin} \frac{C}{R} \right\}$$

$$+ 2 \left(e + C \right) R - \frac{d^2}{2} + (R - 14)(e - C) + d \left[a + (a + 2C)(N - 1) + e \right] (n - 1) + \left[2(a + C)R + (e - b)C \right] (N - 1)$$

$$\text{PERIMETER} = \pi R + \frac{\pi R}{90} \text{Arcsin} \frac{d}{2R} + \frac{77}{45} \left(90 + \text{Arcsin} \frac{2R - d - 28}{2R} \right) + 2(a + C) + (n - 1) \frac{\pi R}{45} \text{Arcsin} \frac{d}{2R} +$$

$$(N - 1) \left[2(a + C) + \frac{\pi R}{90} \text{Arcsin} \frac{C}{R} \right]$$

$$\text{PERIMETER} = \frac{\pi R}{90} \left\{ 90 \left(1 + \frac{19}{R} \right) + \frac{14}{R} \text{Arcsin} \left(\frac{2R - d - 28}{2R} \right) + (2n - 1) \text{Arcsin} \frac{d}{2R} + (N - 1) \text{Arcsin} \frac{C}{R} \right\} + 2(a + C)N$$

CROSS-SECTIONAL AREAS IN SQUARE FEET AND PERIMETERS IN FEET

TYPE TROUGH AT $E = 4'-3"$ FOR $n = 1$ AND $N = 1$ IS				195.4977 ft^2 AND	62.4377 ft
	2			311.0930	71.9733
	1			926.7383	81.7088
	2			887.2330	126.9881
	3			1187.7277	171.2673
TYPE CUA AT $E = 5'-0"$ FOR $n = 1$ AND $N = 1$ IS				155.5029 ft^2 AND	97.8657 ft
	2			282.1740	73.7544
	2			479.6575	88.0573
	3			685.3939	119.0060
TYPE MIZAGD AT $E = 5'-0"$ FOR $n = 1$ AND $N = 1$ IS				162.3779 ft^2 AND	99.1807 ft
	2			295.9240	76.5044
	2			497.4238	90.8073
	3			719.4933	118.1310
	1			429.4701	103.8280

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: J. L. Ash

CHECKED BY: _____

CALCULATIONS FOR: APPLICABLE TRU LEVEL ENTRY AND ROAD CONFIGURATIONS

SHEET 6 OF _____

PROJECT NO. 288

DATE: OCT. 19, 1976
COMPUTED: OCT. 22, 1976

	TYPE 7804W-2 AT R=9'-0"	TYPE 911A AT R=5'-0"	TYPE 1012ACD AT R=5'-0"
N	1	1	1
N	1	2	2
H	8'-0"	10'-0"	10'-0"
H-B		9'-2 1/8"	9'-2 1/8"
Q	25'-9"	17'-3 3/4"	18'-0"
L	22'-3"	12'-9 3/4"	13'-6"
X-SIGHT AREA =	195.9977	155.5022	142.3779
H-60 30 YEARS =	7'-5 1/8"	9'-4"	9'-4"
L AT 30 YEARS =	20'-9 3/16"	11'-1 1/2"	12'-7 3/16"
N	3	2	2
N	2	3	3
H	17'-1 3/4"	16'-6 1/16"	16'-6 1/16"
H-B	16'-5 7/16"	15'-8 1/16"	15'-8 1/16"
Q	25'-9"	48'-0"	31'-6"
L	22'-3"	44'-6"	27'-0"
X-SIGHT AREA =	926.7383	897.2330	719.9933
AVAIL. STOP WIDTH =	19'	23'	23'
REQ'D. RM. LENGTH =	19.90'	7.76'	15.52'
VEHIC. CLEAR =	38.0526	36.1817	36.1817
HOEP. CLEAR =	72.5540	42.3845	49.1673
ENTRY POLLAR =	60 1/2'	65 1/2'	75'
ROAD POLLAR =	8 1/2'	11 7/16'	11 1/2'
SAFETY FACTORS =	2.00	2.07	2.00
SCORE LENGTH =	61'-0"	93'-9"	93'-9"
TOT. STOP LENGTH =	58.800'	23.280'	25.866 2/3'
NUMBER ROADS =	156	69	69
NUMBER PARKS =	12	8	8
ROAD LENGTH =	99,076.9'	977.75'	983,523.8'
DRIVE ON YOL =	8278.75	6806.38	6067.52
TOT. STOP AREA =	251,28.29	157.9736	146.2710
TOT. VOL. MINOR =	98,089.013	28,698.983	27,131.891
ACC. WIDTH AT 15% GRADE =	5'-9 1/16"	3'-9 3/8"	3'-11 1/16"

Oct. 14, 1976

Let x = number of rooms in a panel. y = number of panels A = room width B = room length available for waste storage C = room length at each end required for ramping at a 15% grade D = pillar width between rooms E = wing width F = pillar width between sections U = cross-sectional area of rooms K = cross-sectional area of pillars M = cross width of storage area N = overall length of storage area S = total length of rooms available for waste storage T = total length of rooms U = total length of rooms required for ramping V = total volume of material stored in storage area

Then

$$S = 2(A + D)x + 2(E + F)y - D$$

$$N = (2B + 4C + D + 2E + F)y - \frac{D}{2} - \frac{F}{2}$$

$$S = 8xy$$

$$T = (M - 4E)y + 2N$$

$$U = 2(C - R)xy$$

$$V = \left(C + \frac{U}{2}\right)U + \left(T + \frac{U}{2}\right)K$$

$$\text{Total Area Required for Storage} = MN$$

and this is

OCT. 14, 1976

CASE I, $M = 214.5x + 363.5$

$$N = (0.58 + 118.25)y - 71$$

CASE II, $M = 331x + 227.5$

$$N = (0.58 + 127.25)y - 89$$

CASE III, $M = 467.5x + 201.5$

$$N = (0.58 + 140)y - 119.5$$

CASE IV, $M = 579.25x + 325.5$

$$N = (0.58 + 108.875)y - 80$$

CASE V, $M = 383.875x + 303.5$

$$N = (0.58 + 114.375)y - 91$$

CASE VI, $M = 293x + 336$

$$N = (0.58 + 111.5)y - 82.5$$

CASE VII, $M = 312x + 315$

$$N = (0.58 + 116.75)y - 93$$

ASSUMING THAT

$$B \leq 500 - 2(C \cdot E_{\text{avg}})$$

$$M \leq 3000$$

IT IS GIVEN

THEN, FOR CASE I, $B \leq 386$ AND $xy \geq 151$ WITH $x \leq 12$

CASE II, $B \leq 386$ AND $xy \geq 61$ WITH $x \leq 8$

CASE III, $B \leq 386$ AND $xy \geq 41$ WITH $x \leq 6$

CASE IV, $B \leq 422.5$ AND $xy \geq 111$ WITH $x \leq 11$

CASE V, $B \leq 422.5$ AND $xy \geq 59$ WITH $x \leq 8$

CASE VI, $B \leq 422.5$ AND $xy \geq 111$ WITH $x \leq 11$

CASE VII, $B \leq 422.5$ AND $xy \geq 62$ WITH $x \leq 8$

CORRECTED: OCT. 29, 1976

SHEET 9 OF

OCT. 14, 1976

REWORKING THE ASSUMPTIONS SLIGHTLY TO OBTAIN MORE PRACTICAL
COMBINATIONS OF x AND y , THEN FOR

CASE I AT $x = 13$ and $y = 12$; $M = 3052 \text{ ft.}$, $N = 3586.9619 \text{ ft.}$

$T = 49,733,8956 \text{ ft.}$, $U = 17,784 \text{ ft.}$, and $V = 40,889,013 \text{ ft.}^3$

CASE II AT $x = 8$ and $y = 8$; $M = 3875.5 \text{ ft.}$, $N = 2384 \text{ ft.}$

$T = 31,726 \text{ ft.}$, $U = 7,396 \text{ ft.}$, and $V = 28,698,983 \text{ ft.}^3$

CASE III AT $x = 7$ and $y = 6$; $M = 3474 \text{ ft.}$, $N = 1239.0714 \text{ ft.}$

$T = 27,582,3856 \text{ ft.}$, $U = 4,788 \text{ ft.}$, and $V = 27,131,891 \text{ ft.}^3$

CASE IV AT $x = 11$ and $y = 10$; $M = 2902.25 \text{ ft.}$, $N = 3125.1136 \text{ ft.}$

$T = 40,317,9544 \text{ ft.}$, $U = 8,525 \text{ ft.}$, and $V = 36,708,726 \text{ ft.}^3$

CASE V AT $x = 9$ and $y = 8$; $M = 3138.375 \text{ ft.}$, $N = 3142.6667 \text{ ft.}$

$T = 33,125,6507 \text{ ft.}$, $U = 6,580 \text{ ft.}$, and $V = 31,989,441 \text{ ft.}^3$

CASE VI AT $x = 10$ and $y = 10$; $M = 3000 \text{ ft.}$, $N = 3148.8636 \text{ ft.}$

$T = 41,317,9544 \text{ ft.}$, $U = 8,525 \text{ ft.}$, and $V = 38,800,983 \text{ ft.}^3$

CASE VII AT $x = 6$ and $y = 6$; $M = 3811 \text{ ft.}$, $N = 2957.6667 \text{ ft.}$

$T = 31,312,5007 \text{ ft.}$, $U = 4,960 \text{ ft.}$, and $V = 30,324,706 \text{ ft.}^3$

345

ENTRY AND ROOM SIZES AND SHAPE FOR A TYPE 1012 ACD MARIETTA MINER AT $R = 5'-0"$

DIMENSIONS ARE IN INCHES

J.L. ASH, Oct. 20, 1976
CORRECTED: Oct. 29, 1976

J. L. Ash

PROJ. 888, 11-11-76

MINING RATES FOR BORING MACHINE

GOODMAN 426 CONTINUOUS BORER CUTS A 72" HIGH x 138" WIDE OPENING WITH TWO 250 HP MOTORS. UNDER NORMAL CONDITIONS, THESE MACHINES CAN BE EXPECTED TO MINE AT AN AVERAGE RATE OF 1300 ^{Tons}/day OR 400 ^{Tons}/shift FOR 2-PASS OPENINGS.
1-PASS = 87,122 ^{H²} AND 2-PASS = 146,859 ^{H²}

TYPE 1012 ACD MARIETTA MINER CUTS A 120" HIGH x 216" WIDE OPENING WITH TWO 600 HP MOTORS. 1-PASS = 162,3779 ^{H²}, 2-PASS = 295,9240 ^{H²}, 3-PASS = 429,9701 ^{H²}, ROOM = 719,4933 ^{H²} AND ROOM ENTRANCE AVERAGES $\frac{429,9701 + 719,4933}{2} = 574,9817 \text{ H}^2$
TAKE MINING RATE FOR THE MARIETTA TO BE $2 \times 250 \times 162,3779 \times 400 = 515 \frac{\text{Tons}}{\text{shift}}$ FOR ALL OPENINGS,

AT 135 ⁱⁿ/^{H²}, ENTRIES = $\frac{295,9240 \times 135}{2000} = 19,9799 \frac{\text{Tons}}{\text{foot}}$ FOR 25,78625 ^{H²/shift} ADVANCE
ROOM ENTRANCE = $\frac{574,9817 \times 135}{2000} = 38,7775 \frac{\text{Tons}}{\text{foot}}$ FOR 13,2829 ^{H²/shift} ADVANCE
ROOM = $\frac{719,4933 \times 135}{2000} = 48,5658 \frac{\text{Tons}}{\text{foot}}$ FOR 10,6058 ^{H²/shift} ADVANCE
ROOM EXIT = $\frac{429,9701 \times 135}{2000} = 28,9892 \frac{\text{Tons}}{\text{foot}}$ FOR 17,7679 ^{H²/shift} ADVANCE

USE 20 ^{Tons}/foot, 500 ^{Tons}/shift AND 25 ^{H²/shift} = 525 ^{H²/month} ADVANCE PER MINER PER SHIFT

FOR ENTRIES
HAVE $\frac{38,75(38,7775) + 426,25(48,5658) + 15,00(28,9892)}{58,75 + 426,25 + 15,00} = \frac{22,638,6389}{480} = 47,1638 \frac{\text{Tons}}{\text{foot}}$ FOR

10,9210 ^{H²/shift} ADVANCE. USE 47,2 ^{Tons}/foot, 500 ^{Tons}/shift AND 10,6 ^{H²/shift} = 222,6 ^{H²/month} ADVANCE PER MINER PER SHIFT FOR ROOMS (USE 45,283 ^{shifts}/^{room}).

HAVE 64 ROOMS AND 31,800 FEET OF ENTRIES IN THE STORAGE AREA OF THE TRU

LEVEL 50, USING TYPE 1012 ACD MARIETTA MINERS, WILL REQUIRE

$64(45,283) + \frac{31,800}{25} = 4170 \text{ shifts}$ TO MINE THE STORAGE AREA. ON A 21-DAY PER MONTH BASIS, THIS WILL REQUIRE 16 years, 6 months and 12 days FOR ONE MINER OR 8 years, 3 months and 6 days WITH TWO MINERS.

AREAL EXTENT OF MINING LEVELS

$$\begin{aligned} \text{2BU Level Area} &= 3006.50(3419.63) + (3006.50 - 942.73)(333.56 + 532.10) + (2914.69 - \\ & 900.36)532.53 + 2914.69(932.15) + 0.5(942.73)333.56 + 0.5(532.10)50.56 + \\ & 0.5(599.11)800.36 + 0.5(333.10^2 + 50.56^2)^{1/2} \{1000^2 - [0.5(333.10^2 + 50.56^2)^{1/2}]^2\}^{1/2} + \\ & 1000^2 \pi (40 + 46) + 360 = 10,251,853.60 + 1,786,523.1380 + 1,267,583.1220 + \\ & 2,116,928.2520 + 15,558,5099 + 13,451,4880 + 239,915.9134 + 257,537.9022 + \\ & 75,158,8918 = 17,953,234.81 \text{ ft}^2 = 411.65 \text{ acres} \end{aligned}$$

$$\begin{aligned} \text{2BU Level Area USED FOR STORAGE} &= 2544(1239 + 1323.5) = 6,519,000 \text{ ft}^2 = 149.86 \text{ acres} \\ & \text{OR } 37.8534 \% \text{ OF THE TOTAL} \end{aligned}$$

$$\begin{aligned} \text{EH Level Area} &= 2566.25(5565.50) + 1042.69(5565.50 - 2241.73) + (136.37 - 1095.93 + \\ & 724.59)(2241.73 - 621.73) + 136.37(621.73) + 0.5(621.73)1095.93 + 0.5(724.59)1030.81 + \\ & 1000^2 \pi (46) + 360 = 14,839,019.38 + 3,965,661.741 + 9,987,374.504 + \\ & 88,316.57 + 104,156.1104 + 373,157.509 + 1,323,623.567 = 24,904,258.16 \text{ ft}^2 = \\ & 571.93 \text{ acres} \end{aligned}$$

$$\begin{aligned} \text{EH Level Area USED FOR STORAGE} &= 1433.5(2269.5) + 2836.0(12)1050 + \\ & 2(1391 + 1050)1150 = 3,236,363.75 + 6,196,800.00 + 163,070.00 = 9,586,233.75 \text{ ft}^2 = \\ & 220.11 \text{ acres OR } 38.4843 \% \text{ OF THE TOTAL} \end{aligned}$$

$$\begin{aligned} \text{EH Level EXHAUSTION AREA} &= 552(1656) = 914,112 \text{ ft}^2 = 20.9851 \text{ acres including} \\ & = 432(1536) = 663,552 \text{ ft}^2 = 15.2331 \text{ acres} \\ & = 1432(2296) = 3,287,872 \text{ ft}^2 = 75.4792 \text{ acres including} \end{aligned}$$

60.24 acres

$$\begin{aligned} \angle a &= 29.5667^\circ \\ \angle b &= 95.5379^\circ \\ \angle c &= 59.8959^\circ \end{aligned}$$

$$\begin{aligned} \angle d &= 70.5152^\circ \\ \angle e &= 29.5575^\circ \\ \angle f &= 79.9999^\circ \end{aligned}$$

$$\begin{aligned} \angle g &= 79.9999^\circ \\ \angle h &= 57.7640^\circ \\ \angle i &= 53.1645^\circ \end{aligned}$$

$$\angle j = 5.9279^\circ$$

$$\begin{aligned}
 \text{AREA COMMON TO BOTH LEVELS} &= 932.15(2914.69) + 599.52(2914.69 - 800.36) + (2914.69 - \\
 & 621.73 - 599.52 - 932.15)(2914.69 - 800.36 - 50.56) + 1030.81(2914.69 - 136.37 - 1095.93 - 724.59 - \\
 & 800.36 - 50.56) + 136.37(621.73) + 942.72(3909.63 - 2291.73 - 5806.96 + 5565.50) + \\
 & 0.5(621.73)1095.93 + 0.5(1030.81)724.59 + 0.5(333.56)942.73 + 0.5(532.10)50.56 + \\
 & 0.5(599.52)800.36 + 0.5(532.10^2 + 50.56^2)^{1/2} \left\{ 1000^2 - [0.5(532.10^2 + 50.56^2)]^{1/2} \right\}^{1/2} + \\
 & 1260^2 \pi (36) + 360 + 1000^2 \pi (36 + 36) + 360 + 2291.73(3006.50 - 2914.69 - 2751.14 + 2466.25) = \\
 & 2,710,928.284 + 1,267,583.122 + 1,531,127.463 + 110,172.9728 + 84,785.32 + 873,382.7812 + \\
 & 340,686.2795 + 373,457.309 + 157,128.5094 + 18,451.988 + 239,915.9136 + 257,527.9099 + \\
 & 1,323,622.537 + 762,023.8914 + 15,512.7716 = 10,107,406.50 \text{ ft}^2 = 232.03 \text{ acres}
 \end{aligned}$$

$$\begin{aligned}
 \text{TOTAL AREA} &= 17,456,234.81 + 29,919,298.06 - 10,107,406.50 = 37,259,126.37 \text{ ft}^2 = \\
 & 740.57 \text{ acres} \\
 & = 5565.50(2751.14 + 2914.69) + 3106.50(5806.96 - 5565.50) = 31,533,176.87 + \\
 & 725,949.49 = 32,259,126.36 \text{ ft}^2 = 740.57 \text{ acres}
 \end{aligned}$$

$$\begin{aligned}
 \text{TOTAL AREA USED FOR STORAGE} &= 6,519,000 + 9,588,093.75 - 15,512.7716 = \\
 & 16,091,580.98 \text{ ft}^2 = 369.41 \text{ acres OR } 99.8823\% \text{ OF THE TOTAL} \\
 & + 919,112 \text{ ft}^2 = 20.9851 \text{ acres OR } 2.8937\% \text{ OF THE TOTAL FOR THE} \\
 & \text{EXPERIMENTAL AREA} \\
 & = 17,010,692.98 \text{ ft}^2 = 390.397 \text{ acres OR } 52.7159\% \text{ OF THE TOTAL FOR BOTH}
 \end{aligned}$$

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January 7, 1977

JAN 14 1977

Fenix & Scisson, Inc.
Post Office Box 15609
Tulsa, Oklahoma 74115

FENIX & SCISSON, INC.

ATTENTION: MR. GEORGE SCHAEFER

SUBJECT: Hoist Estimates

**Process Machinery
Division**

P.O. Box 383
Milwaukee, WI 53201
414/744-2345
TELEX 2-6601

Dear Sir:

The following information will confirm what was provided to you
via our phone conversation of 1/4/77:

HOIST DATA

DESCRIPTION	PRODUCTION	SERVICE	PRU SHAFT	RH SHAFT	ESCAPE
TYPE HOIST	D.D.	S.D.	S.D.	S.D.	S.D.
DISTANCE (FT)	3100	3000	2700	3000	3000
TPH	300	N.A.	N.A.	N.A.	N.A.
SAFETY FACTOR	5	5	5	4.5	5
ACC (FT/SEC ²)	1	2	2	2	2
RETARD (FT/SEC ²)	2	2	2	2	2
CREEP (SEC)	6	8	8	8	8
REST (SEC)	22	30	30	30	30
SKIP CAGE LOAD (TON)	13.12	12.5	12.5	10	1
VELOCITY (FPS)	28.72	8.33	8.33	8.33	8.33
SKIP (CAGE) WGT. (TON)	9.84	9.37	15	7.5	0.75
ROPE (INCH)	2.0	1.875	2.125	1.625	0.75
DRUM DIA (INCH)	160	150	170	130	60
RMS H.P.	1859	188	308	723	87
PEAK H.P.	3120	387	765	961	133
MOTOR H.P.	900	400	400	700	Hyd. Drive
# OF MOTORS	2	1	1	1	1
1 LAYER WIDTH (INCH)	174	188	178	183	165
NORM CWT (TON)	N.A.	15.62	21.25	N.A.	N.A.
MAX. LOAD (TON)	N.A.	19.00	N.A.	N.A.	N.A.
MAX. CWT (TON)	N.A.	18.87	N.A.	N.A.	N.A.
ESTIMATED COST	\$1,293,000	\$568,000	\$644,000	\$567,000	\$215,000

We hope that this information will be of use to you in your work, and if any
questions should arise, please do not hesitate to call. The delivery that can

(CONTINUED)

Fenix & Scisson

Page 2

1/14/77

be expected for the double drum hoist is 18-20 months-on all the other hoists, approximately 12 months. The estimated costs indicated above include the hoist mechanicals and the drive equipment.

Rexnord is looking forward to working with you on this project and hopes to either be hearing from you or meeting with you in the near future.

Respectfully

William F. Brown
Senior Sales Application Engineer
Rexnord Inc.
Process Machinery Division
Mine Hoist Department

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JAN 14 1977

WFB:AA

cc: Tom Armesy

FENIX & SCISSON, INC.

Enclosures

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FR 2 1977

February 28, 1977

Fenix & Scisson Inc.
5805 East Fifteenth Street
Tulsa, Oklahoma 74112

FENIX & SCISSON, INC.

**Process Machinery
Division**

P.O. Box 383
Milwaukee, WI 53201
TELEX 2-6601
My No 414/643

ATTENTION: MR. GEORGE SCHAEFER

SUBJECT: Hoist Estimate
RE: Your Letter of 2/9/77

Dear Sir:

For purposes of hoist estimating your items A through F inclusive are part of our hoist estimate you received on 1/7/77. Under the paragraph titled "Production Hoist", the 3000' hoisting distance and the 3100' hoisting distance, we calculated would result in the same estimated hoist. The drum of 160" shown by us is with one layer; if you desire 96 inches, that would be in two layers with no change in the estimated cost. All other items in this paragraph are included in the estimate.

Under the paragraph entitled "Service Hoist" please find the following data:

HOIST DATA

<u>DESCRIPTION</u>	<u>SERVICE HOIST</u>	<u>TRU</u>
TYPE HOIST	Divided S.D.	S.D.
DISTANCE (FT)	3,000	2,300
SAFETY FACTOR	4.6	5
ACC (FT/SEC ²)	2	2
RETARD (FT/SEC ²)	2	2
CREEP (SEC)	8	8
REST (SEC)	60	300
CAGE LOAD (TON)	12.5	12.5
VELOCITY (FPS)	8.33	8.33
CAGE WGT (TON)	15	15
ROPE (INCH)	2	2
DRUM SIA (INCH)	160	160
TOTAL MOTOR H.P.	500	800
FACE WIDTH (INCH)	97	155
NORM CWT (TON)	21.25	N.A.
MAX LOAD (TON)	19	N.A.
MAX CWT (TON)	24.5	N.A.
ESTIMATING COST	\$634,000	\$718,000

(CONTINUED)

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Page Two
2/28/77

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MAR 12 1977

Under paragraph TRU Shaft and in regard to your question, the hoist shown in our letter of 1/7/77 is a single drum hoist with two ropes. If the second rope is a problem, why not go with an "out of balance" condition and eliminate the second rope and counterweight. The hoist that would meet this requirement is shown above and is much less expensive than a two drum arrangement.

Paragraphs "RH Shaft" and "Escape Hoist", please find the following:

<u>HOIST DATA</u>		
<u>DESCRIPTION</u>	<u>R.H. SHAFT</u>	<u>ESCAPE HOIST</u>
TYPE HOIST	Unbalanced S.D.	Unbalanced S.D.
DISTANCE (FT)	3000	3000
SAFETY FACTOR	4.5	5
ACC (FT/SEC ²)	2	2
RETARD (FT/SEC ²)	2	2
CREEP (SEC)	8	8
REST (SEC)	300	300
CAGE LOAD (TON)	12.5	1
VELOCITY (FPS)	8.33	8.33
CAGE WGT (TON)	9.375	1.4
ROPE (INCH)	1.75	0.75
DRUM DIA. (INCH)	140	60
TOTAL MOTOR H.P.	700	100
FACE WIDTH	95 (2 layers)	56 (3 layers)
ESTIMATED COST	\$592,000	\$245,000

The hydraulic escape hoist remains as shown in our 1/7/77 letter at an estimated \$215,000.

All estimated costs are considered as of April 1, 1977 including those provided in our January 7, 1977 letter.

We will be sending the mechanical and electrical components dimension data in a few days when they become available.

We trust that this information will be of use to you in your work.

Very truly yours,

William F. Brown
Senior Sales Application Engineer
Rexnord Inc.
Process Machinery Division
Mine Hoist Department

cc: T. Armesy
B. Elsner

this 16' contains 509 55 gal drums
which is the overflow at 9.8 drums/day $\times$ 46.875 days
(plus an excess of 50 drums)

this 86.222' contains: 2,450 55 gal. drums
52 83 gal. overpacked drums
45 4'x4'x7' RF boxes
1 5'x5'x8' overpacked box

10 day's delivery (less 98 drums which are placed in the 16' entry area)
@ 1300 drums / 23 boxes / week (2% overpack)

$$\therefore 86.222' / 10 \text{ days} = 8.6222' \text{ of storage room required per day}$$

(3000 days of storage requires $3000 \times 8.6222' = 25,866.66'$ of storage)
Not Reg'd.

Section A-A

Section B-B

0 1 2 3 4 5 10 15 20
Scale, ft.

10/27/76

Fork Lift Storage Configuration

*see "Size of Fork Lift Required"

Storage cycle for TRU Waste: Number of *14,000 lb. capacity fork lifts required

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the skid carrying 24 drums will require the most time to unload

Step 1.	clamp Lift-O-Matics onto 4 drums and lift off skid	elapsed time	3 sec.
Step 2.	tram the 4 drums from the skid a maximum distance of 100 ft. @ 13 fpm (5 mph)		14 sec.
Step 3.	position to unclamp drums at storage site		10 sec.
Step 4.	lift load to maximum height and unclamp drums		4 sec.
Step 5.	lower mast		3 sec.
Step 6.	travel 100 ft. back to skid		14 sec.
Step 7.	position to clamp 4 drums		10 sec.

total time per 4 drums 58 sec.

to be conservative use 116 sec. / 4 drums

skid load is 24 drums

$$24 \text{ drums} / 4 \text{ drums/trip} = 6 \text{ trips}$$

$$116 \text{ sec./trip} \times 6 \text{ trips} = 696 \text{ sec.} = 11.6 \text{ min.}$$

Consider 12 min. the maximum time to unload skid with one fork lift

Note: the manufacturer of the Lift-O-Matic states that 80 drums can be unloaded out of a closed van two drums at a time and trammed 100 ft. in about 30 min.
 $80 \text{ drums} / 2 \text{ drums/trip} = 40 \text{ trips}$
 $30 \text{ min.} / 40 \text{ trips} = .75 \text{ min./trip} = 45 \text{ sec./trip}$

*haulage times from "Haulage Cycle For TRU Waste"

A.	Haulage vehicle unloads loaded skid in storage room within 100 ft. of placement site, and loads empty skid	3 1/2 min.
B.	Haulage vehicle trams empty skid out of room	1 min.
C.	Haulage vehicle travels between storage room and TRU shaft @ 880 fpm	X min.
D.	Haulage vehicle unloads empty skid at TRU shaft and loads loaded skid	5 1/2 min.
E.	Haulage vehicle travels between TRU shaft and storage room @ 880 fpm	X min.
F.	Haulage vehicle trams loaded skid from storage room entrance to placement site	1 min.

time fork lift has to unload skid

$$2X + 7 1/2 \text{ min.} \leq 12 \text{ min.}$$

$$2X \leq 4.5 \text{ min.} \rightarrow X \leq 2.25 \text{ min.}$$

$$2.25 \text{ min} \times 880 \text{ fpm} = 1,980 \text{ ft.}$$

This figure, 1980 ft., means that when the haulage distance between the TRU shaft and the entrance to the storage room is less than 1980 ft., the fork lift will not have the skid unloaded by the time the haulage vehicle is ready to return to the TRU shaft. The haulage vehicle would have to wait. However, it would make no sense to add another fork lift to unload more quickly, because the shaft is the bottleneck. If the haulage vehicle wasn't waiting on the fork lift in the storage room, it would be waiting on the cage at the TRU shaft. During the 28 min. hoist cycle time, all but the 3 1/2 min. the haulage vehicle spends loading and unloading skids in the storage room is effective fork lift time. Therefore as long as the fork lift can unload a skid in 24 1/2 minutes, the cycle is not upset. One 14,000 lb capacity fork lift is adequate. A second fork truck will be kept on the TRU level for back up.

Storage room cycle

step 1	60 sec.
step 2	60 sec.
step 3	60 sec.
step 4	90 sec.
step 5	60 sec.
total	330 sec. = 5.5 min.

Use 5.5 min.

Consider the operation of unloading the empty pallet and loading a full one at the TRU shaft to require the same amount of time: 5.5 min.

Haulage Cycle For TRU Waste

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JHO

Unload empty pallet and load full one at TRU shaft	5.5 min.
Unload full pallet and load empty one at storage room	5.5 min.
Round trip travel time	X
total	(11+X) min.

Hoist cycle ≈ 28 min.

Longest possible round trip travel time $X = 28 - 11 = 17$ min.

use 10mph = 880 ft/min

$17\text{ min} \times 880\text{ ft/min} = 14,960\text{ ft.} = 2.83\text{ miles}$

The longest round trip distance in the proposed facility is less than 2 miles, so one truck and trailer are adequate. A second truck and trailer will be kept on the TRU level for back up.

① Consider stacking drums in areas where there is adequate room to right angle stack. If the Lift-O-Matic drum handling attachment is mounted so that the edge of the drum is held four feet from the heel of the fork lift (dimension "x" in the drawing above), then the load center of a 24 in. dia. drum would be $48 + 24\frac{1}{2} = 60$ in. Four drums @ 900# plus four Lift-O-Matic assemblies @ 75# would total 3900#

In the plan drawings above and below, it may be seen that it will be necessary to have a side shifting attachment with a 12 in. stroke in order to "pyramid" the drums. Estimate weight at 300#, thus sum with four drums is $3900 + 300 = 4200$ #

② Next consider the situation when there is inadequate space for the fork lift to right angle stack. Again an "x" dimension of four feet will allow stacking the forth tier of drums and still have adequate horizontal clearance between the fork lift and the first tier of drums (dimension "y" above).

③ Now consider unloading the skid. When picking up the innermost four drum set (either set 2, 4, or 6 above) an "x" dimension of four feet allows an adequate "y". Again the load center is 60 in. and the load is 4200#

The slide-on mounting should be designed so that it will accomodate four Lift-O-Matic devices positioned to lift four drums of 24 in. diameter off of the skid. Also the mounting should allow one of the Lift-O-Matics to be removed, and the remaining three devices repositioned to accomodate drums of 28 in. diameter.

⑤ Boxes would be lifted with standard lift truck forks (the slide-on-mounted Lift-O-Matic assembly would be removed on days when boxes are delivered). The load center on overpacked boxes would be $3 + 60\frac{1}{2} = 33$ ". The load is $11,000 + 300$ # for the side shifter.

⑥ Similarly the load center on a 4'x4'x7' box would be $3 + 48\frac{1}{2} = 27$ ". The load is $10,000 + 300$ #.

⑦ M III bins, if used, would require a fork lift attachment as shown below for the two point lift (estimate attachment weight at 200#)

Load center of bin is $3 + 61\frac{1}{2} = 33.5$ "
Load is $10,000 + 200 + 300 = 10,500$ #

④ If the overpacked drums can be placed fifteen to a skid, then on the day overpacks are to be delivered, the slide-on-mountings for the Lift-O-Matics can be adjusted to handle three overpacks @ 1000# rather than the four 55 gal. drums @ 900# (see picture at left). When picking the innermost set of drums, an "x" dimension of four ft. leaves an adequate space "y" between the tire and the skid of about one ft. Load center $48 + 28\frac{1}{2} = 62$ ". Weight is three drums @ 1000#, 3 Lift-O-Matics @ 75#, plus 300# for side shifter for a total of 3520#.

Number of load (from above drawings)	Load center, in.	Load, lbs.
①②③	60	4200
④	62	3520
⑤	33	11300
⑥	27	10300
⑦	33.5	10500

Size of Fork Lift Required + Types of Attachments Needed

A study of the different loading possibilities reveals that a 14,000# capacity fork lift (rated at 24 in. load center) would be required to handle all possibilities (see graph at right).

11/5/76 J.H.O.