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SAND77-0274

Unlimited Release

WIPP Conceptual Design Report

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

90029040

POOR ORIGINAL

Prepared by Sandia Laboratories, Albuquerque, New Mexico 87115 and Livermore, California 94550 for the United States Energy Research and Development Administration under Contract AT (29-1)-789

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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 } - Solid }	2	-	-
- 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

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WIPP SITE POPULATION

BUILDING OR AREA (Contd)

	Shift 1	Shift 2	Shift 3
-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 1	Shift 2	Shift 3
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	3	-	-
TOTAL THIS SHEET	117	2	0
" SHEET 1	159	11	11
" " 2	73	13	4
TOTAL SITE POPULATION	349	26	15
GRAND TOTAL		390	

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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:

CONDITION	DOSE RATE (mR/hr)		
	4 ft - ordinary concrete	5/6 ft - ordinary concrete	4 ft - Barytes concrete
(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	-	-

CONDITION	DOSE RATE (mR/hr)		
	4 ft - ordinary concrete	5/6 ft - ordinary concrete	4 ft - Barytes concrete
(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 attentuation 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.

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 ($MEV/cm^2/sec$) 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:

Source	Base Rate (mR/hr) @ 10 ft
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 conserva[illegible]m 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:

Neutrons	$= .083\ cm^{-1}$
Gamma	$= .126\ cm^{-1}$

(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.

(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.

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HIGH LEVEL/INT. LEVEL SOURCES

CASK	WT (lbs)	WATT	DIMENS.	γ SURF R/hr	γ 10' ℄ R/hr	n SURFACE R/hr	n 10' ℄ 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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Attachment 1

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Radwaste Calculations

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 radwaste system are tabulated as follows:

R.H. Bldg
(1) Cask decontamination
(2) Lid 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) Railcar Washdown

DAILY - RH BLDG

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(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 ~~unlined~~ casks.

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Frinned 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 radwaste 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.

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

(3) Lab Drains

In accordance with Ref 2, RH lab drains are established at **90 gal/day**

(4) Cask Cooling and Draining

In establishing the cask cool/drain input, data for the GE-IF-300 spent fuel shipping cask was used. This cask can handle 7 PWR assemblies.[3]

CHECKED ________ DATE ________	**HOLMES & NARVER, INC.** ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE ANAHEIM, CALIF. 92801	JOB NO. 8251.00	
APPROVED ________ DATE ________		SHEET 3	OF 13
TITLE LIQUID WASTE VOLUME - DAILY		BY RMB	DATE 3/4/77

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

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

Cooling water inventory = 4800 lbs for 7 PWR assys.

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

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)

Total gal/day = 1.43 (575) ≅ **820 gal./day**

(5) Canister Cleaning.

10 canisters per day will be decomed. Marv Reib, Aerojet, says decon system input will be 50 gal/day.[4] 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.

FORM AT-66(1) (1-75)

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APPROVED ______ DATE ______		SHEET 4 OF 13
TITLE LIQUID WASTE VOLUME — DAILY		BY RMB DATE 3/4/77

TRU 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 187 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 Man/Materials Bldg. Decontamination that is necessary will be done below ground.

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General note – In order to simplify decontamination calcs, water used for decon was all treated on a ft² basis. Based on building leak tests, Jim Ribbins 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" = $100\ ft^2 \times \frac{0.5}{12} ft \times \frac{7.48\ gal}{ft^3} = 32\ gal / 100\ ft^2$

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

Washdown frequency = 4 week intervals

DECONTAMINATION VOLUMES

AREA	APPROX DIMENSION	ft² (x 35 gal / 100 ft²) =	GALLONS
TRU Receiving		12000 =	4200
TRU I & P		27000	9450
TRU O & R	65 x 65	4225	1479
RH Receiving		6720	2352
RH Cask Service		4800	1680
RH Hot Cell	(28 x 60)	1680	588

In all probability the I & P will not be deconned all at once! $\frac{9450}{2}$ = **4725** – design basis decon

Radwaste / laundry

Building has not yet been designed – assume 2500 ft².

$2500\ ft^2 \times \frac{35\ gal}{100\ ft^2}$ = **875 gal / decon**

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FORM AY-66(1) (1-75)

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APPROVED ______ DATE ______		SHEET 6	OF 13
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, RH, storage vent and radwaste. 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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Above ground accident conditions will be considered. For the RH 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) HEPA prefilter sprays.

Fire spray water amounts should be determined based on NFPA Handbook hazard categories

TRU FACILITY

Assumptions: (1) Duration of fire = 1/2 hour
(2) Location - RF box storage
(3) Spray volume = 0.3 gpm/ft² ⑦

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

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

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

Prefilter spray
Expected flow spray = 0.1 gpm / 1000 cfm. For TRU - flow rate = **17 gpm**

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

Grand total for TRU ≅ 16,000 gal

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RH FACILITY

A fire in the RH facility is not too likely, however, for purposes of generating radwaste volumes, a fire in the prep and [illegible] area will be assumed.

(1) Light hazard = 0.08 gpm/ft² ⑧
(2) Pre filter sprays = ½ TRU
(3) Cleanup required after the fire

4800 ft² × .08 gal/min-ft² × 30 min = 11520 gal

Cleanup = 6720 × 35/100 = 2352

Prefilter sprays = 255

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.

Area = (28 × 65) − 120 − (8 × 28) = 1476 ft²
t = 30 min
Group I hazard = 0.05 gpm/ft² ⑧

1476 ft² × .05 gal/min-ft² × 30 min = 2214

Cleanup = 1476 × .35 = 517

Prefilter spray = 510

3241 → 3500 GAL

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FORM AT-66(1) (1-75)

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APPROVED ______ DATE ______		SHEET 9	OF 13
TITLE ACCIDENT CONDITIONS - LIQUID RADWASTE		BY RMB	DATE 2/14/77

RADWASTE BLDG - For our purposes, the laundry will be the only Fire hazard area assumed.

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

1000 × .08 × 30 = 2400 gal.
Cleanup = 1000 × .35 = 350
Proj dt spray = 255
3005 gal

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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') = $2\pi + \pi dh = 32\pi = 100.5 ft^2$

From Fig 6[9] assume a corrosion rate of $60 g/ft^2/yr$ or
$60(100.5) = 6030 g/yr/canister$
Assume canisters are 1 month old.

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

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

→ $10 ft^3$ 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"
compressed volume = $3.2 ft^2 \times 0.5 in \times \frac{ft}{12 in} = .13 ft^3$

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

Flow is 10 gpm ; Effective volume = $.13 \left(\frac{10}{3}\right) = .43$ ft³/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 = $.43 \frac{ft^3}{week} \times 52 \frac{weeks}{yr} = 22.5$ ft³/yr.

Miscellaneous Waste Filters

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

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

Total filter volumes = 20.8 + 22.5 = 43.3 ⟶ **50 ft³/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 = 6x60 = 360 min.
Flow = 8000/360 = 22.2 gpm

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Assume that 1 ft^3 is needed for each 2 gpm flow.[12,13]

Bed is assumed to be $\frac{22.2}{2} = 11.1 \rightarrow$ **12 ft^3**

Even though conditions should be far less severe than San Onofre Unit 1, assume 12 ft^3/year spent resin volume

FORM AT-66(1) (1-75)

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APPROVED ____ DATE ____		SHEET 13	OF 13
TITLE REFERENCES		BY RMB	DATE 2/9/77

(1) Phone Conversation, R.M. Bannister, H&N, to P.H. Pensaynes, 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, NEDC 10084-1

(4) Phone Conversation, R.M. Bannister, H&N, to Marv Reib, AMCC, 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. Bannister to K.R. Brown of October 21, 1976

(7) Fire Protection Handbook (Fig 5-18) 14th Edition, 1976

(8) Fire Protection Handbook, Table 14-4B, 14th Edition, 1976

(9) Metals Handbook Vol 1, Fig 6, pg 27

(10) Pall Western Corporation Bulletin E256

(11) Phone Conversation, R.M. Bannister, 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 Calculations

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PRELIMINARY STRUCTURAL CALCULATIONS

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CHECKED	DATE	HOLMES & NARVER, INC. ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE. ANAHEIM, CALIF. 92801	JOB NO. 120.00	
APPROVED	DATE		SHEET TL-1	OF
TITLE WIPP FACILITY - SANDIA			BY KPS	DATE 4/4/77

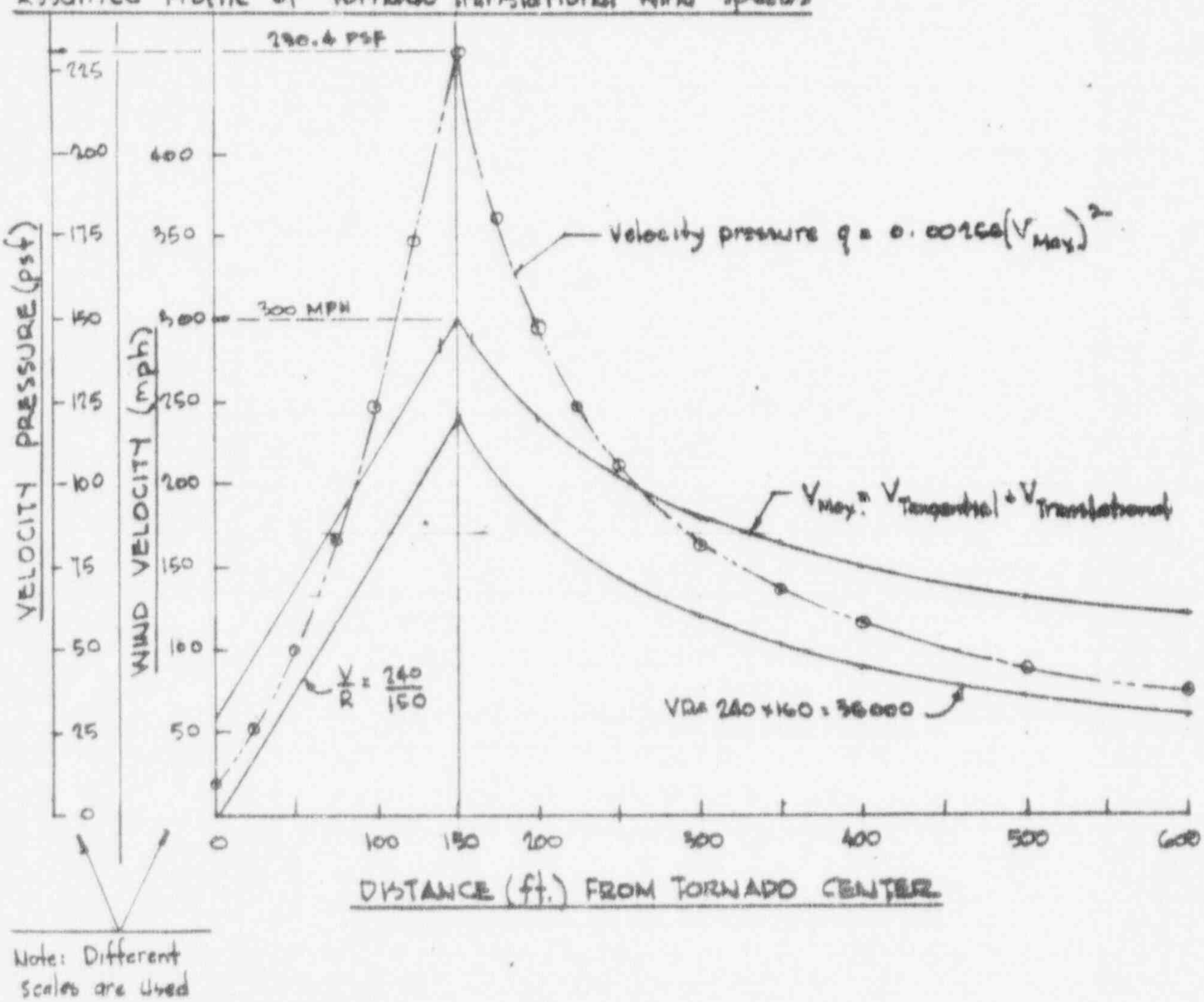
FORM AT-0011 (1-73)

TORNADO LOADING ASSUMPTIONS

Tornado characteristics

Rotational Speed (mph)	Translational Speeds (mph) Maximum	Minimum	Radius of Maximum Rotational Speed (feet)	Pressure Drop (psi)	Pressure Drop Rate (psi/sec)
240	60	5	150	2.25	1.2

Assumed Profile of Tornado Translational Wind speeds



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

CHECKED ______ DATE ______
APPROVED ______ DATE ______
TITLE WIPP FACILITY - SANDIA

JOB NO. ______
SHEET TL-2 OF ______
BY HPB DATE 4/4/77

DESIGN 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.) Region I	II	III
A.	Wood plank	4x12	12.0	115	272	230	190
B.	6"ϕ Sch. 40 pipe	6.625" O.D.	15.0	287	171	138	33
C.	1"ϕ Steel Rod	1.0" O.D.	3.0	9	167	131	26
D.	Wood Utility Pole	13.5" O.D.	35.0	1125	180	157	85
E.	12"ϕ Sch. 40 pipe	12.75" O.D.	15.0	750	154	92	23
F.	Automobile	6.56'x4.27'	16.4	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"ϕ Sch. 40 Pipe	6.625" O.D.	21.0	400	138
Wood Utility Pole	14" O.D.	35.0	1500	157
Automobile	(20 ft² 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&N Letter to Fenix and Scisson, Inc. dated January 21, 1977 and transmitting "Recommendations for the Tornado Generated Design Basis Missile for WIPP.

TYPICAL 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 WALL

General 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 psi
- K = 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)
- V_i = instantaneous velocity @ time t_i
- W = projectile weight (lbs)
- x = total penetration depth
- x_i = penetration depth at t_i.

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

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

$$\frac{s}{d} = 2.12 + 1.36\frac{x}{d} \quad \text{where } \left(3 \le \frac{s}{d} \le 18\right)$$

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.

TYPICAL WALL SECTION

Critical Missile for wall penetration - W14x34, W = 1020#, V=120 ft/sec.

Assume t = 18"

a) Penetration thickness, x

$N = 0.72$; $A = 10.0\ in^2 = \pi d^2/4$, $d = 3.57$; $D = \frac{W}{d^3} = \frac{1020}{(3.57)^3} = 22.45$

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

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

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

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

b) Perforation thickness, e

$\frac{e}{d} = 1.32 + 1.24(2.308) = 4.18$ $\qquad e/d > 3$

$e = (4.18)(3.57) =$ 14.92 in

c) Scabbing thickness, s

$\frac{s}{d} = 2.12 + 1.36(2.308) = 5.26$ $\qquad s/d > 3$

$s = (5.26)(3.57) =$ 18.78 in

Use 18" — Typical Exposed Wall Thickness

TYPICAL ROOF SECTION

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

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

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

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

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

$\frac{s}{d} = 2.12 + 1.36(1.87) = 4.66$ $\qquad e = (4.66)(3.57) =$ 16.64"

Use 17" — Typical Exposed Roof Slab Thickness

TYPICAL WALL SECTION

Wall Response for Impact from Missile with greatest energy input

$4000^{\#}$ Automobile @ V = 171 ft/sec.

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

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

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

$W = 0.150 \times 1.5 \times 30 \times 15 = 101^K$

$W_e = 0.33 \times 101 = 33^K$ (Effective Mass)

Period of Vibration T

$T \approx \left(\frac{L}{d}\right)\frac{L}{3600\sqrt{\phi}} = \frac{30 \times 12}{16} \times \frac{30}{3600} = 0.188$ sec $\phi = 1.0$

Equivalent Static Load

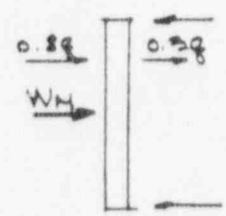
① $q_y = \frac{2\pi m V}{T}\sqrt{\frac{1}{2\mu - 1}} = \frac{2\pi \times 4 \times 171}{32.2 \times 0.188}\sqrt{\frac{1}{(2 \times 10) - 1}} = 163^K$

Wall Response

$W_M = \frac{163}{15} = 11^K$

$1.1\,q = 1.1 \times 0.00256 \times 300^2 = 253$ psf

$W_W = 253 \times 30 = 7.6^K$



$q = 0.00256(300)^2$

Factored Loads per ft. of wall width

Assume $1.2\,W_W + 1.2\,W_M$

$P = 1.2 \times 11 = 13.2^K$ $W = 1.2 \times 7.6 = 9.1^K$

$M_{MAX} = 13.2 \times \frac{30}{4} + 9.1 \times \frac{30}{8} = 133^{K'}$ Des $M = \frac{133}{0.9} = 148^{K'}$

For $p = 0.01$, $a_u = 4.10$ $A_s = \frac{133}{4.1 \times 16} = 2.03^{\square''}$/ft { Reinf. is a reasonable quantity

Maximum Wall Displ. (Missile only)

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

Reference Document ①

"Impact Effect of Fragments Striking Structural Elements"
By R.A. Williamson and R.R. Alvy, Holmes & Narver, Inc., Revised Nov. 1973

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90029072

FORM AT-68(1) (1-78)

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

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TITLE WIPP FACILITY - SANDIA

JOB NO. ________
SHEET YL-6 OF ________
BY WPS DATE 4/11/77

TYPICAL WALL SECTION

18" Wall - Punching Shear   d = 16"

W14×34 Missile $x = 8.24"$, $V = 120$ ft/sec

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

$F_A = \frac{WV}{g T_s} = \frac{1020 \times 120}{32.2 \times 0.0114} = 332{,}000^{\#} = \underline{332^k}$ $f_a = \frac{332}{10.0} = 33.2^{ksi} < 60.0$

∴ Missile crushing likely

Shear Perimeter @ $2[14" + 6.75"] = 41.5"$

Ave $\tau = \frac{332}{41.5 \times 16} = \underline{0.50}$ k/□" $< 0.2f'_c = 0.80^{ksi}$

∴ Punching Shear < Allowable punching shear

Other 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.

90029073

FORM AT-66(1) (1-75)

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TITLE WIPP FACILITY - SANDIA

JOB NO. ______
SHEET TRB-1 OF ______
BY HPB DATE 4/11/77

TRU-WASTE BUILDING

Preliminary 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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90029074

FORM AT-66(1) (1-73)

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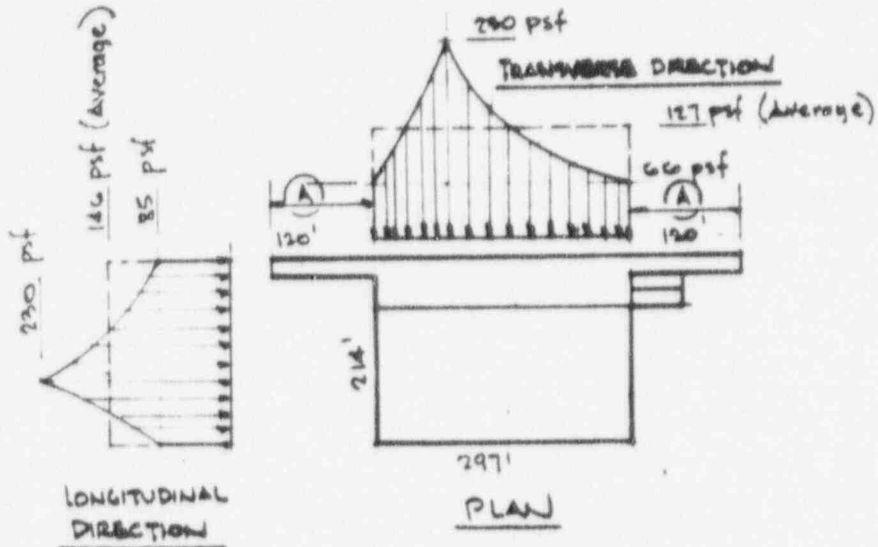
APPROVED ______ DATE ______		SHEET TRB-2 OF ______
TITLE WIPP FACILITY - SANDIA		BY HPS DATE 4/11/77

TORNADO LOADING ASSUMPTIONS

TRU 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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TRU-WASTE BUILDING

WIND LOADING SUMMARY

Design Loading Combinations

W_t = Total Tornado load

W_w = Tornado wind load

W_p = Tornado differential pressure load

W_m = Tornado missile load

$W_t = W_w$

$= W_p$

$= W_m$

$= W_w + 0.5 W_p$ $\qquad$ $W_p = 2.25\text{ psi} = 324\text{ psf}$

$= W_w + W_m$

$= W_w + 0.5 W_p + W_m$

Critical Tornado Wind Loadings - Not including Missile Loads

Local Wall Loading (psf)			Building Translation Loading (psf)	
W_w	$.5W_p$	W_t	Longit Direction	Transverse Direction
-230	-162	-392	146	127
+253	—	+253		

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SHEET TRB-4 OF ________
BY WB DATE 4/11/77

TRU-WASTE BUILDING

HIGH BAY WALL W/ 25 T. CRANE SUPPORT

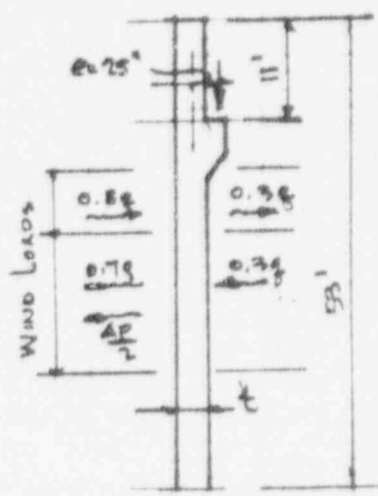
Crane Wheel Load = 20^k @ 25" from Wall ℄

Wind Loads

$W_t = W_w + 0.5 W_p$

$= (0.00256 \times \overline{300}^2) + (0.5 \times \frac{2.25}{2} \times 166)$

$= 230 + 162 = \underline{392\,psf}$



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

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

$M_{above} = 0.79 \times 11 = 8.7^{kf}$, $M_{below} = 33.3^{kf}$

$M_{℄} = 21^{kf}$, Assume 3.0' Strip, $M/ft = 7^{kf}$

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

$M_W = 24.93 \times 53/8 = 165^{kf}$

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

$\Sigma M = 175^{kf}$

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

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

*ACI 318-71, Sec 14.2(d)

$M_u = 175 \times 10/12 = 146^{kf}$ (For 10" wide Section, ACI SP17(73) Vol 1, p 130)

$A_s = 1.55\,in^2 = 0.25\,p_b$ (10" width)

$A_s = 1.55 \times 12/10 = 1.86\,in^2/ft$ · Say #11 @ 10" $p = \frac{100 \times 1.86}{12 \times 22} = 0.70$

∴ Say 24" Wall o.k.

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SHEET TRB - 5. OF ________

TITLE WIPP FACILITY - SANDIA

BY HPB DATE 4/11/77

TRU - WASTE BUILDING

HIGH-BAY WALL W/ 25T. CRANE SUPPORT

Wall Response. - 4000# Automobile Missile

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

$\pi d^2/4 = 20\ ft^2$, $d = 5.046\ ft = 60.56''$

Effective Width $E = 0.45 + 3.75 = (0.4 \times 53) + 3.75 = 25$ ft

Assume $E = 20$ ft

$W = 0.150 \times 53 \times 20 \times 2.0 =$ 318^k

$W_e = 0.33 \times 318 =$ 106^k

Period of Vibration

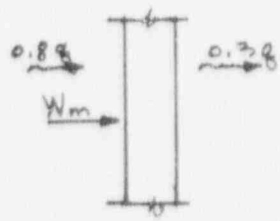
$d = 22''$ $\phi = 1.0\%$

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

Equiv. Static Load $\mu = 10$ (Assumed)

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

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



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

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

Use $1.2 W_w + 1.2 W_m$

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

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

$A_s = 1.4 \times 12/10'' = \underline{1.68\ \square''}/ft.$ (ACI SP-17(73) - Vol 1, P-30)

#11@11 $p = \frac{100 \times 1.68}{12 \times 22} = \underline{0.64\%}$

24" Wall o.k.

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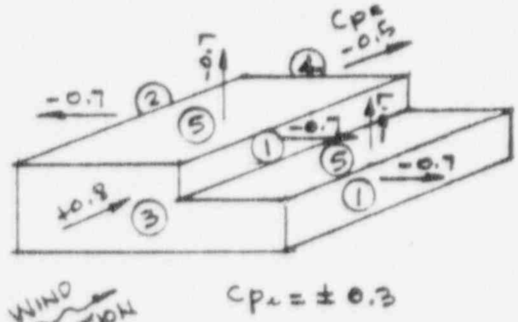
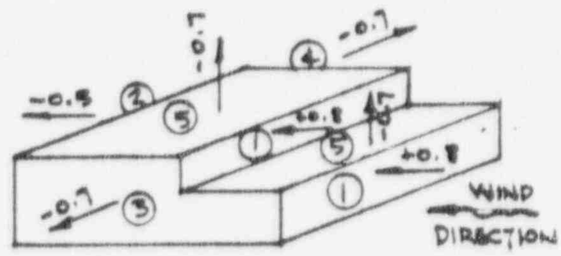
JOB NO. ________
SHEET TRA-6 OF ________
BY HPJ DATE 4/11/77

TRU-WASTE BUILDING

SURFACE WIND PRESSURES





PRESSURE COEFFICIENTS Cp & Cpi

$$p = q_f C_p - q_m C_{pi}$$

Velocity Pressures $q = 0.00256 V^2$; $V_{max} = 300$ mph ; $q = .00256 \times 300^2 = 230$ psf

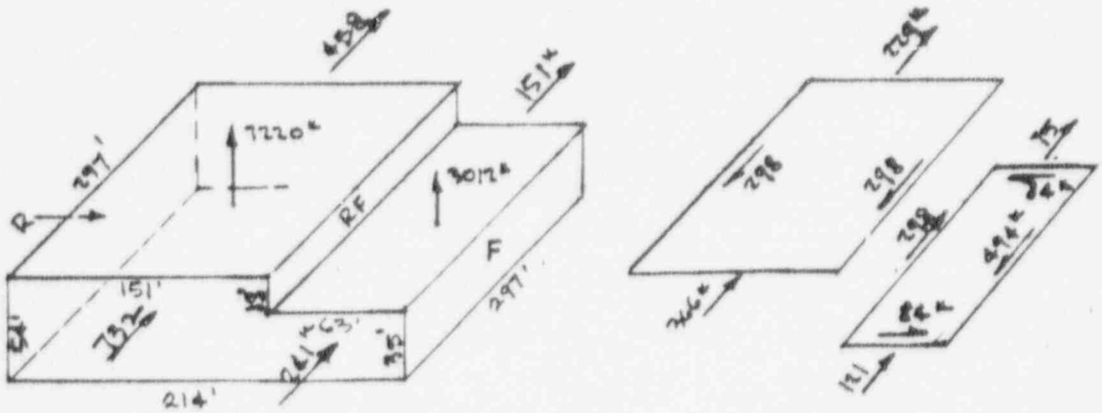
WIND PRESSURES ON BUILDING SURFACES

Surface No.	Cp	qfCp	Cpi	qmCpi	p	Cp	qfCp	Cpi	qmCpi	p
1	-0.7	-161	+0.3 -0.3	+69 -69	-92 -230	+0.8	+184	+0.3 -0.3	+69 -69	+253 +115
2	-0.7	-161	+0.3 -0.3	+69 -69	-92 -230	-0.5	-115	+0.3 -0.3	+69 -69	-46 -184
3	+0.8	+184	+0.3 -0.3	+69 -69	+253 +115	-0.7	-161	+0.3 -0.3	+69 -69	-92 -230
4	-0.5	-115	+0.3 -0.3	+69 -69	-46 -184	-0.7	-161	+0.3 -0.3	+69 -69	-92 -230
5	-0.7	-161	+0.3 -0.3	+69 -69	-92 -230	-0.7	-161	+0.3 -0.3	+69 -69	-92 -230

$q_f = q_m = 230$ psf in above table

TRU - WASTE BUILDING

WIND SHEARS ON WALLS

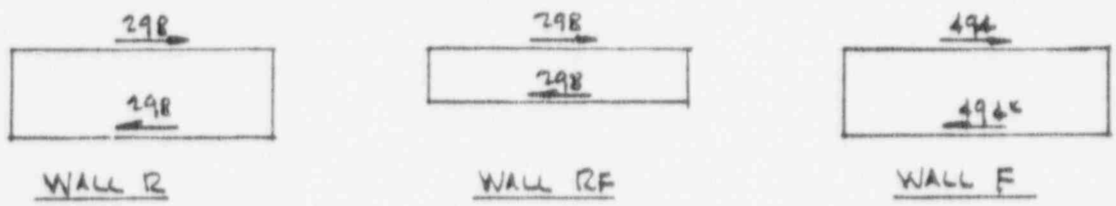


151×54 = 8154 ft² × 146 = 1190k (732k F, 458k R)
63×35 = 2205 × 146 = 392k (241 F, 151 R)
151×297 = 44,847 ft² × 161 = 7220k
63×297 = 18,711 × 161 = 3012k

BUILDING WALL LOADS

298×63 = 18,774
196×63/2 = 6,174
24,948
24,948/297 = 84k

ROOF DIAPHRAGM LOADS



HORIZ WIND SHEARS (kips) ACTING ON SIDE WALLS

494/297 = 1.66 k/ft
v_{ave} = 1660/12×18 = 8 psi
(very low)

90029080

FORM AT-88(1) (1-73)

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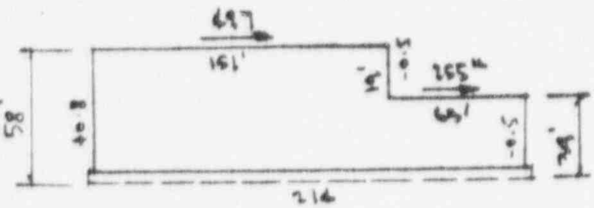
SHEET TRU-8 OF ________
BY KPB DATE 4/11/77

TRU. WASTE BUILDING

End Wall Loads

Tornado Horiz.



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

$\frac{M}{2} \times \frac{297}{2} \times 0.5 \times .127 = 90^k$

$\frac{35}{2} \times \frac{297}{2} \times 0.8 \times .127 = 165^k$

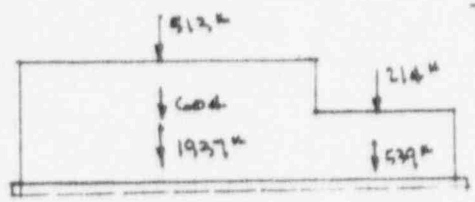
$M = (497 \times 58) + (265 \times 39) = 38{,}771$

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

$S = 3 \times \overline{214}^2 / 6 = 22{,}898$

$f_{p} = 1.69$

Dead Load



$16 \times 22 = 3.4^{k/ft}$

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

$3.4 \times 63 = 214^k$

$x = \frac{M}{P} = \left[(\ \times \frac{151}{2}) + (753 \times 182)\right] / 3807$

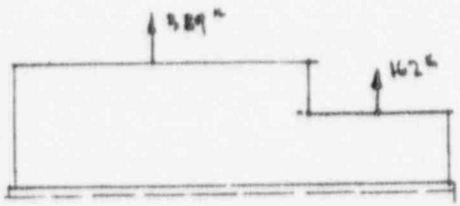
$= 96.6 \qquad e = 10.4$

$M = 10.4 \times 3807 = 39726$

$f_m = 39726 / 22{,}898 = 1.73$

$f_a = 3807 / 642 = 5.93$

Tornado Vertical



$16 \times .161 \times 151 = 389^k$

$16 \times .161 \times 63 = 162^k$

$x = \frac{M}{P} = \left[(389 \times \frac{151}{2}) + (162 \times 182)\right] / 551^k$

$x = 106.8 \qquad e = 0.2$

$M \approx 0$

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

Wall Footing Soil Pressures

DL + Tornado Horiz + Tornado Vertical

f_p(ksf) 5.93 − 1.73 + 1.69 − 0.86 = 5.0 } < 6.0 KSF
5.93 + 1.73 − 1.69 − 0.86 = 5.1 }

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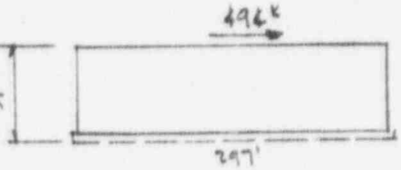
TRU-WASTE BUILDING

Side Wall Loads

Tornado Horiz



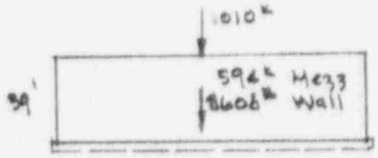
$M = 494 \times 39 = 19{,}266^{kf}$

$A = 3.0 \times 299 = 897\ ft^2$

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

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

Dead Load



Roof
$16' \times .22 = 3.4^k/f$

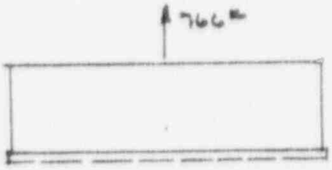
Mezz
$10' \times .20 = 2.0^k/f$

Wall -
$39' \times .225 = 8.78^k/f$

$P = 1010 + 594 + 2608 = 4212^k$

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

Tornado Vertical



$16' \times .161 = 2.58^k/f$

$2.58 \times 297 = 766^k$

$f_p = 766/897 = -0.85\ ksf$

Wall Footing Soil Pressures

	DL	+ Tornado Horiz	+ Tornado Uplift		
f_p (ksf)	4.70	+ 0.43	− 0.85	= 4.28	< 6.0 ksf
	4.70	− 0.43	− 0.85	= 3.42	

Typical Foundation Loads · DL + LL

Roof Loads

LL =	20	LL =	150
Rfg + Ins =	10	Flr	100
17" slab =	213		250
	243 psf		

Column Footings - Typ

Trib Area = 32 × 33 = 1056 □'

Trib Load = 1056 (.243 + .300) = 573^k

Col wt (30" × 30" @ .94^k/f × 31') = 29

602^k

10.0 sq × 2'-6

Wall Footings - Typical

Wall Ht	57'	38'
Wall wt/ft	13.9	9.2
Roof Ld 16 × .243 =	3.9	3.9
Flr Ld 16 × .250 =	4.0	4.0
	21.8	17.1
Width w @ 6.0^ksf =	4.0'	3.0'

24" wall

57' + Crane Load

$17.7 + 100/25 = 21.1^k$

Roof Ld = 27 × .300 = 8.1

29.2^k

5.0'

45-46

90029082

Mechanical Calculations

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

47-48

90029084

TRU

Cost of Electricity

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

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

Cost/MBTU = $\frac{1000\,000}{3413} \times .02724$ = $7.98

90029085

Cost of Electricity (RH Bldg.)

Assume: .016/KWH + 4.50 demand charge

Actual demand rate = 187 × 1.1 = 205.7

Total usage = 895,656 × 1.1 = 985,221

$$\text{Demand charge} = \frac{205.7 \times 4.5 \times 12}{985,221} = .01127$$

+ .016

total cost/KWH .0273

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

9002290086

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

Demand charge = $\frac{176 \times 4.50 \times 12}{642,422}$ = .0148
+ .016
total cost/KWH = .0308

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

Solar Assist.—
200 panels @ 306 × 2 = $122,400
(to supply 1.36×10^9 BTU/yr.)

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Laundry

Laundry — H.W. Energy use

30 KW × 5 hr. = 150 KWH/day
@ 30 KW demand

Cost of electricity — .016 KWH + 4.50 demand

demand = 30 KW total usage = 37,500

Demand charge $\frac{30 \times 4.5 \times 12}{37,500}$ = .0432
+ .016
total cost/KWH 0.0592

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

Solar panels — 30 @ 306 × 2 = $18,360 + $700/yr. maint.

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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

$\therefore$ CONSUMPTION/HR = 3600 BHP (.404 LB/BHP-HR)

= 1454.4 LB/HR

CONSUMPTION/DAY = $24 \frac{HR}{DAY} \left(1454.4 \frac{LB}{HR}\right)$

= $34,905.6 \frac{LB}{DAY}$

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

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

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

= 9308 GALLONS/DAY

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2

7 DAY FUEL SUPPLY = 7(9308 GPD)
= 65,156 GALLONS

Reg Guide 1.108

Houston, Texas (713) 923-2161 3/23/77

Based on conversation with Robert Evans - National Contract Manager 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.

MECHANICAL SYSTEMS

STANDBY GENERATOR RADIATOR AIR FLOW

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

MACHINE RATING = 2600 KW

$\therefore$ Q = (50 BTU/MIN/KW) 2600 KW
= 130,000 BTU/MIN
= 7,800,000 BTU/HR/MACHINE

AIR FLOW BASED ON 30°F ΔT WILL BE 240,000 CFM

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

55-56

ADDENDA

WIPP CONCEPTUAL DESIGN

HIGH LEVEL WASTE SHIPPING CASK
COOLING SYSTEM

DESIGN CALCULATIONS

HOLMES & NARVER, INC.

57-58

90029092

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.

59-60

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ERDA HIGH LEVEL WASTE - MULTIPLE CANISTER CASK

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

CASK SIZE 10' DIA × 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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DESIRED MINIMUM COOLDOWN TIME IS 4 HRS/CASK

CALCULATIONS

PER W. WOWAK

$$Q_{4HRS} = \overset{Ⓐ}{\Delta Q_{75°F}} + \overset{Ⓑ}{\Delta Q_{\substack{CANISTER \\ GENERATION \\ (IN\ 4\ HRS)}}}$$

Ⓐ $\Delta Q_{75°F} = \rho V c_p \Delta T \quad \left(\frac{LB}{FT^3}\right)\left(FT^3\right)\left(\frac{BTU}{LB\ °F}\right)\ °F$

$$= \left[75\ TONS\left(2000\frac{LB}{TON}\right)(.034) + 25(2000)(.11)\right]75$$

$$\Delta Q_{75} = (5.1^{+3} + 5.5^{+3})75\ BTU = 7.95^{+5} = 795{,}000$$

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

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

3

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Ⓑ $\Delta Q_{\substack{CAN\\GEN}} = 7\,CANS\left(300\,\frac{W}{CAN}\right)$

$= 2.1\ KW$

$Q = Ⓐ + Ⓑ$

$= 58.5\ KW + 2.1\ KW$

$Q = 60.6\ KW$ FOR ERDA HIGH WASTE

COMMERCIAL HIGH WASTE

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

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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.

CALCULATIONS

DETERMINE WATER FLOW REQ'D TO INITIALLY COOL THE CASK VIA [redacted] VAPORIZATION OF THE HOT WATER FEED TO STEAM

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

$T = 400°F$
$P = 247.31$ PSIA
$h_f = 374.97$ BTU/LB
$h_{fg} = 826.0$ "
$h_g = 1201.0$ "

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 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:

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

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

$= 49.5$ GPH

$\sim .83$ GPM / CASK

ASSUMING THE COOLING TO BE 3× 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 $h_f = 67.97$ BTU/LB

WATER OUTLET TEMP. = 210°F $h_f = 178.05 \ \frac{BTU}{LB}$

$Q = 341{,}000$ BTU/HR $\Delta h = 110$ BTU/LB

6t

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1/31/77

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

$= 3{,}100$ LB/HR
$= 370$ GPH
$=$ 6.2 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 (~150°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
67 ASSUMED THAT CASK SKIN TEMPERATURE IS THE LIMITING

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 28KW

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$$\text{FLOW} = \frac{28\,\text{KW}\left(3415\ \frac{\text{BTU/HR}}{\text{KW}}\right)}{100\ \text{BTU/LB}}$$

$$= 955\ \frac{\text{LB}}{\text{HR}}$$

$$= 114\ \text{GPH}$$

$$= 1.9\,\text{GPM}$$

5 CASKS = 9.5 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 —

18.6	MAX.
3.8	MAINT.
2.6	MARGIN
25.0 GPM	

∴ 25 GPM WILL BE UTILIZED

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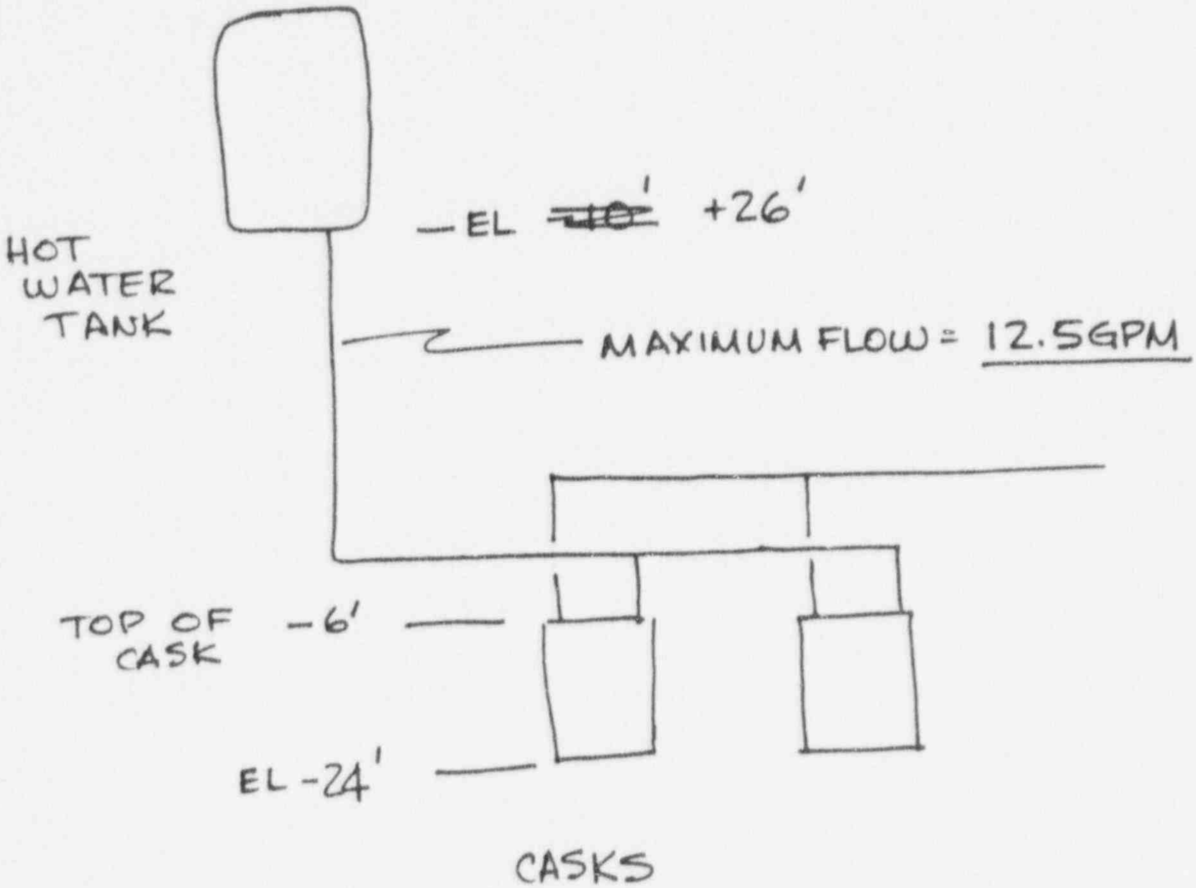
SYSTEM DESIGN



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 1/2 FOR LINE LOSSES 1/2 FOR CONTROL - $\therefore \Delta P_{LINE} = 7$ PSI

FOR 2" PIPE V = 1.3 FEET/SECOND

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

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FOR THE PURPOSES OF CONCEPTUAL DESIGN 2" PIPE WILL BE USED FOR MAJOR SYSTEM ~~BRANCHES~~ SECTIONS 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 ~~LEVEL~~ VOLUME VARIATION IN A 1 HR PERIOD SHOULD NOT BE MORE THAN 20% OF THE VOLUME

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

$$= \underline{3750\ GAL}$$

THIS IS A LARGE VOLUME OF WATER TO MAINTAIN AT A HIGH TEMPERATURE ∴ 40%/HR

WILL BE ASSUMED GIVING A VOLUME OF 1775 GAL
THE TANK WILL BE SIZED AT <u>2000 GAL</u>

~~CATCH TANK~~

<u>LOW TEMP RECEIVER</u>

THE RECEIVER WILL BE SIZED AT 500 GALLONS CAPACITY

<u>SYSTEM CONDENSER</u> — TO BE CALCULATED AFTER SYSTEM BALANCE COMPLETED —

~~SIZED ON THE BASIS OF 5 CASKS IN PHASE I COOLING –~~

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

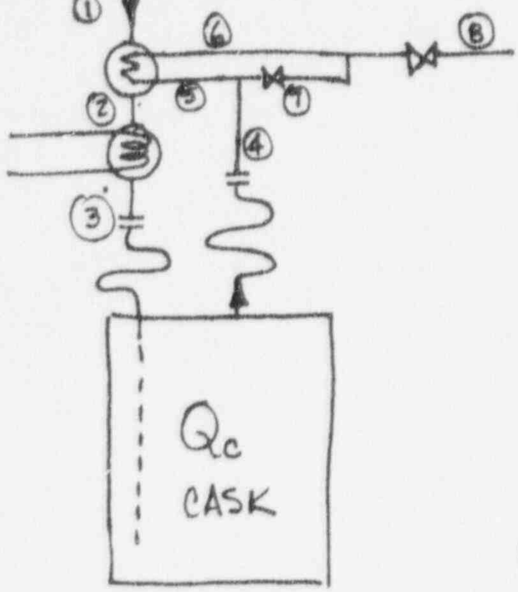
~~$= 1{,}705{,}000 \frac{BTU}{HR}$~~

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

<u>CATCH TANK</u>

THE TANK HAS A 3000 GAL CAPACITY

PARTIAL HEAT BALANCE AND COMPONENT SIZING



ASSUMPTIONS: $T_1 = 150°F$, $P_1 \simeq 250$ PSIA } WATER

$T_3 = 400°F$, $P_3 \simeq 250$ PSIA } WATER

$T_4 = 400°F$, $P_4 \simeq 250$ PSIA } STEAM

$T_5 = T_4$ $P_4 = P_5$

$Q_{c\,\text{VAPORIZATION}} = 341{,}000$ BTU/HR

F = FLOW

COMPONENT DESIGN BASIS

$T_2 = 380°F$ $T_6 = 370°F$

$P_2 = P_1$ $F_8 = F_1 = F_2 = F_3 = F_4 \neq F_5 \neq F_6$

$\therefore Q_{12} = 413 \frac{LB}{HR} (h_{380} - h_{150})$

$= 413(353.45 - 117.89)$

$= 413(235.56)$

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

$Q_{23} = 413$ LB/HR $(h_{400} - h_{380})$

$= 413(374.97 - 353.45)$

$= 413(21.52)$

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

} ELECTRIC HEAT ADDITION

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$$F_5 = F_6 = Q_{12} / \left[h_{fg(400)} + \Delta h_{f\,400-300}\right]$$

$$= \frac{97{,}000 \frac{BTU}{HR}}{\sout{1201.0}\ 826 \frac{BTU}{LB} + (374.97 - 269.59) \frac{BTU}{LB}}$$

$$= \frac{97000}{931.4}\ LB/HR$$

$F_5 = F_6 = 104$ LB/HR

$F_7 = 413 - 104$ LB/HR

$F_7 = 309$ LB/HR

$F_8 = 413$ LB/HR

ΔQ FOR SYSTEM = 341,000 − 97,000 + 9,100
= 244,000 BTU/HR REJECTED IN PHASE I TO AN EXTERNAL SYSTEM 253,000

$\therefore Q_{CONDENSER} =$ ~~244,000~~ 253,000 BTU/HR / CASK (5 CASKS)

= 1,265,000 BTU/HR

~ 1,300,000 BTU/HR MAXIMUM

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

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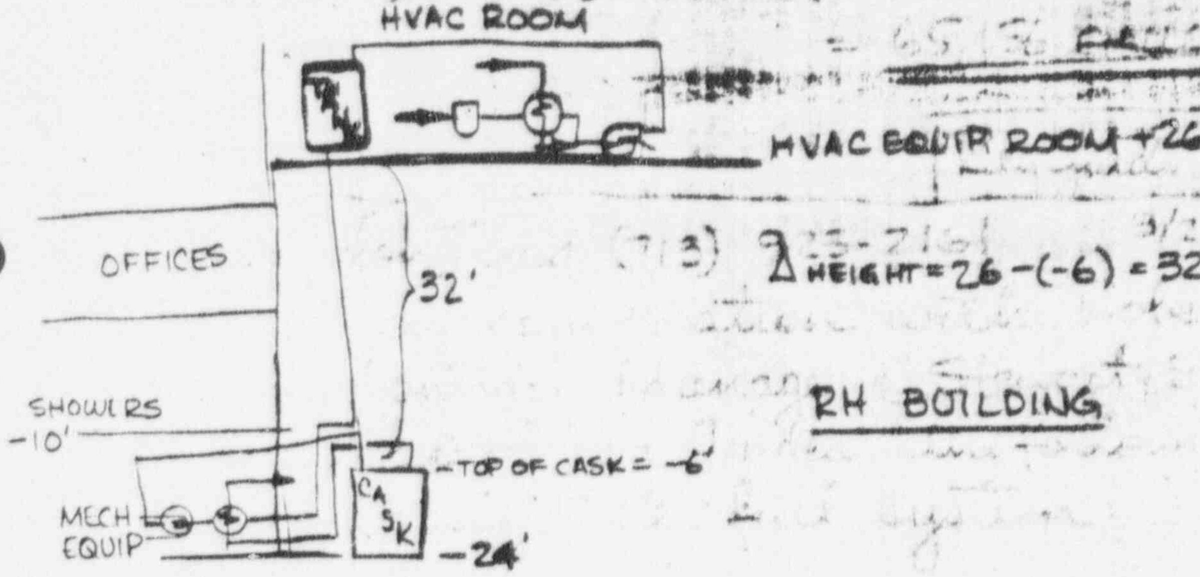
SYSTEM CONFIGURATION



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

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Hot Water Heater (Steam)

MAXIMUM FLOW = 6.2 GPM
" " ΔP = 5 PSI
NORMAL FLOW = 0.83 GPM
INLET PRESSURE ≅ 260 PSIA
INLET TEMPERATURE = 150°F
OUTLET TEMPERATURE = 380°F
Q = 97,000 BTU/HR

SHELL & TUBE
STEAM IN SHELL

Electric Heater (Supplemental)

MAXIMUM FLOW = 6.2 GPM
" " ΔP = 5 PSI
NORMAL FLOW = 0.83 GPM
INLET PRESSURE ≏ 255 PSIA
INLET TEMPERATURE = 380°F
OUTLET TEMPERATURE = 400°F
Q = 9,100 BTU/HR

SHORT TERM DUTY
Q = 107,000 BTU/HR
T_{IN} = 150°F
T_{OUT} = 400°F
FLOW ≈ 0.83 GPM
-THIS IS THE STARTUP MODE

Knock-Out Pot

CAPACITY = 150 GALLONS
DESIGN PRESSURE = 300 PSIA
" TEMPERATURE = ~~400~~ 450 °F

~~two~~ Liquid Receiver

CAPACITY = 500 GAL. PER PAGE 9
DESIGN PRESSURE = 300 PSIA
" TEMPERATURE = 400°F

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2/3/77

VENT CONDENSER

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

OPERATING NOTES

1. RELIEF VALUES 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 -

MAXIMUM ENERGY AVAILABLE/YEAR -

ENERGY/CASK = ~~341,000~~ 253,000 BTU/HR (4 HRS)
= ~~1,364,000~~ 1,012,000 BTU

$$\text{CASKS/YR} = \frac{50\ \text{CANS/WK}}{7\ \text{CANS/CASK}} = 7\ \text{CASKS/WK} = 364\ \frac{\text{CASKS}}{\text{YR}}$$

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

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

APPROXIMATE COST OF SYSTEM = $

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

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2-8-77

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

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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 receival.

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

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waste heat recovery will represent only 1/6th of the annual energy available from the system.

Calculations

From 2-3-77 Calculations, page 15,

Max Energy /year = 3.79×10^8 BTU

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

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

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

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

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.

2-7-77
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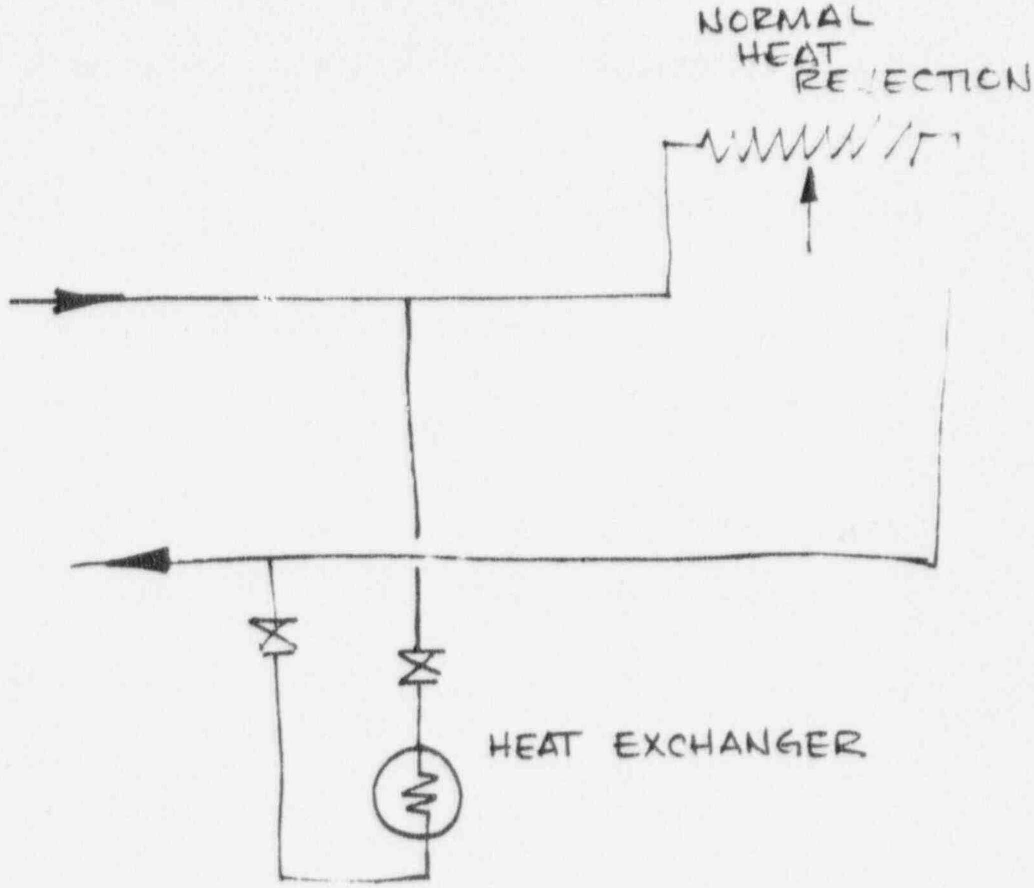
The data sheet is attached.

System would look like



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

PIPE	4,000
Hx	3,000
VALVES	500
BLDG SPACE	5,000

SAY $15,000 TOTAL COST

See Page 10.

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

= 1008 KWHR /YEAR

CONSUMPTION = $\left(1008 \frac{KWHR}{YR}\right)$ 3415 $\frac{BTU}{KWHR}$
= 3.69^{+6}

COST OF ENERGY

FUEL OIL FOR STEAM = \$.35/GALLON
ELECTRICITY = \$0.016/KW + 4.25 DEMAND

STEAM COST

STEAM 1390 BTU/LB

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

= 4.5×10^4 LB/YR

FUEL OIL BURNED TO CREATE STEAM

$$\text{GALLONS OIL} = \frac{6.3^{+7}\ BTU/YR}{1.39^{+5}\ BTU/GAL}$$

COST OF OIL = \$0.35/GAL

= 4.5^{+2}
= 450 GAL/YR
= \$157/YR

2-7-77
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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

[illegible]

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

COST OF 1 KWHR = \$0.016

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

$$= .293^{+3} (.016)$$

$$= \$4.68 \text{ PER } 10^6$$

TOTAL = 4.68 + 4.25 = \$8.93

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2-7-77
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6

COSTS

HEAT EXCHANGER \$25 /FT^2
PIPE \$5.00/FT
VALVES \$55.00 EACH

H_x = 100 FT^2 (\$25)	2500
PIPE = 200' (\$5)	1000
VALVES = \$55 (6)	330
	3830
CONTINGENCY	1200
TOTAL =	5030

Life cycle cost calculations run on LIFCY1 for various assumptions on enery 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                                          LOCATION: CASK COOLING
PROJ. DIR. NO.: WIPP CONCEPTUAL DESIGN            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 UNTS.

RUN COMPLETE.
```

89

77/02/08. 10.15.09.
PROGRAM LIFCY1

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

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 UNTS.

RUN COMPLETE.

PROGRAM LIFCY1

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

INPUT DATA

BLDG: RH LOCATION: CASK COOLING
PROJ. DIR. NO.: WIPP CONCEPTUAL DESIGN DESIGNER: K. BROWN #2

COST OF ELECTRICAL ENERGY USED, PER MILLION BTU = $4.6900
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                                          LOCATION: CASK COOLING
PROJ. DIR. NO.: WIPP CONCEPTUAL DESIGN            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............         $.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       $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.
```

FORM E-65(8-67)

HOLMES & NARVER, INC.
ENGINEERS - CONSTRUCTORS

PHONE-TALK

TO: K. R. Brown

Date: September 3, 1976

FROM: B. Steinbaugh, Sandia Labs. KRB

Page 1 of 1

SUBJECT: WIPP - ENERGY COSTS AND WATER SUPPLY

Bob called with the following energy costs:

	Cost/1,000,000 BTU	Pres	Use
Natural Gas	$ 0.40	.85	1.50/10⁶ BTU
Fuel Oil	2.14	.33	.35 gal
Electricity	6.74	.0134 (3.90)	.016/kw (4.25 demand charge)

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

93-94

90029124

ERDA STANDARD 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 Gal
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

97-97

2-7-77

LIFCY1

INPUT DATA

4030 DATA " TRU Waste Facility "	Bldg. Name - K$
4040 DATA " Carlsbad "	Location - J$
4050 DATA " Brown "	Proj. Dir. No. - P$
4060 DATA " ~~Klatskin~~ BROWN "	Designer - D$
4070 DATA $8.93 4.68	Cost of Electricity, Per MBTU - C2 ~~[illegible]~~ 40
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 ~~[illegible]~~ 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~~ 10,000	Installation First Cost - C
4210 DATA ~~[illegible]~~ 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

79-100

90029127

Design Criteria (Work Areas)

Summer	Outside	99°F	
	Inside	82°F	ΔT = 17°F
Winter	Outside	21°F	
	Inside	65°F	ΔT = 44°F

(Offices)

Winter	Inside	72°	ΔT = 51°F

"U" Factors

Walls	0.097
Roof	0.08
Slab	0.16

Total Equiv. Temp Dif. Correction

Inside 75 - 82 = -7° outside 99 - 85 = 14°

total correction = 14-7 = 7°F

High Level Fac. (High Bay only)

Summer Inside = $\frac{T_o + T_i}{2} = \frac{99 + 82}{2} = 90.5$ ΔT = 8.5°F

Winter Inside = $\frac{T_o + T_i}{2} = \frac{21 + 65}{2} = 43$ ΔT = 22.0°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°F

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
	10.31

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

Roof

f_o	0.25
Roofing	0.33
Insulation (Rigid-3½")	9.68
Slab (Concrete-12")	1.32
f_i	0.92
	12.50

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

Exterior Wall (High Level-High Bay)

f_o	0.17
Concrete (12")	1.14
f_i	0.68
	1.99

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

FORM AT-66(1) (1-75)

CHECKED	DATE	HOLMES & NARVER, INC. ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE. ANAHEIM, CALIF. 92801	JOB NO. 8251.00
APPROVED	DATE		SHEET 3 OF 3
TITLE WIPP - HVAV			BY M 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)	6.27
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

103-104

90029130

FORM AT-66(1) (1-75)

CHECKED ______ DATE ______ APPROVED ______ DATE ______

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

JOB NO. 8251.00
SHEET 1 OF 6

TITLE TRU Waste Facility BY MK DATE 1-20-77

Internal Heat Gain Assumptions

Unloading/Loading Area

Lighting	4 watts/sq.ft.	= 13.65 BTU/#
Drums	320 @ 10 w	= 10,052
Hoists (50% use)	2@40 HP = $\frac{80 \times 750 \times 3.413}{2}$	= 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 = $\frac{40 \times 3 \times 750 \times 3.413}{1.334}$	= 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. 92801	JOB NO. 8251.00	
APPROVED ______ DATE ______		SHEET 2	OF 6
TITLE TRU Waste Facility		BY MK	DATE 1-20-77

Unloading / Loading Area

		Area	Factor	Cooling	Factor	Heating
NE Wall	297×40 =	11,880	2.037	24,200	4.267	50,692
NW Wall	(54×40)-324 =	1836	1.94	3562	4.267	7,834
NW Door	18×18 =	324	17/2 = 8.5	2754	44/2 = 22	7,128
SE Wall	(54×40)-972 =	1188	2.134	2535	4.267	5,069
SE Door	3 @ 18×18 =	972	8.5	7880	22	20,394
Roof	297×54 =	16,038	2.4	38,491	3.52	56,454
Lights	@ 4 w/ft²	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 §		6×1.08	138,237	15.4×1.08	354,810
				552,020		**502,351**

FORM AT-88(1) (1-75)

CHECKED ____ DATE ____

APPROVED ____ DATE ____

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

JOB NO. 8251.00

SHEET 3 OF 6

TITLE TRU Waste Facility

BY MK DATE 1-20-77

Inventory & Preparation

	Area	Factor	Cooling	Factor	Heating
NW Wall 64×24	1536	1.94	2980	4.267	6554
SW Wall 100×24	2400	2.134	5122	4.267	10241
SE Wall 160×24	3840	2.134	8195	4.267	16385
Roof 37,000 ft²	37,000	2.4	88800	3.52	130,240
Lights @ 4 w/ft²	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 cfm		6×1.08	777,600	15.4×1.08	1,995,840
			1,676,400		**2,159,240**

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90029133

CHECKED ______ DATE ______	**HOLMES & NARVER, INC.** ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE. ANAHEIM, CALIF. 92801	JOB NO. 8251.00	
APPROVED ______ DATE ______		SHEET 4	OF 6
TITLE TRU Waste Facility		BY MK	DATE 1-20-77

Overpack & Repair & Lab

		Area	Factor	Cooling	Factor	Heating
NW Wall	96×40	3840	1.94	7,450	4.26	16,358
SW Wall	33×40	1320	2.134	2,817	4.26	5,623
SW Wall	33×25	825	2.134	1,760	4.26	3,515
SE Wall	64×15	960	2.134	2,049	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		6×1.08	67,780	15.4×1.08	173,970
				202,541		**221,966**

90029134 108

CHECKED ______ DATE ______	HOLMES & NARVER, INC. ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE. ANAHEIM, CALIF. 92801	JOB NO. 8251.00
APPROVED ______ DATE ______		SHEET 5 OF 6
TITLE TRU Waste Facility		BY MK DATE 1-20-77

Office Area

	Area	Factor	Cooling	Factor	Heating
SW Wall 130×24	3120	2.134	6,658	4.267	13,313
SW Doors 10×7=	70	17	1190	44	3,080
Lights 5290☐ @ 3w			54,164		
People 10 @ 250 BTU (sens)			2,500		
OSA - 10% of total air = 700$		17×1.08	12,852	44×1.08	32,264
			77,364		48,657

90029135

1C9

FORM AT-66(1) (1-75)

CHECKED ______ DATE ______	**HOLMES & NARVER, INC.** ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE. ANAHEIM, CALIF. 92801	JOB NO. 8251.00	
APPROVED ______ DATE ______		SHEET 6	OF 6
TITLE TRU Waste Facility		BY 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
	2,430,961	2,886,557	736,100

110

90029136

Internal heat gain assumptions

Preparation & Decon

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

Hot Cell

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

Decon

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 × 3072 × 1.0	=	368 640
Brushes	2 @ 25 HP @ 100% usage	50 × 3072 × 1.0	=	153 600
				550 936

total 1,646,093 BTU

111

90029137

CHECKED ________ DATE ________
APPROVED ________ DATE ________

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

JOB NO. 8251.00
SHEET 2 OF 6
BY MK DATE 2-14-77

TITLE WIPP-HVAC-RH Facility

Preparation & Decon

	Area ft²	Factor	Cooling BTU	Factor	Heating BTU
SE Wall	54×50=2700	2.134	5 761	4.267	11 520
Roof	54×72 3888	2.4	9 331	3.52	13 686
Lights	3888	13.652	53 079		
Casks	48 × 11945.5		573 384		
Hoists	160× 3072 ×.1		49 152		
Carts	20 × 3072 ×1.0		61 440		
Turntable	5 × 3072 ×.1		1 536		
Water Wash	20×3072 ×.5		30 720		
People	1200 + 500		1 700		
OSA (w/recovery)	19,440 ft³	6×1.08	125 971	15.4×1.08	323326
			912 074		348 532

90029138

CHECKED ______ DATE ______	HOLMES & NARVER, INC. ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE. ANAHEIM, CALIF. 92801	JOB NO. 8251.00	
APPROVED ______ DATE ______		SHEET 3	OF 6
TITLE WIPP – HVAC – RH Facility		BY MK	DATE 2-14-77

Hot Cell

			Area ф	Factor	Cooling BTU	Factor	Heating BTU
SE Wall	28×48	=	1344	2.134	2868	4.267	5735
Roof	28×60	=	1680	2.4	4032	3.52	5914
Lights			1680	13.652	22935		
Casks		13 × 11945.5			155291		
Hoist		40 × 3072 × 1.0			122880		
Elevator		25 × 3072 × .1			7680		
Misc. Motors		10 × 3072 × .5			15360		
OSA	8,064 ∮			6 × 1.08	52254	15.4 × 1.08	134120
					383300		145769

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90029139

CHECKED ______ DATE ______	HOLMES & NARVER, INC. ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE. ANAHEIM, CALIF. 92801	JOB NO. 8251.00	
APPROVED ______ DATE ______		SHEET 4	OF 6
TITLE WIPP-HVAC-RH Facility		BY MK	DATE 2-14-77

Decon

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

Shipping & Receiving

	Area	Factor	Cooling	Factor	Heating
NW Wall					
SW Wall					
SW Door	(No Refrig.)				
NE Wall					
NE Door					
Roof					
Lights					
Hoist					
People					
OSA (w/recovery) 23,466 ξ					

90029141

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FORM AT-66(1) (1-75)

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

CHECKED ______ DATE ______
APPROVED ______ DATE ______
JOB NO. 8251.00
SHEET 6 OF 6
TITLE WIPP-HVAC-RH Facility
BY MK DATE 2-14-77

Offices & Control Room

		Area #	Factor	Cooling BTV	Factor	Heating BTU
NW Wall	167 × 15	2505	1.94	4860	4.267	10 689
SW Wall	82 × 15	1230	2.134	2625	4.267	5248
SE Wall	39 × 15	585	2.134	1248	4.267	2496
Roof	82 × 39	3198	2.4	7675	3.52	11 257
Lights	3198 @ 3 watts/#		10.239	32 744		
Equipment	3198 @ 2 watts/#		6.826	21 830		
People	10 @ 250 BTU sensible			2500		
OSA	7300$ @ 10% = 730$		17 × 1.08	13 403	44 × 1.08	34 690
				86 885		64 380

FORM AT-66(1) (1-75)

CHECKED ______ DATE ______	**HOLMES & NARVER, INC.** ENGINEERS—CONSTRUCTORS 400 E. ORANGETHORPE AVE. ANAHEIM, CALIF. 92801	JOB NO. 8251.10	
APPROVED ______ DATE ______		SHEET 1	OF 1
TITLE Use of Mine Exh. Air as Heat Sink		BY MK	DATE 11-12-76

Assume maximum mine exh. air = 500,000 ¢

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 × 20 × 1.08 = 10,800,000 BTU

Sink required per ton of absorption refrigeration
= 12,000 + 18,000 = 30,000 BTU

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

Note: Total facility load approx. 800 - 900 tons

90029143

117-118

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
			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
			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
			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)	

Plus

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

121-122

90029146

ESTIMATE SHEET

MOORE & HARVEY, INC.
ENGINEERS - CONSTRUCTORS

Action By: GW | Date: 3-15-77

DESCRIPTION	MANHOURS	LABOR	MATERIAL	SUBCONTRACTS		TOTAL
ALTERNATE 1	6468	226 380	338 500	150 000		714 850
ALTERNATE 2	700	24 500	217 900	23 800		266 200
ALTERNATE 3	3324	116 340	320 860	36 500		473 700
NOTE: ABOVE ARE DIRECT COST NO MARKUP NO INDIRECTS						
TOTAL						

WASTE ISOLATION PILOT PLANT LOCATION

COST STUDY JOB NO. 3251.10 SHEET NO. 6 [illegible] ITEM NO. [illegible]

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90029147

ESTIMATE SHEET

HOLMES & NARVER INC.
ENGINEERS - CONSTRUCTORS

By: [illegible] Date: 3-15-77

Description	Quantity	Unit	Labor Unit	Labor Total	[illegible]	Labor Amount	Material Cost Unit	Material Amount	Cost Unit	[illegible]	Total
ALTERNATE I											
300 TON CHILLER	3	EA		300				111 000			
300 " COOLING TOWER	3	EA		~~0~~						17 500	
40HP CIRC PUMPS	6	EA		120				9000			
5000#/HR BOILER	2	EA		300				49 500			
CONVERTORS	3	EA		60				4500			
PIPE-VALVE FTGS. IN BUILDING	LS			1500				15 000			
DISTRIBUTION PIPE											
8" ϕ STL. PIPE INSULATED	3720	LF		2250				83 500			
6" ϕ "	1860	LF		750				37 500			
4" ϕ "	1860	LF		600				33 500			
TRENCH & BACKFILL 5'0" W x 3'0" D	2200	CY		—				—		19 500	
BUILDING PREFAB	2400	SF		—				—		29 000	
CONCRETE	150	CY		—				—		34 000	
ELECTRICAL	LS			—				—		50 000	
TEST & SUPV				588							
				6468	35	226 380		338 500		150 000	714 880

WASTE ISOLATION PILOT PLANT

COST STUDY JOB NO. 8251.10 SHEET NO. 01 ALT I

[illegible] ESTIMATE SHEET

HOLMES & NARVER, INC.
ENGINEERS - CONSTRUCTORS

ACTION	BY	DATE	CHECKED	DATE
PRICED	ORO ✓	3-15-77		

DESCRIPTION	QUANTITY	UNIT	LABOR UNIT	TOTAL HOURS	RATE/HR	LABOR AMOUNT	MATERIAL COST UNIT	MATERIAL AMOUNT	SUBCONTRACT COST UNIT	SUBCONTRACT AMOUNT	[illegible]
ALTERNATE II											
TRU BLDG.											
225 TON HEAT PUMPS	2	EA		160				87000		8 600	
" COOLING TWR	2										
25 HP PUMPS	4			64				4600			
HEAT EXCHANGER	1			16				1 000			
2 H BLDG											
150 TON HEAT PUMPS	2	EA		120				76 800		6 600	
" COOLING TOWERS	2										
15 HP PUMPS	4			60				3 800			
HEAT EXCHANGER	1			16				900			
ADM. BLDG											
45 TON RECIP HEAT PUMP	2	EA		100				40 000		4 600	
" COOLING TOWER	2										
10 HP PUMP	4			48				3 000			
HEAT EXCHANGER	1			16				800			
TEST / SUPV	4/3			100							
CONCRETE	13	CY		~~0~~						4 000	
				700	35	24 500		217 900		23 800	266 200

[illegible] WASTE ISOLATION PILOT PLANT

[illegible] COST STUDY JOB NO. 8251.10 SHEET NO. 01 PRINCIPAL SUB ACCT. NO. ALT. II

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90029149

ESTIMATE SHEET

HOLMES & NARVER, INC.
ENGINEERS - CONSTRUCTORS

3-15-76

DESCRIPTION	QUANTITY	UNIT	TOTAL MHRS	RATE	AMOUNT	[illegible] AMOUNT	[illegible] AMOUNT	TOTAL
<u>ALTERNATE III</u>								
300 TON COOLING TWR	3	EA	-0-				17 400	
50 HP PUMPS	3	↓	72			4 600		
10" Ø PIPE INSULATED	3 720	LF	2604			104 160		
TRENCH & BACKFILL	1800	CY					16 600	
<u>TRU BLDG</u>								
225 TON HEAT PUMPS	2	EA	160			87 000		
25 HP PUMPS	2	↓	32			2 300		
HEAT EXCHANGER	1	↓	16			1 000		
<u>RH BLDG</u>								
150 TON HEAT PUMP	2	EA	120			76 800		
15 HP PUMP	2	↓	30			1 900		
HEAT EXCHANGER	1	↓	16			900		
<u>ADM. BLDG</u>								
75 TON HEAT PUMP	2	EA	100			40 000		
10 HP PUMP	2	↓	24			1 500		
HEAT EXCHANGER	1	↓	16			700		
CONCRETE	11	CY	-0-				2 500	
TEST & SUPV	4/5		300					
			3324	35	116 540	320 860	36 500	473 900

RH Bldg.

RUN 1

Alt. 1 – Base System (no recovery – no evap. cool.)

energy use cool. = 914,499 KW = 3121 therms
(therms) heat. = 1336
4457 @1.1 = 4903

Install cost =

Alt. 2 – Base System (w/recovery)

energy use cool = 895,656 KW = 3057
heat = 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 – = 441
3199 = 3519

Install cost =

1.27

90029151

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

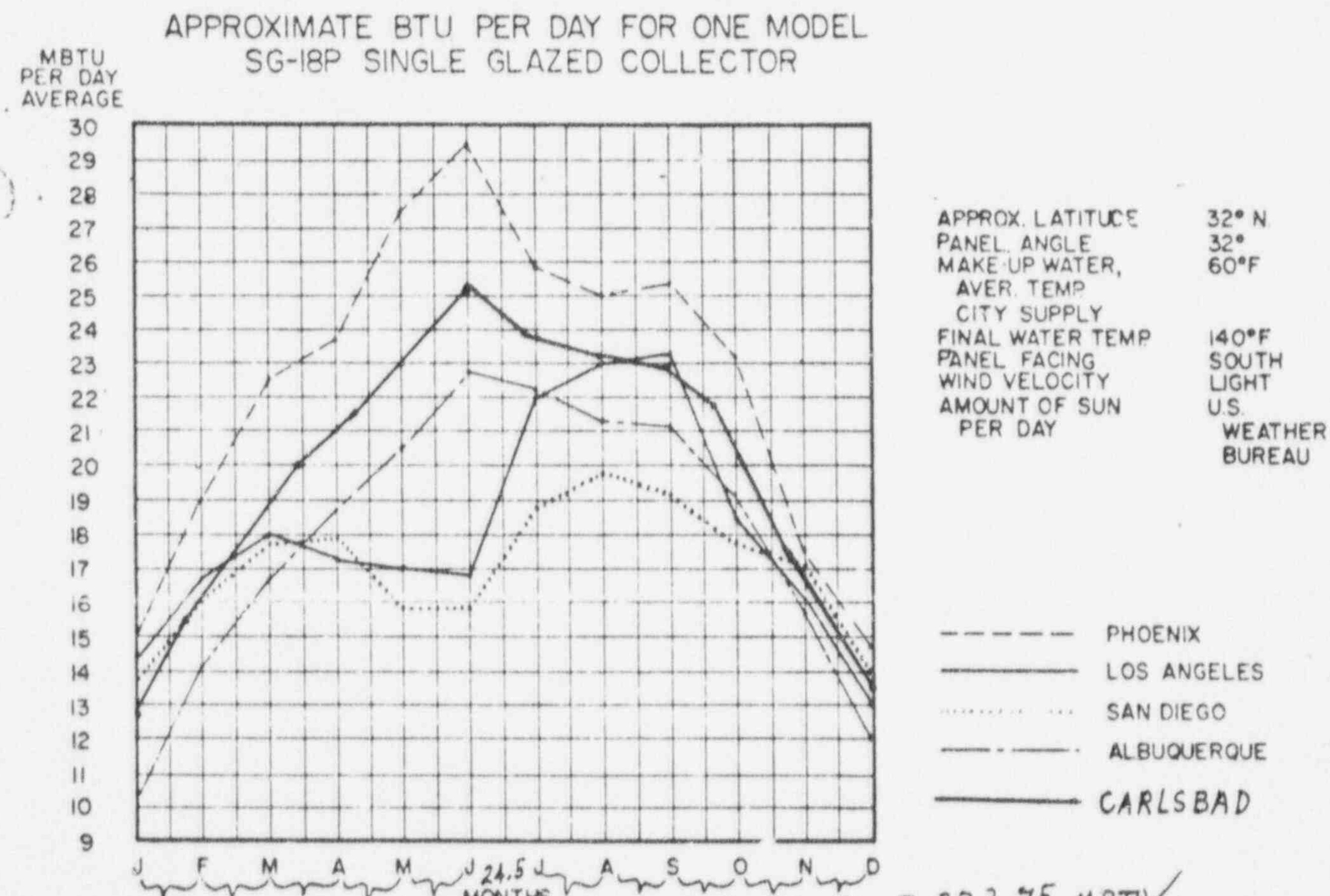
60 gal. X 8.33 wt. per gal. water=499.80 lbs.

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



14 17.5 20 22 24 24.5 23.5 23 21.75 18.5 15 = 223.75 MBTU/12 =

18.646 MBTU/day

=18,646 BTU/day

Double Glazing – [illegible]

Single Glazing – [illegible] storage tank)

3

= .000253/BTU (.795/KWH) = 6,805,790 BTU/yr. 128

90029152

5

Civil Calculations

POOR ORIGINAL

90029153

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:

	Gallons/Day/Person
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:

	Capacity Gallons
Fire System Make-Up*	135,000
Domestic Demand - 400 x 50	20,000
Process Demand	5,000
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

(34)

90029154

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

Average Demand = 400 people ($\frac{50 \text{ gpd}}{\text{person}}$) + 5000 gpd (Process)

= 20,000 gpd + 5000 gpd

Average Demand = 25,000 gpd

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

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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 DEMANDS BY ERQ DATE 2-22-77

No	BUILDING	PLUMBING FIXTURES						
		W.C	U.	LAV	SH.	D.F	J.S	F.WASH
5	MAN/MATERIALS	10	6	10	23	2	2	2
2	ADMINISTRATION	15	6	15			3	
10	TRU WASTE	5	3	5	8		1	
3	WAREHOUSE/SHOPS	6	3	6	2		1	
11	HOIST HOUSE	2		2				
4	VEHICLE MAINTENCE	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 × 10	= 400
URINAL	24 × 5	= 120
LAVATORY	40 × 2	= 80
SHOWER	40 × 4	= 160
DRINK FT.	10 × 1	= 10
JAN. SINK	8 × 3	= 24
FOOT WASH	2 × 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.

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TITLE WIPP - WATER DEMANDS

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 ____

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

JOB NO. 8251.00

SHEET 3 OF ____

TITLE WIPP - WATER DEMAND

BY ERQ DATE 2-22-77

WAREHOUSE & SHOPS

FIXTURE UNITS

WC - 6 × 10 = 60

U - 3 × 5 = 15

LAV - 6 × 2 = 12

SHOWER - 2 × 4 = 8

J. SINK 1 × 3 = 3

TOTAL = 98 FIXTURE UNITS

TOTAL DEMAND = 67 GPM PEAK

HOIST HOUSE

FIXTURE UNITS

WC - 2 × 10 = 20

LAV - 2 × 2 = 4

TOTAL = 24 FIXTURE UNITS

TOTAL DEMAND = 40 GPM PEAK.

VEHICLE MAINTENANCE

FIXTURE UNITS

WC - 1 × 10 = 10

U - 1 × 5 = 5

LAV - 1 × 2 = 2

TOTAL = 17 FIXTURE UNITS

TOTAL DEMAND = 33 GPM PEAK

GATE HOUSE

FIXTURE UNITS

WC - 1 × 10 = 10

LAV - 1 × 2 = 2

TOTAL = 12

TOTAL DEMAND 26 GPM PEAK

MINE FILTER

FIXTURE UNITS

WC - 1 × 10 = 10

LAV - 1 × 2 = 2

SHOWER 1 × 4 = 4

D.F 1 × 1 = 1

TOTAL = 17

TOTAL DEMAND = 35 GPM PEAK.

90029158

123

CHECKED ______ DATE ______

APPROVED ______ DATE ______

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

JOB No. 8251.00
SHEET 4 OF ______
BY ERQ DATE 2-22-77

TITLE WIPP - WATER DEMAND

EMERGENCY POWER

FIXTURE UNITS

WC - 1 x 10 = 10
LAV - 1 x 2 = 2
TOTAL = 12 F.U.

TOTAL DEMAND = 26 GPM PEAK

RAD. WASTE LAUNDRY

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 F.U.

TOTAL DEMAND = 33 GPM PEAK

R.H. WASTE

FIXTURE UNITS

WC. - 7 x 10 = 70
U. - 5 x 5 = 25
LAV. - 7 x 2 = 14
SHOWER - 5 x 4 = 20
D.F. - 2 x 1 = 2
J. SINK - 1 x 3 = 3
TOTAL = 134 F.U

TOTAL DEMAND = 76 GPM PEAK.

SUSPECT WATER POND

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

@ AVE. DEPTH USE 70' × 70'

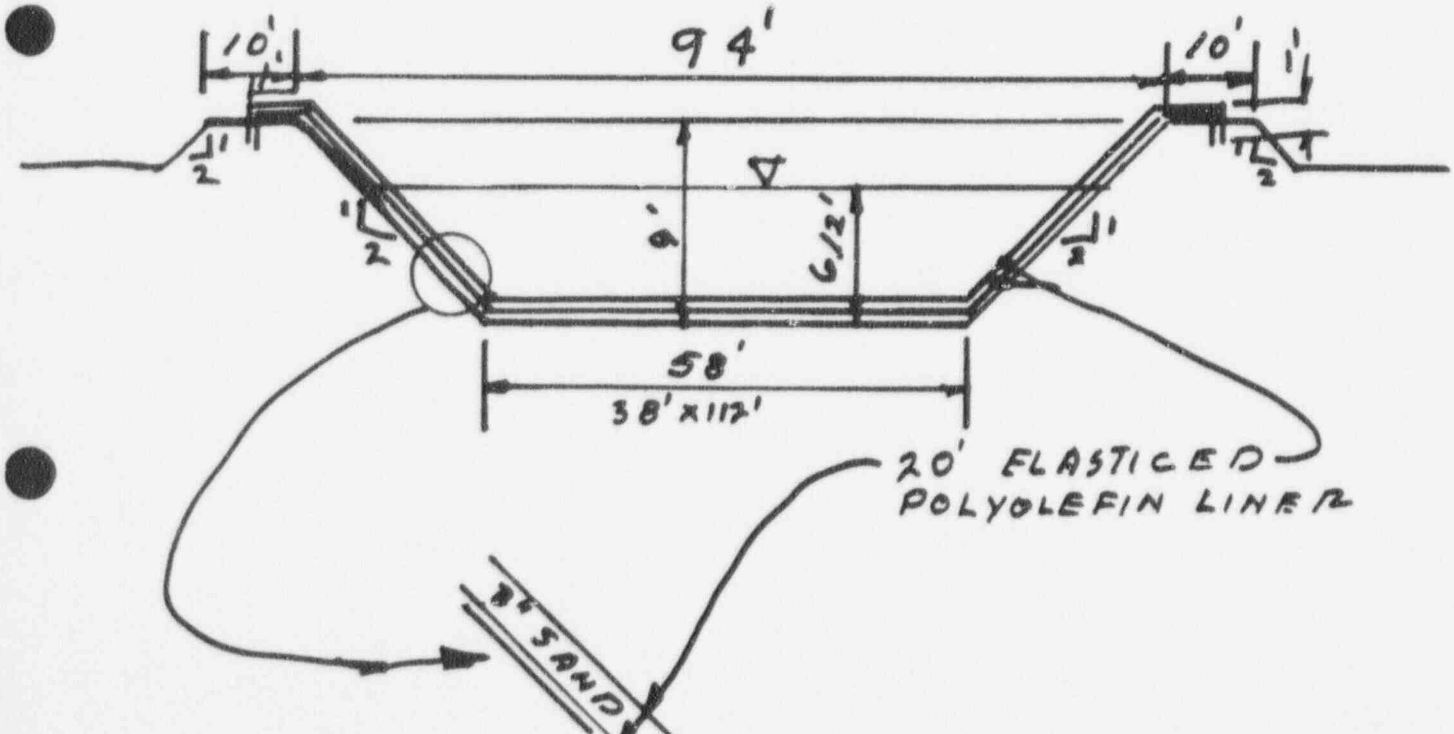
70×70 = 4900 SF

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

MAKE DEPTH 7'

SIDE SLOPES 2:1

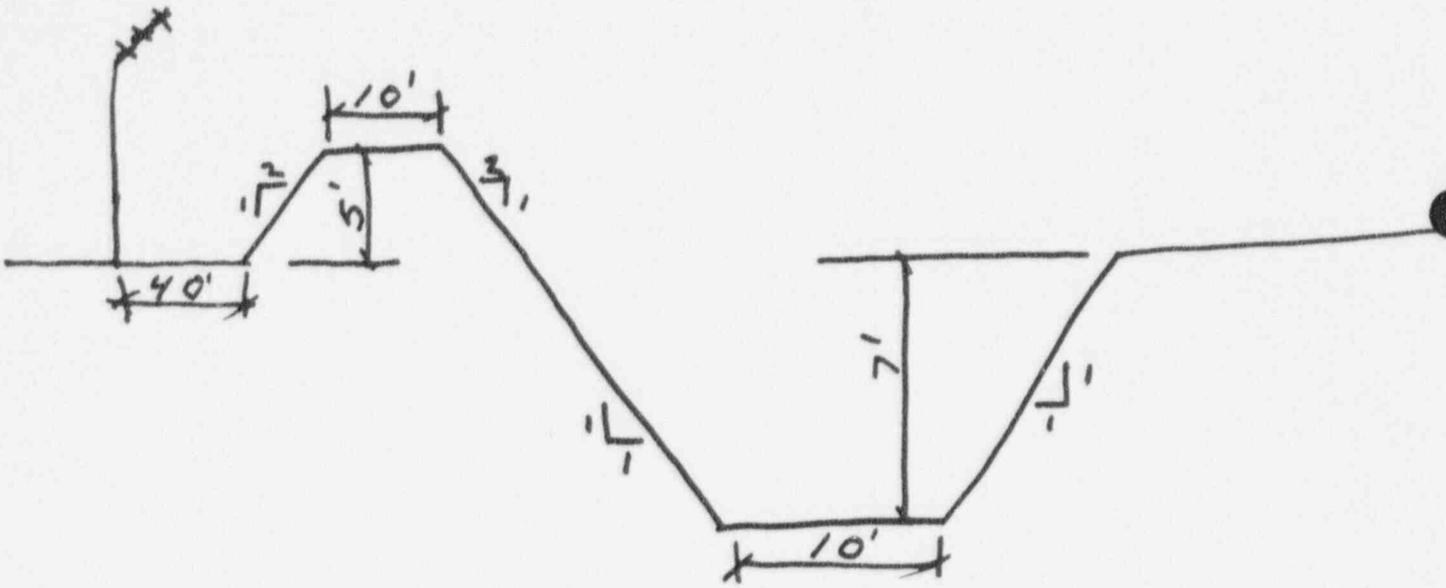
BOTTOM DIM 58' × 58'



90029160

135

INTERCEPTER DITCH
& BERM



C = 17×7 = 119 SF

F = 20×5 = 100 SF

= 100×119% = 119 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 x 14 = 6496
104 x 104 = 10816
4x128x2 = 1024
18336
1004
19340 SF 3110 LINER

137-138

90029162

Electrical Calculations

6

CHECKED ______ DATE ______

APPROVED ______ DATE ______

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

JOB NO. ______

SHEET ______ OF ______

TITLE REFERENCE ELECTRICAL LOAD CALCS

BY 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.

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

90029164

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<u>RH WASTE FACILITY</u>

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

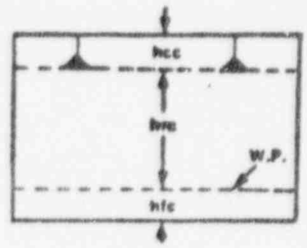
Company name and address .... H.L. BLDG ....

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



8

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

...... 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~~ .... 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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

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

1.

14

90029166

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

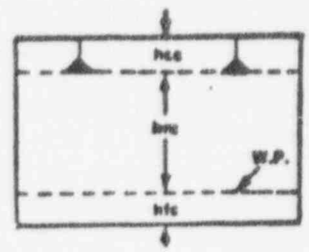
Company name and address .... H.L. BLDG ....

Area to be lighted .... Toilet #1 ....

Design level of illumination .... 10 F.C. .... (initial) (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE



14

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

.... Walls above luminaire plane

......50...... Walls between luminaire & work plane

.... Walls below work plane

......20...... Floor

Luminaire

Manufacturer ....

Catalog No. ......3100......

No. & Type lamps ......1 F40CW......

Lumens/Lamp ......3100......

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 = 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_{fc} = 20%) C.U. = .26

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

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

142

90029167

9002916б

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

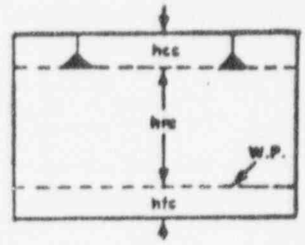
Company name and address ....H. L. BLDG..................

Area to be lighted ....Toilet #2..................

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

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

DESCRIPTION OF AREA AND LUMINAIRE



14

Dimensions

........14........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

................Walls above luminaire plane

........50........Walls between luminaire & work plane

................Walls below work plane

........20........Floor

Luminaire

Manufacturer ....

Catalog No. ......6100......

No. & Type lamps ......1-F40CW......

Lumens/~~Lamp~~ ......3100......

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 = 11 ; Ceiling Cavity Ratio = .4 ; Floor Cavity Ratio = 0
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} = 20
4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .26

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 160}{3100 \times .26 \times .75} = \frac{1600}{604.5} = 2.6 \quad - 3\ \text{ea}$$

3

143

90029168

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

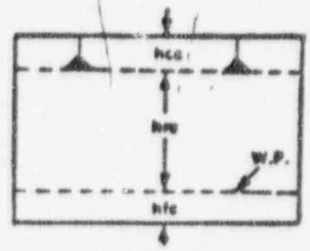
Company name and address .... H.L. BLDG ....

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



14

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

.... 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 - F40 CW ....

Lumens/~~Lamp~~ .... 6200 ....

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 = 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_{fc} = 20%) C.U. = .26

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

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

144

90029169

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

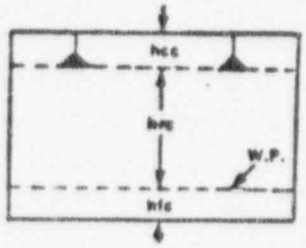
Company name and address .... H.L. BLDG ....

Area to be lighted .... OFFICE 4F5 ....

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

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

DESCRIPTION OF AREA AND LUMINAIRE



14

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

...... 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~~ ... 6200 ...

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 = 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_{fc} = 20%) C.U. = .26

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

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

145

90029170

5

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

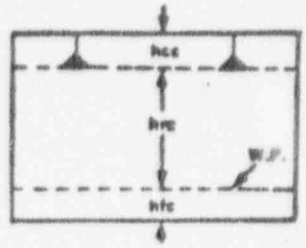
Company name and address .... H. L. BLDG ....

Area to be lighted .... OFFICE ACCESS CLOSET ....

Design level of illumination .... 10 F.C. .... (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 / Walls between luminaire & work plane / Walls below work plane
20	Floor

Luminaire

Manufacturer ....

Catalog No. ...... 7200 ......

No. & Type lamps .. 2 - F40 CW ......

Lumens/~~Lamp~~ ...... 6200 ......

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 = 5.5 ; 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

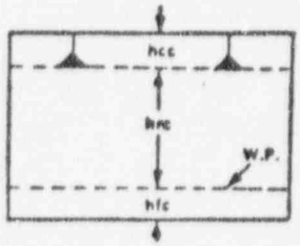
Company name and address .... H.L. BLDG ....

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



13

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

...... 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 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

NO OF FIXTURES = FOOT CANDLES X AREA / LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF

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

147

90029172

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 ....

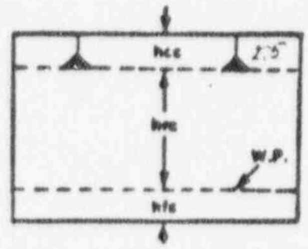
Area to be lighted .... SHIPPING & RECEIVING (DOCK) ....

Design level of illumination .... 20 FC .... (initial) (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions



65

.... 216 ...... Room Length

.... 36 ...... Room Width

.... 56.5 ...... 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 10 %

.... 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 ....

Lumens/Lamp .... 50000 ....

Light loss Factor (LLD x LDD) .... .9 x .9 = .81 ....

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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{20 \times 7776}{50000 \times .36 \times .81} = \frac{155520}{14580} = 10.6 \rightarrow 12$$

18' apart

2 rows of 6 ea 36' apart

148

90029173

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

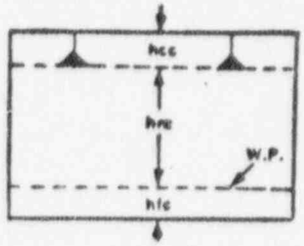
Company name and address .... H. L. BLDG ....

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



16

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 (LLD x LDD) .... .81 ....

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

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

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

149

9

90029174

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

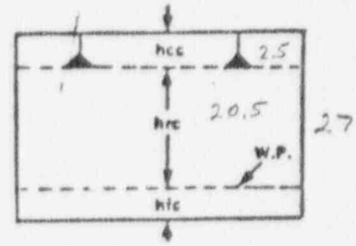
ompany name and address .... H.L. BLDG ....

Area to be lighted .... CASK 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

.... Walls above luminaire plane

...... 50 ...... Walls between luminaire & work plane

.... Walls below work plane

...... 20 ...... Floor

Luminaire

Manufacturer .... HOLO ....

Catalog No. .... * 1230 ....

No. & Type lamps .... 1: 100 W HPS ....

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 = 7.9 ; 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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

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

150

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

(See individual data sheets on luminaires for coefficients of utiliz...ion)

GENERAL INFORMATION

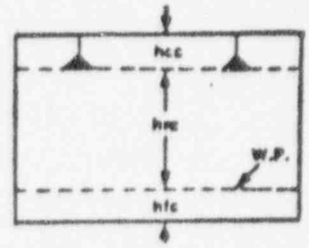
Company name and address .... H.L. BLDG ....

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



46

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 ....

Catalog No. ..... 1047 EG-PI-277 ....

No. & Type lamps . ONE 400 W HPS ....

Lumens/Lamp ..... 50,000 ....

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 = 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

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

$$= \frac{50 \times 5580}{50000 \times .81 \times .55} = 12.5$$

3 rows of 4 ea 20 center 22 center

151

11

90029176

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

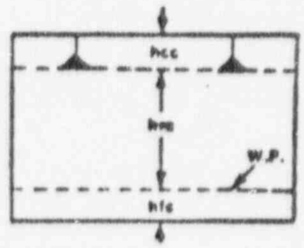
Company name and address .... H. L BLDG ....

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



40

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

.... Walls above luminaire plane

...... 50 ...... Walls between luminaire & work plane

.... Walls below work plane

...... 20 ...... Floor

Luminaire

Manufacturer .... HOLOPHANE ....

Catalog No. .... 10 47 - EG - P1 - 277 ....

No. & Type lamps .... ONE - 400 WATT HPS

Lumens/Lamp .... 50 000 ....

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 = 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

152

90029177

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

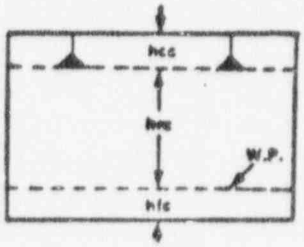
Company name and address .... H L BLDG ....

Area to be lighted .... STORAGE ROOM 2EA ....

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

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

DESCRIPTION OF AREA AND LUMINAIRE



16

Dimensions

.... 30 ..... Room Length

.... 16 ..... 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 .... 100W ....

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 = 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} = 18
4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = 54

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

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

153

90029178

19

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

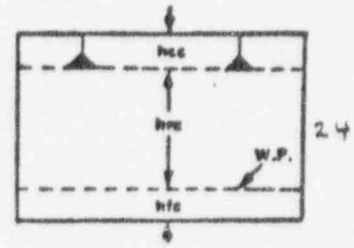
Company name and address .... H. L. BLDG ....

Area to be lighted .... EQUIP PASS THRU (-14' LEVEL) ....

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

.... 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 = 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

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

$$= \frac{10 \times 684}{9500 \times .44 \times .81} = \frac{6840}{3386} = 2.02$$

15#

90029179

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

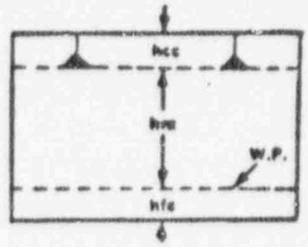
Company name and address .... H.L. BLDG ....

Area to be lighted .... MECH / ELEC +18' LEVEL ....

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

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

DESCRIPTION OF AREA AND LUMINAIRE



21

Dimensions

...... 73 ...... Room Length

...... 64 ...... 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 Factor (LLD x LDD) .... .81

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_{fc} = 20%) C.U. = .69

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

$$= \frac{20 \times 4672}{9500 \times .69 \times .81} = \frac{93440}{5309.5} \approx 17.6 - 18$$

155

15

90029180

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

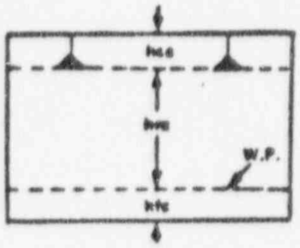
Company name and address .... H. L. BLDG ....

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



10

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

...... Walls above luminaire plane

...... 50 ...... Walls between luminaire & work plane

...... Walls below work plane

...... 20 ...... Floor

Luminaire

Manufacturer ....

Catalog No. .... 6100 ....

No. & Type lamps .... 1-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 = 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_{fc} = 20%) C.U. = .32

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

$$= \frac{10 \times 318}{3100 \times .32 \times .75} = \frac{3180}{744} = 4.3$$

156

90029181

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

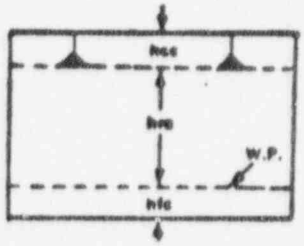
Company name and address............ H.L. BLDG. ....

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



10

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

..................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 F40 CW ....

Lumens/~~Lamp~~ .... 6200 ....

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 = 5.24 ; 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_{fc} = 20%) C.U. = .43

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 187}{6200 \times .43 \times .75} = \frac{13090}{1999.5} = 6.5 - 7$$

157

90029182

17

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

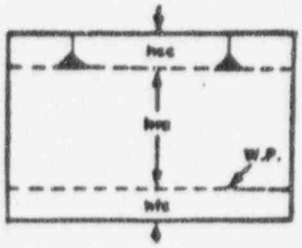
Company name and address.................. H. L. ALDE ....

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



10

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

...............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 F 40 CW ....

Lumens/~~Lamp~~ .... 6200 ....

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 = 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

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

$$= \frac{70 \times 270}{6200 \times .48 \times .75} = \frac{18900}{2232} = 8.46 - 9$$

158

90029183

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

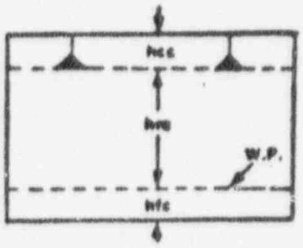
Company name and address .... H. L. BLDG ....

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

...... 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 - F40 CW ......

Lumens/~~Lamp~~ ...... 6200 ......

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 = 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_{fc} = 20%) C.U. = .43

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

$$= \frac{70 \times 200}{6200 \times .43 \times .75} = \frac{14000}{1999.5} = 7$$

90029184

159

19

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 ....

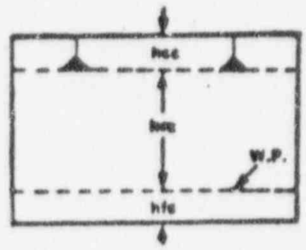
Area to be lighted .... CORRIDOR #2 ....

Design level of illumination .... 10 F.C. .... ~~(initial)~~ (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions



14

...... 19 ...... 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

...... Walls above luminaire plane

...... 50 ...... Walls between luminaire & work plane

...... Walls below work plane

...... 20 ...... Floor

Luminaire

Manufacturer ....

Catalog No. .... 6100 ....

No. & Type lamps .... 1-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 = 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_{fc} = 20%) C.U. = .25

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

$$= \frac{10 \times 95}{3100 \times .75 \times .25} = \frac{950}{581} \quad 1.6 - 2$$

160

90029185

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

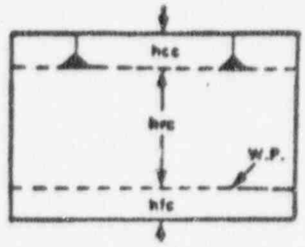
Company name and address .... H.L. BLDG ....

Area to be lighted .... CORRIDOR #3 ....

Design level of illumination .... 10 F.C. .... (initial) (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE



14

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

.... Walls above luminaire plane

.... 50 .... Walls between luminaire & work plane

.... Walls below work plane

...... 20 .... Floor

Luminaire

Manufacturer ....

Catalog No. .... 6100 ....

No. & Type lamps ... 1-F110 CW ....

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 = 15.7 ; 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_{fc} = 20%) C.U. = .25

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

$$= \frac{10 \times 90}{3100 \times .25 \times .75} = \frac{900}{581} \quad 1.5 - 2$$

161

90029186

21

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

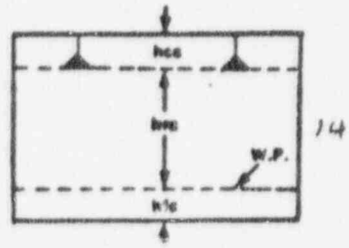
Company name and address .... H.L. BLDG ....

Area to be lighted .... CORRIDOR #4 ....

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 in %

....70...... Ceiling

.... Walls above luminaire plane

....50.... Walls between luminaire & work plane

.... Walls below work plane

....20...... Floor

Luminaire

Manufacturer ....

Catalog No. .... A100 ....

No. & Type lamps ..... 1-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 = 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

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

$$= \frac{10 \times 103 \times 5}{3100 \times .26 \times .75} = \frac{5150}{604.5} = 8.5 - 9 \text{ ea}$$

90029187

1A

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

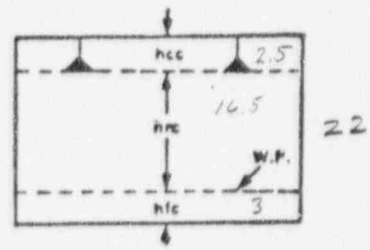
Company name and address .... H. L. BLDG ....

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

.... Walls above luminaire plane

.... 50 .... Walls between luminaire & work plane

.... Walls below work plane

.... 20 .... Floor

Luminaire

Manufacturer ....

Catalog No. .... 1930 ....

No. & Type lamps .... 1 - 100 W HPS ....

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 = 8.7 ; Ceiling Cavity Ratio = 1.3 ; Floor Cavity Ratio = 1.6

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

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

$$= \frac{20 \times 528}{9500 \times .43 \times .81} = \frac{10560}{3308.8} = 3$$

90029188

163

23

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

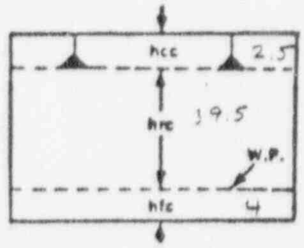
ompany name and address .... H.L BLDG ....

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 (LLD x LDD) .... .81 ....

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; $\rho_{cc} =$ 66
3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; $\rho_{fc} =$ 20
4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .55

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{50 \times 5580}{50000 \times .81 \times .55} = \frac{279,000}{22275} = 12.5$$

$20\frac{1}{3}$ center

3 rows of 4

$22\frac{1}{2}$ center

1A

90029189

TRU WASTE FACILITY

90029190

165-166

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

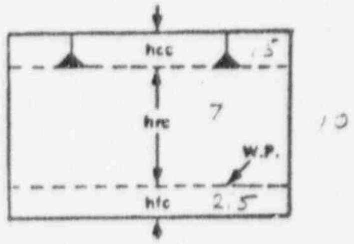
Company name and address .... L L BLDG ....

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

.... 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 (LLD x LDD) .... .75 ....

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 = [illegible]
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

NO OF FIXTURES = FOOT CANDLES X AREA / LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF

$$\frac{10 \times 44 \times 25}{6200 \times .61 \times .75} = \frac{11000}{2837} = 3.8$$

90029191

167

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

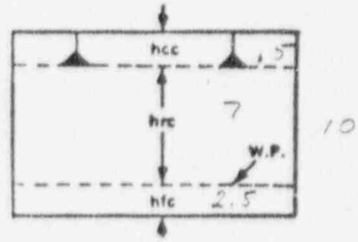
Company name and address .... L. L. BLDG ....

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

...... 16 ...... Room Width

.... 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

.... Walls above luminaire plane

.... 50 .... Walls between luminaire & work plane

.... Walls below work plane

.... 20 .... Floor

Luminaire

Manufacturer ....

Catalog No. .... 1102 ....

No. & Type lamps ... 2 - F40CW ....

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 = 3.6 ; 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

No of Fixtures = FOOT CANDLES X AREA / LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF

50 X 25 X 16 / 6200 X .45 X .75 = 20000 / 2093 = 9.5

168

90029192

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

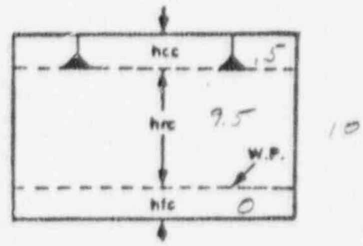
Company name and address .... L. L. BLDG ....

Area to be lighted .... P.V. - LOCKER - R.R AREA ....

Design level of illumination .... 10 F.C. .... ~~(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 (LLD x LDD) .... .75 ....

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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 90 \times 45}{6200 \times .75 \times .60} = \frac{40500}{2790} = 14.5$$

169

90029193

3

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

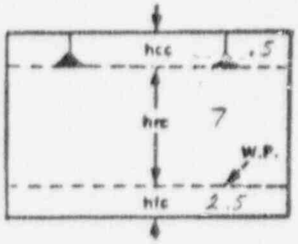
Company name and address .... L. L. BLDG ....

Area to be lighted .... LABORATORY ....

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

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

DESCRIPTION OF AREA AND LUMINAIRE



10

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

..... 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 (LLD x LDD) .... .75

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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 60 \times 22}{3100 \times 2 \times .60 \times .75} = \frac{92400}{2790} = 33$$

17

90029194

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

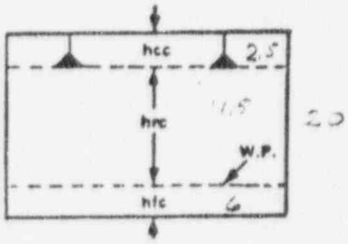
Company name and address .... L.L. BLDG ....

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

...... 84 ...... 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 10 %

...... 70 ...... Ceiling

.... Walls above luminaire plane

...... 50 ...... Walls between luminaire & work plane

.... Walls below work plane

.... 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 (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. = .74

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{30 \times 200 \times 84}{9500 \times .81 \times .74} = \frac{504000}{5694} = 88$$

171

90029195

6

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

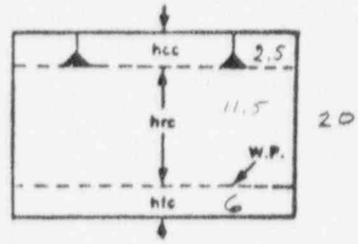
Company name and address........ L.L BLDG ....

Area to be lighted........ AIR LOCK #1 #2 ....

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

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

DESCRIPTION OF AREA AND LUMINAIRE



Dimensions

....120......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........100W........

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 = 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

$$\text{NO OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 20 \times 120}{9500 \times .53 \times .81} = \frac{24000}{4078} = 5.8 \rightarrow 6$$

× 2 AL 1 & 2 = 12 fix

20' centers

2/172

90029196

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

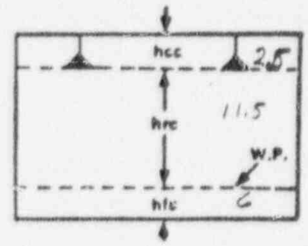
Company name and address .... L.L. BLDG ....

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



20

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 Factor (LLD x LDD) .... .81

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

$$\text{NO OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{10 \times 60 \times 20}{9500 \times .57 \times .81} = \frac{12000}{4386} = 2.7 \rightarrow 3 - 6 \text{ for } 2\ A/Ls$$

3 on 20' centers

173

90029197

7

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

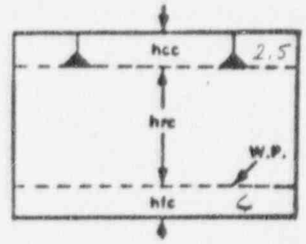
Company name and address .... L.L. BLDG ....

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 (LLD x LDD) .....81.....

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. = .56

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 36 \times 22}{9500 \times .56 \times .81} = \frac{7920}{4309} = 1.8 - 2 \text{ fix}$$

8 174

90029198

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

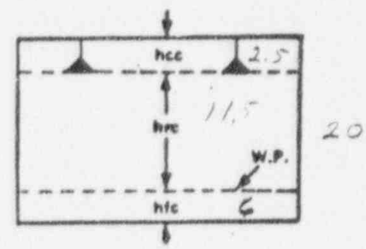
Company name and address .... L.L. BLDG ....

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 10 %

.... 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 = 7.6 ; Ceiling Cavity Ratio = 1.6 ; Floor Cavity Ratio = 3.9
2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; $\rho_{cc} =$ 39
3. Obtain effective floor cavity reflectance (ρ_{fc}) from Table B; $\rho_{fc} =$ 17
4. Find coefficient of utilization from published data (for $\rho_{fc} = 20\%$) C.U. = .44

NO. OF FIXTURES = FOOT CANDLES X AREA / (LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF)

$$\frac{10 \times 20 \times 12}{9500 \times .81 \times .44} = \frac{2400}{3385} = 1$$

90029199

175

9

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

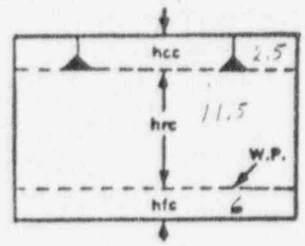
Company name and address .... L.L. BLDG ....

Area to be lighted .... SHAFT ROOM ....

Design level of illumination .... 50 .... ~~(initial)~~ (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE



20

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 %

[illegible]	Ceiling
	Walls above luminaire plane
50	Walls between luminaire & work plane
	Walls below work plane
[illegible]	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 = [illegible] ; 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_{fc} = 20%) C.U. = .64

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 60 \times 32}{9500 \times .64 \times .81} = \frac{[illegible]}{[illegible]} = 17.5$$

9002920096

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

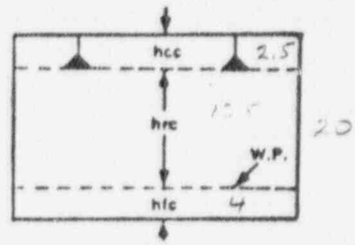
Company name and address .... L. L. BLDG ....

Area to be lighted .... OVER PACK AREA ....

Design level of illumination .... 50 F.C. .... (initial) (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE



Dimensions

...... 70 ...... Room Length

...... 40 ...... Room Width

...... 12.5 ...... 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 ....

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 = 2.65 ; 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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 70 \times 40}{9500 \times .64 \times .81} = \frac{140000}{4925} = 28$$

90029201

(7) 11

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

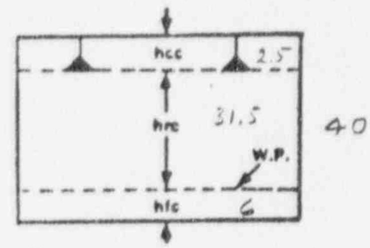
Company name and address .... L L BLDG ....

Area to be lighted .... DOCK 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

.... Walls above luminaire plane

.... 50 .... 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 Factor (LLD x LDD) .... .81 ....

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

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

$$= \frac{20 \times 300 \times 60}{16000 \times .7 \times .81} = \frac{360,000}{9072} = 40$$

12

178

90029202

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

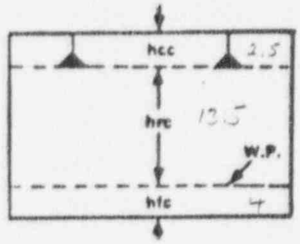
Company name and address .... L.L. BLDG ....

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

..... 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 = 2.6 ; 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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{20 \times 60 \times 45}{9500 \times .62 \times .81} = \frac{54000}{4771} = 11.3$$

90029203

179

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

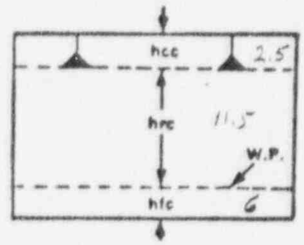
Company name and address .... L L BLDG ....

Area to be lighted .... MISC STORAGE #1 ....

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

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

DESCRIPTION OF AREA AND LUMINAIRE



20

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

.... 20 .... Floor

Luminaire

Manufacturer ....

Catalog No. .... 1930 ....

No. & Type lamps .... 100W ....

Lumens/Lamp .... 9500 ....

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 = .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

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

$$\frac{10 \times 90 \times 48}{9500 \times .66 \times .81} = \frac{43200}{5078} = 8.5$$

14
180

90029204

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

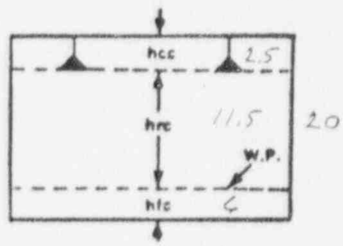
Company name and address ....

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

...... 52.5 ...... Walls between luminaire & work plane

.... Walls below work plane

...... 20 ...... Floor

Luminaire

Manufacturer ....

Catalog No. .... 1932 ....

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 = 1
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

NO. OF FIXTURES = FOOT CANDLES X AREA / LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF

$$\frac{10 \times 56 \times 56}{9500 \times .66 \times .81} = \frac{31360}{5078.7} = 6$$

181-182

90029205

5

ADMINISTRATION FACILITY

183-184

9002920 6

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

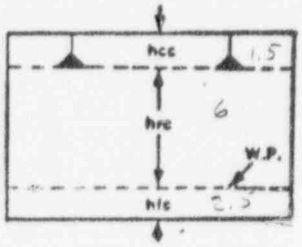
Company name and address .... AD BLDG ....

Area to be lighted .... 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

...... 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 = 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

$$\text{No. of Fixtures} = \frac{\text{Foot Candles} \times \text{Area}}{\text{Lamps/Fixture} \times \text{Lumens/Lamp} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 30 \times 18}{6200 \times .63 \times .75} = \frac{5400}{2929} = 2$$

90029207

185

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

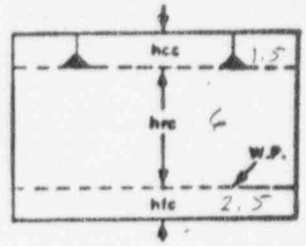
Company name and address .... AD BLDG ....

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

.... 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 ....75.... (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_{fc} = 20%) C.U. = .60

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

$$= \frac{70 \times 648}{6200 \times .60 \times .75} = \frac{45360}{2790} = 16$$

90029208

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

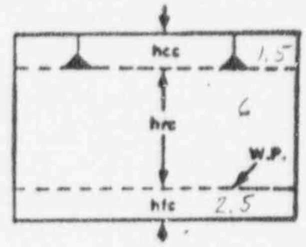
Company name and address.................. AD BLDG ....

Area to be lighted.................. W.I.P.P. OFFICE ....

Design level of illumination.............. 70 F.C. .... ~~(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

.... 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 .... .75 .... (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_{fc} = 20%) C.U. = .60

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 648}{6200 \times .60 \times .75} = \frac{45360}{2790} = 16$$

9002920

90029209

187

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

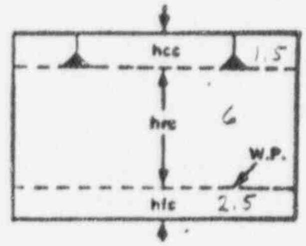
Company name and address .... AD BLDG ....

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



10

Dimensions

..... 24 ..... 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_{fc} = 20%) C.U. = .55

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

$$\frac{50 \times 12 \times 24}{6200 \times .55 \times .75} = \frac{14400}{2557} \quad 5.6$$

90029210

188

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

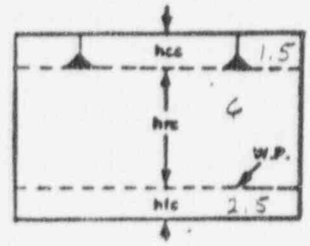
Company name and address .... AD BLDG ....

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



10

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 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_{cc}) from Table B; ρ_{cc} = 73
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. = .70

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

$$\frac{50 \times 1152}{6200 \times .70 \times .75} = \frac{57600}{3255} = 17.6$$

90029211

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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

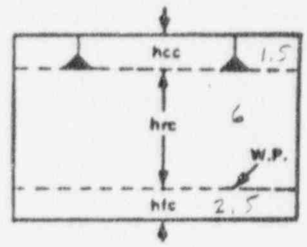
Company name and address .... AD BLDG.

Area to be lighted .... VIP SEATING

Design level of illumination .... 50 .... (~~initial~~) (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE



10

Dimensions

..... 12 ..... 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

.... 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 Factor (LLD x LDD) ..... .75 ....

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_{fc} = 20%) C.U. = .54

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

$$\frac{50 \times 12 \times 18}{6200 \times .54 \times .75} = \frac{10800}{2511} = 4.3$$

90029212

190

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

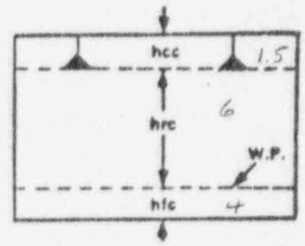
Company name and address .... A.D. BLDG ....

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

.... Walls above luminaire plane

...... 50 ...... Walls between luminaire & work plane

.... 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

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

$$\frac{70 \times 36 \times 18}{6200 \times .63 \times .75} = \frac{45360}{2929} = 15.5$$

90029213

191

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

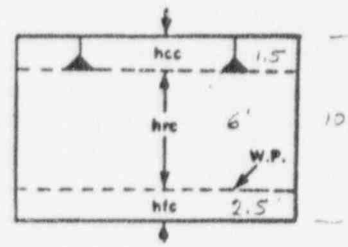
Company name and address .... ADMIN. BLDG ....

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

.... 72 .... 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 .... SMOOT HOLMAN ....

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 = 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

NO OF FIXTURES = FOOT CANDLES X AREA / LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF

= 50 X ([illegible]) / 2 X 3100 X .71 X .75 = 86400 / 3301 = 26

192

90029214

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

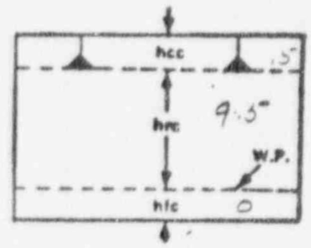
Company name and address .... AD BLDG ....

Area to be lighted .... CORRIDOR ....

Design level of illumination .... 10 F.C. ...... ~~(initial)~~ (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE



10

Dimensions

......108......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 .... HOLOPHANE ....

Catalog No. .... # 6100 ....

No. & Type lamps .... 1 - 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 = 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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 648}{3100 \times .31 \times .75} = \frac{6480}{721} = 8.9$$

193

90029215

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

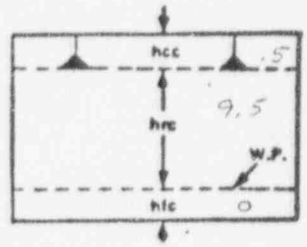
Company name and address .... A.P. BLDG ....

Area to be lighted .... 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

.... Walls above luminaire plane

..... 50 ..... Walls between luminaire & work plane

.... Walls below work plane

..... 20 ..... Floor

Luminaire

Manufacturer ....

Catalog No. ..... #6100 .....

No. & Type lamps ..... 1-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 = 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_{fc} = 20%) C.U. = .28

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

$$\frac{10 \times 360}{3100 \times .28 \times .75} = \frac{3600}{651} = 5.5$$

6 in part corridor

194

90029216

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

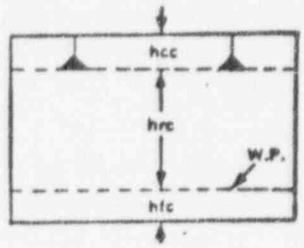
Company name and address .... AD BLDG ....

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

..... 8.5 ..... 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 Factor (LLD x LDD) .... .75 ....

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

$$\text{No. of Fixtures} = \frac{\text{Foot Candles} \times \text{Area}}{\text{Lamps/Fixture} \times \text{Lumens/Lamp} \times \text{CU} \times \text{LLF}}$$

$$\frac{10 \times 192 \times 6}{3100 \times .31 \times .75} = \frac{11520}{721} = 16$$

195

90029217

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

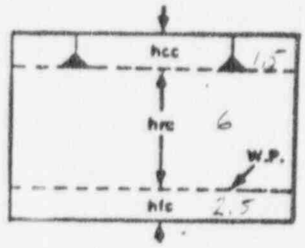
Company name and address .... AD BLDG ....

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

.... 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 = .8 ; Ceiling Cavity Ratio = .18 ; Floor Cavity Ratio = .3
2. Obtain effective ceiling cavity reflectances (ρ_{cc}) from Table B; ρ_{cc} = 77
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. = .80

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

$$\frac{50 \times 108 \times 60}{6200 \times .80 \times .75} = \frac{324000}{3720} = 87$$

90029218

196

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

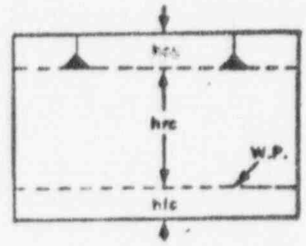
Company name and address .... A.D. BLDG ....

Area to be lighted .... SECURITY / 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)

...1.5... 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 = 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

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

$$\frac{70 \times 24 \times 48}{6200 \times 67 \times .75} = \frac{80640}{3116} = 26$$

197

90029219

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

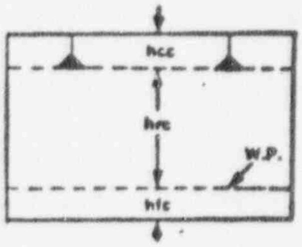
Company name and address .... AD BLDG ....

Area to be lighted .... INVENTORY & CONTROL ....

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

...... – ...... 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 = 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

$$\text{No. of Fixtures} = \frac{\text{Foot Candles} \times \text{Area}}{\text{Lamps/Fixture} \times \text{Lumens/Lamp} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 24 \times 48}{6200 \times .67 \times .75} = \frac{80640}{3116} = 26$$

198

90029219

90029220

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

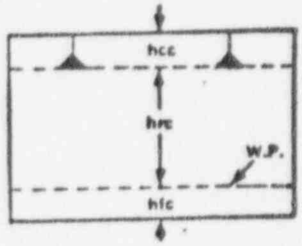
Company name and address........ AD BLDG ....

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

..............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 = 2.5 ; Ceiling Cavity Ratio = .6 ; Floor Cavity Ratio = 1.0
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} = 19
4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = .63

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

$$\frac{50 \times 24 \times 24}{6200 \times .63 \times .75} = \frac{28800}{2929} = 10$$

99

90029221

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

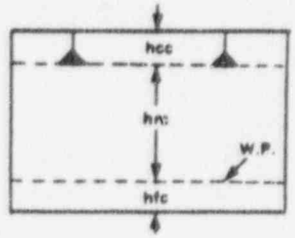
Company name and address .... AD BLDG ....

Area to be lighted .... M/HL 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

.... 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 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
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} = 19
4. Find coefficient of utilization from published data (for ρ_{fc} = 20%) C.U. = 63

$$\text{NO OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIX.} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{50 \times 24 \times 24}{6200 \times .63 \times .75} = \frac{28800}{2929} = 10$$

90029222 200

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

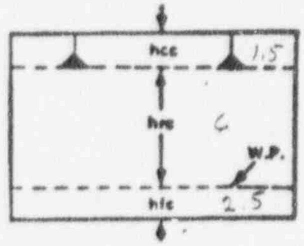
Company name and address .... A.D. BLDG ....

Area to be lighted .... 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

.... 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 = 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

$$\text{NO OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$\frac{70 \times 24 \times 48}{6200 \times .67 \times .75} = \frac{80640}{3116} = 26$$

201

90029223

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

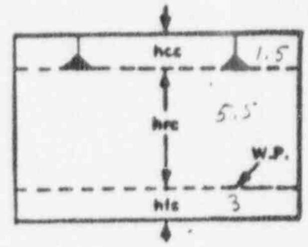
Company name and address.................. AD BLDG ....

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



10

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 Factor .... .75 ....
(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

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

$$\frac{100 \times 12 \times 22}{6200 \times .55 \times .75} = \frac{26400}{2557} = 10$$

90029224

203

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

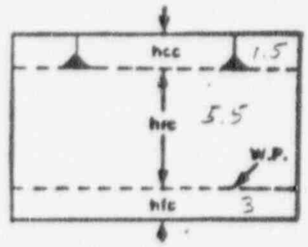
Company name and address .... AD. BLDG ....

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

.... 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) ..... .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_{fc} = 20%) C.U. = .63

$$\text{No. of Fixtures} = \frac{\text{Foot candles} \times \text{Area}}{\text{Lamps/Fixture} \times \text{Lumens/Lamp} \times CU \times LLF}$$

$$\frac{20 \times 24 \times 19}{6200 \times .63 \times .65} = \frac{9120}{2539} = 3.6 - 4$$

203

90029225

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

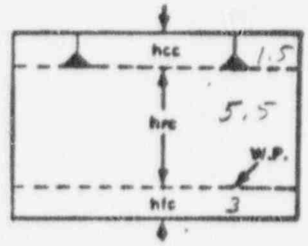
Company name and address .... AD BLDG ....

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 (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) .... .65 ....

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 = 0.6

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

$$\text{No. of Fixtures} = \frac{\text{Foot candles} \times \text{Area}}{\text{Lamps/Fixture} \times \text{Lumens/Lamp} \times \text{CU} \times \text{LLF}}$$

$$\frac{20 \times 42 \times 48}{6200 \times .76 \times .65} = \frac{40320}{3063} = 13$$

204

90029226

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

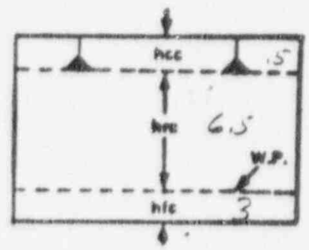
Company name and address .... A.D. BLDG ....

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



10

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 Factor (LLD x LDD) ...... .75 ......

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

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

$$\frac{20 \times 936}{6200 \times .67 \times 75} = \frac{18720}{3115} = 6$$

90029227

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

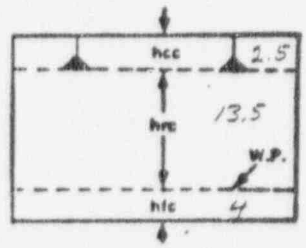
Company name and address .... AD BLDG ....

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



20'

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 Factor (LLD x LDD) .... .81 ....

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

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

$$\frac{20 \times 44 \times 76}{16000 \times .81 \times .62} = \frac{66880}{8035} = 8$$

90029228

207

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

Company name and address ....

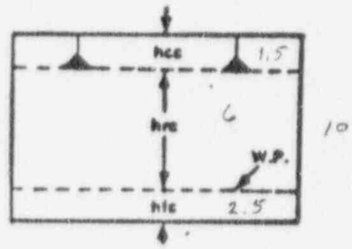
Area to be lighted .... Lab (Security bldg) ....

Design level of illumination .... 70 Fc .... ~~(initial)~~ (maintained)

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

DESCRIPTION OF AREA AND LUMINAIRE

Dimensions



...... 30 ...... Room Length

...... 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

.... 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 = 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_{fc} = 20%) C.U. = .64

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

$$\frac{70 \times 540}{6200 \times .64 \times .75} = \frac{37800}{2976} = 12.7$$

90029229

208

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

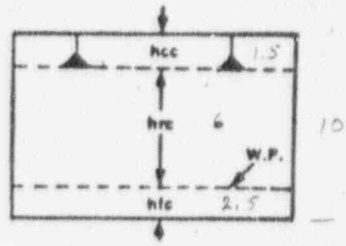
Company name and address .... Security BLDG ....

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

.... Walls above luminaire plane

...... 50 ...... Walls between luminaire & work plane

.... Walls below work plane

...... [illegible] ...... Floor

Luminaire

Manufacturer ...... SMOOT HOLMAN ......

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 = 1.5 ; 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

$$\text{NO. OF FIXTURES} = \frac{\text{FOOT CANDLES} \times \text{AREA}}{\text{LAMPS/FIXTURE} \times \text{LUMENS/LAMP} \times \text{CU} \times \text{LLF}}$$

$$= \frac{70 \times 59 \times 31}{6200 \times .71 \times .75} = \frac{128030}{3301} = 38.7$$

209

90029230

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

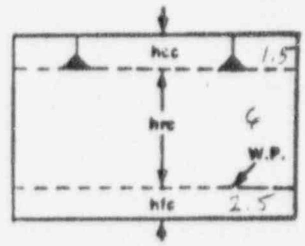
Company name and address .... Security BLDG ....

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 10 %

..... 80 ..... Ceiling

.... Walls above luminaire plane

..... 50 ..... Walls between luminaire & work plane

.... Walls below work plane

..... 20 ..... Floor

Luminaire

Manufacturer ..... S.H. .....

Catalog No. ..... GR-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 = 2.0 ; 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

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

$$= \frac{70 \times 32 \times 31}{6200 \times .75 \times .67} = \frac{69440}{3115} = 22$$

90029231

210

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

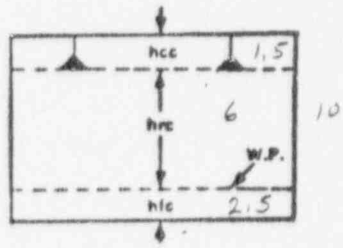
Company name and address .... Security BLD'G ....

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

.... 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 ...... .75 ......
(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

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

$$\frac{70 \times 74 \times 36}{6200 \times .73 \times .75} = \frac{186\,480}{3394} = 55$$

90029232

21-212

WAREHOUSE/SHOPS

213-214

90029233

ILLUMINATION CALCULATION SHEET

For Use with IES Zonal-Cavity Method

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

GENERAL INFORMATION

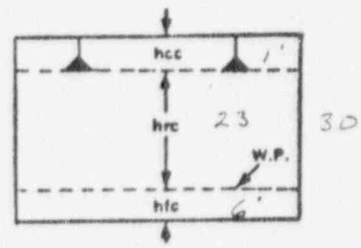
Company name and address ....

Area to be lighted .... WAREHOUSE ....

Design level of illumination .... 10 .... ~~(initial)~~ (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 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 = .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

No. of Fixtures = FOOT CANDLES X AREA / LAMPS/FIXTURE X LUMENS/LAMP X CU X LLF

= (10 x 270 x 75) / (16000 x .55 x .81) = 202500 / 7128 = 28

... 14 ...

90029234

25-26

TRU Waste Surface Facility Time and Motion Analysis

7

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.

217-218

ITEM 1

HOLMES & NARVER, INC.

400 EAST ORANGETHORPE AVENUE | ANAHEIM, CALIFORNIA 92801 | (714) 870-5700

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.

2/9

90029237

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 attachs.)

9002923B

220

WIPP PROJECT

TRU WASTE HANDLING FACILITY

MATERIAL HANDLING TIME

AND SEQUENCING ANALYSIS

AUGUST 20, 1976

HOLMES & NARVER, INC.

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 levelized 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:

a. Flatbed truck [1-ST (33-55D-P, 42-55D-UP)]

b. Flatcar [3-ST (99-55D-P, 126-55D-UP)]

c. ATMX [2-CC (86-55D-P, 120-55D-UP)]

d. 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	5.5	min
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	1	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	80	min
		116	min
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	1.5	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	1	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	10	min
	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:

3 ATMX (CC) = 276 X 3	=	828
1 ATMX (RF) = 229 X 1	=	229
		1,057 min

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:

2 ATMX (M3) = 376 X 2	=	752
1 ATMX (RF) = 229 X 1	=	229
		981

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
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	24	24	24	24	24	4
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 Reloaded)	(Not Re-loaded)	24	6
Remove vehicle lid	15	15			--	--
Reload container(s)	50	100			40	22
Replace vehicle lid and restraints	25	25			--	--
Move vehicle to hold yard	24	24			24	4
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 Flatcars (ST) = 180 X 3	=	540	6 hrs total 360 min
1 ATMX (RF) = 229 X 1	=	229	

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 Flatbed trucks (ST) = 8 X 58 = 464 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:

	% of cycle	% of time
ATMX (CC) shipment	58	
ATMX (RF) shipment	64	
ATMX (M3) shipment	70	
Truck (ST) shipment	66	
ATMX (CC) + ATMX (RF) worst day		68

	% of cycle	% of time
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:

	Min
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	15
	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:

	Remove	Replace
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 cylce times would be:

Unload	(Minutes) ATMX (CC)	(Minutes) ATMX (M3)	(Minutes) ATMX (RF)
Spot vehicle	6	6	6
Unload container	50	100	116
Move out vehicle	5	5	5
	61	111	127
Reload	61	111	0
Total cycle	122	222	127

Utilization factors would be:

	Station % Each		Cranes
	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

5

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.

14
20
280

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.

The large portion of the time that a door to the loading area must be unsealed appears to cast do[illegible] the acceptability of a facility concept witho[illegible]ir lock between the loading area and the contai[illegible] area.

It also is observed that with these large ut[illegible] factors for the doors, the doors could becom[illegible] 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 18 M3s and each ~~10~~ 12 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.)

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	Time (min)	Utilization %
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.

Three or 4 req'd? 4 UTILIZED 4/14/77 + start/stop time for vehicle in the lock

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.

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	24	24	24	24	24	4
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	24	24			24	4
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

TIME SUMMARY FOR VEHICLE UNLOADING/RELOADING

UTILIZING AIR LOCKS FOR BUILDING ACCESS

ASSUMING EMPTY CONTAINERS AVAILABLE FOR RETURN TO SENDER

Unload - Reload Cycle \ Vehicle/Container Combination	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	24	24	24	24	24	4
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. Without close wait, without lid station						
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. Without close wait, without lid station						
3 ATMX (CC) + ATMX (RF)	87	58	68			55
2 ATMX (M3) + ATMX (RF)			73			60
3 Flatcar (ST) + ATMX (RF)						
3. With close wait, with lid station (lid only)						
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. With close wait, with lid station (lid + bracing)						
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. Air lock lids (add for lids)						
3 ATMX (CC) + ATMX (RF)			6			
2 ATMX (M3) + ATMX (RF)			8			
6. Building air locks (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. Return of containers to sender on different vehicle plus addition for air locks (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. Building air locks with close wait, with lid station (lid and bracing)						
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	

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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.

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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

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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 ~~5T~~ 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	Vertical In	Vertical Out	Horizontal 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 space to stack the M3 lids when they

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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.

o 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.

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. The ramp for the ST will be about 10" high; for the CC about 6-1/2" high.

o 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.

o 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.

o 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.

o 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, if feasible, 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, or for availability of crane, if necessary (if ST, CC or uncontaminated M3)

h) Move ST, CC or uncontaminated M3s 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, Sample air at laydown, no wait for vehicle.	
1.1 Move ST-P from flatcar or truck to laydown and disengage sling	8
1.2 Sample air in ST	15

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			Min.
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	25	
		47	
1.4	Place ramp on floor		10
1.5	Remove 33 55Ds from ST (3 per lift) 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)		55
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		8
			200

2. Supertiger, Unprocessed Waste (ST-U), Flatcar or Truck

Sample air at laydown, no wait for vehicle.

		Min.
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.	65
		215

3. Supertiger, Processed Waste (ST-P), ST remains on Flatbed truck

		Min.
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). (ST must be shipped on shims to raise it off flatbed.)	47
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	

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		Min.
	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	10
		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.

		Min.
4.1	CC, unprocessed waste (CC-U), sample air at laydown, no wait for vehicle.	
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 55 Ds 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	8
		159
4.2	CC, processed waste (CC-P) sample air at laydown, no wait for vehicle	
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	8
		134

5. Mark 3 — Min.

Eight M3s are moved from an ATMX (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 ATMX 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.)

Total: 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.

Min.

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 ST-UP = 215 x 9 =	2130
24 RF (2 spaces) = 144 x 2 =	288
	2418 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.

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b. Since the RFs are received only once per week, the average day would require

9 ST-UP = 215 x 9 =	2130
24 RF = 144 x 2/5 =	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 RFs 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:

6CC-U = 159 x 6 =	954
24 RF (2 binloads) =	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 uhload station, decouple tractor.	6
c.	Unload ST	193
d.	Move truck out of unloading station through airlock	8
		213

8 x 213 = 1704 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.

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2.4 UNLOAD ATMX/M3

Basis and Assumptions

- Maximum of two ATMXs (20 M3s each) arrive per day.
- Each M3 contains 8 55Ds.
- On worst day an ATMX with 24 RFs will also arrive.
- Flow through (in one airlock, out the other) used for vehicles.
- 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.
- M3s are lifted 4 at a time from the ATMX and placed in position for unloading by a forklift.
- 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.
- 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.
- 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.
- 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.
- 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.)

	Min.
- 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	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 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

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- 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.
- 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.
- 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.
- 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.

	Min.
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.)	0
	6

- 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.)

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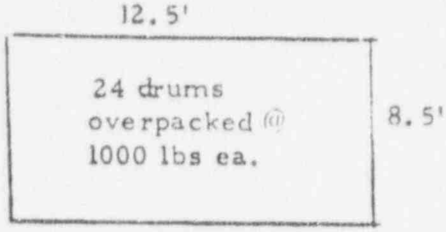
5.1 Calculation of Forklift size to handle loaded pallet.



Load	
drums	24,000
pallet	5,000
forks	1,000
	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

$$\frac{2,250,000}{(30 + 24)} = 42,000 \text{ lbs}$$

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)

Capacity	Dimensions (unloaded) Length	Width	Min. aisle for 90° stacking
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/	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"

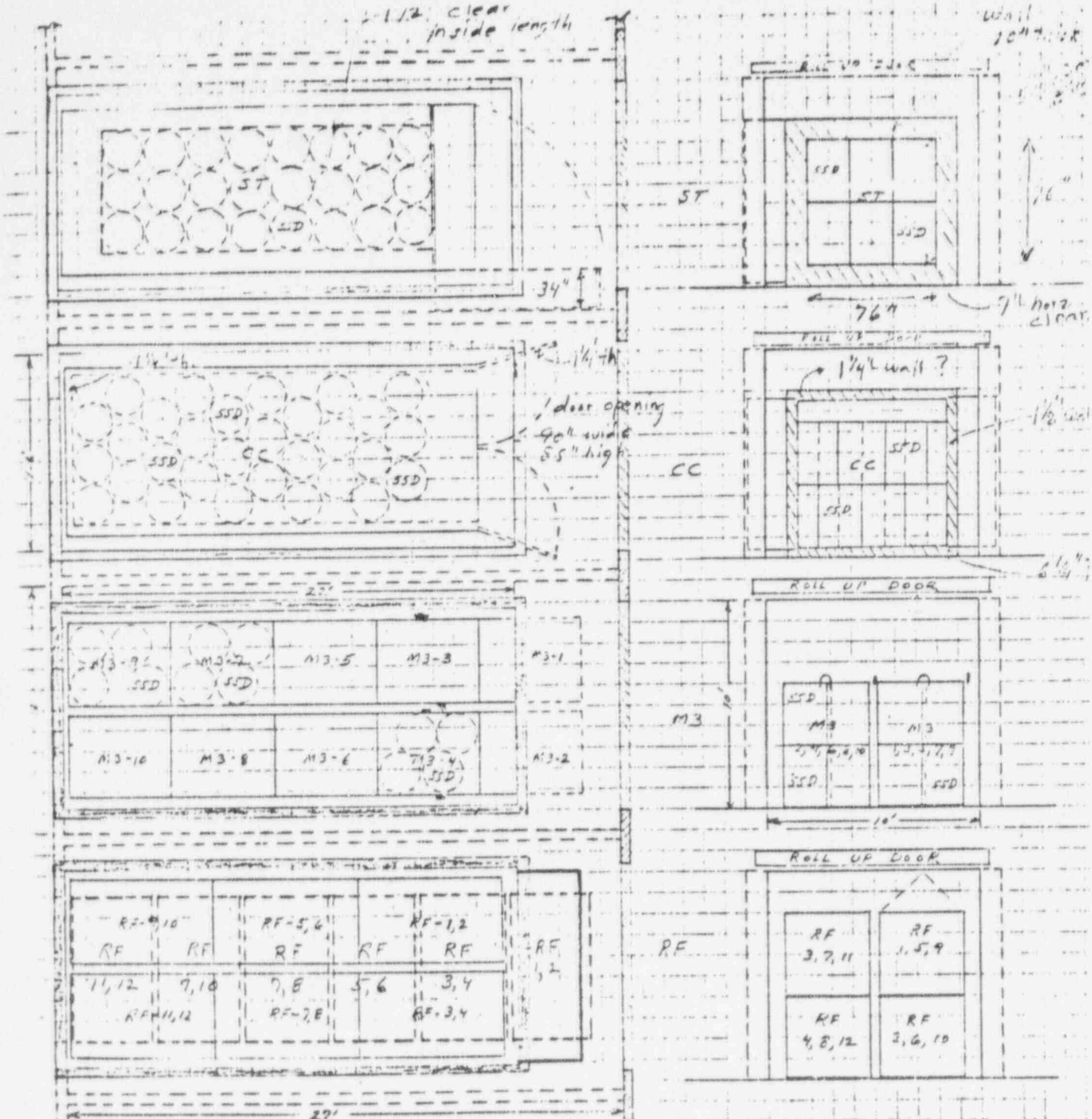
o Ten M3s in a bin is one-half an ATMX carload (This is desirable).

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 172" 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 sq ft

R251 WIPP PROJECT
ITEM ARRANGEMENT IN BINS AND CONTAINERS

55D Drum: 23" od. × 35 1/16" hi.

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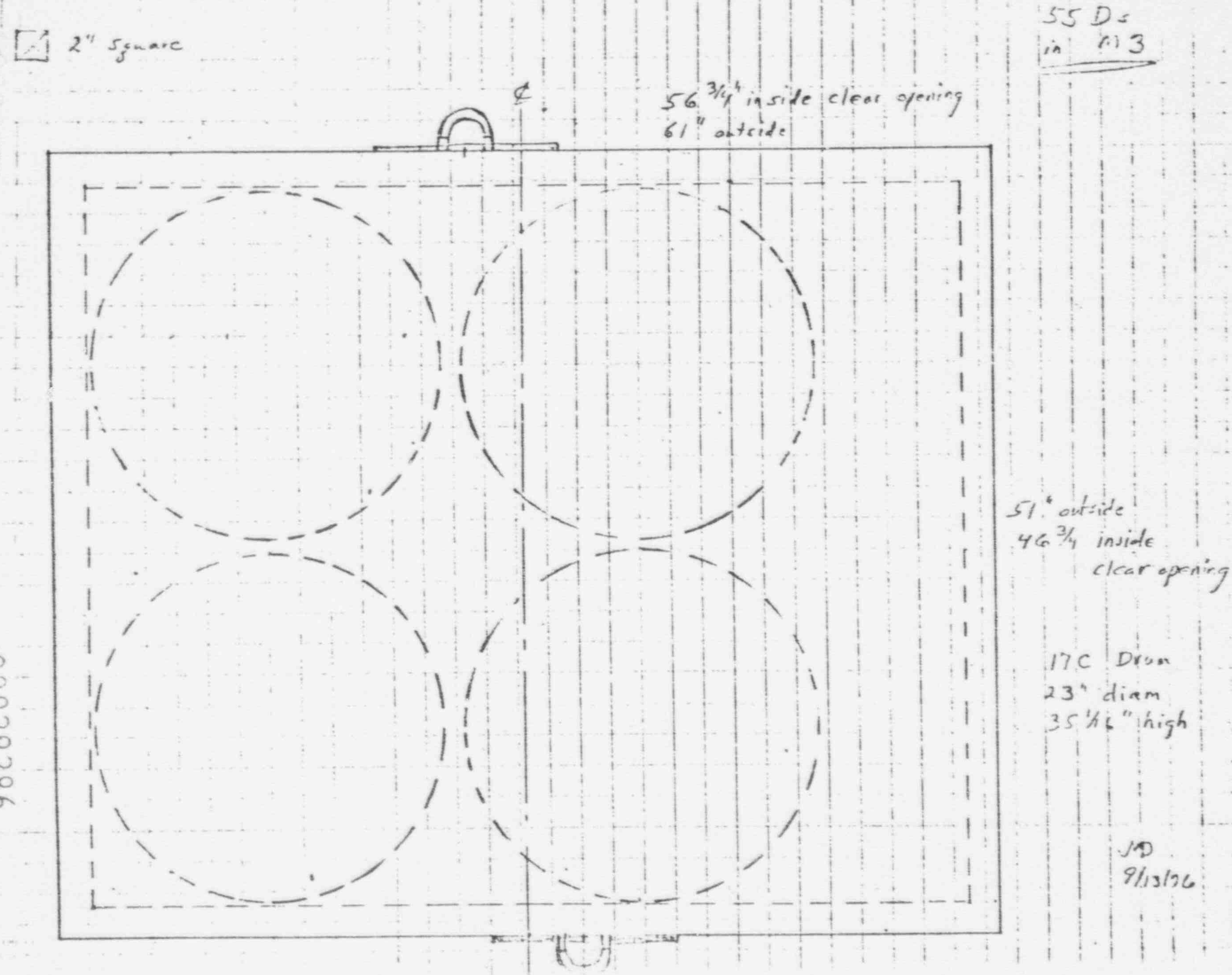
2" Square
55 Ds
in M3
¢
56 3/4" inside clear opening
61" outside
51" outside
46 3/4 inside
clear opening
17C Drum
23" diam
35 1/16" high
JMD
9/13/76

90029286

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.

- Above comments regarding unloading also apply to the CC.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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) (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)	44
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
	169

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2. Supertiger, Unprocessed Waste (ST-U), Flatcar or Truck, Bin Airlock, Sample air at laydown, wait for vehicle.

		Min.
1.1- 1.6	Time elements from moving the ST through 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- 1.13	Time elements from removing ramp through returning ST to vehicle are the same as Case 1.	70
		181

3. Supertiger, Processed Waste (ST-P), ST remains on Flatbed Truck, No airlock.

		Min.
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	15
		109

Shaft Sinking Procedures

8

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.

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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 slacking 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 compatiblity 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.

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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 Solado 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.

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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 [illegible], 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

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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 Solado 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

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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

Function	Time Allotted (Minutes)
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

Action Item	Elapsed Time Min.	Elapsed Time S
Signal, Hoist	0	05
Hoist Cage off Chairs	0	03
Signal, Stop	0	02
Release Chairs	0	05
Signal, Lower	0	05
Lower Cage to Station	4	36
Signal, Stop	0	02
Inspect Cage	2	04
Signal, Hoist	0	05
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	12 min.	

Load Cycles

Action Item	Elapsed Time Min.	Elapsed Time S
Open Cage Doors	0	15
Load Cage (incl. securing load)	8	03
Close Cage Doors	0	15
Signal, Hoist	0	05
Hoist Cage off Chairs	0	03
Signal, Stop	0	02
Release Chairs	0	05
Signal, Lower	0	05
Lower Cage to Station	4	36
Open Cage Doors	0	15
Unload Cage, Load Empty	8	03
Close Cage Doors	0	15
Signal, Hoist	0	05
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

FUNCTION	TIME ALLOTTED (MINUTES)
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.)..	350
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

Action Item	Elapsed Time Min.	Sec.
Signal Hoist	0 -	05
Hoist Cage off Chairs	0 -	03
Signal, Stop	0 -	02
Release Chairs	0 -	05
Signal, Lower	0 -	05
Lower Cage to Station	5 -	00
Signal, Stop	0 -	02
Lower Cage into Transfer Cell	0 -	33
Check Cage	1 -	00
Check Turntable Operation	1 -	00
Signal, Hoist	0 -	05
Hoist Cage	5 -	00
Hoist Cage into Clean Cell	0 -	33
Close Landing Chairs	0 -	15
Signal, Lower	0 -	05
Lower Cage onto Chairs	0 -	07

Total Elapsed Time 14 min.

Load Cycles

Action Item	Elapsed Time Min.	Sec.
Load Cage (incl. securing load)	0 -	30
Signal, Hoist	0 -	05
Hoist Cage off Chairs	0 -	03
Signal, Stop	0 -	02
Release Chairs	0 -	05
Signal, Lower	0 -	05
Lower Cage to Station	5 -	00
Signal, Stop	0 -	02
Signal, Lower	0 -	05
Lower Cage into Transfer Cell	0 -	30
Unload Cage in Transfer Cell	0 -	26
Load Empty Cart onto Cage	0 -	30
Signal, Hoist	0 -	05
Hoist Cage	5 -	00
Signal Stop	0 -	02
Signal, Hoist	0 -	05
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.

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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 premaintenance 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

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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 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

POOR ORIGINAL

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VENTILATION

BASIC GENERAL EQUATIONS: The following equations have been used in designing the underground ventilation systems for the conceptual design of WIPP.

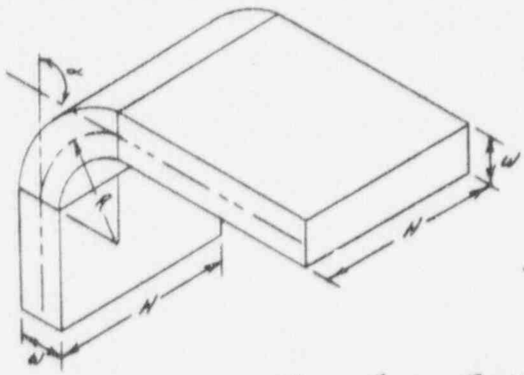
PRESSURE LOSS DUE TO FRICTION

$$H_f = \frac{\rho k P L V^2}{5.1918 \times 0.075 A} = \frac{\rho k P L V^2}{0.3893805 A}$$

PRESSURE LOSS DUE TO SHOCK

$$H_s = X(V_p) = \frac{X \rho V^2}{2 \times 32.174 \times 3600 \times 5.1918} = \frac{X \rho V^2}{1,202,695.00709} = 83.1466 \rho X V^2 \cdot 10^{-8}$$

SHOCK 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

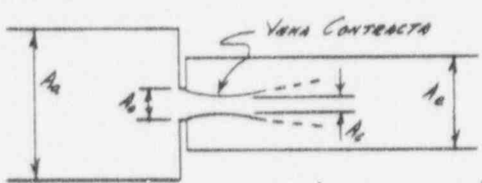
For a Normal Bend,

$$X_N = \frac{0.25}{r^2 a^{1/2}} \left(\frac{\alpha}{90}\right)^2$$

For a Square Bend,

$$X_S = \frac{0.60}{r a^{1/2}} \left(\frac{\alpha}{90}\right)^2 = 2.40 r X_N$$

SHOCK FACTORS FOR AREA CHANGES (change in the airflow velocity)



$\frac{A_c}{A_o} = C$ = coefficient of contraction

$\frac{A_o}{A_a} = N_c$ = ratio of contraction (areas)

$\frac{A_o}{A_e} = N_e$ = ratio of expansion (areas)

$$c = \left(\frac{1}{Z - Z N_c^2 + N_c^2}\right)^{1/2}$$ where Z is the contraction factor

$$X_c = \left(\frac{1}{c} - N_c\right)^2 \qquad X_e = \left(\frac{1 - c N_c}{c N_c}\right)^2 \qquad X_e = \left(\frac{1 - c N_e}{c N_e}\right)^2$$

SHOCK 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

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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 E.

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 $\frac{2-N}{N^3}$ 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 occupied 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

From $H_f = H_s$, $L_{eq} = \frac{5.1918 \times 0.075 \times AX}{2 \times 32.174 \times 3600 \times 5.1918 \times kP} = \frac{XA}{3{,}088{,}789\, kP} = \frac{32.3760\, AX}{kP \times 10^8}$

AIRFLOW LEAKAGE THROUGH STOPPINGS

$Q = m(\Delta H)^n A$ where m = 355.0 and n = 0.7 for Jute @ 14 sq per yd

0.05	1.0	w/1-inch of foam
0.10	0.8	w/⅛-inch of latex
0.05	1.0	Nylon, 20 mil thickness

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Use $Q = 0.05A\Delta H$ for both stoppings and ventilation overpasses.

Based upon the temperature logs run in the ERDA #9 Hole, the virgin rock temperature on the TRU 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 TRU 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 95°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 46.5° and 75.5° F. [illegible] on surface at

Temperature	Dry Air Density	Density @ Saturation	Absolute Humidity @ Saturation
0°F	$\frac{b}{396.52186}$	$\frac{b - 0.0192320584}{396.52186}$	$\frac{0.0233679416}{b - 0.0376}$
46.5°F	$\frac{b}{381.57356}$	$\frac{b - 0.1202692128}{381.57356}$	$\frac{0.1977307872}{b - 0.3180}$
61°F	$\frac{b}{392.50366}$	$\frac{b - 0.2093986939}{392.50366}$	$\frac{0.3363013066}{b - 0.5407}$
75.5°F	$\frac{b}{403.43376}$	$\frac{b - 0.3361530022}{403.43376}$	$\frac{0.5536469978}{b - 0.8898}$
110°F	$\frac{b}{429.43986}$	$\frac{b - 0.9783479039}{429.43986}$	$\frac{1.6176520961}{b - 2.596}$

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 $k = 20 \times 10^{-10}$ 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 TRU LEVEL; $k = 42.2120 \times 10^{-10}$ for $L = 2170$ feet

from $k \times 10^{-10} = \frac{20 \times 965}{2170} + \frac{60 \times 1205}{2170}$

SHAFT BETWEEN THE TRU AND RH LEVELS; $k = 60 \times 10^{-10}$ for $L = 570$ feet

SHAFT COLLAR; $X = 0.39$ and $L_{eq} = 149.95$ 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 $L_{eq} = 30,111.60$ feet for between the collar and TRU level and $X = 57 \times 0.3161 = 18.0177$ and $L_{eq} = 5590.36$ feet for between the TRU and RH levels at $Z = 5.00$

EACH SKIP; $X = 0.01312 + 0.04315 + 0.00387 = 0.0601$ and $L_{eq} = 26.52$ feet

CAGE MOVING UPWARD; $X = 0.39215 + 0.18837 + 0.20313 = 0.7836$ and $L_{eq} = 323.55$ feet

TRU SHAFT

Using a diameter of 17.5 feet and $k = 20 \times 10^{-10}$ 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; $k = 42.2120 \times 10^{-10}$ 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 $L_{eq} = 8096.04$ feet at $Z = 5.00$

CAGE MOVING DOWNWARD; $X = 1.69036 + 0.69965 + 1.33629 = 3.7263$ and $L_{eq} = 1250.38$ feet.

RH SHAFT

Using a diameter of 8 feet and $k = 20 \times 10^{-10}$ to a 985-foot depth, = 60×10^{-10} between the 985-foot and 2720-foot depths and = 20×10^{-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; $k = 45.1906 \times 10^{-10}$ for $L = 2755$ feet from $k \times 10^{-10} = \frac{20 \times 985}{2755} + \frac{60 \times 1735}{2755} + \frac{20 \times 35}{2755}$

CAGE MOVING DOWNWARD; X = 7.01781 + 31.32378 + 8.[illegible] = 47.7686 and L_{eq} = 6849.[illegible] feet

VENTILATION SHAFTS

Using a diameter of 14 feet and $k = 20 \times 10^{-10}$ to a 965-foot (960) depth and = 60×10^{-10} below the 965-foot (960) 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 TRU LEVEL; $k = 42.2120 \times 10^{-10}$ (42.2633) for $L = 2170$ (2165) feet

SHAFT BETWEEN THE TRU AND RH LEVELS; $k = 60 \times 10^{-10}$ for $L = 570$ feet

SHAFT DIVIDERS; X = 0.0329 per set and if assumed to be on 10-foot centers then X = 216 × 0.0329 = 7.1064 and L_{eq} = 1907.68 (1905.36) feet for between the collar and TRU level and X = 57 × 0.0329 = 1.8753 and L_{eq} = 354.17 feet for between the TRU and RH levels at Z = 5.00

EMERGENCY CAGE; X = 0.22939 + 0.21411 (0.21937) + 0.10374 = 0.5472 (0.5475) and L_{eq} = 146.9[illegible] (146.80) feet

CONSTRICTION VENT. COLLAR; $X = 0.25 + 0.0010 + (0.25 + 0.12375)\left(\frac{0.17^2}{7^2}\right)^2 = 0.3620$ and L_{eq} = 97.24 feet

TRU-RH VENT. COLLAR; $X = 0.60 + \frac{0.6764}{4} = 0.7692$ and L_{eq} = 288.52 feet

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TRU 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 dead-end 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

storage operations, use 36,000 cfm of fresh air per room and assume two rooms at a time require ventilation.

development operations, use 43,000 cfm of fresh air per room with the brattice curtain wall [illegible] 9'-6" from the left wall while cutting [illegible] and use 24,000 cfm of fresh air per entry with the brattice curtain wall [illegible] 7'-0" from the left wall. Assume that there can be two rooms being driven simultaneously.

For determining the quantities of airflow that are [illegible] circulated through openings and ventilation compressors, use $Q = 14.7962\sqrt{H}$ for those [illegible], $Q = 21.473505\sqrt{H}$ for those openings in rooms and $Q = 4?.?125\sqrt{H}$ for ventilation compressors.

Using an air temperature of 83.?°F at the TRU level, the dry air density will be 410.78331^{6} lbs/ft³, the density @ saturation will be $\frac{6-0.9617806879}{410.78331}$ lbs/ft³ and the absolute humidity @ saturation will be $\frac{0.7612193421}{6-1.223}$ lbs water vapor / lb of dry air.

Taking the barometric pressures at surface and the TRU level to be 26.35 and 28.59 inches of mercury respectively and a temperature change of 11.75°F between surface and the TRU level, then the natural ventilation pressure can be expected to range from about 4.?037 inches of water, in the winter [illegible] 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 $k = 25 \times 10^{-10}$, $\mathcal{R} = 1.50$ and Square Bends with $r = 0.5$, the shock factors and equivalent lengths for the various shock losses are as follows:

Entry Bends and Splits; $X = 2.13$ and $L_{eq} = 1066.00$ feet for $\alpha = 90°$

$X = 0.53$ and $L_{eq} = 266.72$ feet for $\alpha = 45°$

Entry Junctions; $X = 3.19$ and $L_{eq} = 1600.31$ feet for $\alpha = 90°$

$X = 0.80$ and $L_{eq} = 400.08$ feet for $\alpha = 45°$

Room Entrances; $X = \left\{0.75(0.0037) + 2.5956 + 0.42(0.1625)\right\}\left(\frac{719.9933}{429.9701}\right)^2 = \frac{(2.7666)}{7.7648}$ and $L_{eq} = \frac{(1382.01)}{6124.59}$ ft.

Room Exit when not joining; $X = \left\{0.0224 + 0.0280 + 2.5956 + 0.1322\right\}\left(\frac{719.9933}{429.9701}\right)^2 = \frac{(2.6282)}{7.3765}$ and $L_{eq} = \frac{(1407.86)}{5818.31}$ feet

Room Exit when joining; $X = \left\{0.0224 + 0.0280 + 1.5(2.5956) + 0.0322\right\}\left(\frac{719.9933}{429.9701}\right)^2 = \frac{(3.9110)}{10.9987}$ and $L_{eq} = \frac{(2089.67)}{8635.93}$ feet

Restricted Overpass; $X = \left\{0.0159 + 0.1107 + 0.1018\right\}\left(\frac{295.9240}{201.4998}\right)^2 = 0.4927$ and $L_{eq} = 246.81$ feet

Man & Materials Shaft Station; $X = \left\{0.60 + 0.0888\right\}\left(\frac{295.9240}{207.7378}\right)^2 = 1.3977$ and $L_{eq} = 700.15$ feet for $r = 1.0$

TRU Shaft Station; $X = 0.60$ and $L_{eq} = 333.95$ feet for $r = 1.0$ and using the shaft A and ?

Construction Vent Shaft and TRU-RH Vent Shaft Stations; $X = \left\{0.9318 + 0.90\right\} \times \left(\frac{295.9240}{153.9380}\right)^2 = 5.9216$ and $L_{eq} = 2965.38$ feet for $r = 1.0$ and a 14-foot shaft diameter.

The quantity of fresh air required on the TRU Level under what appears to be the worst condition will be 215,000 cfm plus the amount upcast through the TRU Shaft. If 9,500 cfm is taken as the airflow quantity upcast through the TRU Shaft, then the total quantity of fresh air required on the TRU Level will be 229,500 cfm and the efficiency factor thus resulting is $\frac{72{,}000 + 86{,}000 + 9500}{229{,}500} = 0.7461 = 74.6\%$

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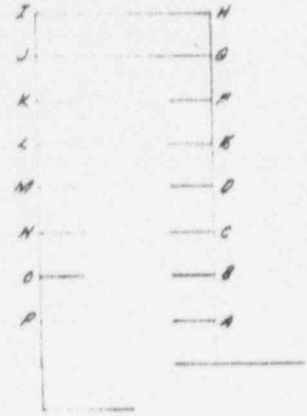
VENTILATION OF A PANEL DURING STORAGE OPERATIONS:



AB = BC = CD = DE = EF = FG = GH = IJ = JK = KL = LM = MN = NO = OP = 156.00 feet

GJ = HI = 511.50 feet

Using $k = 85 \times 10^{-10}$ and $\rho = 0.0690$ lbs/ft³,

$H_f = 0.727356 (L + L_{eq}) V^2 \times 10^{-10}$ for GJ and HI

$= 1.145291 (L + L_{eq}) V^2 \times 10^{-10}$ for all the other airways

At 36,333 cfm per room, $V^2 = 0.250352 \times 10^{6}$ fpm for GJ and HI

$= 1.979942 \times 10^{6}$ fpm for GH and IJ

$= 5.919767 \times 10^{6}$ fpm for FG and JK

$H_{f\,GHIJ} = 1.145291 (156.00 + 156.00) 1.979942 \times 10^{-6} + 0.727356 (6125 + 511.50 + 5818) 0.250352 \times 10^{-6}$

$= 0.000529 + 0.002268 = 0.002797$ inches of water

$H_{f\,GJ} = 0.727356 (6125 + 511.50 + 8636) 0.250352 \times 10^{-6} = 0.002781$ 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 though and then

$H_{f\,FGJK} = \frac{0.002797 + 0.002781}{2} + 1.145291 (156.00 + 156.00) 5.919767 \times 10^{-6}$

$= 0.002789 + 0.002115 = 0.004905$ 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 1000 cfm through an entry stopping, 1500 cfm through a room stopping

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and 3500 cfm through a ventilation overpass.

Based on the above discussion, $V^2 = 0.250352 \times 10^6$ fpm for HI and GJ

1.479942×10^6 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

6.947504×10^6 fpm for BC and NO

7.217286×10^6 fpm for AB and OP

7.492205×10^6 fpm for A and P.

Hence for a Panel during storage operations,

$$H = H_f = 1.145291(156.00 + 156.00)(1.479942 + 5.919767 + 6.168993 + 6.423358 + 6.682862 + 6.947504 + 7.217286) \times 10^{-6} + 1.145291(1067 + 156.00 + 156.00)\,7.492205 \times 10^{-6} + 0.727356(6125 + 511.50 + 5818)\,0.250352 \times 10^{-6}$$

$$= 0.014593 + 0.011833 + 0.002268 = 0.028694 \text{ inches of water}$$

315

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[illegible] OF A PANEL DURING CONSTRUCTION:

[illegible] the same conditions as for a Panel during Storage Operations except for the air[illegible] quantity that is required per room which is [illegible], then V^2 = 1.002469 × 10⁴ fpm for HI and GJ

2.111429 × 10⁴ fpm for GH and IJ

8.445717 × 10⁴ fpm for FG and JK

8.742904 × 10⁴ fpm for EF and KL

9.045230 × 10⁴ fpm for DE and LM

9.35[illegible]695 × 10⁴ fpm for CD and MN

9.665299 × 10⁴ fpm for BC and NO

9.983091 × 10⁴ fpm for AB and OP

10.305922 × 10⁴ fpm for -A and P-

In addition; H_f = 1.071005 ([illegible]) V^2 × 10^{-10} for GJ and HI

= 1.145291 ([illegible]) V^2 × 10^{-10} for all the other airways

[illegible] $H_{[illegible]}$ = 1.145291 (156.00 + 156.00) 2.11429 × 10^{-6} + 1.071005 (1482 + 511.50 + 1408) 1.002469 × 10^{-6}

= 0.[illegible] + 0.003652 = 0.[illegible] inches of water

H_{f_2} = 1.071005 (1482 + 511.50 + 2190) 1.002469 × 10^{-6} = 0.004388 inches of water

This difference of 0.[illegible] inches of water can be ignored for all practical purposes [illegible] a Panel during construction;

H_f = 1.145291 (156.00 + 156.00)(2.11429 + 8.445717 + 8.742904 + 9.045230 + 9.352695 + 9.665299 + 9.983091) × 10^{-6} + 1.145291 (1067 + 156.00 + 156.00) 10.305922 × 10^{-6} + 1.071005 (1482 + 511.50 + 1408) 1.002469 × 10^{-6}

= 0.020495 + 0.016077 + 0.003652 = 0.040421 inches of water

RH LEVEL

Use the same minimum airflow velocities and procedure for ventilating dead-end headings as on the TRU 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 29,000 cfm of fresh air per entry and/or room with the brattice 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 $Q = 21.473505\,\Delta H$ for the stoppings and $Q = 49.6175\,\Delta H$ for ventilation overpasses.

Using an air temperature of 87.75 °F on the RH Level; the dry air density will be $\frac{b}{412.66781}$ lbs/ft³, the density @ saturation will be $\frac{b - 0.5880270508}{412.66781}$ lbs/ft³ and the absolute humidity @ saturation will be $\frac{0.8299729992}{b - 1.3245}$ lbs water vapor/lb. of dry air. Taking the barometric pressure at surface and the RH Level to be 26.35 and 29.17 inches of mercury respectively and a temperature change of 19.80 °F between surface and the RH Level, then the natural ventilation pressure can be expected to vary from about 6.2056 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 $k = 25 \times 10^{-10}$, $Z = 150$ and Square Bends with $r = 0.5$, the shock factors and equivalent lengths for the various shock losses are as follows:

ENTRY BENDS AND SPLITS; $X = 2.13$ and $L_e = 1066.88$ feet for $\alpha = 90°$

$X = 0.53$ and $L_e = 266.72$ feet for $\alpha = 45°$

317 [illegible]

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ENTRY JUNCTIONS; X = 3.19 and L_q = 1600.31 feet for $\alpha = 90°$

X = 0.80 and L_q = 400.08 feet for $\alpha = 45°$

ROOM ENTRANCE; X = 2.13 and L_q = 1066.88 feet

ROOM EXIT when not joining; X = 2.13 and L_q = 1066.88 feet

ROOM EXIT when joining; X = 3.19 and L_q = 1600.31 feet

0.3732

CONSTRUCTION OVERCAST; $X = \{0.0159 + 0.1107 + 0.1018\}\left(\frac{295.9240}{201.9998}\right)^2 = 0.4927$ and L_q = 246.81 ft.

MAN & MATERIALS SHAFT STATION; $X = \{0.60 + 0.0888\}\left(\frac{295.9240}{207.7978}\right)^2 = 1.3977$ and L_q = 700.15 feet for r = 1.0

RH SHAFT STATION; $X = \{1.1497 + 0.60\}\left(\frac{295.9340}{60.26598}\right)^2 = 22.5182$ and L_q = 3226.56 feet for r = 1.0 and a diameter of 8 feet for the RH shaft.

CONSTRUCTION VENT SHAFT AND TRU-RH VENT SHAFT STATIONS; $X = \{0.9318 +$ [illegible]$\}\left(\frac{295.9240}{153.9380}\right)^2 = 3.8130$ and L_q = 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 one of 24,000 cfm for construction [illegible] in the [illegible] area, will be 200,500 cfm under [illegible]. This value of 200,500 cfm allows for [illegible] of 26,000 cfm [illegible]. The efficiency [illegible] thus resulting is $\frac{30,000 + 72,000 + 26,000}{200,500} = 0.6085 = 60.8\%$

VENTILATION OF A PANEL DURING STORAGE OPERATIONS:

AB = BC = CD = DE = EF = FG = GH = IJ = JK = KL = LM = MN = NO = OP = 115 ft.

HI = 598 feet

Using $k = 25 \times 10^{-10}$ and $\rho = 0.0701$ lbs/ft^3

$H_f = 1.163550 (L + L_{eq}) V^2 \times 10^{-10}$ for all the airways

At 15,000 cfm per room, $V^2 = 0.256939 \times 10^{4}$ fpm for HI and taking the quantity of airflow leakage through a stopping to be 1000 cfm, then $V^2 =$ 0.223818 $\times 10^4$ fpm for GH

0.256939 $\times 10^4$ fpm for FG and HI

0.292339 $\times 10^4$ fpm for EF

0.330018 $\times 10^4$ fpm for DE and IJ

0.369985 $\times 10^4$ fpm for CD and JK

0.412237 $\times 10^4$ fpm for BC and KL

0.456772 $\times 10^4$ fpm for AB and LM

0.503591 $\times 10^4$ fpm for -A and MN

0.552694 $\times 10^4$ fpm for NO

0.604081 $\times 10^4$ fpm for OP

0.657752 $\times 10^4$ fpm for P-

[illegible] so for a panel [illegible] [illegible] operations,

$H_{f} = 1.163550 (115) (0.223818 + 0.256939 + 0.292339 + 0.503591 + 0.552694 + 0.609081 + 0.657752) \times 10^{-6} + 1.163550 (115) 2 (0.330018 + 0.369985 + 0.412237 + 0.456772) \times 10^{-6} + 1.163550 (1067 + 115) 0.503591 \times 10^{-6} + 1.163550 (1067 + 598 + 1000) 0.256939 \times 10^{-6}$

$= 0.000414 + 0.000420 + 0.000693 + 0.000975 = 0.002502$ inches of water

Ventilation of a Panel During Construction

AB = BC = CD = DE = EF = FG = GH = IJ = JK = KL = LM = MN = NO = OP = 115 ft

[illegible] = [illegible] = 500 feet

Using $k = 25 \times 10^{-10}$ and $\rho = 0.0701$ lb/ft³

$H_L = 1.163550\,(L + L_{eq})\,V^2 \times 10^{-10}$ for all the airways

At [illegible] cfm per room, $V^2 = 0.657752 \times 10^4$ fpm for GJ and HI

and [illegible] the quantity of airflow leakage through a [illegible] then

$V^2 = 3.509081 \times 10^4$ fpm for IJ

[illegible] $\times 10^4$ fpm for GJ and HI

[illegible] $\times 10^4$ fpm for GH

[illegible] $\times 10^4$ fpm for JK

2.631005 $\times 10^4$ fpm for KL

[illegible]1775 $\times 10^4$ fpm for FG and LM

[illegible] $\times 10^4$ fpm for EF and MN

5.970161 $\times 10^4$ fpm for DE and NO

3.067780 $\times 10^4$ fpm for CD and OP

3.107382 $\times 10^4$ fpm for BC and [illegible]

3.329869 $\times 10^4$ fpm for AB

3.454339 $\times 10^4$ fpm for [illegible]

[illegible] H_L = [illegible] (1067 + 594 + [illegible]) [illegible] $\times 10^{-6}$ = 0.002496 inches of water

$H_{[illegible]}$ = [illegible] (1067 + 594) 0.657752 $\times 10^{-6}$ +

[illegible] (1067 + 115) [illegible] $\times 10^{-6}$

= [illegible] + [illegible] + [illegible] = [illegible] inches of water

[illegible] 0.00[illegible] inches of water can be ignored for all practical [illegible]

[illegible]

[illegible] H_L = [illegible] ([illegible] + 115) [illegible] $\times 10^{-6}$ + [illegible] (115) ([illegible] +

$2.631008 + 3.207682 + 3.329869) \times 10^{-6} + 1.163550(115)2(2.741775 +$

$2.859826 + 2.970161 + 3.087780) \times 10^{-6} + 1.163550(115 + 1600) \times$

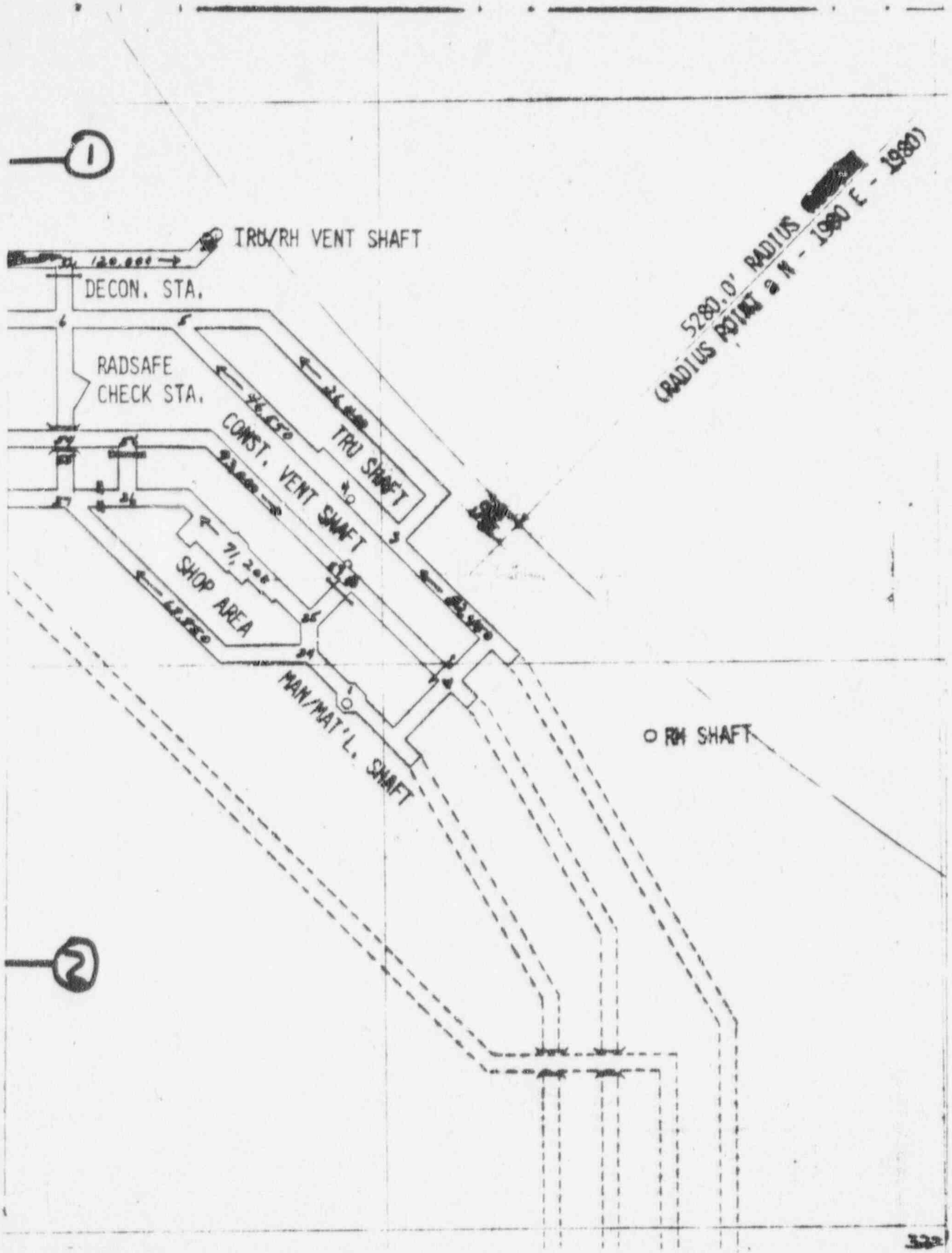
$3.207682 \times 10^{-6} + 1.163550(1067 + 115)3.454339 \times 10^{-6}$

000462

$= 0.002496 + 0.001564 + 0.003119 + 0.006401 + 0.004751$

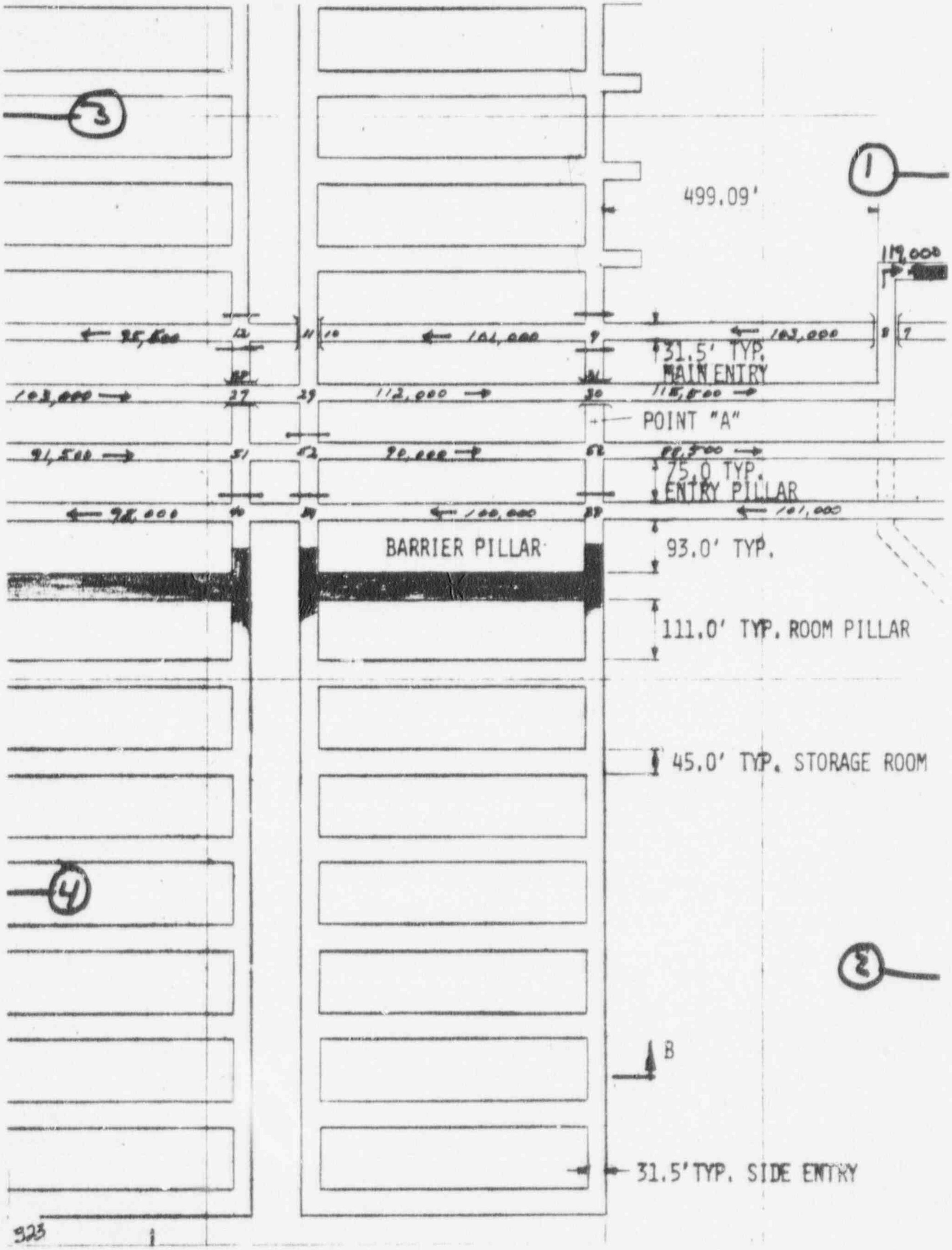
.014042

$= 0.018331$ inches of water



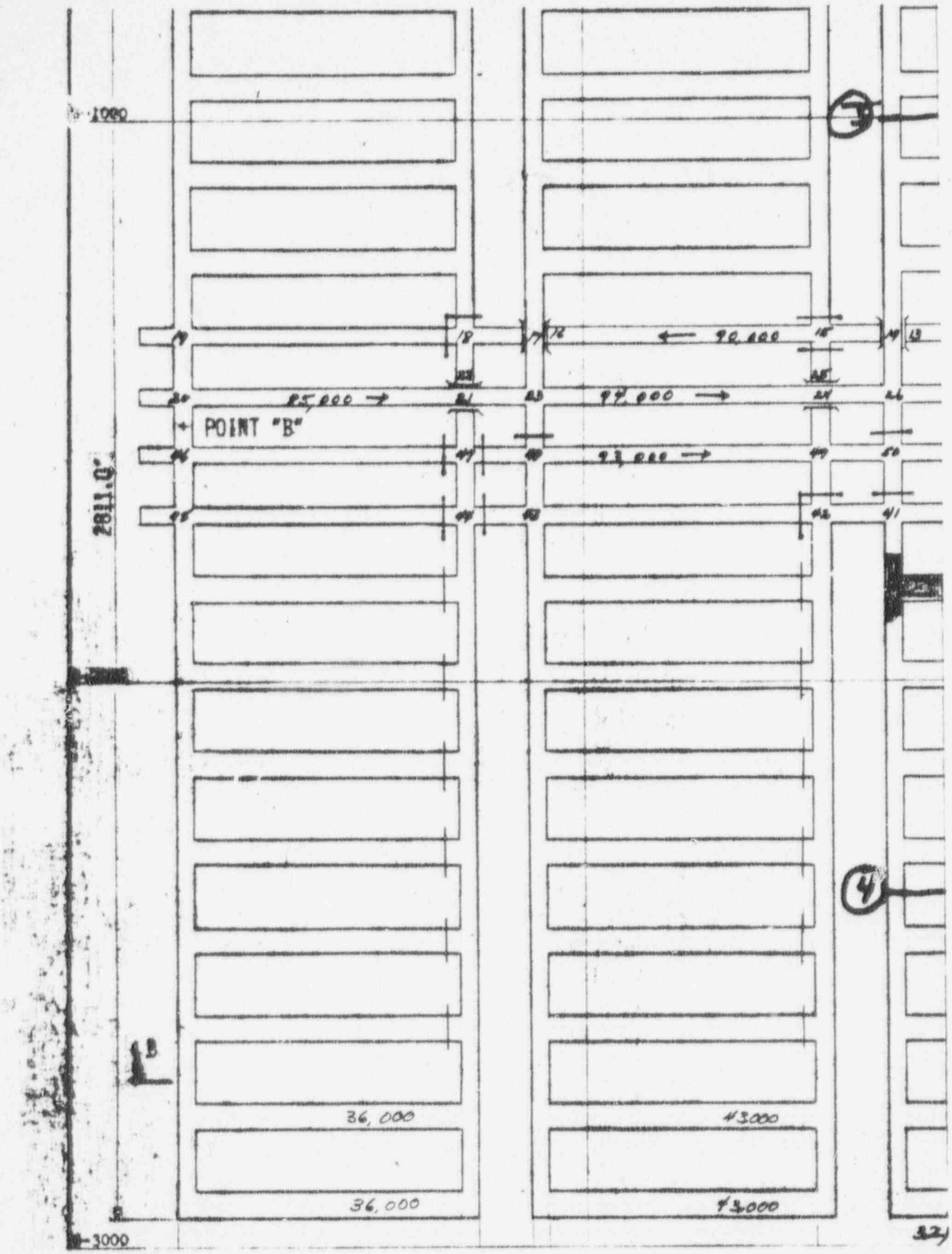
TRU/RH VENT SHAFT
120,000
DECON. STA.
RADSAFE
CHECK STA.
TRU SHAFT
CONST. VENT SHAFT
71,200
SHOP AREA
MAN/MAT'L. SHAFT
RH SHAFT
5280.0' RADIUS [redacted]
(RADIUS POINT @ N - 1980 E - 1980)

90029339

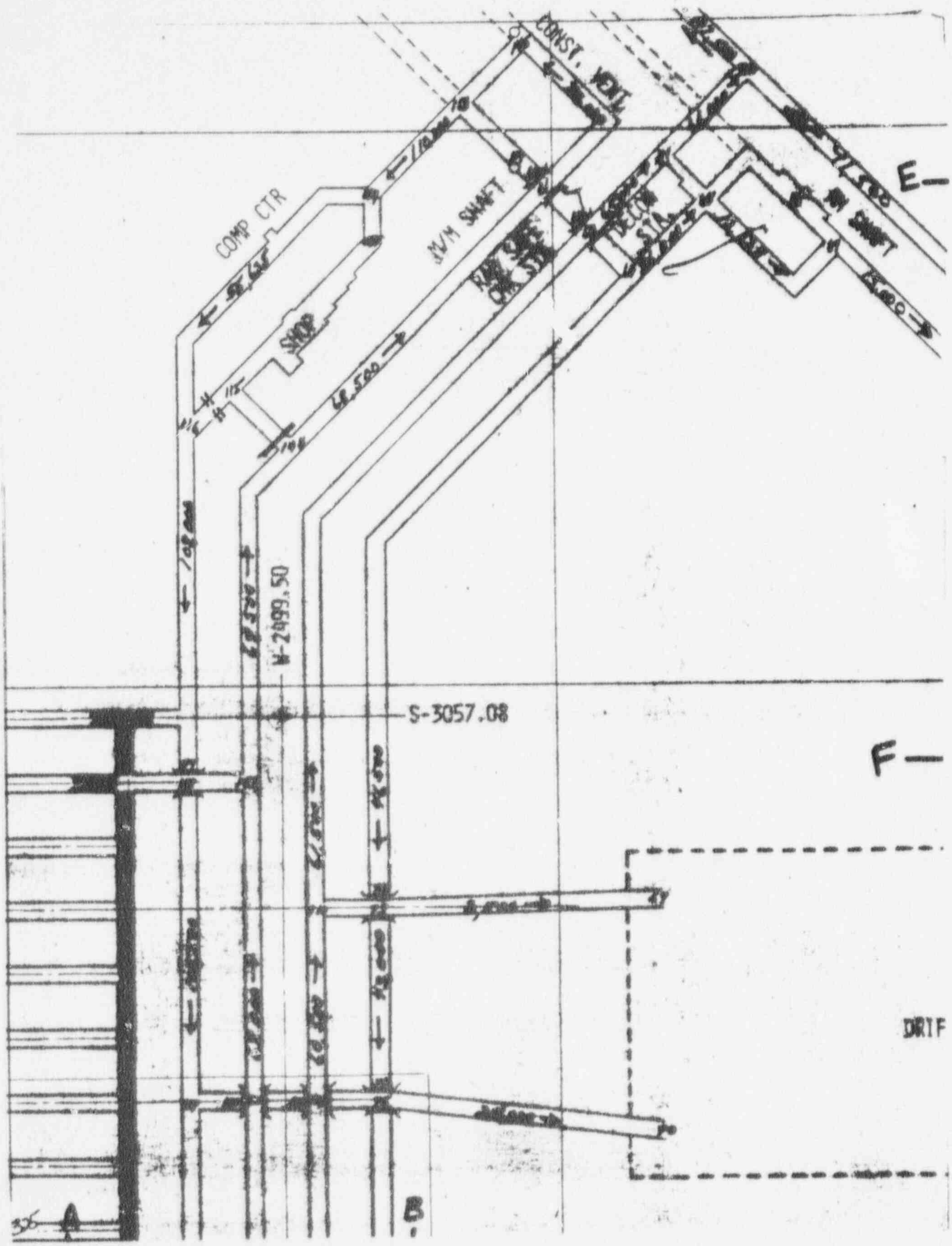


3
1
499.09'
119,000
95,500
101,000
103,000
31.5' TYP.
MAIN ENTRY
103,000
112,000
115,500
POINT "A"
91,500
90,000
88,500
75.0 TYP.
ENTRY PILLAR
98,000
100,000
101,000
BARRIER PILLAR
93.0' TYP.
111.0' TYP. ROOM PILLAR
45.0' TYP. STORAGE ROOM
4
2
B
31.5'TYP. SIDE ENTRY

90029340

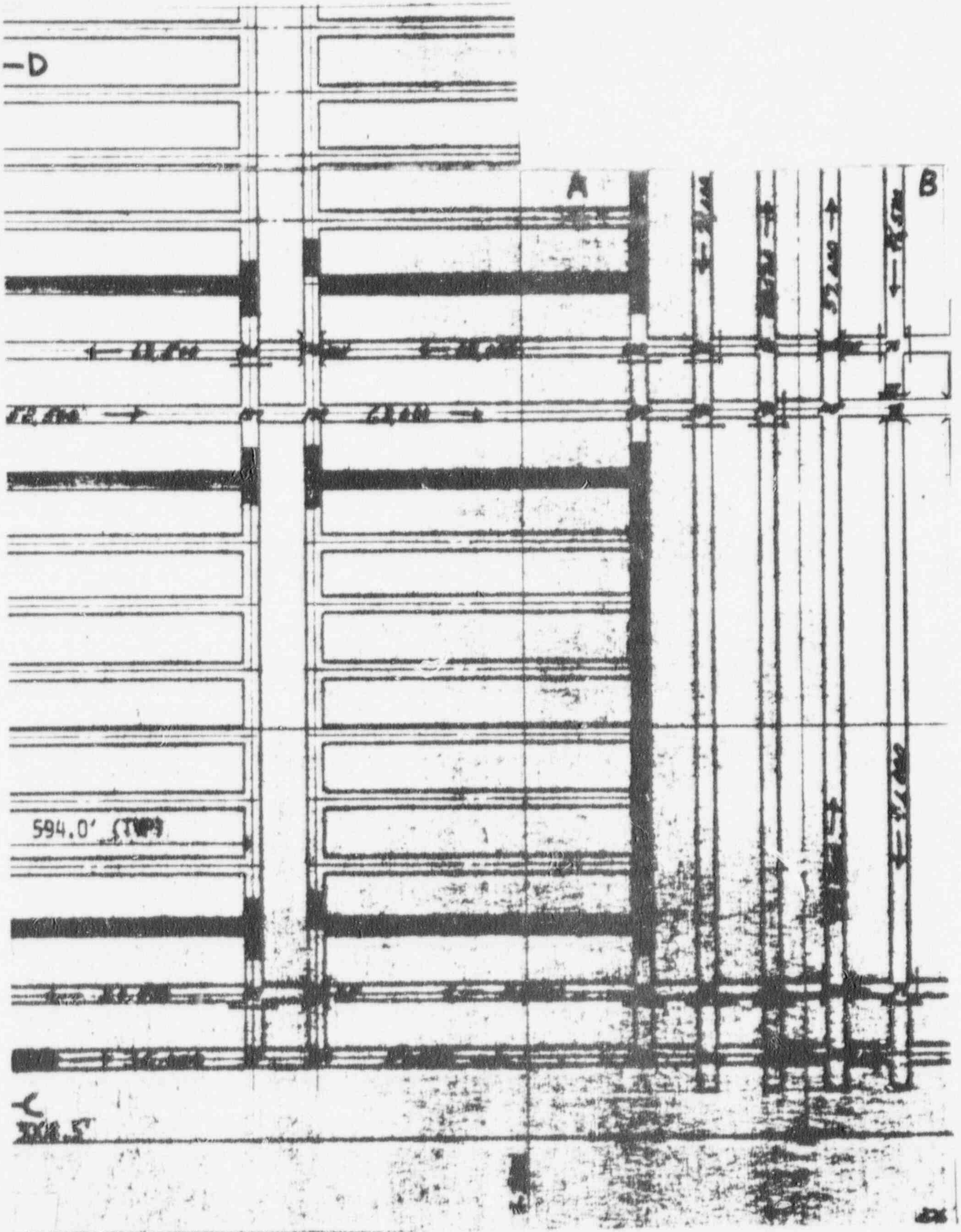

1000
POINT "B"
2811.0"
25,000
97,000
93,000
90,000
36,000
43000
3000
B
4

90029341

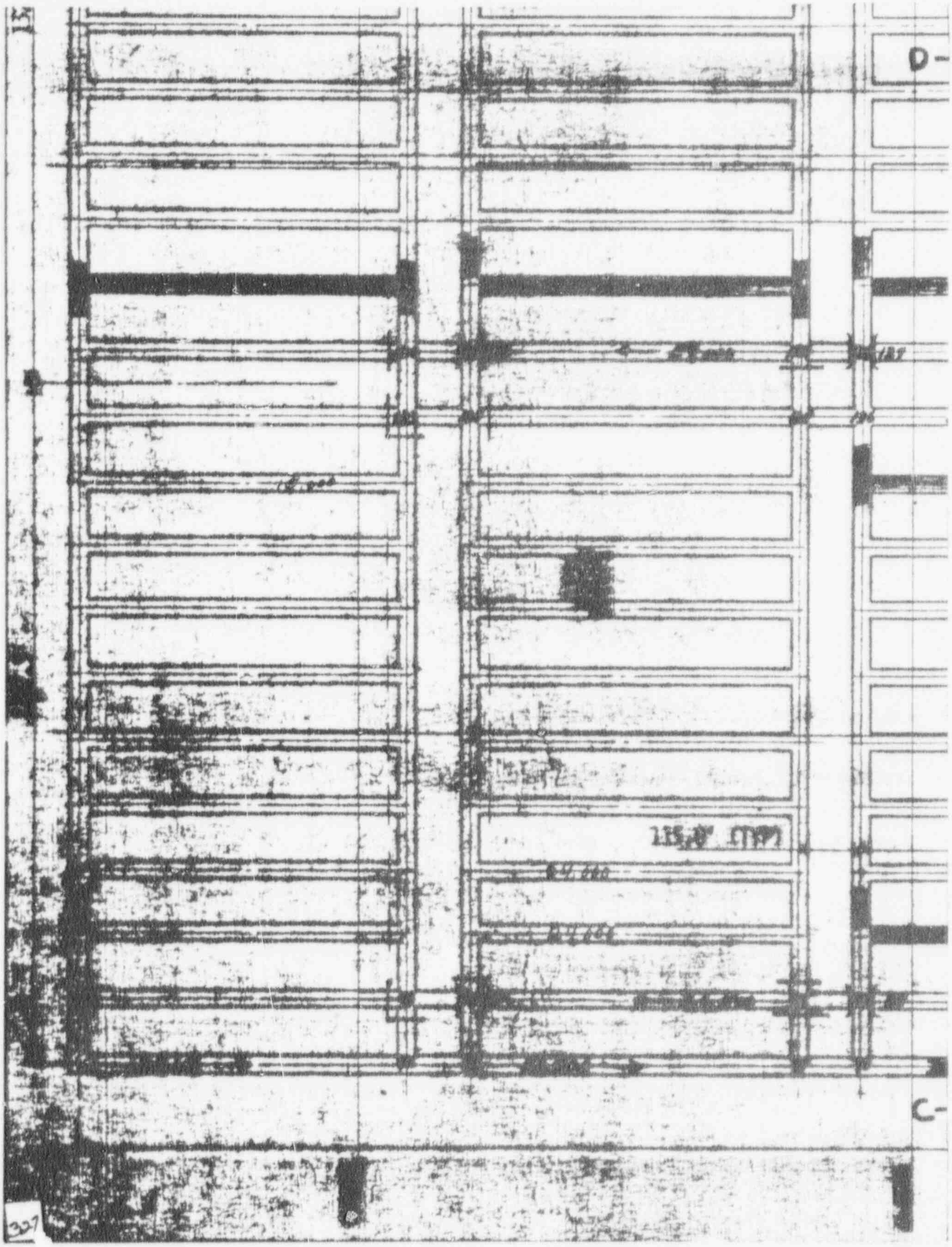


CONST. VENT
COMP CTR
SHOP
M/M SHAFT
DECON STA
E—
F—
W-2499.50
S-3057.08
DRIF
68,500

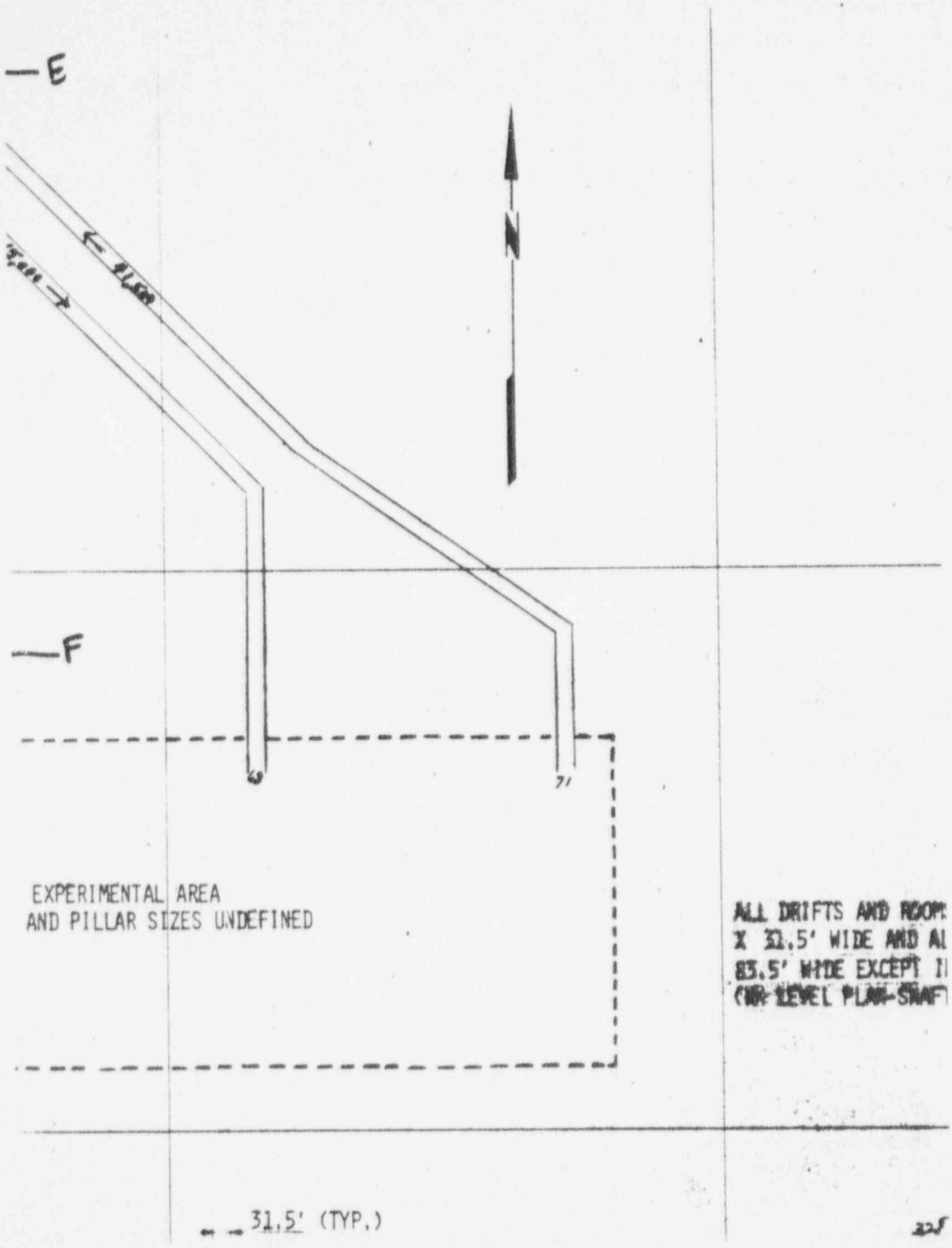
90029342



90029343.



90029344


—E
N
—F
7'
EXPERIMENTAL AREA
AND PILLAR SIZES UNDEFINED
ALL DRIFTS AND ROOM
X 31.5' WIDE AND AL
83.5' WIDE EXCEPT I
(NR LEVEL PLAN-SHAFT
31.5' (TYP.)
325

90029345

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: ______ SHEET 10 OF ______

CHECKED BY: ______ PROJECT NO. 288

CALCULATIONS FOR: Mine Airway Airflow Pressure Losses DATE: ______

Airway	Size	Cross-Section Area Sq. Ft.	Perimeter Ft.	Actual Length Ft.	Friction Factor ×10⁻¹⁰	Shock Factor	Equiv. Length Ft.	Total Length Ft.	Airflow Volume CFM	Pressure Loss Airway (Inches of Water)	Pressure Loss Cumul. (Inches of Water)	Remarks
0-1	23-ft ϕ	415.48	72.26	2170	42.212	69.47	30,638	32,808	425,000	4.5370		Used ρ = 0.0701 pcf
1-2	10×31.5	295.92	76.50	250.75	25.0	3.53	1767	2018	83,450	0.0184	4.5554	Used ρ = 0.0690 pcf
1-34				106.5		1.40	780	887	191,050	0.0210	4.5580	
2-58									1000	0.1595		
2-3				356.5		2.13	1067	1423	82,450	0.0127	4.5681	
3-5				716.50		4.79	2400	3117	26,400	0.0028	4.5709	
3-4	10×31.5	295.92	76.50	106.5	25.0			106.5	56,050	0.0004	4.5685	
4-0	17.5-ft ϕ	240.53	54.98	2170	42.212	28.45	9686	11,856	9500	0.0031	4.5716	Used ρ = 0.0671 pcf
4-5	10×31.5	295.92	76.50	447.36	25.0	0.80	400	847.5	46,550	0.0024	4.5709	Used ρ = 0.0690 pcf
5-6				192.15				193	72,950	0.0013	4.5722	
34-37				547.81		1.86	933	1481	68,850	0.0092	4.5672	
34-35				53.39		0.53	267	320	72,200	0.0022	4.5612	
35-58									1000	0.1547		
35-36				419.19		1.06	534	953	71,200	0.0063	4.5665	
36-56									1400	0.1120		
36-37				106.5				106.5	70,200	0.0007	4.5672	
37-38				742.59				742.5	101,000	0.0099	4.5771	
37-55				106.5		2.13	1067	1173	38,050	0.0022	4.5694	
55-59									3500	0.1052		
55-6				213.0		3.19	1600	1813	39,550	0.0028	4.5722	
6-32									1000	0.2276		
6-7				213.0				213	106,500	0.0032	4.5754	
7-8									3500	0.1942		
7-9				530.59				530.5	103,000	0.0074	4.5828	
9-31									1000	0.0842		
9-11									1000	0.1443		
9-10				514.5				514.5	101,000	0.0068	4.5896	
10-11									3500	0.1375		
10-12				129.5				129.5	97,500	0.0015	4.5911	
12-28									1000	0.0692		
12-14									1000	0.1234		
12-13				514.5				514.5	95,500	0.0061	4.5972	
13-14									3500	0.1173		
13-15				129.5				129.5	92,000	0.0014	4.5986	
15-25									1000	0.0597		

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90029346

FENIX & SCISSON, INC.
TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY:
CHECKED BY:
CALCULATIONS FOR: Mine Airway Airflow Pressure Losses

SHEET 19 OF
PROJECT NO: 288
DATE:

Airway	Size	Cross-Section Area Sq. Ft.	Peri-meter Ft.	Actual Length Ft.	Friction Factor	Shock Factor	Equiv. Length Ft.	Total Length Ft.	Airflow Volume CFM	Pressure Loss Airway Inches of Water	Pressure Loss Cumul.	Remarks
15-17									1000	0.1059		
15-16				514.5				514.5	90,000	0.0059	9.6090	
16-17									3500	0.1000		
16-18				129.5				129.5	86,500	0.0012	9.6052	
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	1600	1707	2000	0.0800	9.6955	
38-53									1000	0.0899		
38-39				514.5				514.5	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	0.0749		
40-41				514.5				514.5	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	0.0404	9.6337	
42-43				514.5					1000	0.0404		
43-46				106.5		2.13	1067	1173	95,000	0.0138	9.6475	
43-44									1000	0.0168		
47-44				106.5				106.5	81,000	0.0009	9.6505	
44-45									81,000	0.0287	9.6792	
49-45									1000	0.0287		
45-46				106.5				106.5	82,000	0.0009	9.6801	
46-20				106.5		3.19	1600	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	Add 0.0325 inches of water resistance
20-21				514.5				514.5	85,000	0.0098	9.7003	
22-21									3500	0.0891		
21-23				129.5		0.49	247	371	88,500	0.0038	9.7041	
17-23				106.5		3.68	1897	1959	4500	0.0001	9.7041	
48-23									1000	0.0866		
48-49				514.5				514.5	93,000	0.0058	9.6533	

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FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: ______ CHECKED BY: ______

SHEET 20 OF ______ PROJECT NO: 288 DATE: ______

CALCULATIONS FOR: Mine Airway Airflow Pressure Losses

Airway	Size	Cross-Section Area Sq Ft	Perimeter Ft	Actual Length Ft	Friction Factor	Shock Factor	Equiv Length Ft	Total Length Ft	Airflow Volume CFM	Pressure Loss Airway Inches of Water	Pressure Loss Cum Inches of Water	Remarks
49-50				129.5				129.5	91,500	0.0014	4.6547	
49-25				106.5				106.5	2500	0.0000	4.6533	
23-29				514.5				514.5	99,000	0.0059	4.7100	
25-29									3500	0.0567		
29-26				129.5		0.99	247	371	97,500	0.0046	4.7146	
14-26				106.5		3.68	1497	1959	4500	0.1001	4.7146	
50-26									1000	0.0599		
50-51				514.5				514.5	91,500	0.0056	4.6603	
51-52				129.5				129.5	90,000	0.0013	4.6616	
51-28				106.5				106.5	2500	0.0000	4.6603	
26-27				514.5				514.5	103,000	0.0071	4.7217	
28-27									3500	0.0614		
27-29				129.5		0.99	247	371	106,500	0.0055	4.7272	
11-29				106.5		3.68	1497	1954	4500	0.0001	4.7272	
52-29									1000	0.0656		
52-53				514.5				514.5	90,000	0.0054	4.6670	
53-54				743.59				743.5	88,500	0.0076	4.6746	
53-31				106.5				106.5	2500	0.0000	4.6670	
29-30				514.5				514.5	112,000	0.0084	4.7356	
31-30									5500	0.0686		
30-8				637.09		2.62	1319	1951	115,500	0.0340	4.7696	
8-32				319.5		2.62	1314	1633	119,000	0.0302	4.7998	
32-33				274.61		5.95	2732	3007	120,000	0.0566	4.8564	Add 0.2953 inches of water resistance
54-56				106.5		0.99	247	353	93,000	0.0039	4.6785	
56-57				284.67		5.95	2782	3214	93,000	0.0364	4.7149	Add 0.3488 inches of water resistance
58-57	14×31.5	295.92	76.50	25.75	25.0	4.92	2465	2491	2000	0.0000	4.7149	
1-59	23-ft Ø	415.48	72.26	570	60.0	18.02	5590	6160	200,500	0.2757	4.8157	Used ρ = 0.0725 pcf
59-60	14×31.5	295.92	76.50	67.0	25.0	1.90	700	767	89,500	0.0082	4.8239	Used ρ = 0.0704 pcf
59-113				198.5		1.90	700	898.5	111,000	0.0139	4.8296	
60-61									3500	0.1208		
60-62				115.0				115	86,000	0.0011	4.8250	
62-63									3500	0.1820		
62-64				115.0				115	82,500	0.0010	4.8260	
64-72				1335.08		2.46	1334	2669	46,500	0.0077	4.8337	Add 0.0825 inches of water resistance
64-65				185.12		2.13	1067	1252	36,000	0.0022	4.8282	

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FENIX & SCISSON, INC.
TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: ____________ SHEET 21 OF ______

CHECKED BY: ____________ PROJECT NO: 288

CALCULATIONS FOR: Mine Airway Airflow Pressure Losses DATE: ____________

Airway	Size	Cross-Section Area Sq. Ft.	Perimeter Ft.	Actual Length Ft.	Friction Factor	Shock Factor	Equiv. Length Ft.	Total Length Ft.	Airflow Volume CFM	Pressure Loss Airway Inches of Water	Pressure Loss Cumul. Inches of Water	Remarks
65-111									1000	0.1312		
65-67				345.0		7.95	3734	4079	12,625	0.0009	4.8291	
65-66	10×31.5	295.92	76.50	230.0	25.0	2.13	1067	1297	22,375	0.0009	4.8291	
66-0	8-ft ϕ	50.27	25.13	2755	45.191	47.77	6845	9600	20,000	0.5971	5.4262	Used ρ = 0.0677 pcf
66-67	10×31.5	295.92	76.50	115.0	25.0			115	2375	0.0000	4.8291	Used ρ = 0.0781 pcf
67-68				1429.79		0.53	267	1696.5	15,000	0.0005	4.8296	
72-73									3500	0.0323		
72-74				345.0				345	43,000	0.0808	4.9170	
75-74									3500	0.0901		
74-76				575.0				575	46,500	0.0017	4.9187	
76-107									1000	0.0091		
76-78									1000	0.0229		
76-77				115.0				115	44,500	0.0003	4.9190	
77-78									3500	0.0226		
77-79				1035.0				1035	41,000	0.0023	4.9213	
79-78									1000	0.0203		
79-109									1000	0.0163		
79-80				115.0		2.13	1067	1182	39,000	0.0024	4.9237	
80-81									3500	0.0142		
80-82				115.0				115	35,500	0.0002	4.9239	
82-103									1000	0.0109		
82-83				115.0				115	35,500	0.0002	4.9241	
83-102									1000	0.0104		
83-84				115.0				115	35,500	0.0002	4.9243	
84-101									1000	0.0099		
84-85				599.0				599	34,500	0.0009	4.9252	
85-86									3500	0.0078		
85-87				115.0				115	31,000	0.0001	4.9253	
87-99									1000	0.0075		
87-88				599.0				599	30,000	0.0007	4.9260	
88-89									3500	0.0058		
88-90				115.0				115	26,500	0.0001	4.9261	
90-97									1000	0.0055		
90-91				599.0				599	26,500	0.0006	4.9267	
91-92									3500	0.0041		

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90029349

FENIX & SCISSON, INC.
TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: ______ SHEET 22 OF ______
CHECKED BY: ______ PROJECT NO: 288
CALCULATIONS FOR: Mine Airway Airflow Pressure Losses DATE: ______

Airway	Size	Cross-Section Area Sq. Ft.	Perimeter Ft.	Actual Length Ft.	Friction Factor	Shock Factor	Equiv. Length Ft.	Total Length Ft.	Airflow Volume CFM	Pressure Loss Airway Inches of Water	Pressure Loss Cumulative Inches of Water	Remarks
91-93				115.0				115	23,000	0.0001	4.9268	
93-94									21,000	0.0025	4.9293	
93-94									1000	0.0025		
93-95									1000	0.0040		
94-95				709.0		2.13	1067	1776	25,000	0.0015	4.9308	
95-96				115.0				115	26,000	0.0001	4.9309	
92-96				115.0		3.68	1847	1962	4500	0.0001	4.9309	
96-97				599.0				599	30,500	0.0007	4.9316	
97-98				115.0				115	31,500	0.0002	4.9318	
89-98				115.0		3.68	1847	1962	3500	0.0000	4.9318	
98-99				599.0				599	35,400	0.0010	4.9328	
99-100				115.0				115	36,000	0.0002	4.9330	
86-100				115.0		3.68	1847	1962	3500	0.0000	4.9330	
100-101				599.0				599	39,500	0.0012	4.9342	
101-102				115.0				115	40,500	0.0003	4.9345	
102-103				115.0				115	41,500	0.0003	4.9348	
103-104				115.0		2.13	1067	1182	42,500	0.0028	4.9376	
104-81				115.0				115	43,500	0.0003	4.9379	
81-105				1035.0		0.49	247	1282	47,000	0.0038	4.9417	
78-105				115.0		3.68	1847	1962	3500	0.0001	4.9417	
113-145									1000	0.1268		
113-114				230.0		2.13	1067	1297	110,000	0.0209	4.8505	
114-116				621.37		1.59	800	1421.5	55,625	0.0059	4.8564	
114-115				454.10		1.06	533	987.5	54,375	0.0039	4.8544	
115-144									1000	0.0862		
115-116				119.63		0.80	400	520	53,375	0.0020	4.8564	
116-117				628.77				629	149,000	0.0099	4.8663	
117-118									3500	0.0688		
117-119				575.0				575	145,500	0.0085	4.8748	
119-120				115.0		2.13	1067	1182	34,500	0.0019	4.8767	
120-121									3500	0.0539		
120-109				115.0				115	31,000	0.0001	4.8768	
109-108									3500	0.0688		
109-75				115.0				115	27,500	0.0001	4.8769	
75-70				527.15				527	29,000	0.0004	4.8773	

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

SHEET 23 OF

PROJECT NO. 233

COMPUTED BY:

CHECKED BY:

DATE:

CALCULATIONS FOR: Mine Airway Airflow Pressure Losses

Airway	Size	Cross-Section Area Sq Ft	Perimeter Ft	Actual Length Ft	Friction Factor	Shock Factor	Equiv Length Ft	Total Length Ft	Airflow Volume CFM	Pressure Loss Airway Inches of Water	Pressure Loss Cum Inches of Water	Remarks
119-122				575.0				575	71,000	0.0839	4.8787	
122-142									1000	0.0491		
122-140									1000	0.0425		
122-123				.5.0		2.13	1067	1182	69,000	0.0075	4.8862	
123-139									1000	0.0394		
123-124				594.0				594	68,000	0.0036	4.8898	
124-125									3500	0.0277		
124-126				115.0				115	64,500	0.0006	4.8904	
126-137									1000	0.0266		
126-127				594.0				594	63,500	0.0032	4.8936	
127-128									3500	0.0207		
127-129				115.0				115	60,000	0.0006	4.8942	
129-135									1000	0.0196		
129-130				594.0				594	59,000	0.0027	4.8969	
130-131				115.0		4.26	2134	2249	30,175	0.0027	4.8996	
130-132				115.0				115	28,825	0.0002	4.8971	
132-94									1000	0.0322		
132-133				115.0		2.13	1067	1182	27,825	0.0012	4.8983	
133-94									2000	0.0310		
133-134				115.0		3.19	1600	1715	25,825	0.0015	4.8998	
131-134				115.0				115	30,175	0.0002	4.8998	
134-92									1000	0.0310		
134-90									1000	0.0263		
134-135									53,000	0.0140	4.9138	
134-135									1000	0.0140		
135-136				115.0				115	55,000	0.0005	4.9143	
128-136				115.0		3.68	1847	1962	3500	0.0000	4.9143	
136-137				594.0				594	58,500	0.0027	4.9170	
137-138				115.0				115	59,500	0.0005	4.9175	
125-138				115.0		3.68	1847	1962	3500	0.1000	4.9175	
138-139				594.0				594	63,000	0.0031	4.9206	
139-140				115.0				115	64,000	0.0006	4.9212	
140-83									1000	0.0029		
140-141				115.0				115	64,000	0.0006	4.9218	
141-82									1000	0.0021		

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90029351

FENIX & SCISSON, INC.

TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: ______

CHECKED BY: ______

CALCULATIONS FOR: Mine Airway Airflow Pressure Losses

SHEET 29 OF ______

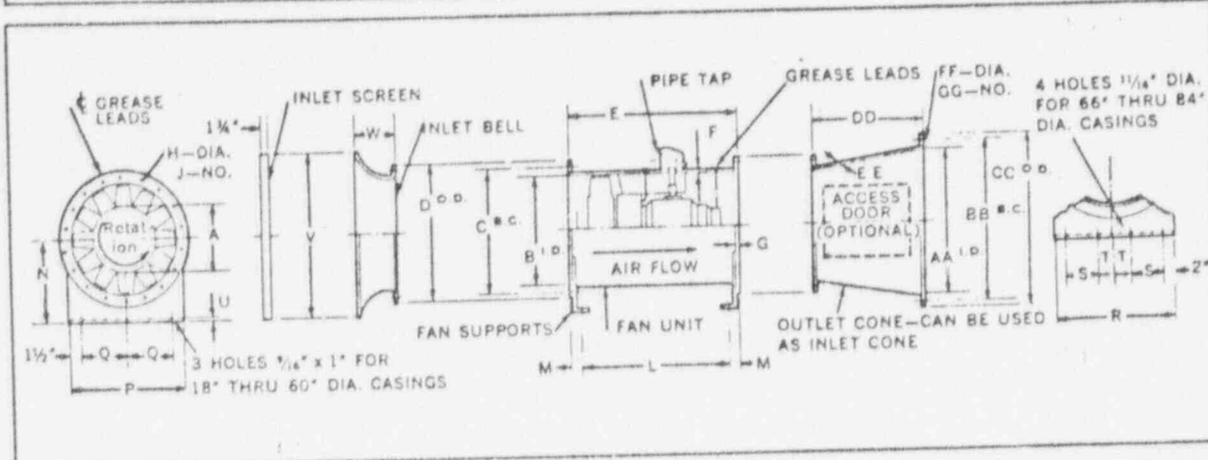
PROJECT NO: 288

DATE: ______

Airway	Size	Cross-Section Area Sq Ft	Peri-meter Ft	Actual Length Ft	Friction Factor	Shock Factor	Equiv Length Ft	Total Length Ft	Airflow Kcuft CFM	Pressure Loss Airway Inches of Water	Pressure Loss Cumm Inches of Water	Remarks
191-105									1000	0.0199		
191-142				115.0		2.13	1067	1182	62,000	0.0061	4.9278	
142-107				115.0				115	2500	0.0000	4.9278	
142-121				575.0				575	60,500	0.0028	4.9306	
121-143				575.0		0.59	297	822	69,000	0.0045	4.9351	
145-106				115.0				115	53,500	0.0009	4.9421	
107-106									3500	0.0143		
106-108				575.0		0.59	297	822	57,000	0.0035	4.9456	
108-110				345.0		0.59	297	592	60,500	0.0029	4.9485	
73-110				115.0		0.37	187	382	1000	0.0000	4.9485	
73-69				525.08		0.37	187	712	2500	0.0000	4.9485	
110-63				1430.35		0.53	267	1697	61,500	0.0085	4.9570	
63-111				185.12		0.59	297	482	65,000	0.0024	4.9594	
111-112				230.0		3.19	1600	1830	66,000	0.0106	4.9700	
71-112				2097.99		0.53	267	2365	41,500	0.0054	4.9700	
112-33	10×31.5	295.92	76.50	932.0	25.0	3.81	1910	2842	107,500	0.0436	5.0136	
	14-ft ϕ	153.94	43.98	570	60.0	1.08	354	924	107,500	0.1381	5.1517	Used ρ = 0.0696 pcf
33-150	14-ft ϕ	153.94	43.98	2165	42.263			2165	227,500	0.9839	6.1356	Used ρ = 0.0671 pcf
118-143	10×31.5	295.92	76.50	115.0	25.0	3.68	1847	1962	3500	0.0000	4.9351	Used ρ = 0.0701 pcf
143-144				635.33		0.53	267	902	67,500	0.0055	4.9406	
144-61				660.29				660	68,500	0.0041	4.9447	
61-145				379.5		2.62	1314	1693	72,000	0.0117	4.9564	
145-57	10×31.5	295.92	76.50	11.5	25.0	3.81	1910	1922	73,000	0.0136	4.9700	
	14-ft ϕ	153.94	43.98	570	60.0	1.08	354	924	73,000	0.0637	5.0337	Used ρ = 0.0696 pcf
57-0	14-ft ϕ	153.94	43.98	2170	42.212	7.47	2005	4175	168,000	1.0335	6.0672	Used ρ = 0.0671 pcf
150-0	11×14	154.0	50.0	230	20.0	0.77	389	619	227,500	0.1502	6.2858	Used ρ = 0.0672 pcf
68-71										0.1350		
69-71										0.0461		
70-71										0.0873		

JOY MANUFACTURING COMPANY

air moving products · NEW PHILADELPHIA, OHIO



DIMENSIONS (Inches) JOY AXIVANE FANS

A HUB DIA	B CASING DIA	FAN UNIT PROPER C	D	E	F	G	H	J	FAN UNIT WEIGHT—LESS MOTOR	FAN SUPPORTS L	M	N	P	Q	R	S	T	U	INLET BELL V	W	RECOMMENDED OUTLET CONE (1.5/1.0 AREA RATIO) AA	BB	CC	DD	FF	GG
14	18	19¾	21¾	28	10 GA	¼	9/16	12	165	25½	1¼	13	19½	8¼				3/16	23½	4	23¼	25¼	26¾	15	9/16	14
	21¼	23¼	24¾	31	10 GA	¼	9/16	12	195	28½	1¼	15	22½	9¾				3/16	27¾	4½	27¾	29¼	30¾	17	9/16	16
	23¼	25¼	26¾	33	10 GA	¼	9/16	14	215	30½	1¼	16¼	26½	11¼				3/16	30¼	5	29¼	31¼	32¾	17	9/16	16
	25½	27⅜	28⅞	33	10 GA	¼	9/16	14	230	30½	1¼	17½	28½	12¼				3/16	33	5½	32	33⅞	35⅛	19½	9/16	18
	27½	29¾	30⅞	33	10 GA	¼	9/16	16	250	30½	1¼	19	29	13				3/16	35½	6	34	35⅞	37⅛	19½	9/16	18
	29½	31¾	32⅞	33	10 GA	¼	9/16	16	260	30½	1¼	20	31	14				3/16	38	6¼	36	38	39½	19½	9/16	20
	32	33⅞	35⅝	33	10 GA	¼	9/16	18	295	30¼	1¼	22	31½	14¼				3/16	41¾	6½	42¼	44¼	45¼	29½	9/16	24
	34	35⅞	37⅝	36	10 GA	¼	9/16	18	320	33¼	1¼	23½	33½	15¼				3/16	44¼	7¼	42¼	44¼	45¼	23½	9/16	24
	36	38	39½	36	3/16	¼	9/16	20	400	33¼	1¼	24½	38	17½				3/16	47	7½	45	47	48½	25½	9/16	24
17½	21¼	23¼	24¾	31	10 GA	¼	9/16	12	215	28½	1¼	15	22½	9¾				3/16	27¾	4½	27¾	29¼	30¾	17	9/16	16
	* 23¼	25¼	26¾	33	10 GA	¼	9/16	14	235	30½	1¼	16¼	26½	11¼				3/16	30¼	5	29¼	31¼	32¾	17	9/16	16
	25½	27⅜	28⅞	33	10 GA	¼	9/16	14	250	30½	1¼	17½	28½	12¼				3/16	33	5½	32	33⅞	35⅛	19½	9/16	18
	27½	29¾	30⅞	33	10 GA	¼	9/16	16	270	30½	1¼	19	29	13				3/16	35½	6	34	35⅞	37⅛	19½	9/16	18
	* 29½	31¾	32⅞	33	10 GA	¼	9/16	16	285	30½	1¼	20	31	14				3/16	38	6¼	36	38	39½	19½	9/16	20
	32	33⅞	35⅝	33	10 GA	¼	9/16	18	315	30¼	1¼	22	31½	14¼				3/16	41¾	6½	42¼	44¼	45¼	29½	9/16	24
	34	35⅞	37⅝	36	10 GA	¼	9/16	18	345	33¼	1¼	23½	33½	15¼				3/16	44¼	7¼	42¼	44¼	45¼	23½	9/16	24
	* 36	39	39½	36	3/16	¼	9/16	20	425	33¼	1¼	24½	38	17½				3/16	47	7½	45	47	48½	25½	9/16	24
	* 38	40	41½	40	3/16	⅜	9/16	20	470	37¼	1¼	26	40	18½				3/16	49½	8	48	50	51½	28½	9/16	30
	42½	44½	45¼	42	3/16	⅜	9/16	24	530	39¼	1¼	29½	40½	18¼				3/16	55	9	54	56½	58½	33½	11/16	30
	45	47	48½	44	3/16	⅜	9/16	24	575	41¼	1¼	30½	42½	19¼				3/16	58½	9¼	60	62½	64½	43	11/16	30
21	25½	27⅜	28⅞	33	10 GA	¼	9/16	14	320	30½	1¼	17½	28½	12¼				3/16	33	5½	32	33⅞	35⅛	19½	9/16	18
	* 27½	29¾	30⅞	33	10 GA	¼	9/16	16	335	30½	1¼	19	29	13				3/16	35½	6	34	35⅞	37⅛	19½	9/16	18
	* 29½	31¾	32⅞	33	10 GA	¼	9/16	16	355	30½	1¼	20	31	14				3/16	38	6¼	36	38	39½	19½	9/16	20
	* 32	33⅞	35⅝	33	10 GA	¼	9/16	18	395	30¼	1¼	22	31½	14¼				3/16	41¾	6½	42¼	44¼	45¼	29½	9/16	24
	* 34	35⅞	37⅝	36	10 GA	¼	9/16	18	425	33¼	1¼	23½	33½	15¼				3/16	41¼	7¼	42¼	44¼	45¼	23½	9/16	25
	* 36	38	39½	36	3/16	¼	9/16	20	505	33¼	1¼	24½	38	17½				3/16	47	7½	45	47	48½	25½	9/16	24
	38	40	41½	40	3/16	⅜	9/16	20	555	37¼	1¼	26	40	18½				3/16	49½	8	48	50	51½	28½	9/16	30
	42½	44½	45¼	42	3/16	⅜	9/16	24	620	39¼	1¼	28½	40½	18¼				3/16	55	9	54	56½	58½	33½	11/16	30
	45	47	48½	44	3/16	⅜	9/16	24	670	41¼	1¼	30½	42½	19¼				3/16	58½	9½	60	62½	64½	43	11/16	33
	* 48	50	51½	48	3/16	⅜	9/16	30	715	45¼	1¼	32½	45½	21¼				3/16	62½	10	60	62½	64½	34	11/16	30
26½	34	35⅞	37⅝	36	10 GA	¼	9/16	18	470	33¼	1¼	23½	33½	15¼				3/16	44¼	7¼	42¼	44¼	45¼	23½	9/16	24
	* 36	38	39½	36	3/16	¼	9/16	20	580	33¼	1¼	24½	38	17½				3/16	47	7½	45	47	48½	25½	9/16	24
	* 38	40	41½	40	3/16	⅜	9/16	20	610	37¼	1¼	26	40	18½				3/16	49½	8	48	50	51½	28½	9/16	30
	42½	44½	45¼	42	3/16	⅜	9/16	24	705	39¼	1¼	28½	40½	18¼				3/16	55	9	54	56½	58½	33½	11/16	30
	45	47	48½	44	3/16	⅜	9/16	24	760	41¼	1¼	30½	42½	19¼				3/16	58½	9½	60	62½	64½	43	11/16	30
	* 48	50	51½	48	3/16	⅜	9/16	30	840	45¼	1¼	32½	45½	21¼				3/16	62½	10	60	62½	64½	34	11/16	30
	54	56½	58½	48	3/16	⅜	11/16	30	960	45¼	1¼	36½	56	26				3/16	70	10½	66	69	71½	34	11/16	32
	60	62½	64½	48	3/16	⅜	11/16	30	1055	45¼	1¼	40½	62	29½				3/16	78	11½	73½	76½	78½	38½	11/16	32
	66	69	71½	48	¼	⅜	11/16	32	1350	43¼	2¼	45			66	21	10	¼	86	12	81	84½	87½	43	11/16	32
	72	75	77½	48	¼	⅜	11/16	32	1465	43¼	2¼	46			72	23	11	¼	92	12	88¼	91¼	94¼	46½	11/16	32
	78	81½	84½	48	¼	⅜	11/16	32	1605	43¼	2¼	51			78	25	12	¼	98	12	95¼	91¾	102¼	52	11/16	32
	84	87½	90½	48	¼	⅜	11/16	32	1720	43¼	2¼	54			84	27	13	¼	104	17	103	106½	109 1/16	54	11/16	32

* Indicates non-stock sizes

Form No. D 2100

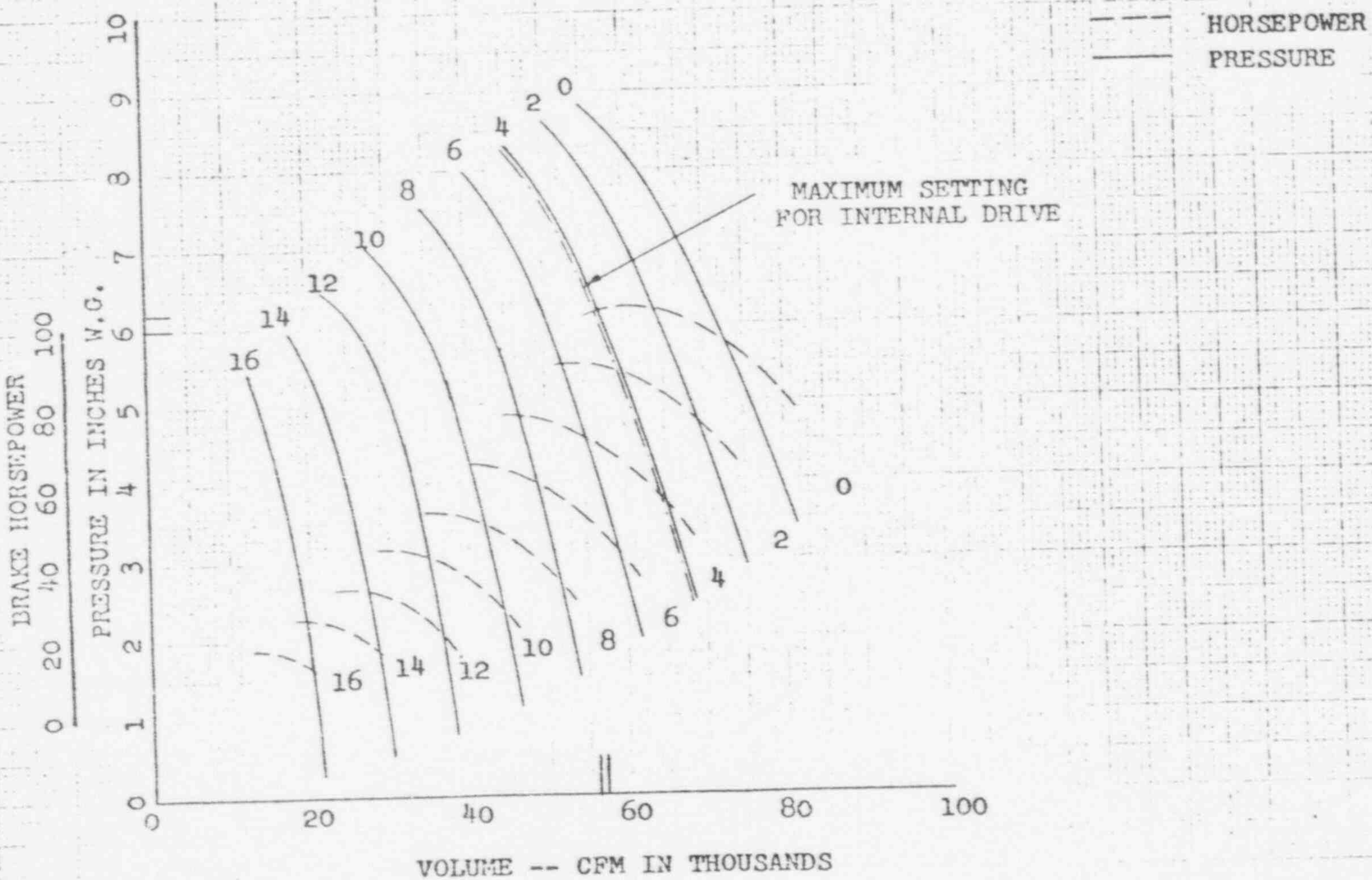
336

90029353

C-1336

JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

MODEL 45-26½-1750
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

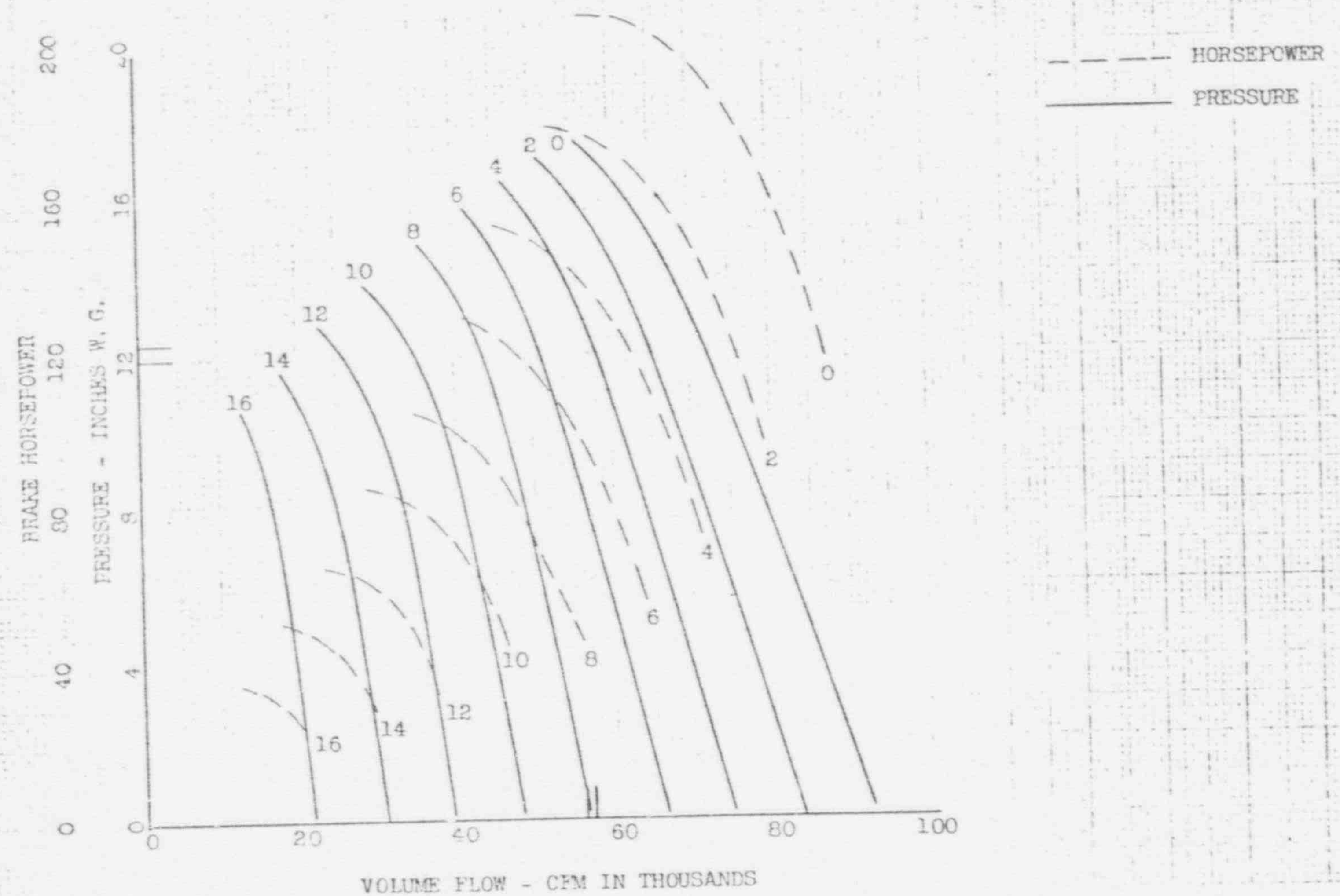


9002029354

JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

MODEL 45-26½-1750 2-STAGE
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

C-2446



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90029355

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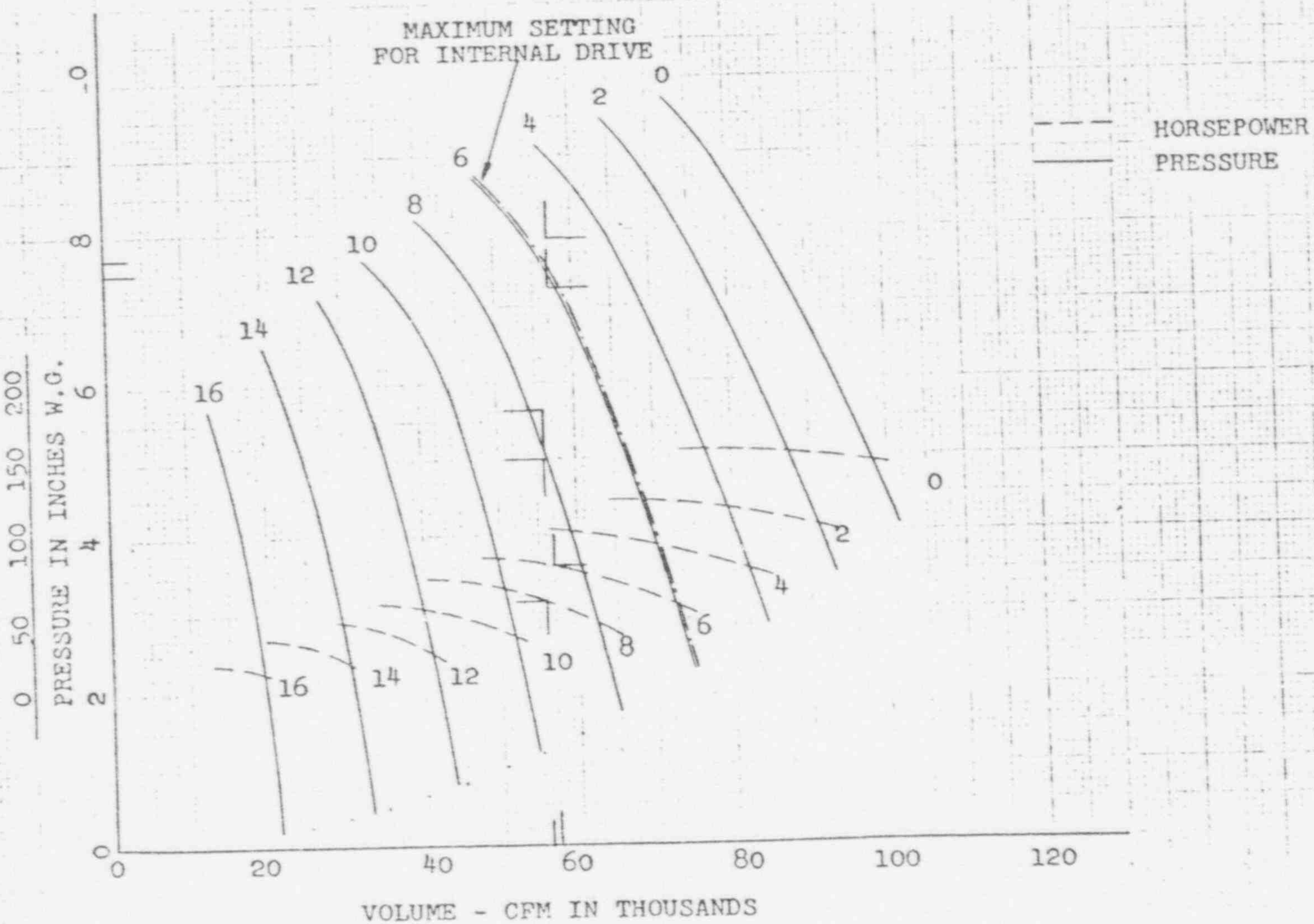
JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

C-1339

MODEL 48-26½-1750
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS



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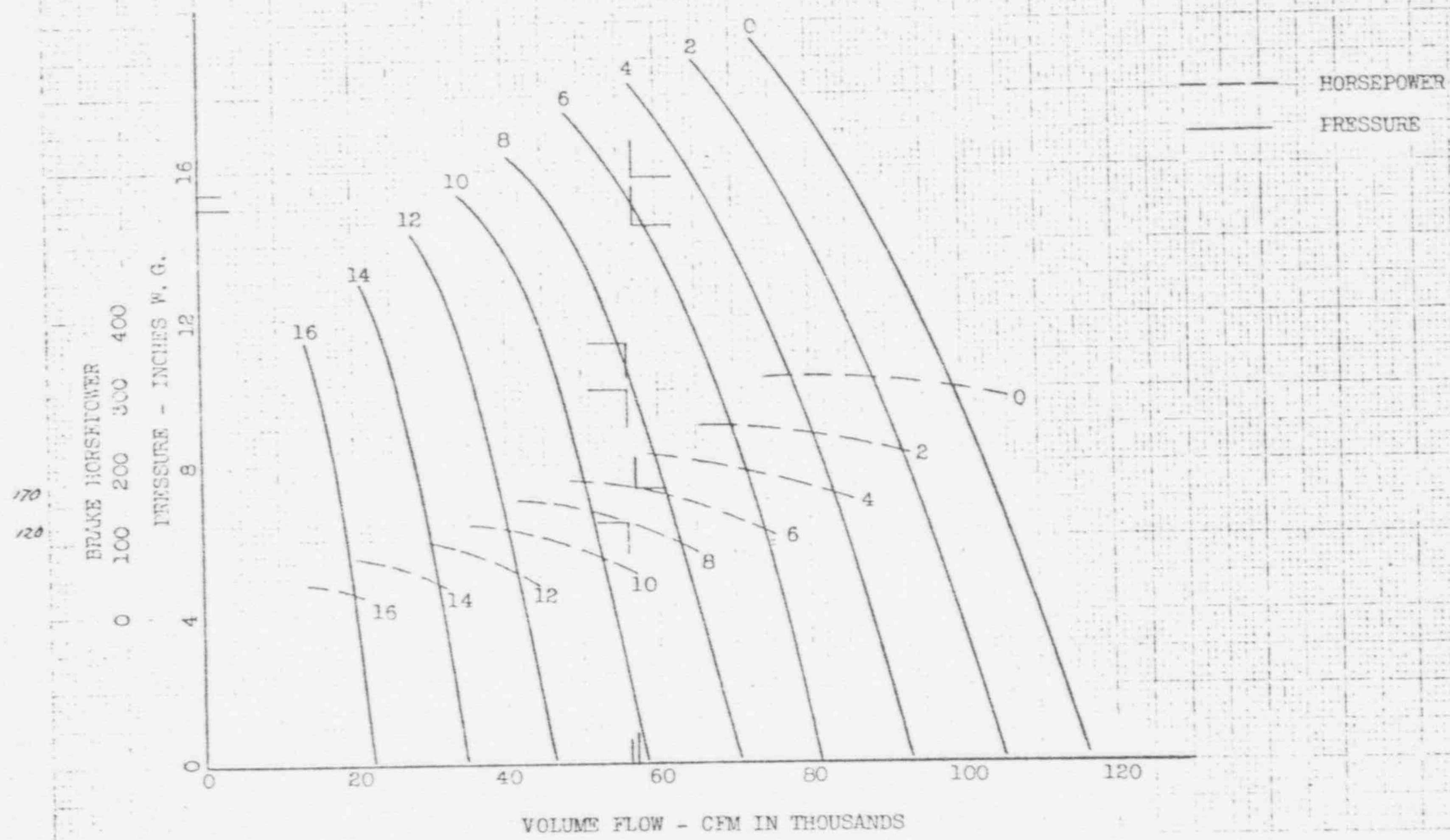
JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

MODEL 48-26½-1750 2-STAGE
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

C-2509



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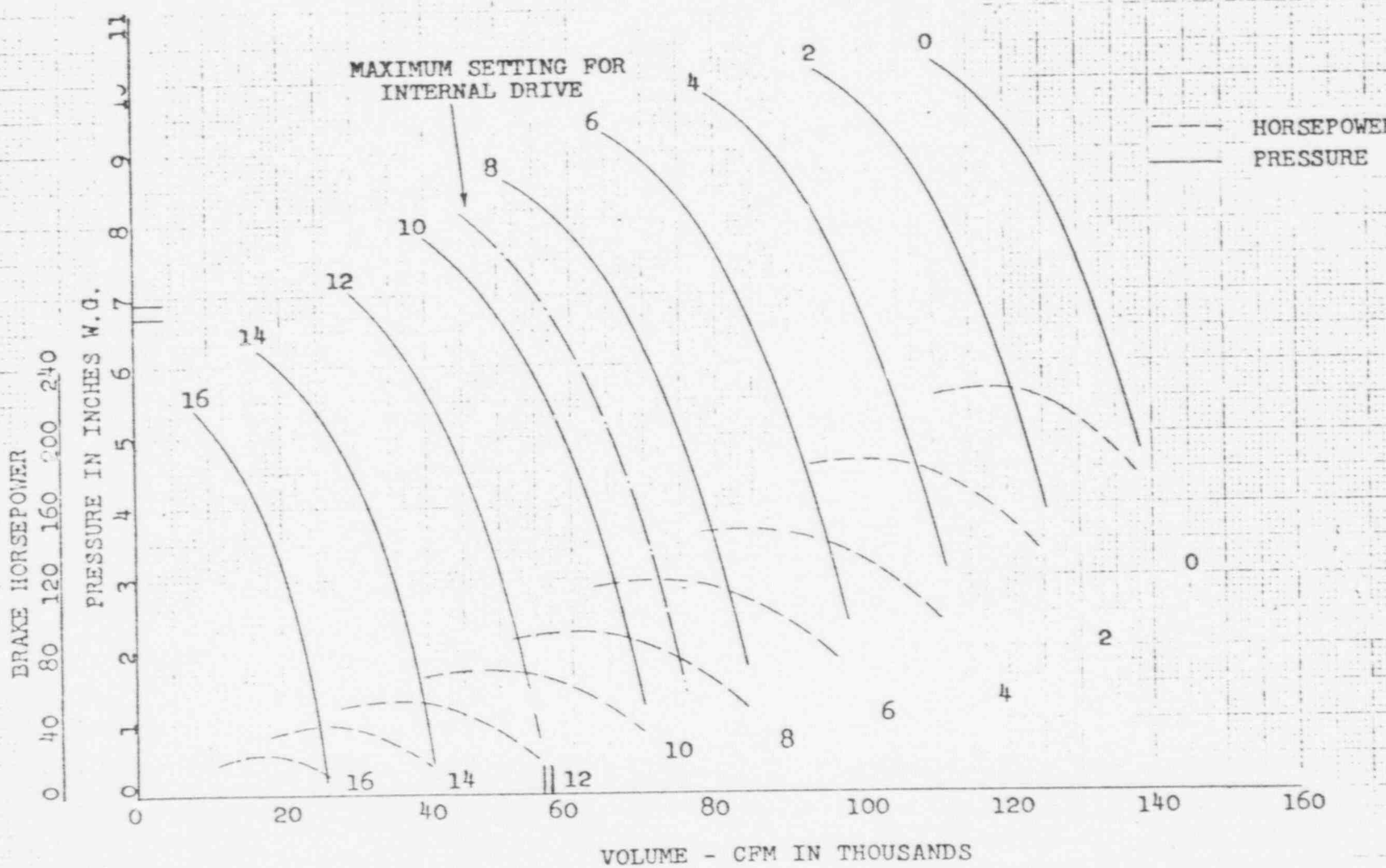
90029357

JOY MANUFACTURING COMPANY
HENRY W. OLIVER BUILDING
PITTSBURGH 22, PA.

C-1342

MODEL 54-26½-1750
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS

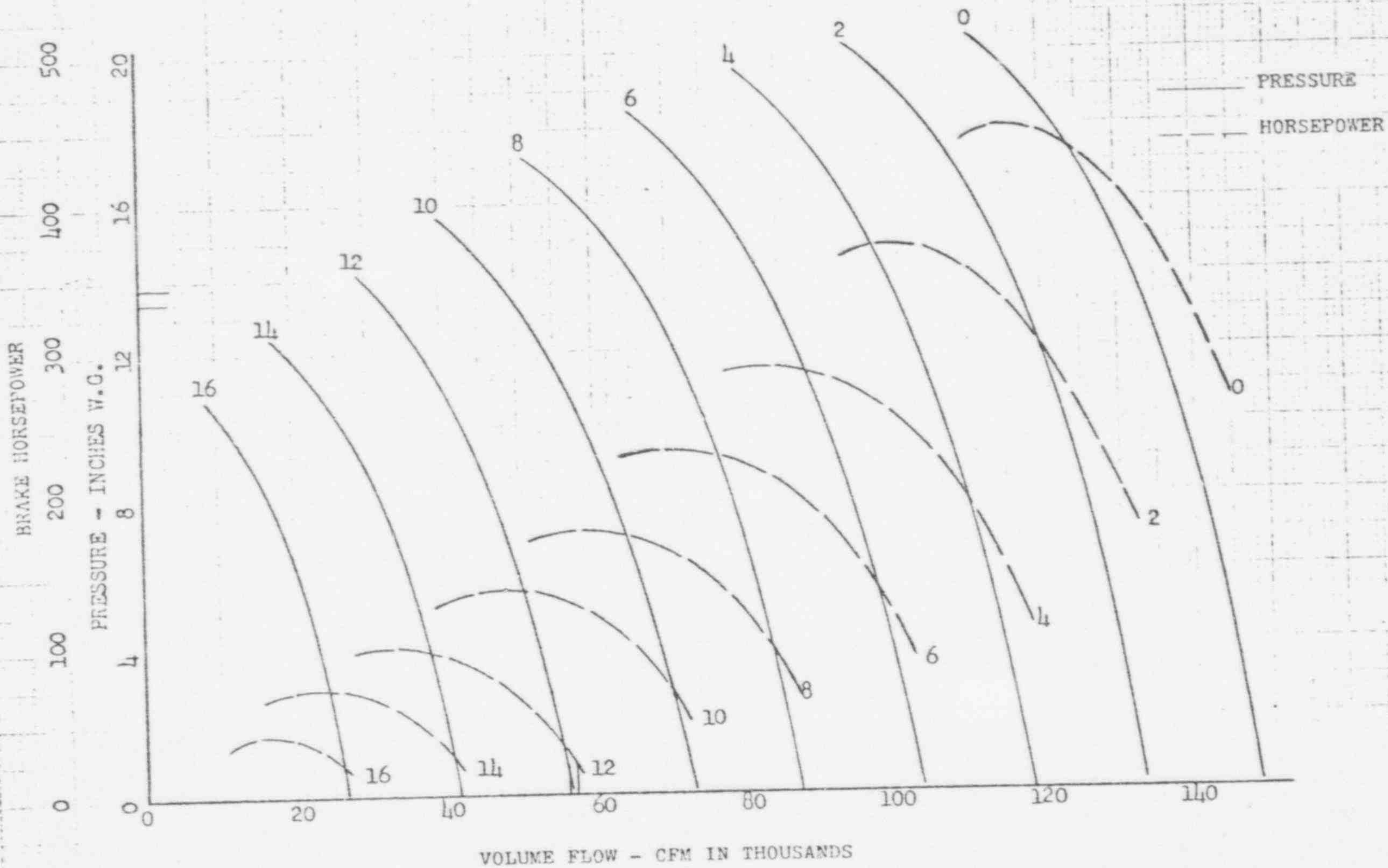


90029358

C-2606

JOY MANUFACTURING COMPANY
338 S. BROADWAY
NEW PHILADELPHIA, OHIO 44663
SEPTEMBER 14, 1955

MODEL 54-26½-1750 2-STAGE
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS



9002959

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Mine Structural Analysis

12

Sept 16, 76

SHAFT PILLAR DESIGN
-EVALUATION-

Depth = 2225 ft   Entry Height — 10 ft
Density = 150 lb/ft^3 Pillar Radius = 1000 ft

Arch Distance = 0.154 (Depth - ft) + 70 = 408.8 ft

SHAFT TRIBUTARY-AREA-LOAD-(TAL)

$$\underline{TAL} = \frac{\pi(1000+408.8)^2 150(2225)}{2000} = \underline{1,040,500,000 \text{ Tons}}$$

LOAD CARRYING CAPABILITY (L)

I. Most Likely Physical Properties

Φ = 30° (Metcalf) σ_0 (cohesion) = 450 psi (Boulby)

$\hat{\sigma}_v$ = 7399 psi $\hat{y}$ = 8.08 ft

L = 1,660,000,000 Tons

F.S. = L/TAL = 1.60

II. "Pure" Wilson, A. H. σ_0 = 1 psi

Φ = 30° σ_0 = 1 psi

$\hat{\sigma}_v$ = 6950 psi $\hat{y}$ = 25.54 ft

L = 1,532,000,000 Tons   F.S. = 1.47

III Cohesion Equals Unconfined Compression Strength Divided by Two—SHORT-TERM COHESION

Φ = 30° σ_0 = 1600 psi

$\hat{\sigma}_v$ = 8549 psi $\hat{y}$ = 4.84 ft

L = 1,924,000,000 Tons   F.S. = 1.85

343

90030001

IV Cohesion for Long-term (Infinite) Pillar Life
Friction Angle of Repose

$\Phi = 35°$ $\sigma_o = 450$ psi

$\hat{\sigma}_v = 9997$ psi $\hat{\rho} = 5.80$ ft

$L = 2,023,000,000$ Tons **FS = 1.94**

V Minimum Unconfined Compression Strength
for 10-ft High Pillar Rib to Stand

$\Phi = 30°$ $\sigma_o = 10$ psi

$\hat{\sigma}_v = 69.59$ psi $\hat{\rho} = 18.89$ ft

$L = 1,594,500,000$ Tons **FS = 1.48**

PILLAR RADIUS NEEDED FOR FACTOR OF SAFETY OF ONE

I. $\Phi = 30°$ $\sigma_o = 450$ psi **R = 529 ft**

$TAL = \frac{\pi(R+408.8)^2(150)(2225)}{} = 524(R^2 + 817.6R + 167,100)$

$TAL = 524(R^2 + 817.6R + 167100) = 524R^2 + 428600R + 87,610,000$

$L = 0.05655\hat{\sigma}_v[4R^2 - 4R\hat{\rho} + 4/3\,\hat{\rho}^2]$

$L = 418.4[4R^2 - 32.32R + 87.05]$

$L = 1674R^2 - 13520R + 36422$

$-TAL = -524R^2 - 428,600R - 87,610,000$

$L - TAL = 1149R^2 - 442,200R - 87,580,000 = 0$

$R = \frac{-b \pm \sqrt{b^2-4ac}}{2a} = 528.8$ ft

II $\Phi = 30°$ $\sigma_o = 1$ psi **R = 589 ft**

$L - TAL = 1048R^2 - 468,800R - 87,270,000 = 0$

$R = 588.8$ ft

90030002

344

III. $\Phi = 30°$ $\sigma_o = 1600$ psi **R = 449 ft**

$I - TAL = 1410R^2 - 438{,}000R - 87{,}600{,}000 = 0$

R = 449.1 ft

IV. $\Phi = 35°$ $\sigma_o = 450$ psi **R = 427 ft**

$I - TAL = 1511R^2 - 440{,}400R - 87{,}590{,}000 = 0$

R = 427.2 ft

V. $\Phi = 30°$ $\sigma_o = 10$ psi **R = 580 ft**

$I - TAL = 1050R^2 - 458{,}400R - 87{,}425{,}000 = 0$

R = 580.1 ft

STORAGE DRIFT PILLAR DESIGN FOR **FS = 1.5**

Depth = 2225 ft Room Height = 16.5 ft
Density = 150 lb/ft³ Room Width (Max) = 42 ft
Pillar Length = 500 ft R = ? %

$F.S. = 1.5 = I/TAL$ Design for 1-ft Slice

$I = 1.5\,TAL$

I. Most Likely Physical Properties

$\Phi = 30°$ $\sigma_o = 450$ psi p = pillar width

$\hat{\sigma}_v = 7399$ psi $\hat{p} = 13.34$ ft

$$TAL = \frac{(1)(p+42)(150)(2225)}{2000} = 166.9(p+42)$$

$TAL = 166.9p + 7009$ Tons

$I = 0.072\,\hat{\sigma}_v[p - \hat{p}] = 0.072(7399)[p - 13.34]$

$I = 532.7p - 7104$

:345

90030003

$L = 1.5\ TAL$

$532.7p - 7104 = 1.5(166.9p + 7009)$

$532.7p - 7104 = 250.4p + 10510$

$282.4p = 17620$

$p = 62.4\ ft$

II "Pure" Wilson $\Phi = 30°$ $\sigma_o = 1psi$, $\hat{\sigma_v} = 6950 psi$

$L = 0.072(6950)[p - 42.14] = 500.4[p - 42.14]$

$L = 500.4p - 21085$ $\hat{y} = 25.54 ft$

$-1.5TAL = -250.4p - 10510$

$+250.0p - 31595 = 0$

$p = 126.4\ ft$ R = 24.9

III. Cohesion Equals Unconfined Compression Strength Divided by Two - SHORT-TERM COHESION

$\Phi = 30°$; $\sigma_o = 1600 psi$; $\hat{\sigma_v} = 8549 psi$; $\hat{y} = 4.84 ft$

$L = 0.072(8549)[p - 7.98]$

$L = 615.5p - 4913$

$-1.5TAL = -250.4p - 10510 = 0$

$365.1p - 15422 = 0$

$p = 42.2\ ft$

IV Friction Angle of Repose - Long-Term Cohesion

$\Phi = 35°$; $\sigma_o = 450 psi$; $\hat{\sigma_v} = 8997 psi$; $\hat{y} = 9.56 ft$

$L = 0.072(8997)[p - 9.56]$

$L = 647.8p - 6196$

$-1.5TAL = -250.4p - 10510$

$397.4p - 16706 = 0$

$p = 42.0\ ft$

5

V Minimum Unconfined Compression Strength for 16.5-ft High Pillar Rib to Stand

$\Phi = 30°$; $\sigma_o = 16.5$ psi ; $\hat{\sigma}_v = 6965$ psi ; $\hat{y} = 28.79$ ft

$I = 0.072(6965)[p - 28.79]$

$I = 501.5p - 14440$

$-1.5TAL = -250.4p - 10510$

$p = 99.4$ ft

MAIN ENTRY PILLAR DESIGN FOR

FS = 1.5

Depth = 2225 ft

Density = 150 lb/ft³

Pillar Lengths − 500 ft and "p" from Storage Drift Design

Pillar Height − 10 ft

Room Width − 32 ft

I. $\Phi = 30°$; $\sigma_o = 450$ psi

$\hat{\sigma}_v = 7399$ psi ; $\hat{y} = 8.08$ ft

$p = 43.6$ ft R = 42.3%

II. $\Phi = 30°$; $\sigma_o = 1$ psi

$\hat{\sigma}_v = 6950$ psi ; $\hat{y} = 25.5$ [illegible]

$p = 83.1$ ft R = 2[illegible]

III $\Phi = 30°$; $\sigma_o = 1600$ [illegible]

$\hat{\sigma}_v = 8549$ psi ; $\hat{y} = 4.$[illegible]

$p = 30.1$ ft ; R = 51.5%

IV $\Phi = 35°$; $\sigma_o = 450$ psi

$\hat{\sigma}_v = 8997$ psi ; $\hat{y} = 5.80$ ft

90030005

$p = 29.6$ ft ; 51.9%

V $\Phi = 30°$; $\sigma_o = 10$ psi

$\hat{\sigma}_v = 6959$ psi ; $\hat{y} = 18.89$ ft ; $p = 69.7$ ft ; R = 31.5%

347

9003000[illegible]

16.5-ft High

42-ft Wide Storage Drifts

FS	I ○ p(ft)	I ○ R(%)	II + p(ft)	II + R(%)	III × p(ft)	III × 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

FS	IV □ p(ft)	IV □ R(%)	V ⊕ p(ft)	V ⊕ R(%)
1.25	34.05	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

I

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	56.72	36.07
1.25	33.88	48.57

p. II +

FS	p (ft)	R %
1.25	66.67	32.43
1.50	83.13	27.79
1.625	93.61	25.40
1.75	106.19	23.19
1.875	121.56	20.84
2.00	140.78	18.52
2.125	165.51	16.20
2.25	198.49	13.88
2.50	314.08	9.25

III ×

p (ft)	R %
23.72	57.43
30.09	51.59
38.09	45.65
48.47	39.76
62.46	33.88
82.33	27.99

I ⊙

	p (ft)	R (%)
	33.80	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	124.57	20.99
	152.84	17.3

IV p(ft) R %

FS	P ▫	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	30.14
2.55	78.16	29.05

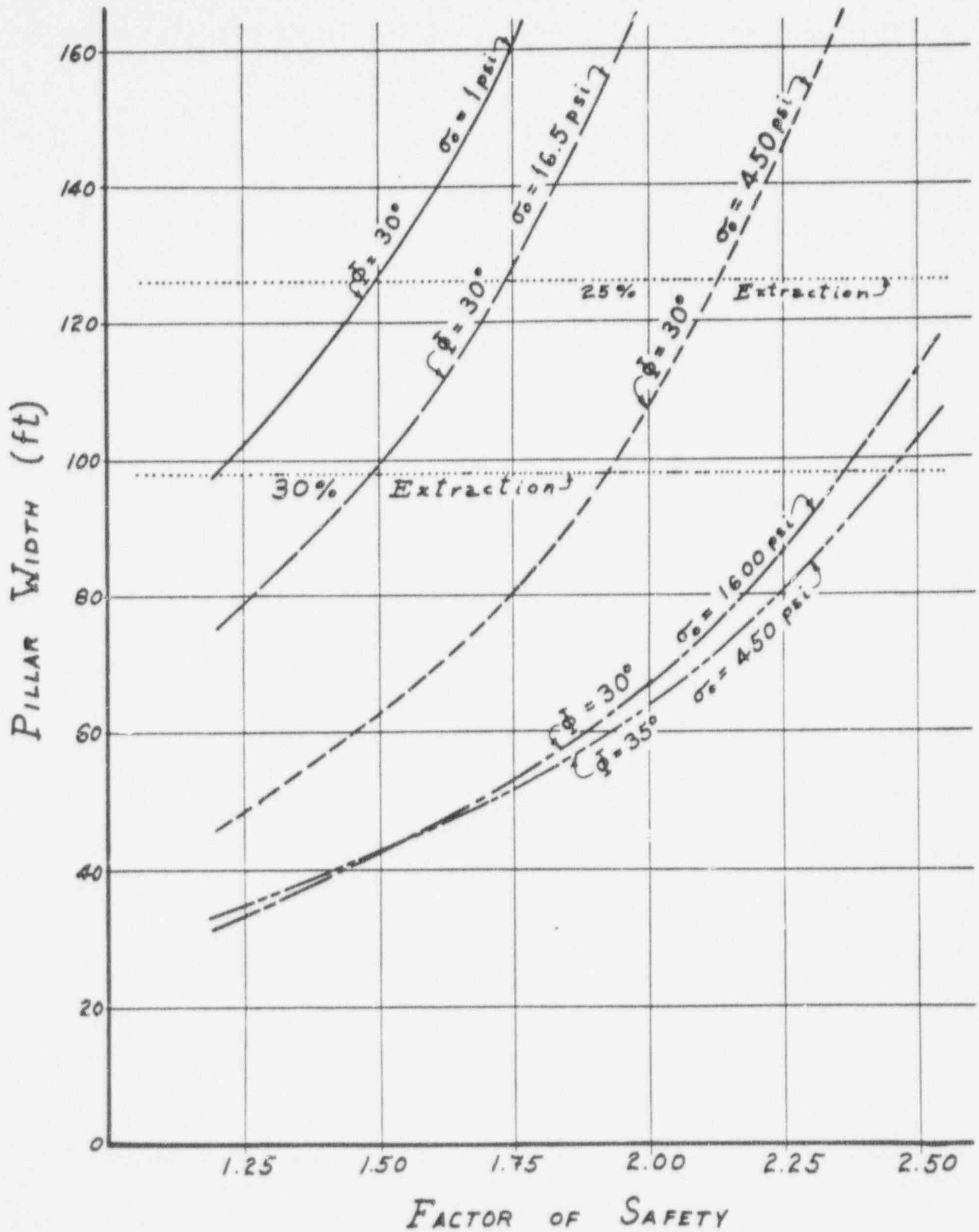
V ⊕

	p (ft)	R (%)
	55.20	36.70
	69.71	31.46
	90.01	26.23
1.875	120.44	20.99
2.125	142.16	18.37
	171.09	15.76
	272.15	10.52

349

90030007

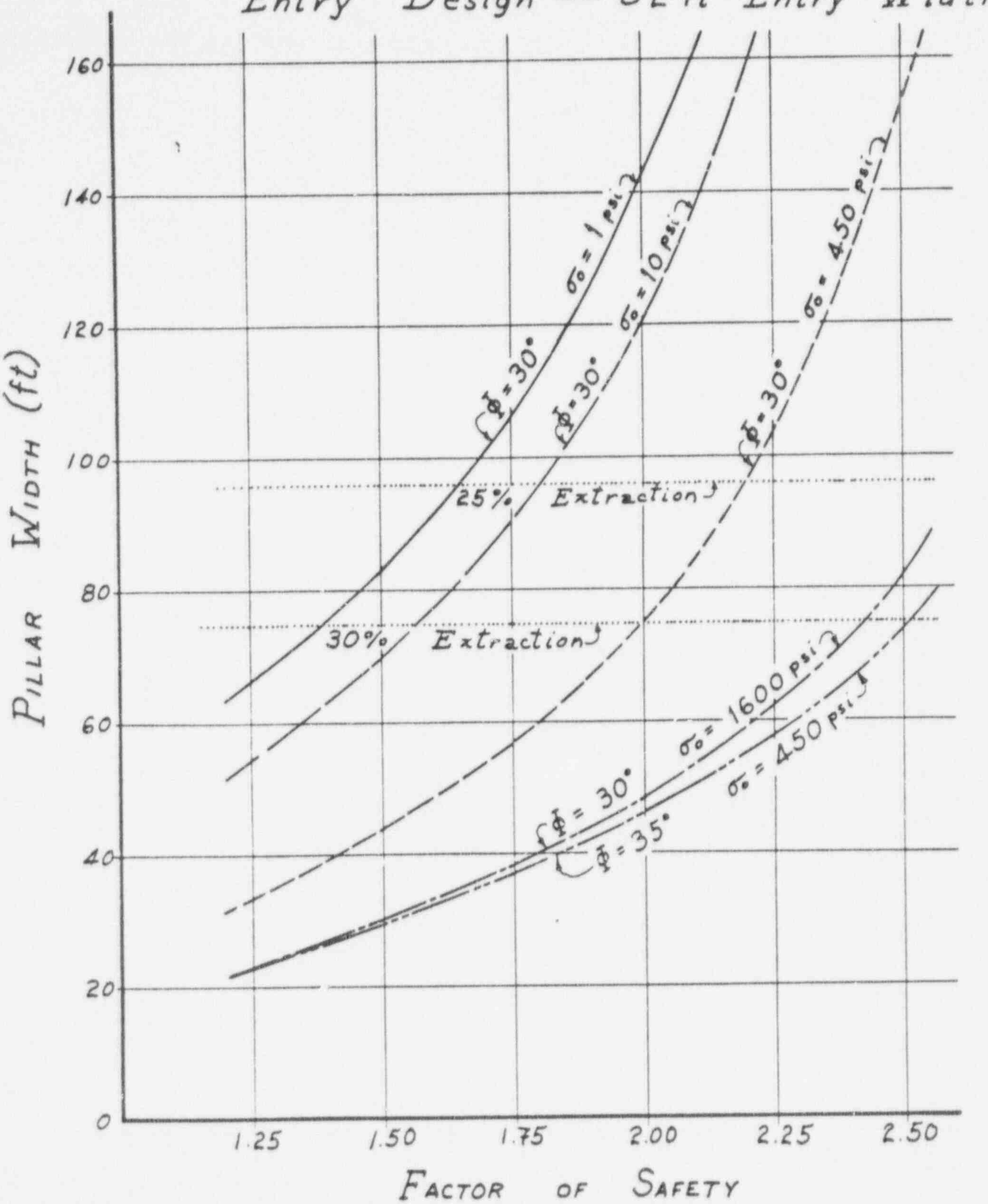
Storage Drift Design — 42-ft Room Width



350

90030008

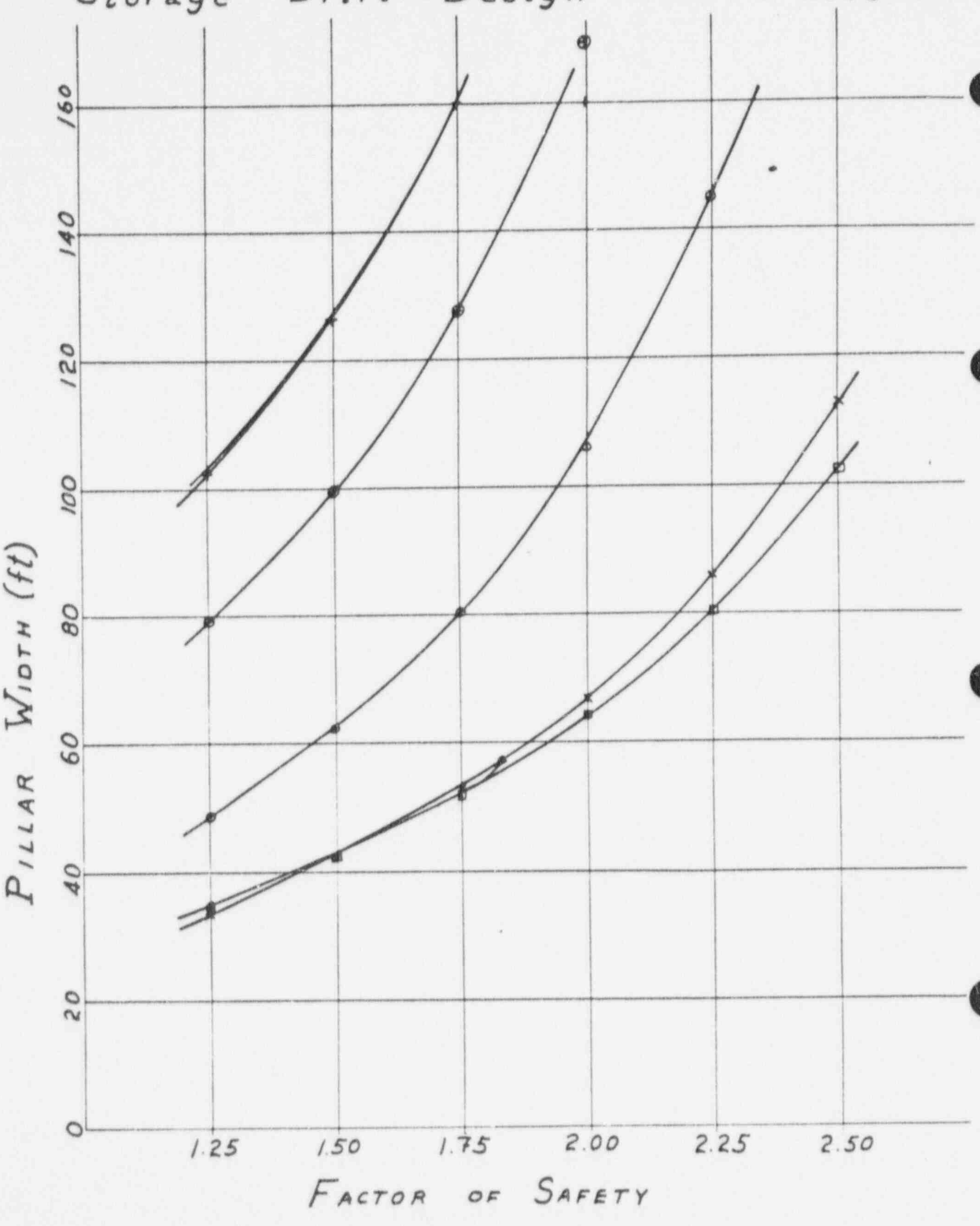
Entry Design — 32-ft Entry Width



351

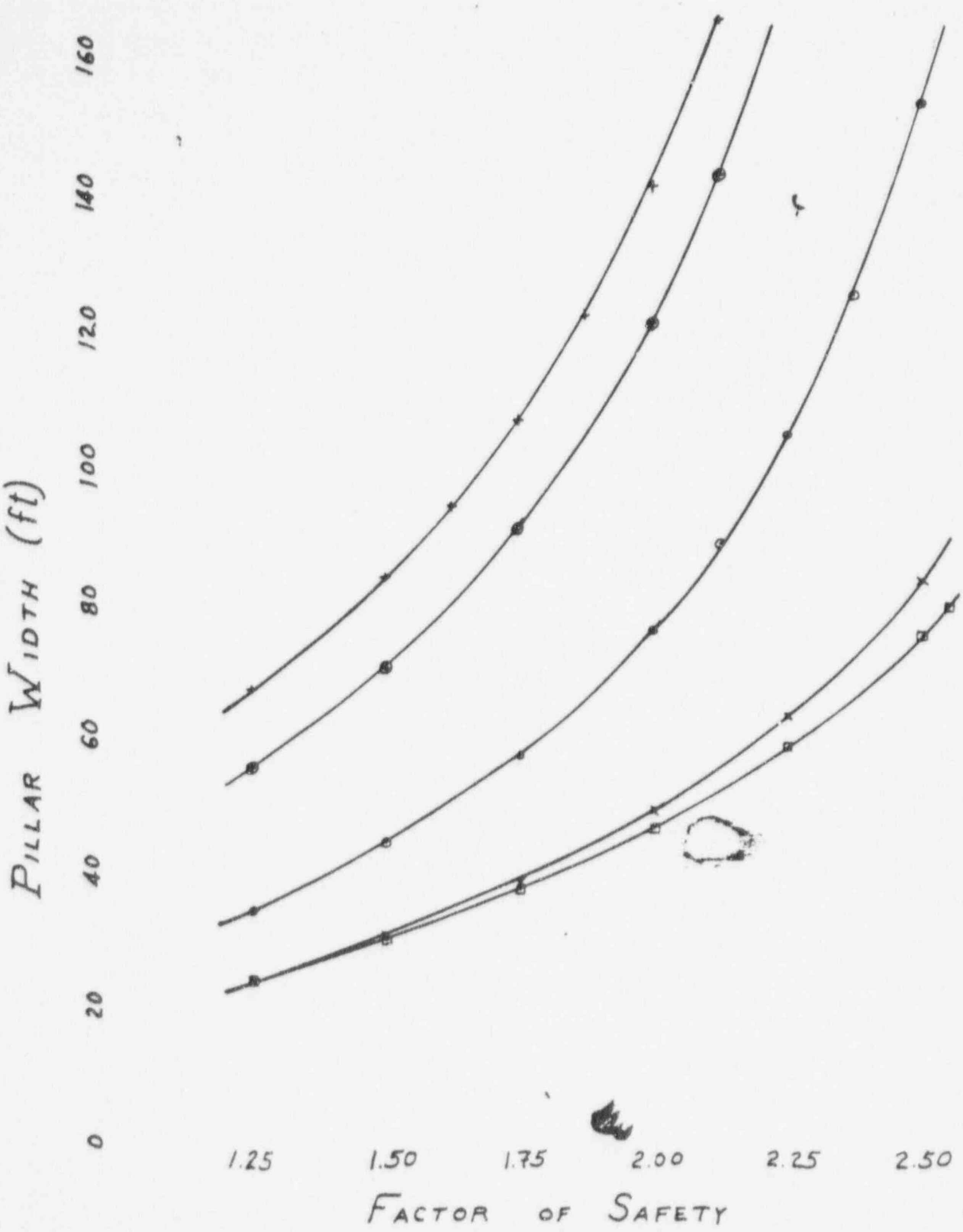
90030009

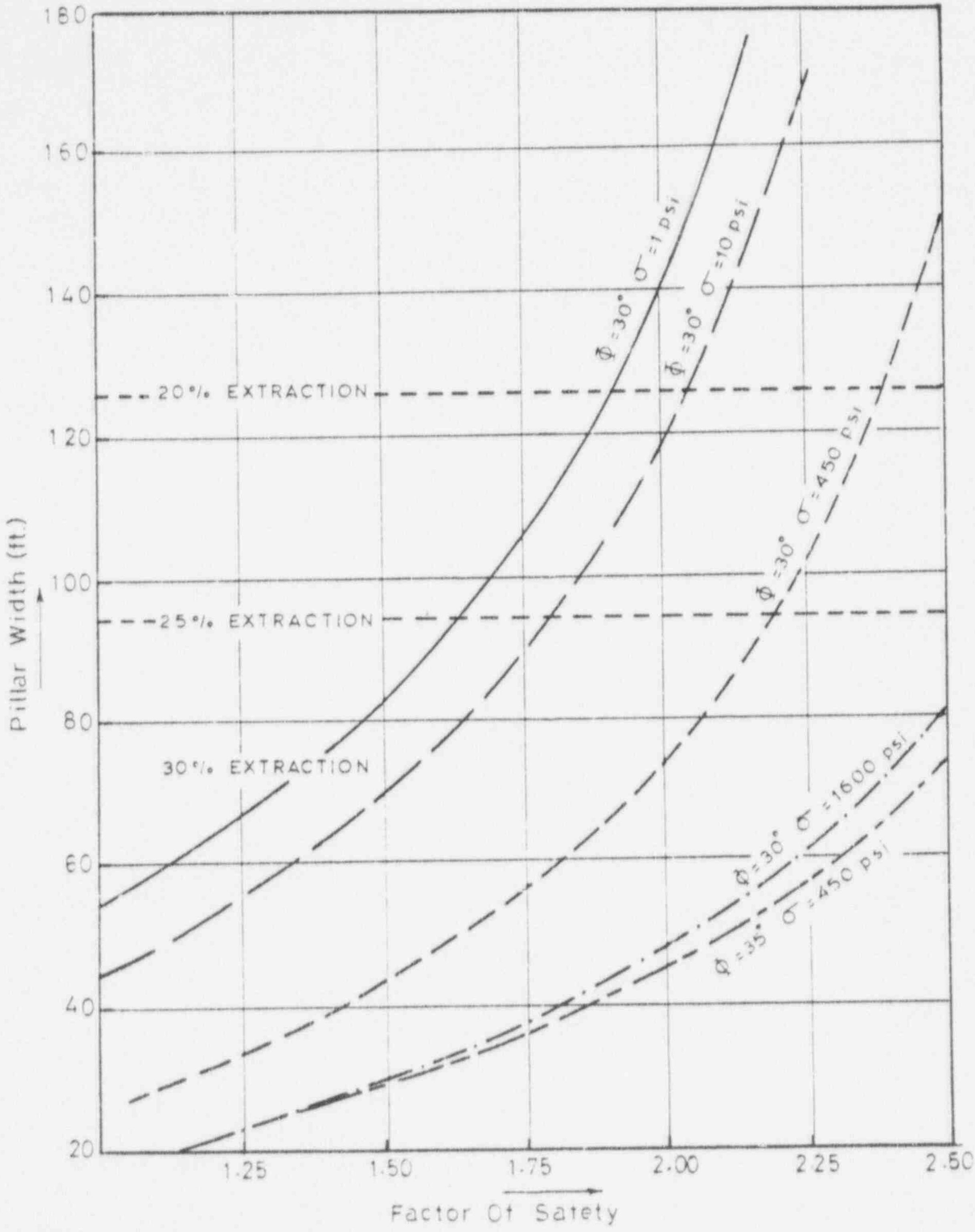
Storage Drift Design - 42-ft Wide Room



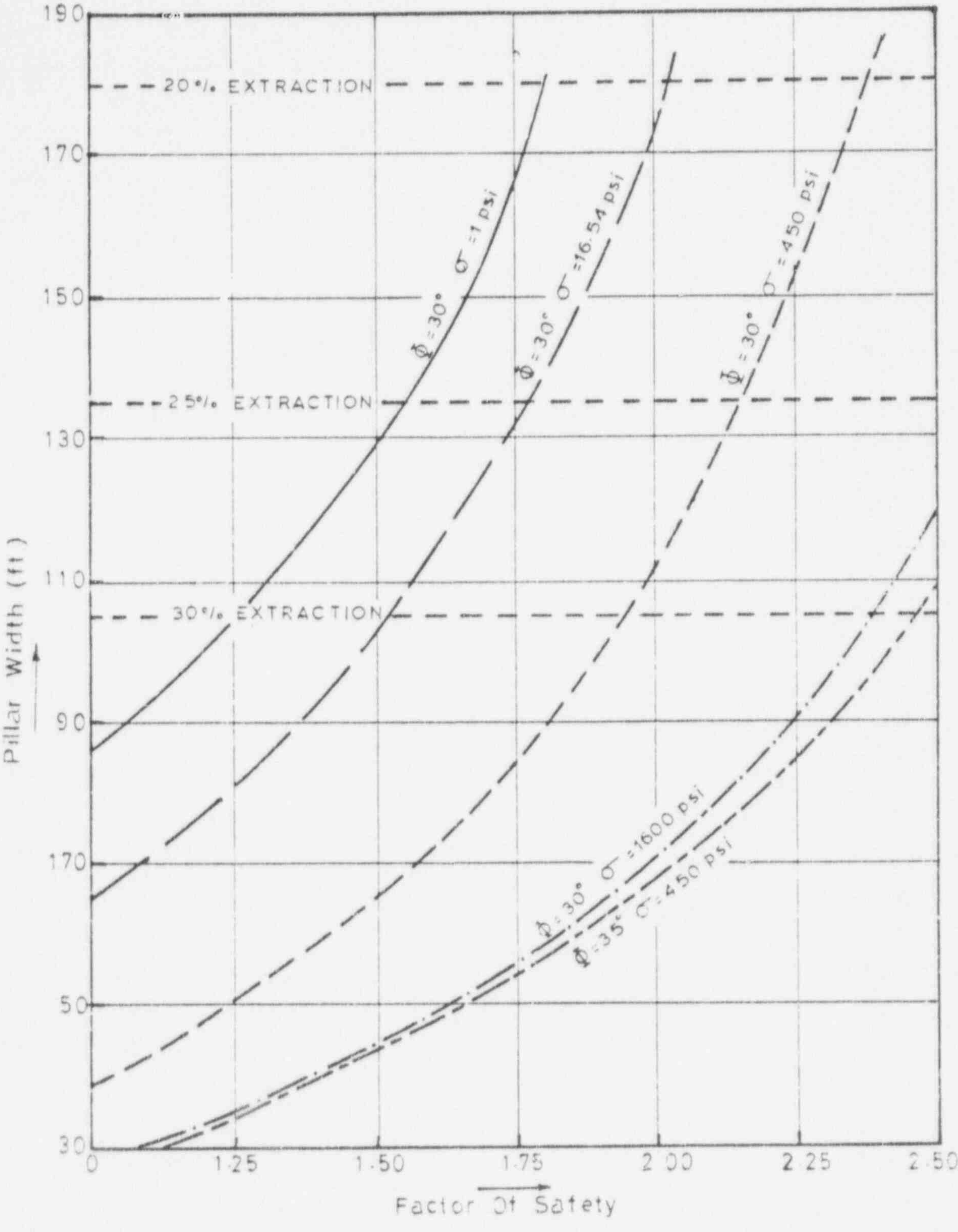
90030010

32-ft Entry Width





TRU LEVEL ENTRY DESIGN— 31.50 FT. WIDTH
10.00 FT. HEIGHT
2,225.00 FT. DEPTH

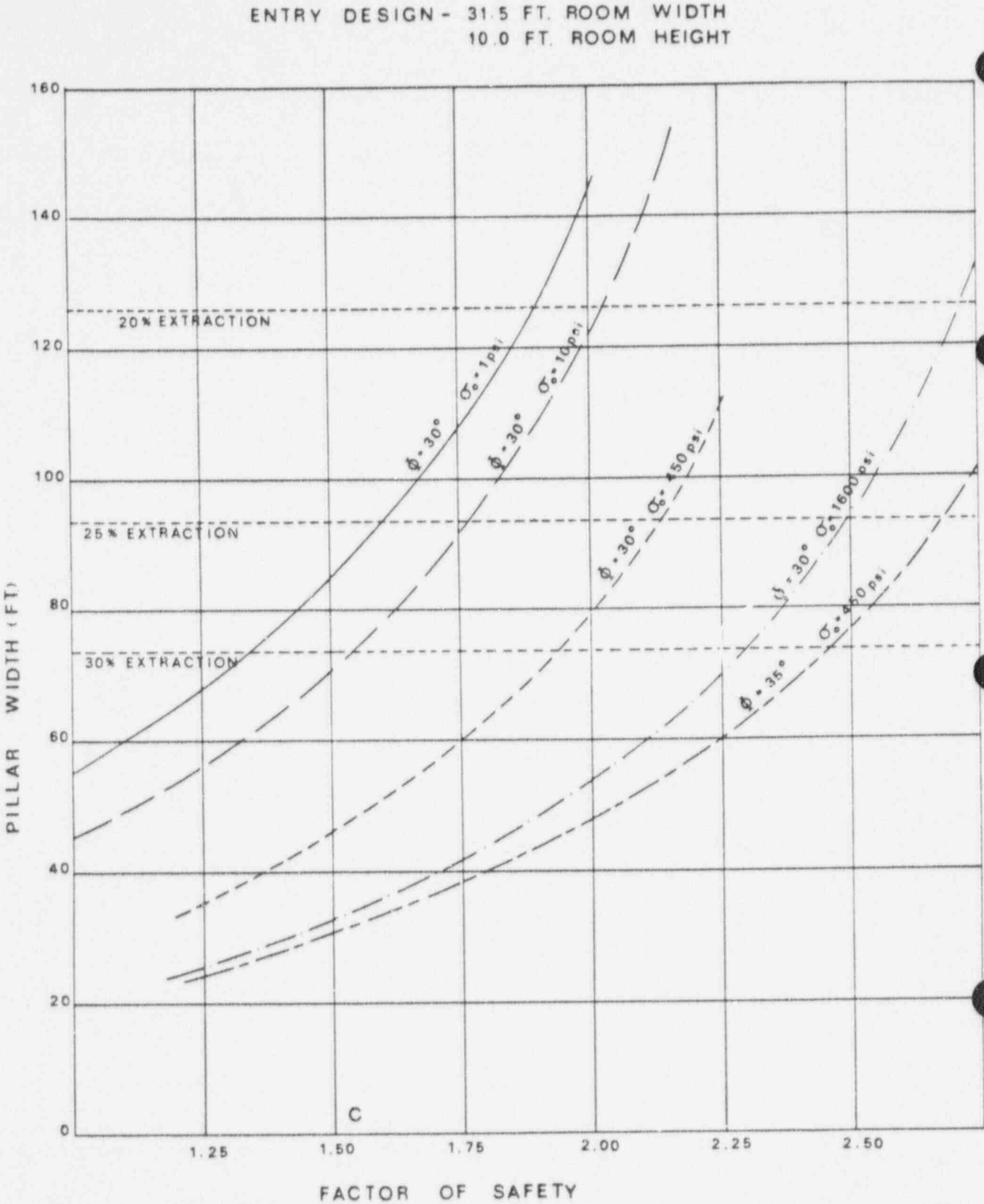


TRU STORAGE ROOM DESIGN - 45.00 FT. WIDTH
16.54 FT. HEIGHT
2,225 FT. DEPTH

90030013

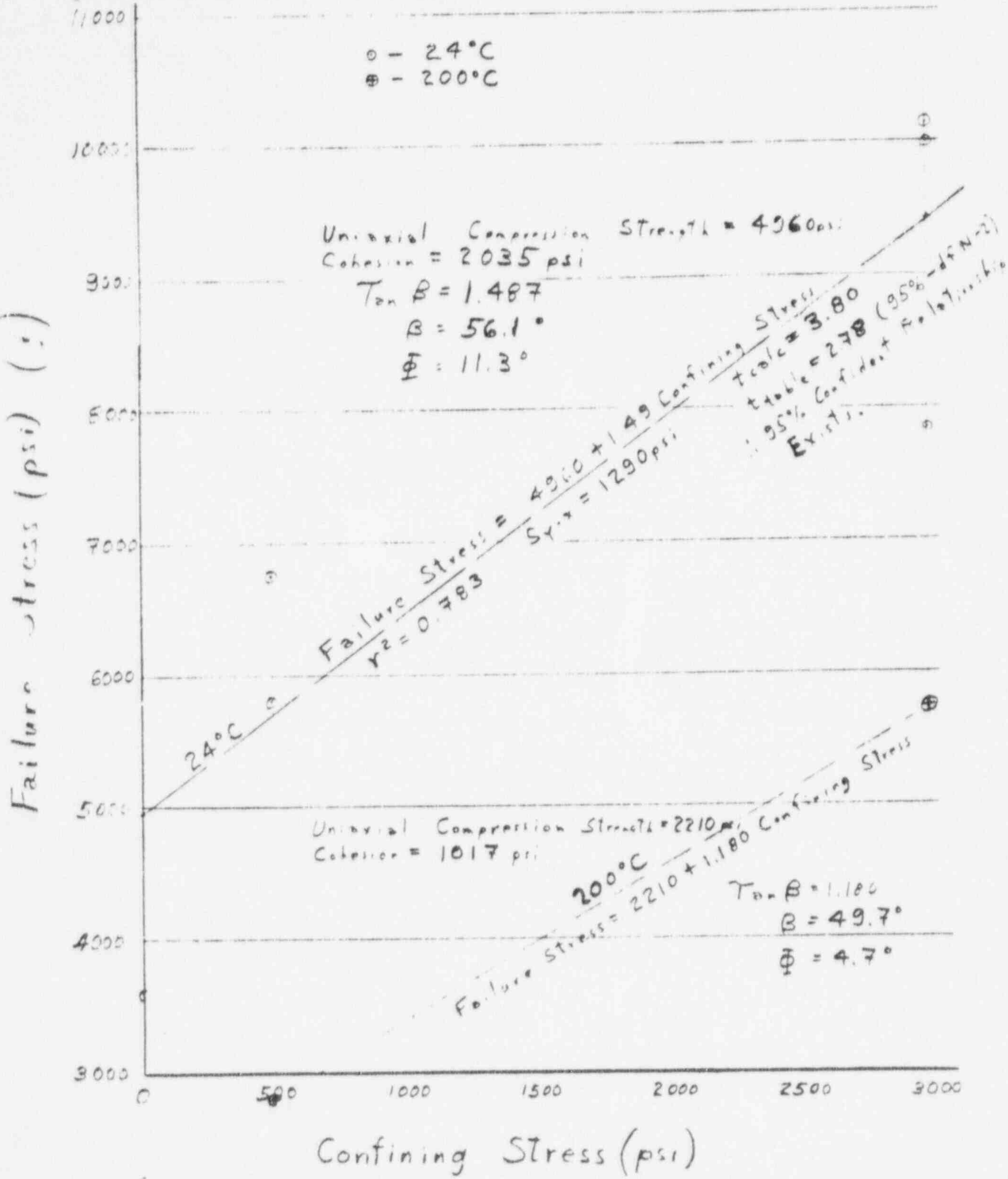
355

HR Level
2800 ft Depth



90030014 356

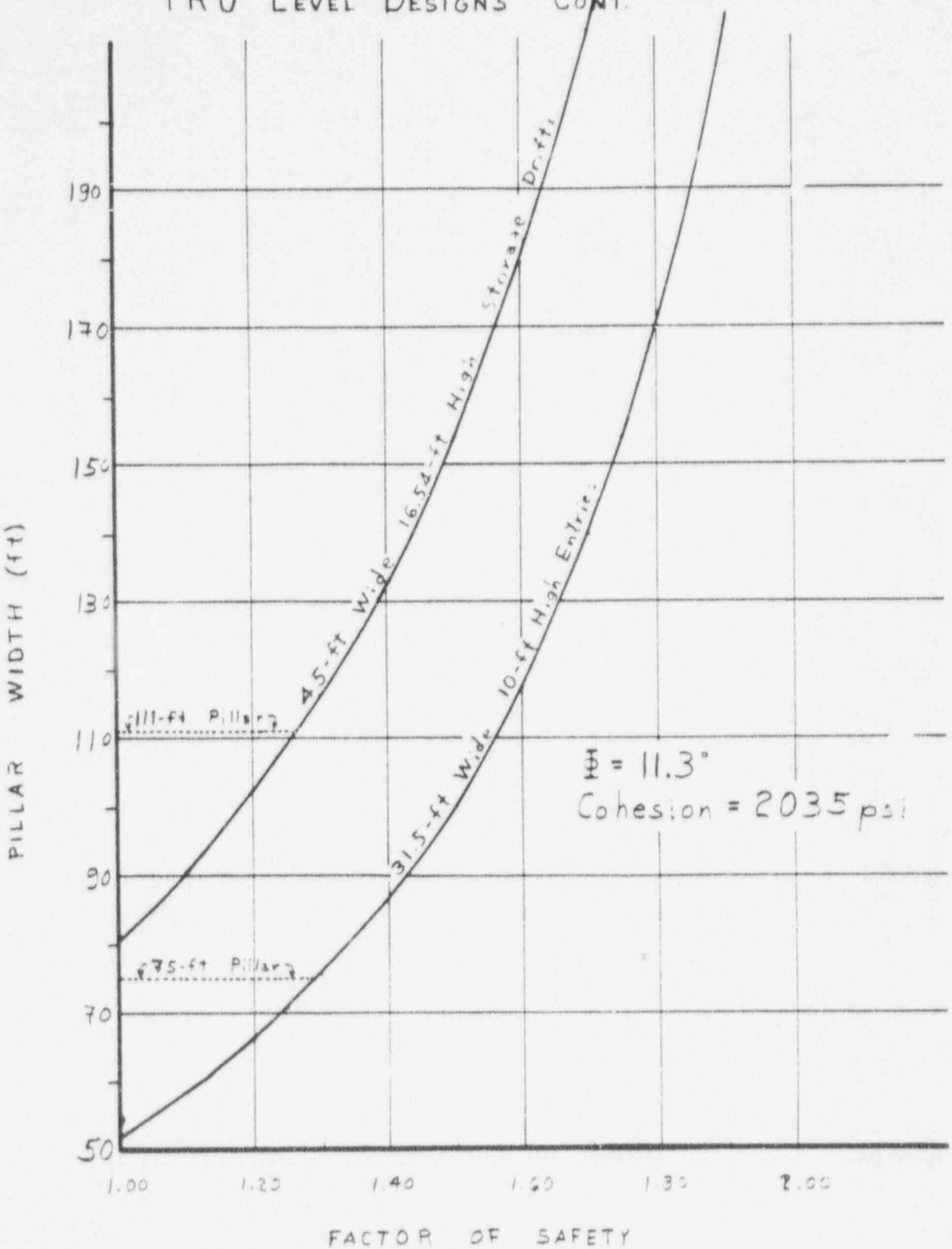
① TRU Level Nov. 16, '76 Triaxial Test
Quasi-static Results – Wawersik



90030015

②

TRU Level Designs Con't.



358

90030016

Depth - 2800 ft ; Temperature - Start 305.2°K, at 10yrs 373°K, then steady.
Pillar Width - 83.5 ft ; Room Width - 31.5 ft ; Room Height - 10 ft.

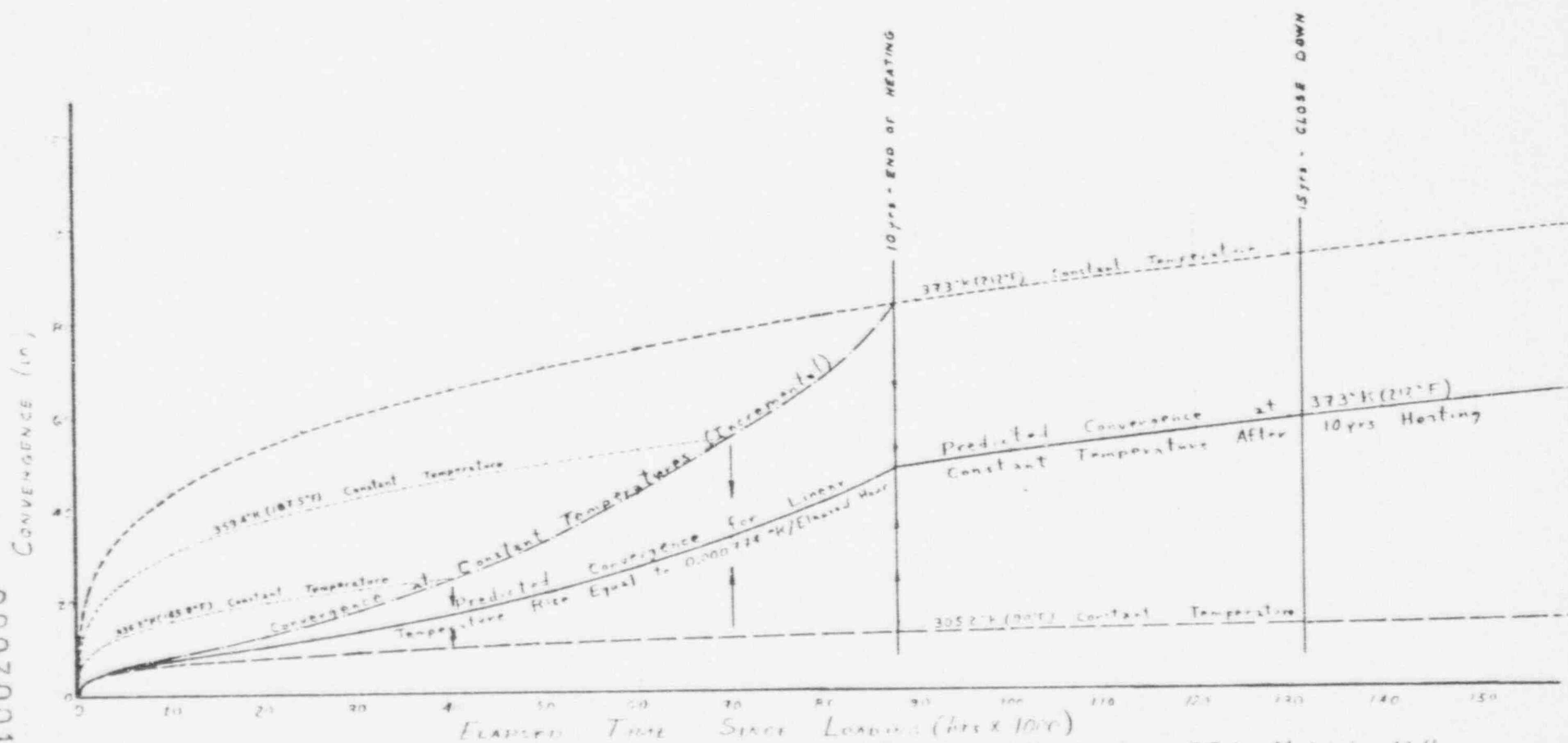


Figure ___ HR Level Convergence Versus Elapsed Time for 83.5 ft Wide Pillars.

9003001?

Depth 2800 ft ; Temperature - Start 305.2°K, at 10 yrs 373°K, then steady.
Room Width - 31.5 ft , Room Height - 10 ft

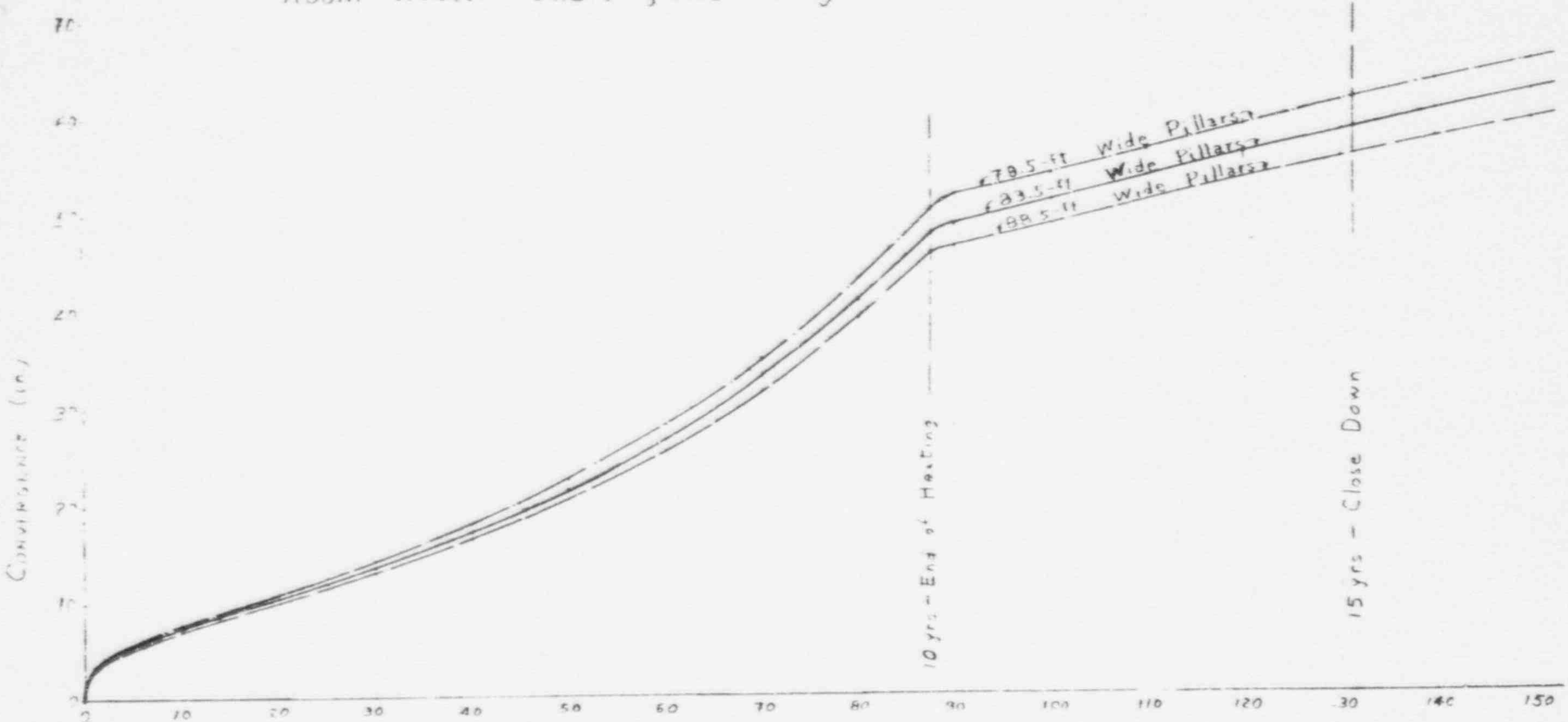


Figure ___. HR Level Convergence Versus Time Since Loading

9003001B

HP [illegible] Drift [illegible]

Premises Vertical Stress [illegible]; Pillar [illegible]; Room Width - 31.5 ft

Pillar Depth (ft)	Temperature Start (°F)	Temperature After 10 yr (°F)	Rise Rate (°F/hr)	P (%)	Init σ / σ_p	Time Interval (hr) From	To	Pillar Width 78.5 ft: Δl No Temp Increase	Δl At Final Temp	Avg Δl (in)	Pillar Width - 88.5 ft: Δl (in) No Temp Increase	Δl At Final Temp (in)	Avg Δl (in)	Pillar Width - 83.5 ft: Δl (in) No Temp	Δl At [illegible]	Avg Δl (in)
78.5	305.2	373.0	0.0007790		[illegible]	0	24	1.1091	1.1097	1.1099	1.0049	1.0055	1.0052	1.0530	1.0536	1.0533
						0	50	1.3823	1.3840	1.3831	1.2524	1.2539	1.2532	1.3124	1.3140	1.3132
						0	100	1.7018	1.7057	1.7038	1.5403	1.5456	1.5432	1.6157	1.6196	1.6177
							200	2.0952	2.1053	2.1002	1.8983	1.9074	1.9029	1.9892	1.9988	1.9940
							500	2.7580	2.7914	2.7747	2.4989	2.5291	2.5140	2.6186	2.6503	2.6344
							1000	3.3955	3.4782	3.4369	3.0765	3.1514	3.1137	3.2238	3.3023	3.2631
							2000	4.1804	4.3862	4.2833	3.7876	3.9741	3.8808	3.9690	4.1649	4.0667
							4000	5.1467	5.6646	5.4056	4.6630	5.1323	4.8977	4.8864	5.3781	5.1323
							6000	5.8124	6.7090	6.2607	5.2662	6.0786	5.6724	5.5185	6.3698	5.9441
							8000	6.3363	7.6684	7.0023	5.7409	6.9478	6.3443	6.0159	7.2806	6.6482
							10000	6.7750	8.5748	7.6749	6.1384	7.7872	6.9628	6.4324	8.1602	7.2963
							12000	7.1559	9.5137	8.3398	6.4835	8.6197	7.5516	6.7940	9.0326	7.9133
							15000	7.6513	10.9087	9.2800	6.9323	9.8836	8.4080	7.2644	10.3570	8.8107
							20000	8.3410	13.3459	10.8437	7.5572	12.0918	9.8245	7.9192	12.6710	10.2951
							25000	8.9185	15.9923	12.4554	8.0804	14.4896	11.2850	8.4675	15.1837	11.8256
							30000	9.4198	18.9048	14.1623	8.5347	17.1284	12.8315	8.9435	17.9489	13.4462
							40000	10.2688	25.7137	17.9912	9.3040	23.2972	16.3006	9.7497	24.4132	17.0814
							50000	10.9797	34.1312	22.5555	9.9482	30.9240	20.4361	10.4247	32.4053	21.4150
							60000	11.5972	44.5383	28.0677	10.5074	40.3532	25.4303	11.0108	42.2861	26.6485
							70000	12.1461	57.3649	34.7555	11.0048	51.9745	31.4896	11.5319	54.4641	32.9980
							80000	12.6425	73.1068	42.8747	11.4546	66.2373	38.8457	12.0033	69.4101	40.7067
						0	87600	12.9915	87.3708	50.1811	11.7707	79.1609	45.4658	12.3346	82.9527	47.6436
No Change in Temp						0	90000	[illegible]		5[illegible].[illegible]929		79.8054	46.1703		83.6281	48.3790
							100000		90.9107	53.7210		82.3682	48.6734		86.3137	51.[illegible]
							110000		93.5476	56.3579		84.7573	51.0622		88.8173	53.5402
							120000		96.0217	58.8320		86.9089	53.3038		91.1662	55.8571
							130000		98.3553	61.1656		89.1133	55.4182		93.3819	58.0720
							1319[illegible]		98.6719	61.4827		89.4001	55.7050		93.6824	58.3338
							140000		100.5665	63.3768		91.1167	57.4216		95.4812	60.1721
							150000		102.6697	65.4800		93.0222	59.3271		97.4781	62.1690
							170000		106.5981	69.4084		96.5815	62.8864		101.2075	65.8984
							200000		111.9242	74.7345		101.4071	67.7120		106.2646	70.9555
							225000		115.9497	78.7600		105.0544	71.3593		110.0866	74.7775
							250000		119.6732	82.4835		108.4280	74.7329		113.6218	78.3127
							262800		121.4794	84.2897		110.0644	76.3693		115.3366	80.0275

90030019

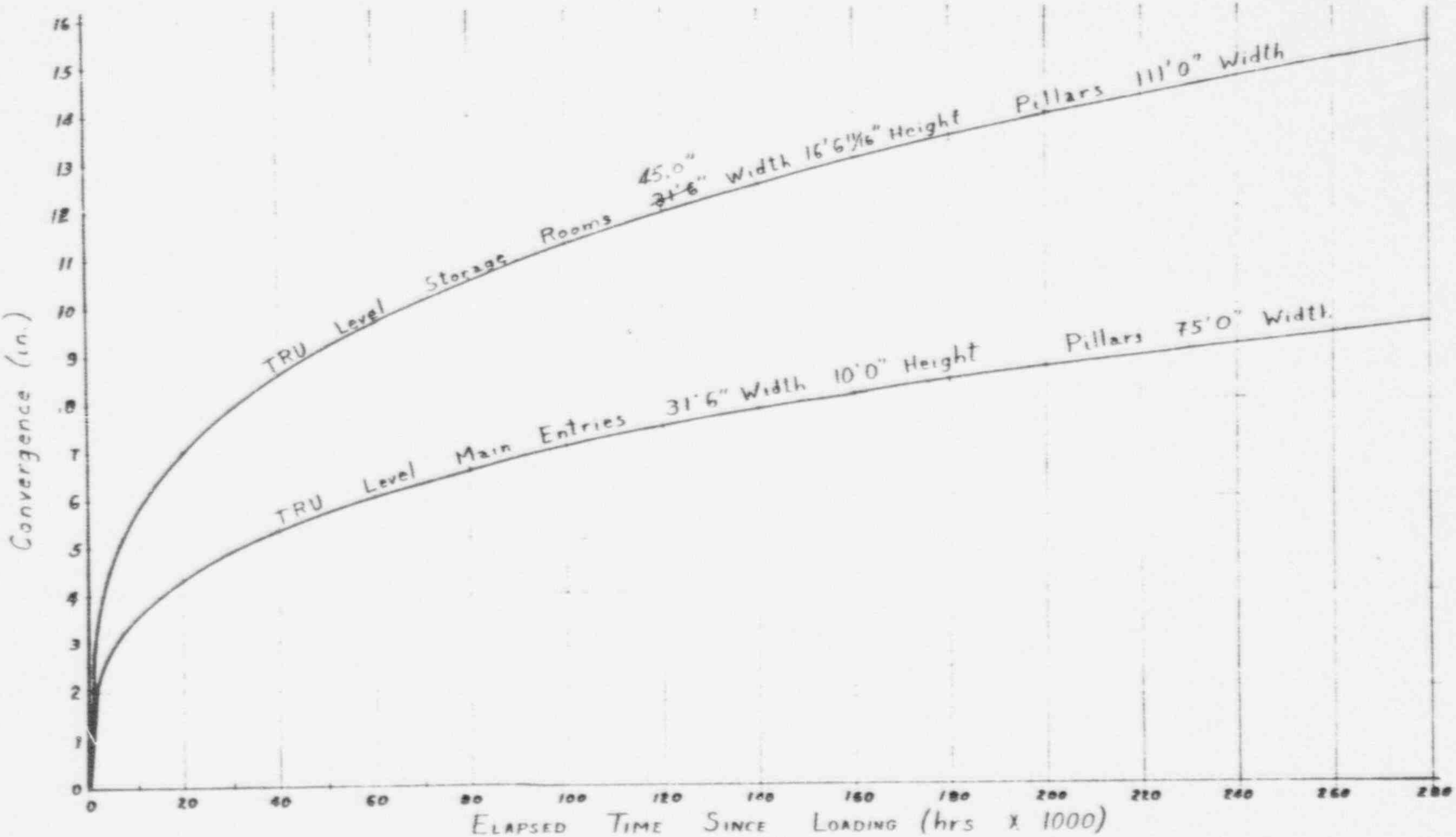


Figure ___ TRU Level Convergence Versus Elapsed Time

90030020

342

DESIGN SHEET

COMPUTED BY: J.L. Ain
CHECKED BY: ______
CALCULATIONS FOR: MINE STABILITY BASED ON HISTORICAL DATA

SHEET 1 OF ____
PROJECT NO. 288
DATE 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	645	75
WINNFIELD	811	66
LYONS	1024	68
RETSOF	1063	73,5
DETROIT	1100	65
BELLE ISLE	1250	52,8
COTE BLANCHE	1354	56
* GODERICH	1760	32,2
WHISKEY ISLAND	1775	54
SENECA LAKE	2000	55
MOAB (AVG)	3200	38
ESTERHAZY	3400	36,6

* GODERICH ~ 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.

363

90030021

FENIX & SCISSON, INC.
LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: ____________
CHECKED BY: ____________
CALCULATIONS FOR: ____________

SHEET 5 OF ____
PROJECT NO. 286
DATE: Sept 17 1975

n =	12 (no Goderich)	13
Σx =	17,622	19,382
Σx^2 =	36,808,732	39,906,332
Σx^3 =	94,507,440,966	99,959,216,966
Σx^4 =	274,666,206,979,400	284,261,332,739,400
Σx^5 =	851,676,759,220,000,000	868,564,175,565,680,000
Σx^6 =	2,728,521,676,019,000 × 10^6	2,758,242,937,567,000 × 10^6
Σx^7 =	8,889,872,769,926,000 × 10^9	8,948,183,245,661,000 × 10^9
Σx^8 =	29,230,076,506,060,000 × 10^{12}	29,322,142,949,410,000 × 10^{12}
Σy =	739.90	772.10
Σxy =	919,877.50	971,549.50
Σx^2y =	1,695,132,796.50	1,794,875,516.50
Σx^3y =	3,970,977,029,239.	4,146,589,216,439.
Σx^4y =	10,919,093,566,930,000.	11,223,006,616,900,000

364

90030022

FENIX & SCISSON, INC.
LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: ____
CHECKED BY: ____
CALCULATIONS FOR: ____

SHEET 9 OF ____
PROJECT NO. 888
DATE Sept. 17 1975

$y = a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4$

$12a_0 + 17,622a_1 + 36,808,732a_2 + 99,507,440,966a_3 + 279,666,206,979,400a_4 = 739.90$

$17,622a_0 + 36,808,732a_1 + 99,507,440,966a_2 + 279,666,206,979,400a_3 + 851,676,754,228,000,000a_4 =$

$919,877.50$

$36,808,732a_0 + 99,507,440,966a_1 + 279,666,206,979,400a_2 + 851,676,754,228,000a_3 \times 10^3 +$

$2,728,521,076,013,000a_4 \times 10^6 = 1,695,132,796.50$

$99,507,440,966a_0 + 279,666,206,979,400a_1 + 851,676,754,228,000a_2 \times 10^3 + 2,728,521,076,013,000a_3 \times 10^6 +$

$8,889,872,769,326,000a_4 \times 10^9 = 3,970,977,029,239.$

$279,666,206,979,400a_0 + 851,676,754,228,000a_1 \times 10^3 + 2,728,521,076,013,000a_2 \times 10^6 +$

$8,889,872,769,326,000a_3 \times 10^9 + 28,230,096,504,000,000a_4 \times 10^{12} = 10,917,093,566,930,000.$

965

90030023

FENIX & SCISSON, INC.
LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: ______
CHECKED BY: ______
CALCULATIONS FOR: ______

SHEET 2 OF ___
SUBJECT NO. ___
DATE Sept 17 1975

2-1

$10,930,825\,a_1 + 90,153,818,029\,a_2 + 135,882,029,920,800\,a_3 + 498,329,929,278,800,000\,a_4 = -171,665.65$

3-1

$90,453,818,029\,a_1 + 161,759,311,025,900\,a_2 + 561,785,165,351,100\,a_3 \times 10^3 + 1,886,011,509,167,000\,a_4 \times 10^6 =$

$-579,938,270.7830$

4-1

$135,882,029,920,800\,a_1 + 561,785,165,351,100\,a_2 \times 10^3 + 1,989,216,376,185,080\,a_3 \times 10^6 +$

$6,726,706,079,209,080\,a_4 \times 10^9 = -1,856,199,268,383$

5-1

$498,329,929,278,700\,a_1 \times 10^3 + 1,886,011,509,167,080\,a_2 \times 10^6 + 6,726,706,079,209,000\,a_3 \times 10^9 +$

$22,993,252,739,690,000\,a_4 \times 10^{12} = -6,021,916,978,914,000$

366

90030024

FENIX & SCISSON, INC.
LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: ______
CHECKED BY: ______
CALCULATIONS FOR: ______

SHEET 5 OF ____
PROJECT NO. 288
DATE Sept. 17, 1975

7-6

$12,044,043,173,300\,a_2 + 58,900,258,571,600\,a_3 \times 10^3 + 226,792,086,402,350\,a_4 \times 10^6 = 60,883,999.18$

8-6

$58,900,258,571,700\,a_2 \times 10^3 + 295,055,122,996,000\,a_3 \times 10^6 + 1,153,489,206,355,000\,a_4 \times 10^9 = 277,796,257,522$

9-6

$226,792,086,402,000\,a_2 \times 10^6 + 1,153,489,206,356,000\,a_3 \times 10^9 + 9,554,953,849,890,000\,a_4 \times 10^{12} =$

$1,019,975,941,999,000$

11-10

$7,008,956,946,200\,a_3 \times 10^6 + 44,378,871,968,000\,a_4 \times 10^9 = -19,951,205,101.80$

12-10

$44,378,871,971,000\,a_3 \times 10^9 + 289,407,014,870,000\,a_4 \times 10^{12} = -126,984,181,560,000$

14-13

$-3,941,669,570,700\,a_4 \times 10^{12} = -658,398,183,600$

$a_4 = 192.984159208890 \times 10^{-15}$

367

90030025

at $a_4 = 192.984159288890 \times 10^{-15}$

$7,008,956,996,208\ a_3 \times 10^{6} = -28,515,624,395.18$ $\qquad a_3 = -4.068454780656 0 \times 10^{-9}$

$44,378,871,971,008\ a_3 \times 10^{9} = -181,870,230,197,800$ $\qquad = -4.098126475965 0 \times 10^{-9}$

at $a_3 = -4.0832906283110 \times 10^{-9}$

$12,094,043,173,300\ a_2 = 257,623,592.9010$ $\qquad a_2 = 21.390125325370 \times 10^{-6}$

$58,900,358,571,700\ a_2 \times 10^{3} = 1,259,987,896,363$ $\qquad = 21.391890747960 \times 10^{-6}$

$226,792,086,402,000\ a_2 \times 10^{6} = 4,850,452,752,756,000$ $\qquad = 21.387222233840 \times 10^{-6}$

at $a_2 = 21.3897461022280 \times 10^{-6}$

$10,930,825\ a_1 = -568,637.20502580$ $\qquad a_1 = -52.021435255360 \times 10^{-3}$

$40,453,808,024\ a_1 = -2,104,961,112.6780$ $\qquad = -52.021322972690 \times 10^{-3}$

$135,882,029,920,800\ a_1 = -7,068,651,901,736.00$ $\qquad = -52.020505624340 \times 10^{-3}$

$448,339,429,276,700\ a_1 \times 10^{-3} = -23,323,312,771,680,000$ $\qquad = -52.022711980350 \times 10^{-3}$

FENIX & SCISSON, INC.
LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY: ______
CHECKED BY: ______
CALCULATIONS FOR: ______

SHEET 1 OF ____
PROJECT NO. 560
DATE Sept 17 1985

at $a_1 = -52.0214993833130 \times 10^{-3}$

$12\,a_0 = 1202.1884539880$ $\qquad a_0 = 100.1823711240$

$17{,}622\,a_0 = 1{,}765{,}414{,}384252$ $\qquad = 100.1824079595$

$36{,}808{,}722\,a_0 = 3{,}687{,}592{,}986.9030$ $\qquad = 100.1825595868$

$94{,}507{,}440{,}966\,a_0 = 9{,}468{,}113{,}889{,}657$ $\qquad = 100.1837819626$

$274{,}666{,}206{,}979{,}400\,a_0 = 27{,}516{,}165{,}751{,}640{,}000$ $\qquad = 100.1803827790$

at $a_0 = 100.1823025824$

$$y = 100.1823025824 - 52.0214928331\,3\,x \times 10^{-3} + 21.3897461022\,2\,x^2 \times 10^{-6} - 4.0832906283\,11\,x^3 \times 10^{-9} +$$

$$192.9891592083\,x^4 \times 10^{-15}$$

at $x = 0$	$y = 100.1823$	at $x = 1400$	$y = 58.8129$	at $x = 2800$	$y = 44.4432$
200	90.6012	1600	56.2952	3000	42.0089
400	85.5397	1800	54.0585	3200	39.1791
600	75.8127	2000	52.1197	3400	35.8742
800	70.2929	2200	50.3033	3600	32.0200
1000	65.6602	2400	48.4910	3800	27.5501
1200	61.9020	2600	46.5721	4000	22.4056
				4661.25	0.00024906195

369

90030027

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LAS VEGAS, NEVADA 89101

DESIGN SHEET

COMPUTED BY:
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CALCULATIONS FOR:

SHEET 9 OF
PROJECT NO. 318
DATE Sept. 19, 1978

$y = 100.0980626787 - 50.5466804662\,x \times 10^{-3} + 18.2$ [illegible]

at x = 0	, y = 100.0981	at x = 1400	, y = 58.7494	at x = 2800	, y = 44.8506
200	90.7250	1600	56.1420	3000	42.3839
400	82.7333	1800	53.9947	3200	39.3858
600	75.8365	2000	52.1357	3400	35.7196
800	70.3478	2200	50.4284	3600	31.2487
1000	65.6806	2400	48.7362	3800	25.8364
1200	61.6484	2600	46.9225	4000	19.3462
				4451.85	0.000199

$y = 96.6880394222230 - 34.4131638065820\,x \times 10^{-3} + 5.0551429968520\,x^2 \times 10^{-6}$

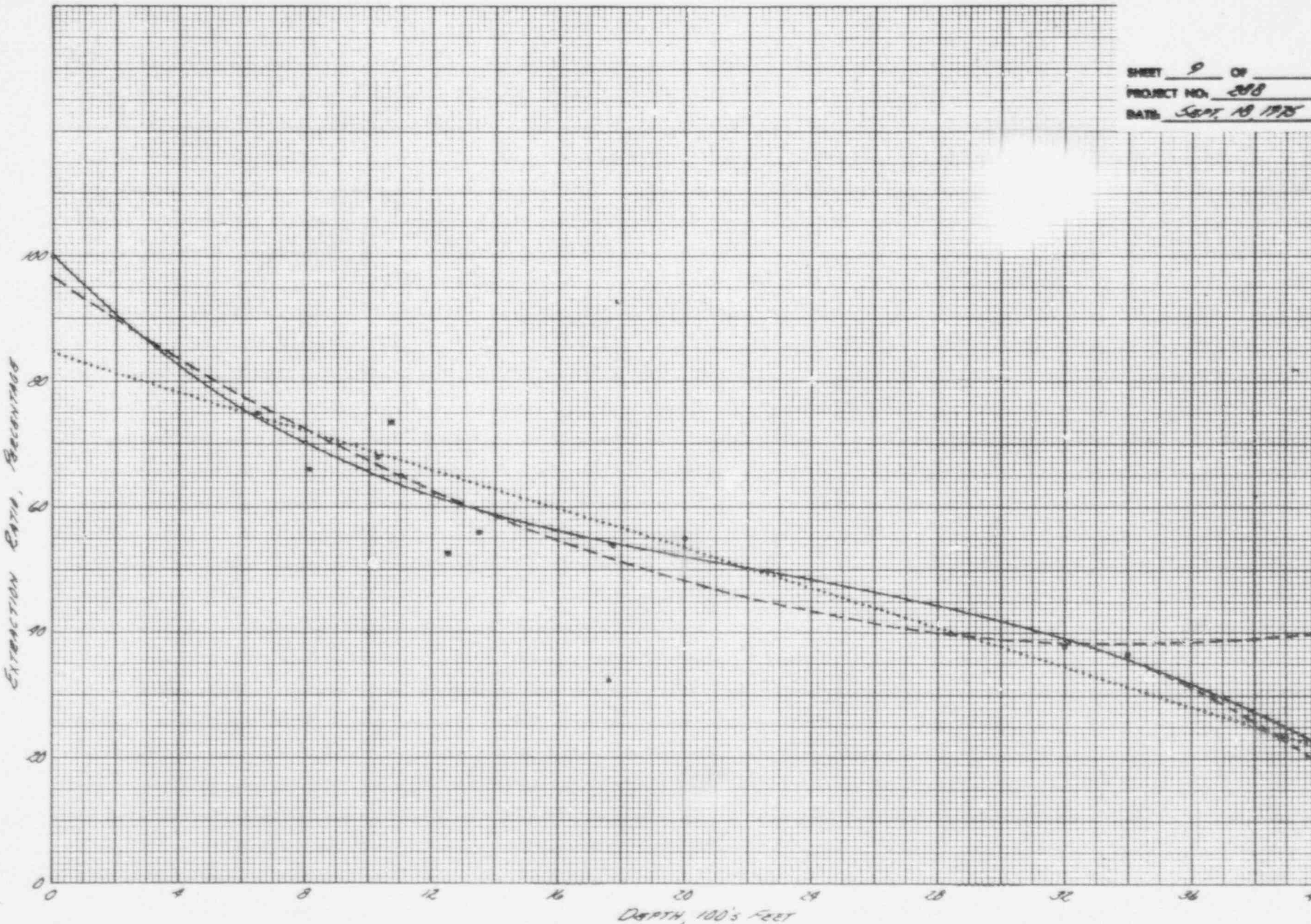
at x = 0	, y = 96.6880	at x = 1400	, y = 58.4176	at x = 2800	, y = 39.9633
200	90.0076	1600	54.5681	3000	38.9446
400	83.7316	1800	51.1229	3200	38.3303
600	77.8600	2000	48.0822	3400	38.1204
800	72.3928	2200	45.4458	3600	38.3149
1000	67.3300	2400	43.2139	3800	38.9138
1200	62.6716	2600	41.3864	4000	39.9172

$y = 89.7207282595 - 25.7097295149930\,x \times 10^{-3}$

at x = 0, y = 89.7207   at x = 2000, y = 53.3113   at x = 4000, y = 21.9018

K+E 10 X 10 TO ½ INCH 46 1322
7 X 10 INCHES
KEUFFEL & ESSER CO.

SHEET 9 OF ______
PROJECT NO. 288
DATE: Sept. 18, 1975



90030029

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TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: J. L. Ash

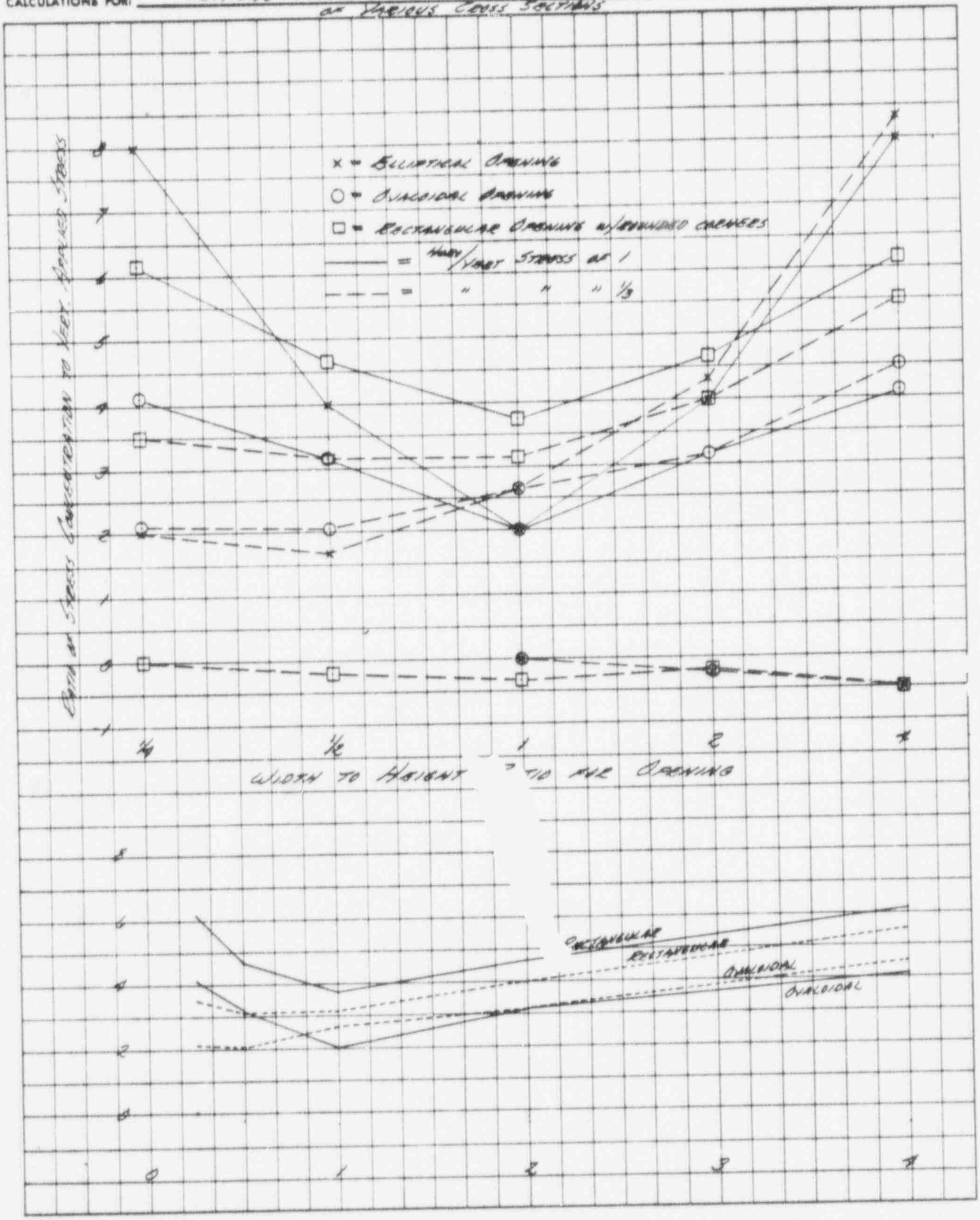
CHECKED BY: ____________

CALCULATIONS FOR: Critical Stress Concentrations for Openings of Various Cross Sections

SHEET ______ OF ______

PROJECT NO: 868

DATE: Sept 16, 1976



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90030030

Critical Stresses on Opening Boundary

Ratio of Horz. to Vert. Applied Stress	Angle from Horizontal	0.25	0.50	1.00	2.00	4.00
		Width to Height Ratio (w/h) for Opening				
Elliptical Opening						
0	0°	1.5	2.0	3.0	5.0	9.0
	90°	-1.0	-1.0	-1.0	-1.0	-1.0
1/3	0°		1.67	2.67	4.33	8.33
	90°	3.0			-0.33	-0.5
1	0°			2.0	4.0	8.0
	90°	9.0	4.0	2.0		
Ovaloidal Opening						
0	0°	1.9	2.0	3.0	3.4	4.85
	90°	-1.0	-0.9	-1.0	-0.9	-1.0
1/3	0°				3.15	4.5
	90°	3.1	2.05	2.67	-0.33	-0.5
1	0°			2.0	3.15	4.1
	90°	4.1	3.15			
Rectangular Opening with Rounded Corners Having a Fillet Radius of Opening Short Dimension Ratio of 1:6						
0	Corner	3.5	2.67	3.15	4.0	5.33
	90°	-1.0	-1.0	-1.0	-0.9	-0.9
1/3	Corner	3.5	3.1	3.15	4.0	5.5
	90°		-1.2	-0.33	-0.5	-0.5
1	Corner	6.15	4.67	3.75	4.67	6.15
	90°					

9003003l

J. L. Ash
9/20/76

CREEP RATES AND TOTAL CLOSURE FOR ISOLATED OPENINGS

Use $\dot{\epsilon} = k\sigma^n t^{-0.85}$ for first year and then assume to be constant thereafter

where $\dot{\epsilon}$ 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 $= \int_{t_0}^{t} k\sigma^n t^{-0.85}\,dt = k\sigma^n t^{0.15}/0.15$ in inches per inch

At a density of 150 pounds per cubic foot for the overlying material,

$\sigma = 150 \times \text{depth}/144 = 150 \times 2230/144 = 2325$ psi for the TRH level

$= 150 \times 2800/144 = 2920$ psi for the RH level

Taking $k = 4.75 \times 10^{-15}$ and $n = 3.55$; then for the

TRH level, $\dot{\epsilon} = 77.069914 \times 10^{-5} t^{-0.85}$ and Total Closure $= 513.7961 \times 10^{-5} t^{0.15}$

for the first year plus $0.511613 \times 10^{-5} \times (t-365)$ thereafter

RH level, $\dot{\epsilon} = 149.598712 \times 10^{-5} t^{-0.85}$ and Total Closure $= 1097.3187 \times 10^{-5} t^{0.15}$

for the first year plus $1.09262 \times 10^{-5} \times (t-365)$ thereafter

t	For $\sigma = 2325$: $\dot{\epsilon}$	For $\sigma = 2325$: Total Closure	For $\sigma = 2920$: $\dot{\epsilon}$	For $\sigma = 2920$: Total Closure
1	7.7069×10^{-4}	5.1380×10^{-3}	1.6960×10^{-3}	1.0973×10^{-2}
10	1.0886×10^{-4}	7.2576×10^{-3}	2.3956×10^{-4}	1.5500×10^{-2}
100	1.5377×10^{-5}	1.0252×10^{-2}	3.3841×10^{-5}	2.1899×10^{-2}
365	5.1160×10^{-6} (2.1721×10^{-6})	1.2999×10^{-2} (1.4481×10^{-2})	1.0926×10^{-5} (4.6389×10^{-6})	2.6587×10^{-2} (3.0926×10^{-2})
1000	5.1160×10^{-6}	1.5698×10^{-2} (2.0955×10^{-2})	1.0926×10^{-5}	3.3525×10^{-2} (4.3689×10^{-2})
10^4		6.1792×10^{-2} (2.8893×10^{-2})		1.3186×10^{-1} (6.1706×10^{-2})
10^5		5.2218×10^{-1}		1.1152×10^{0}
$8.9[illegible] \times 10^4$				1.0000×10^{0}
$1.9[illegible] \times 10^5$		1.0000×10^{0}		

J. L. Ash
9/22/76

Creep Rates and Total Closure for Isolated Openings

Use $\epsilon_c = k\sigma^n t^{-0.85}$ during the first year and $\epsilon_c = k\sigma^n (365)^{-0.85}$ thereafter

where ϵ_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

The total closure at any time during the first year will thus be = $\int_0^t k\sigma^n t^{-0.85}\,dt = k\sigma^n t^{0.15}/0.15$ inches per inch and after the first year, it will be = $k\sigma^n (365)^{0.15}/0.15 + k\sigma^n (365)^{-0.85}(t-365)$ inches per inch

Using a density of 150 pounds per cubic foot for the overlying material,

$\sigma = 150 \times \text{depth} = 150 \times 2230/144 = 2325$ psi for the TRU level

$= 150 \times 2800/144 = 2920$ psi for the RH level

Taking $k = 4.75 \times 10^{-15}$ and $n = 3.33$, then

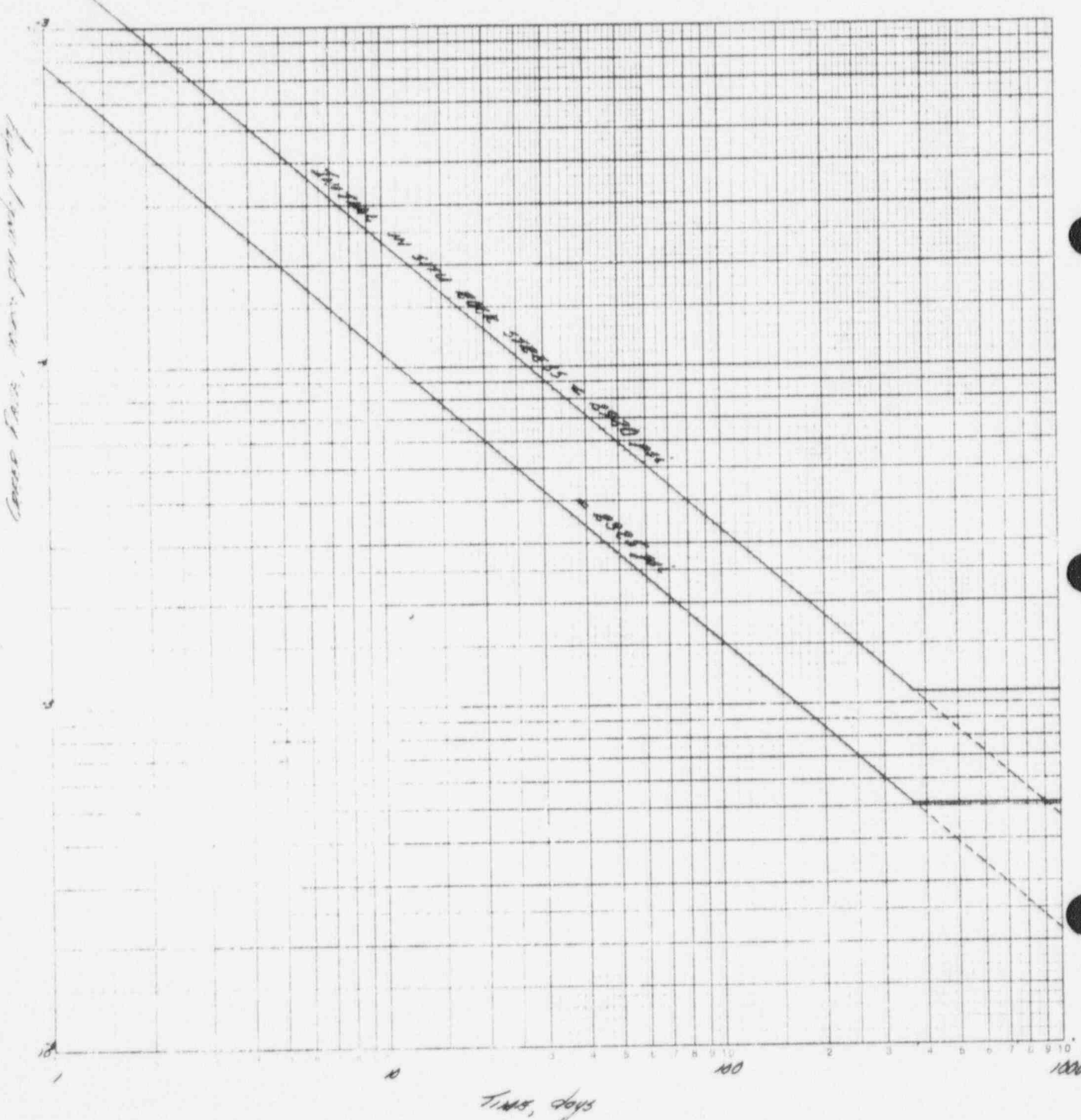
$k\sigma^n = 77.0 [illegible] 941406 \times 10^{-5}$ for the TRU Level

$= 169.59570796 \times 10^{-5}$ for the RH Level

Therefore:

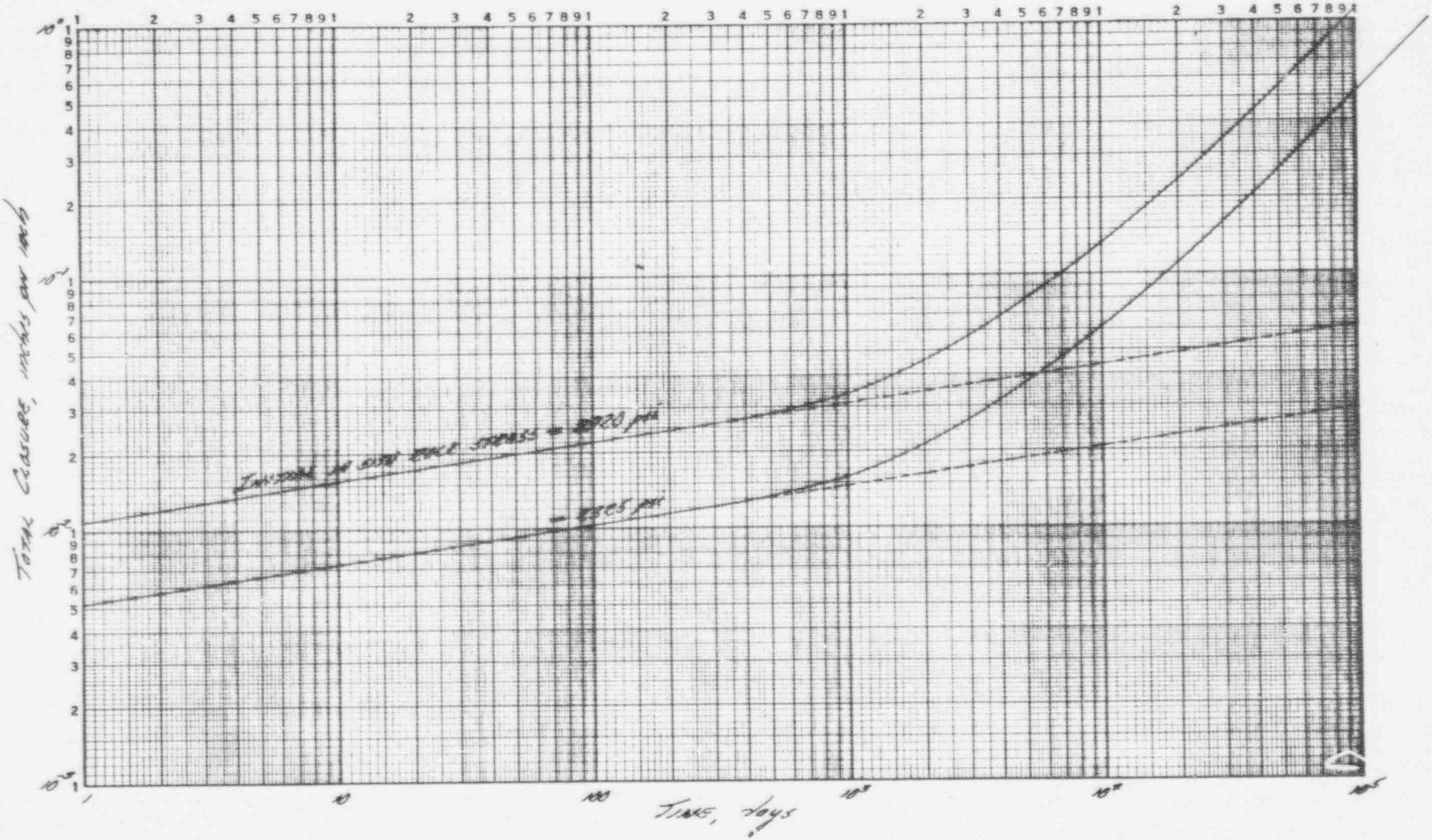
t	For $\sigma = 2325$: ϵ_c	For $\sigma = 2325$: Total Closure	For $\sigma = 2920$: ϵ_c	For $\sigma = 2920$: Total Closure
1	7.7069×10^{-4}	5.1380×10^{-3}	1.6960×10^{-3}	1.0973×10^{-2}
10	1.0886×10^{-4}	7.2576×10^{-3}	2.3250×10^{-4}	1.5500×10^{-2}
100	1.5377×10^{-5}	1.0252×10^{-2}	3.2841×10^{-5}	2.1899×10^{-2}
365	5.1161×10^{-6}	1.2449×10^{-2}	1.0926×10^{-5}	2.6587×10^{-2}
1000	5.1160×10^{-6}	1.5698×10^{-2}	1.0926×10^{-5}	3.3525×10^{-2}
10^4	5.1160×10^{-6}	6.1747×10^{-2}	1.0926×10^{-5}	1.3186×10^{-1}
10^5	5.1160×10^{-6}	5.2216×10^{-1}	1.0926×10^{-5}	1.1152×10^{0}
1.93031×10^5		1.0000×10^{0}		
8.90897×10^4				1.0000×10^{0}

Creep Rate for Isolated Openings



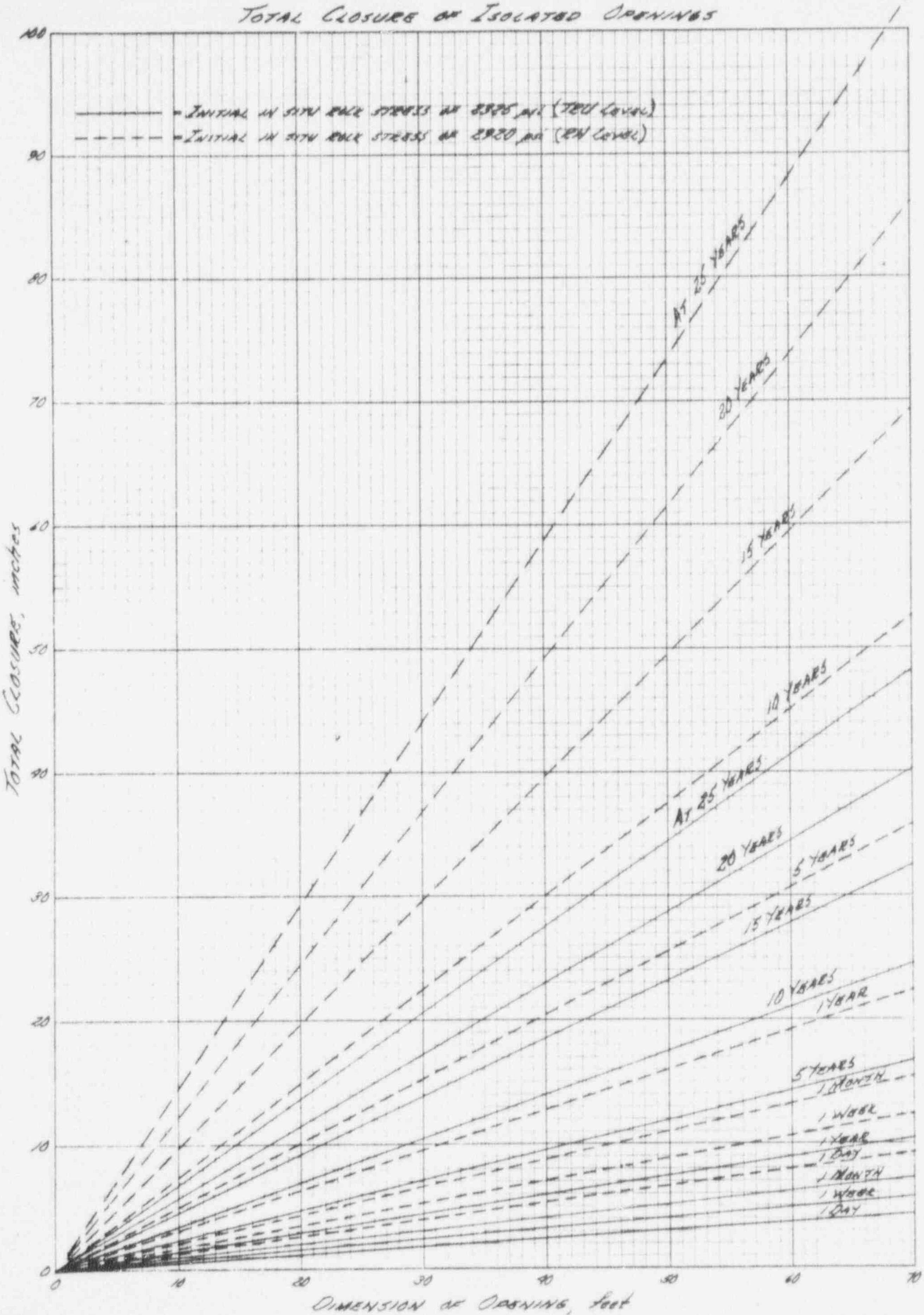
90030034

TOTAL CLOSURE OF ISOLATED OPENINGS



90030035

	@ 2325 psi		@ 2920 psi	
After 1 day, total closure will be	5.1380×10^{-3}	and	1.0973×10^{-2}	inches per [illegible]
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		1.8314	
2 months	9.5151×10^{-3}		2.0321	
3 months	1.0112×10^{-2}		2.1595	
4 months	1.0558		2.2548	
6 months	1.1220		2.3962	
[illegible]	1.1923		2.5964	
1 year	1.2999		2.6587	
[illegible]	1.4316		3.0575	
[illegible] years	1.6189		3.4563	
[illegible] years	1.8231		3.8551	
[illegible] years	2.0018		4.2539	
[illegible] years	2.1786		4.6527	
[illegible] years	2.3358		5.0516	
[illegible] years	2.5520		5.4504	
[illegible] years	2.7388		5.8492	
[illegible] years	2.9255		6.2480	
[illegible] years	3.8592		8.8920×10^{-2}	
[illegible] years	4.7929		1.0236×10^{-1}	
[illegible] years	5.7265×10^{-2}		1.2230×10^{-1}	



379-380

90030037

Miscellaneous Underground Calculations

POOR ORIGINAL

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90030038

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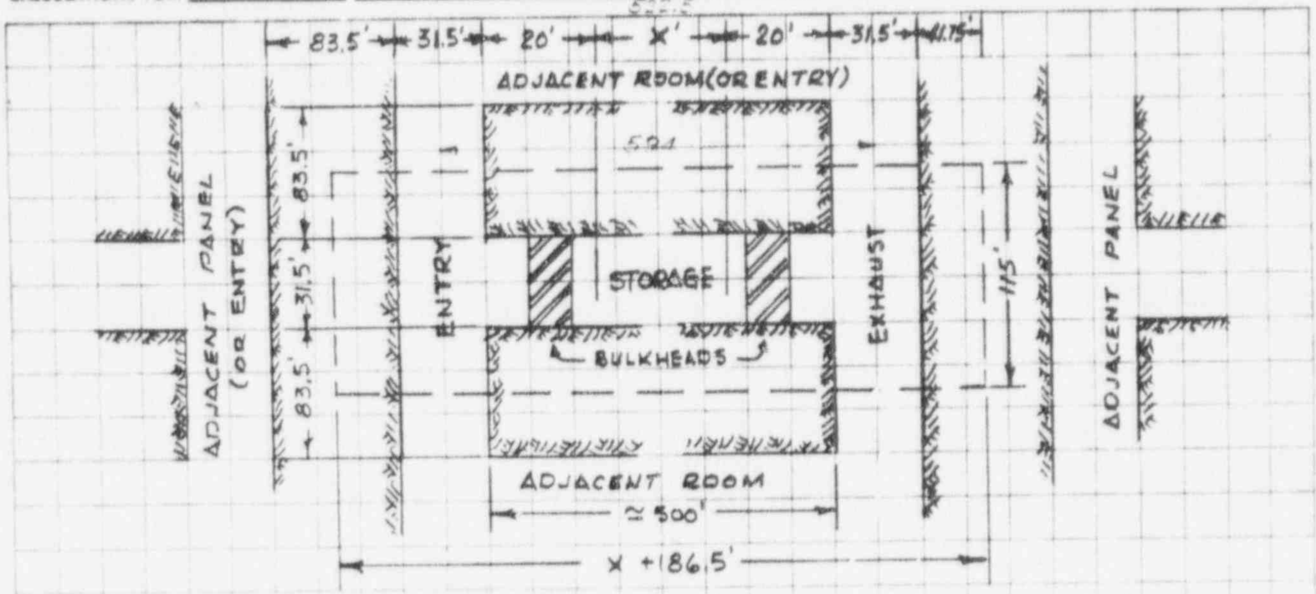
CALCULATIONS FOR: ____________ DATE: ______



ASSUMPTIONS:

AREA OF LOADING INFLUENCE $= \frac{115(X+186.5)}{43560}$ ACRES

TOTAL WASTE STORAGE	1,970000	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
594 = C-C Distance Between Entries

Area of Influence = 115' W x 709' lg. = 81535 SqFt = 1.8718 Ac
@ 75 KW/Ac = 140.3840 KW/Rm
@ 300 w/Can = 468 Cans/Rm
or 107.95, SAY 108 Rms.
or 18,250 CuFt/Rm

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90030039

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TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: ____ SHEET ____ OF ____
CHECKED BY: ____ PROJECT NO. ____
CALCULATIONS FOR: MINED SALT STORAGE DATE: ____

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 (@135 #/CF)	2,290,218 TONS	2,965,841 TONS
SPACE EXCAVATED	33,929,156 CuFt	43,938,385 CuFt
RADWASTE STORED	~~5,835,020~~ 6,500,136 CuFt	~~1,970,000~~ 2,337,611 CuFt
VOLUME TO BACKFILL	28,094,136 CuFt 27,429,020	~~41,968,385~~ CuFt 41,600,774
TOTAL SALT STORED (WGT.)	2,290,218 TONS	2,965,841 TONS
(@ 90 #/CF) " " " (VOL.)	50,893,733 CuFt	65,907,578 CuFt

[illegible] [illegible] drums (24"⌀ × 34") — 764,850 × 2π = 1,533,793 π ft³
15,[illegible] 83- " " 28"⌀ × 25" — 15,650 × 343π/108 = 2,683,975 π/54 "
(8,498,416) — 85,[illegible] 775 π/54 ft³ drums

13,144 78 × 28 × 89" boxes — 13,144 × 112 = 1472128 ft³
266 [illegible] " — 266 × 200 = 53600 "
1,525,728 ft³ boxes

49,514 24"⌀ × 15' canisters — 49,514 × 15π = 742710 π
1010 26"⌀ × 16' " — 1010 × 343π/36 = [illegible] π/36
26,787,050 π/36 ft³ [illegible]

90030040

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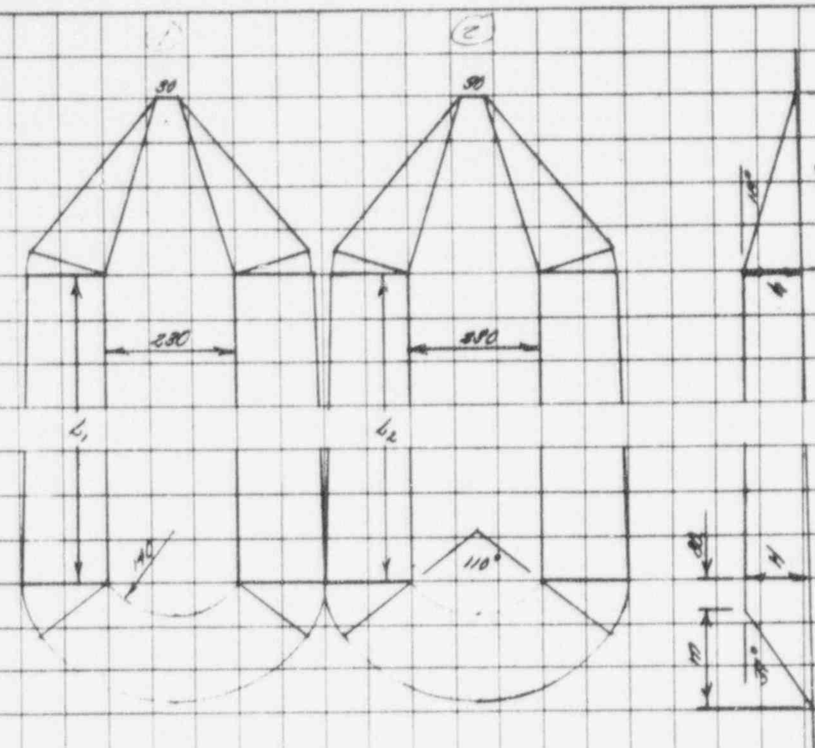
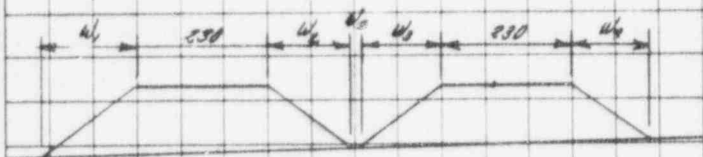


ASSUME GROUND SLOPES 2 FT PER 100 FT BOTH ALONG AND PERPENDICULAR TO AXIS OF PILES

$H = h + 0.02L$

$M = \frac{h}{0.02 + \tan 18°}$

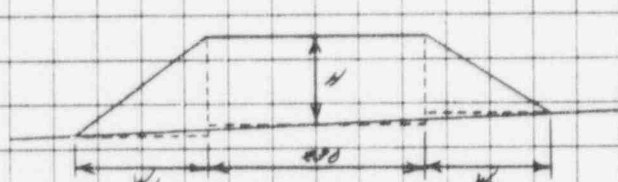
$m = \frac{H + 2.60}{\tan 37° - 0.02}$



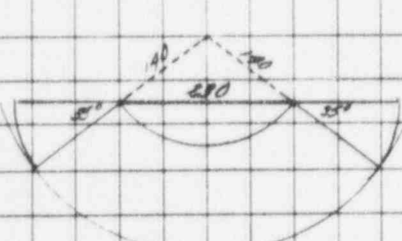
$h_1 = h_2 + 0.02(W_2 + W_0 + W_3 + 230)$

$W_1 = \frac{H_1 + 2.30}{\tan 37° - 0.02}$ $W_3 = \frac{H_2 + 2.30}{\tan 37° - 0.02}$

$W_2 = \frac{H_1 - 2.30}{\tan 37° + 0.02}$ $W_4 = \frac{H_2 - 2.30}{\tan 37° + 0.02}$



$A = 0.50(W_a \tan 37° - 0.04)W_a + 230H + 0.50(W_b \tan 37° + 0.04)W_b$



$A_{top} = 140^2\pi\left(\frac{11}{36}\right) - 115(80)$

$A_{bot} = (140 + m)^2\pi\left(\frac{11}{36}\right) - 115(80) + m^2\pi\left(\frac{7}{36}\right)$

$= 140^2\pi\left(\frac{11}{36}\right) - 115(80) + 280m\pi\left(\frac{11}{36}\right) + \frac{m^2\pi}{2}$

$= \left(140^2 + 280m + \frac{18m^2}{11}\right)\pi\left(\frac{11}{36}\right) - 9200$

DESIGN SHEET

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CALCULATIONS FOR: ______

SHEET ____ OF ____
PROJECT NO. ______
DATE: ______

$W_0 = 0$ WHEN THE MINIMUM L IS AT A MAXIMUM AND AT THAT CONDITION

$$h_1 (\text{Tan } 37° - 0.02) = h_2 (\text{Tan } 37° + 0.02) + 9.9 \text{ Tan } 37° + 0.0008L$$

$$h_1 = 1.059529 h_2 + 9.519969 + 0.00109058L = 109.972868 + 0.00109058L$$

$$= 0.00109058 (100838.85 + L)$$

Assuming RH Pile is Pile #1, TRU Pile is Pile #2, $h_2 = 100$

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DESIGN SHEET

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CALCULATIONS FOR: ______ DATE: ______

TRU LEVEL - PILE #2 - h = 100 Assume L = 1006.41 ft. ∴ $H = h + .02L = 120.13$ ft.

VOLUME RAMP $= \frac{1}{3}(A_1)M$ = 3,511,710.715 SAY = 3,511,711 CuFT

$A_1 = 0.50(W_3 \tan 37° - 0.04)W_3 + 230h + 0.50(W_4 \tan 37° + 0.04)W_4 = 36{,}337.74579\ ft^2$

if, $W_3 = \frac{h+2.30}{\tan 37° - 0.02} = 139.4580263$ say 139.46 ft

$W_4 = \frac{h+2.30}{\tan 37° + 0.02} = 126.3001596$ " 126.30 ft

& $M = \frac{h}{0.02 + \tan 18°} = 289.9225562$ " 289.92 ft

VOLUME CENTER $= \frac{1}{2}(A_1 + A_2)L$ = 41868145.93 SAY 41,868,146 CuFT

$A_1 = 36{,}337.74579$

$A_2 = 0.50(W_d \tan 37° - 0.04)W_d + 230H + 0.50(W_u \tan 37° + 0.04)W_u = 46866.04182$

if, $W_d = \frac{H+2.30}{\tan 37° - 0.02} = 166.8973131$ say 166.90 ft

$W_u = \frac{H-2.30}{\tan 37° + 0.02} = 152.320578$ say 152.32 ft

VOLUME END $= \frac{1}{3}(A_B + A_T + \sqrt{A_B \times A_T})H$ = 5513877.712 say 5513878 CuFT

if $A_T = 140^2\pi(\frac{11}{36}) - 115(80) = 9614.649336$

$A_B = (140^2 + 280m + \frac{18m^2}{11})\pi(\frac{11}{36}) - 9200 = 97{,}472.11214$

if $m = \frac{H+1.60}{\tan 37° - 0.02} = 165.9427822$ say 165.94 ft

TOTAL TRU SALT STORED (when L = 1006.41 ft) 50,893,735 CuFT.

RH LEVEL - PILE #1 TOP ELEV. SAME AS PILE #2

Also, $h_1 = 0.0010958(100838.88 + L) = 111.0704364$ say 111.07 ft

Assume L = 1128.90 ft ∴ H = 133.65 ft

VOLUME RAMP = 4507709.313 SAY = 4,507,709 CuFT

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 CuFT

$A_1 = 41994 +\ ft^2$

$A_2 = 54543 +\ ft^2$

$W_d = 185.33$ ft

$W_u = 169.86$ ft

VOLUME END 6,908,792 CuFT

if $A_T = 9614 +\ ft^2$

$A_B = 112568 \pm\ ft^2$

& $m = 184.37$ ft

TOTAL RH SALT STORED (when L = 1128.90 ft) 65,907,577 CuFT

385

90030043

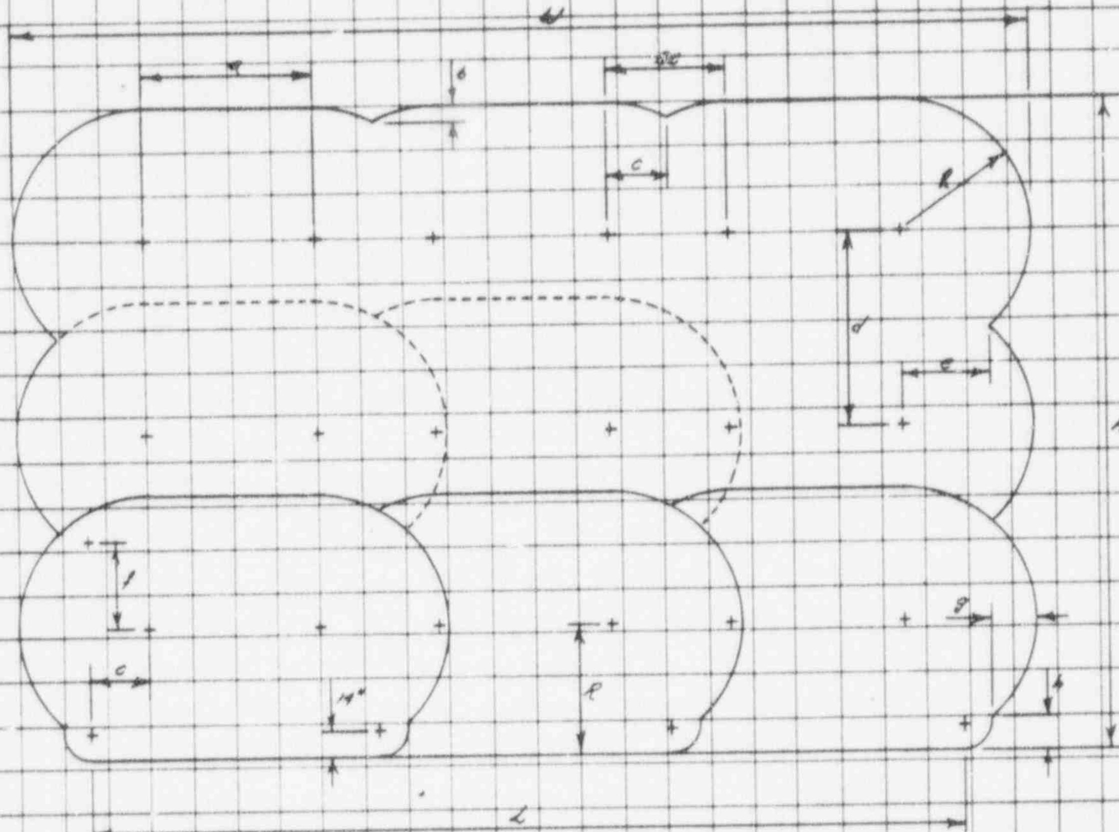
FENIX & SCISSON, INC.

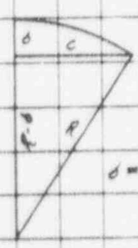
TULSA, OKLAHOMA 74112

DESIGN SHEET

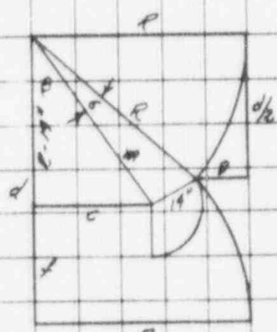
COMPUTED BY: J L Ash
CHECKED BY:
CALCULATIONS FOR: Preliminary Entry and Room Dimensions

SHEET 1 OF
PROJECT NO. 288
DATE: Sept. 15, 1976





$b = R - (R^2 - c^2)^{1/2}$

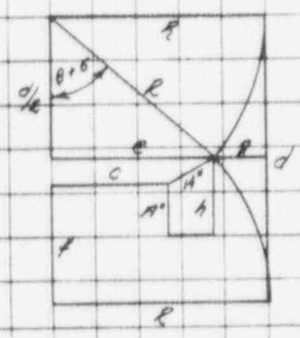


$\tan\beta = \frac{c}{R - 14"}$

$m = \left[c^2 + (R - 14")^2\right]^{1/2}$

$\cos\sigma = \frac{R^2 + m^2 - 14"^2}{2Rm}$

$e = R\sin(\beta + \sigma)$



$d = 2(R^2 - e^2)^{1/2}$ $\qquad$ $f = d - R + 14"$

$g = R - c$ $\qquad$ $h = R - \frac{d}{2}$

386

90030044

FENIX & SCISSON, INC.
TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: J L ASN
CHECKED BY:
CALCULATIONS FOR: PRELIMINARY ENTRY AND ROOM DIMENSIONS

SHEET 2 OF
PROJECT NO. 388
DATE: SEPT 15 1976
CORRECTED: OCT 5 1976

										One Pass			Two Passes			Three Passes		
Type	a	c	R	b	d	e	f	g	h	W	H	L	W	H	L	W	H	L
	17'-9"	2'-3"	3'-6"	9 3/16"	37 5/8"	37 9/16"	9 5/8"	4 7/16"	23 3/16"	24'-9"	7'-0"	22'-3"	47'-0"	10'-1 1/2"	44'-6"	69'-3"	13'-3 1/4"	66'-9"
[illegible]			3'-9"	9"	46 5/16"	38 9/16"	15 5/16"	6 7/16"	21 7/8"	25'-3"	7'-6"		47'-6"	11'-9 1/4"		69'-9"	15'-2 1/2"	
			4'-0"	8 5/16"	54 7/8"	39 3/16"	20 7/8"	8 5/8"	20 9/16"	25'-9"	8'-0"		48'-0"	12'-6 3/4"		70'-3"	17'-1 3/4"	
	7'-3 3/4"	2'-9"	4'-6"	11 1/4"	62 5/16"	44"	22 5/8"	10"	22 1/16"	16'-3 3/4"	9'-0"	12'-9 3/4"	29'-1 1/2"	14'-2 1/2"	25'-7 1/2"	91'-11 1/4"	19'-5 1/4"	38'-5 3/4"
			4'-9"	10 1/2"	70 11/16"	44 3/4"	27 11/16"	12 1/4"	21 11/16"	16'-9 3/4"	9'-6"		29'-7 1/2"	15'-9 1/2"		92'-5 1/4"	21'-3 1/4"	
[illegible]			5'-0"	9 7/8"	78 11/16"	45 5/16"	32 11/16"	14 11/16"	20 11/16"	17'-3 3/4"	10'-0"		30'-1 1/2"	16'-6 1/2"		92'-11 1/4"	23'-1 1/4"	
			5'-3"	9 5/16"	86 9/16"	45 3/4"	37 9/16"	17 1/4"	19 11/16"	17'-9 3/4"	10'-6"		30'-7 1/2"	17'-8 1/2"		93'-5 1/4"	24'-11"	
			5'-6"	8 13/16"	94 3/8"	46 1/8"	42 3/8"	19 7/8"	18 9/16"	18'-3 3/4"	11'-0"		31'-1 1/2"	18'-10 1/4"		93'-11 1/4"	26'-9 3/4"	
	8'-0"	2'-9"	5'-0"	9 7/8"	78 11/16"	45 5/16"	32 11/16"	14 11/16"	21 11/16"	18'-0"	10'-0"	13'-6"	31'-6"	16'-6 1/2"	27'-0"	45'-0"	23'-1 1/4"	40'-6"
			5'-3"	9 5/16"	86 9/16"	45 3/4"	37 9/16"	17 1/4"	19 11/16"	18'-6"	10'-6"		32'-0"	17'-8 1/2"		45'-6"	24'-11"	
[illegible]			5'-6"	8 13/16"	94 3/8"	46 1/8"	42 3/8"	19 7/8"	18 13/16"	19'-6"	11'-0"		32'-6"	18'-10 1/4"		46'-0"	26'-9 3/4"	
			5'-9"	8 3/8"	102 1/16"	46 7/16"	47 1/16"	22 9/16"	17 13/16"	19'-6"	11'-6"		33'-0"	21'-0"		46'-6"	28'-6"	
			6'-0"	8"	109 11/16"	46 5/8"	51 11/16"	25 3/8"	17 1/8"	20'-0"	12'-0"		33'-6"	21'-1 1/2"		47'-0"	30'-3 1/4"	

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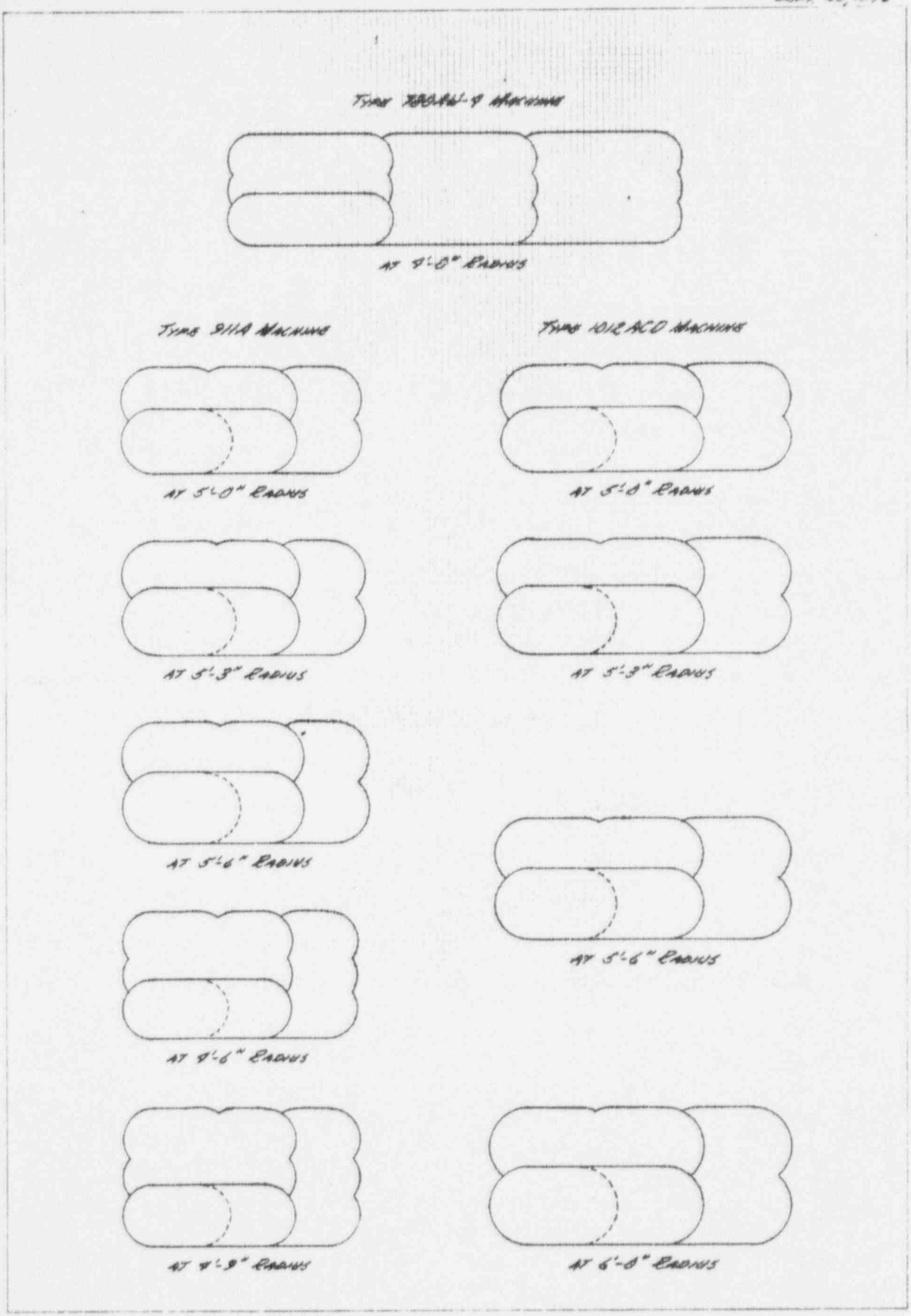
90030045

J.L. Ash

SHEET 3 OF
SEPT. 22, 1976
CORRECTED: OCT. 5, 1976

APPLICABLE CONFIGURATIONS

TYPE MACHINE	℄	VERTICAL PASSES	HORIZONTAL PASSES
710 AW-4	4'-0"	3 for 17'-1¾" ~ 58.0526 yrs to 14'-6" 16'-5½"	1 for 22'-3" ~ 78.5540 yrs to 19' 2 for 44'-6" ~ 12.3895 yrs to 43' 3 for 66'-9" ~ 29.4188 yrs to 63'
[illegible]	[illegible]	2 for 16'-6½" ~ 36.1817 yrs to 14'-6" 15'-8¾"	2 for 25'-7½" ~ 49.1909 yrs to 23' 3 for 38'-5¼" ~ 42.2250 yrs to 35'
	5'-3"	2 for 17'-8½" ~ 8.16618 yrs to 16'-6" 16'-11¼"	2 for 25'-7½" 3 for 38'-5¼"
	[illegible]	2 for 18'-10¼" ~ 27.5725 yrs to 17'-0" 18'-1½"	2 for 25'-7½" 3 for 38'-5¼"
	4'-6"	3 for 19'-5¼" ~ 37.7536 yrs to 17'-0" 18'-6"	2 for 25'-7½" 3 for 38'-5¼"
	4'-9"	3 for 21'-3½" ~ 17.0544 yrs to 19'-6" [illegible] 4¾"	2 for 25'-7½" 3 for 38'-5¼"
[illegible]	5'-0"	2 for 16'-6½" ~ 36.1817 yrs to 14'-6"	2 for 27'-0" ~ 79.6683 yrs to 23' 3 for 40'-6" ~ 14.1673 yrs to 39'
	5'-3"	2 for 17'-8½" ~ 8.16618 yrs to 16'-6"	2 for 27'-0" 3 for 40'-6"
	5'-6"	2 for 18'-10¼" ~ 27.5725 yrs to 17'-6"	2 for 27'-0" 3 for 40'-6"
	6'-0"	2 for 21'-1½" ~ 19.9185 yrs to 19'-6" [illegible]	2 for 27'-0" 3 for 41'-6"



J.L. ASH

90030047

Let n be the number of vertical passes and N be the number of horizontal passes, then

$$\text{Area} = \frac{\pi R^2}{2} + \frac{\pi R^2}{180}\text{Arcsin}\frac{d}{2R} + \frac{cd}{2} + 2\left(R-\frac{d}{2}\right)c + \left(R-\frac{d}{2}-14\right)(e-c) + \frac{49\pi}{45}\left(90 + \text{Arcsin}\frac{2R-d-28}{28}\right) + 28R + \left(ad+ed-\frac{\pi R^2}{90}\text{Arcsin}\frac{d}{2R}\right)(n-1) + \left[2(a+c)R + \frac{\pi R^2}{180}\text{Arcsin}\frac{c}{R} + (R-b)c + (a+2c)(n-1)d\right](N-1)$$

$$\text{Area} = \frac{\pi R^2}{180}\left\{90\left(1+\frac{196}{R^2}\right) + \left(\frac{14}{R}\right)^2\text{Arcsin}\left(\frac{2R-d-28}{28}\right) + (2n-1)\text{Arcsin}\frac{d}{2R} + (N-1)\text{Arcsin}\frac{c}{R}\right\} + 2(a+c)R - \frac{dc}{2} + (R-14)(e-c) + d\left[a+(a+2c)(N-1)+e\right](n-1) + \left[2(a+c)R+(R-b)c\right](N-1)$$

$$\text{Perimeter} = \pi R + \frac{\pi R}{90}\text{Arcsin}\frac{d}{2R} + \frac{7\pi}{45}\left(90+\text{Arcsin}\frac{2R-d-28}{28}\right) + 2(a+c) + (n-1)\frac{\pi R}{45}\text{Arcsin}\frac{d}{2R} + (N-1)\left[2(a+c)+\frac{\pi R}{90}\text{Arcsin}\frac{c}{R}\right]$$

$$\text{Perimeter} = \frac{\pi R}{90}\left\{90\left(1+\frac{14}{R}\right) + \frac{14}{R}\text{Arcsin}\left(\frac{2R-d-28}{28}\right) + (2n-1)\text{Arcsin}\frac{d}{2R} + (N-1)\text{Arcsin}\frac{c}{R}\right\} + 2(a+c)N$$

Cross-sectional areas in square feet and perimeters in feet

	n	N		Area		Perimeter	
Type [illegible] at R = [illegible] for	n = 1 and	N = 1	is	195.4477	ft² and	62.2377	ft
	2	1		311.0930		71.9733	
	3	1		426.7383		81.7088	
		2		807.2330		126.4881	
		3		1187.7277		171.2673	
Type 911A at R = [illegible] for	n = 1 and	N = 1	is	155.5029	ft² and	47.8057	ft
		2		282.1740		73.7544	
	2	2		479.6575		88.0573	
		3		685.3939		114.0060	
Type 1312ACP at R = [illegible] for	n = 1 and	N = 1	is	162.3779	ft² and	49.1807	ft
		2		295.9240		76.5044	
	2	2		497.9238		90.8073	
		3		719.4933		118.1310	
	1	3		429.4701		103.8280	

390

9003004B

FENIX & SCISSON, INC.
TULSA, OKLAHOMA 74112

DESIGN SHEET

COMPUTED BY: J. C. Ash
CHECKED BY:
CALCULATIONS FOR: Applicable TRU Level Entry and Room Configurations

SHEET 6 OF
PROJECT NO: 288
DATE: Oct. 14, 1976
Corrected: Oct. 29, 1976

		Type 780AW-4			Type 911A		Type 1012ACO	
		at ℓ = 4'-0"			at ℓ = 5'-0"		at ℓ = 5'-0"	
A =		1			1		1	
N =		1		1	2	1	2	
H' =		8'-0"			10'-0"		10'-0"	
H'-6 =					9'-2⅛"		9'-2⅛"	
W' =		25'-9"		17'-3¾"	30'-1½"	18'-0"	31'-6"	
L =		22'-3"		12'-9¾"	25'-7½"	13'-6"	27'-0"	
X-Sect. Area =		195.9477		155.5029	282.1798	162.3779	295.9240	ft²
H-6 @ 30 Years =		7'-5 5/16"		9'-4"	8'-6¾"	9'-4"	8'-6¾"	
L at 30 Years =		20'-9 3/16"		11'-11½"	23'-11"	12'-7 3/16"	25'-2 3/16"	
A =		3			2		2	
N =	1	2	3	2	3	2	3	
H =		17'-1¾"			16'-6 11/16"		16'-6 11/16"	
H-6 =		16'-5 7/16"			15'-8 13/16"		15'-8 13/16"	
W' =	25'-9"	49'-0"	74'-3"	30'-1½"	42'-11¼"	31'-6"	45'-0"	
L =	22'-3"	44'-6"	46'-9"	25'-7½"	38'-5¼"	27'-0"	40'-6"	
X-Sect. Area =	426.7383	847.2330	1187.7277	472.6575	685.8939	497.4238	719.4933	ft²
Avail. Stor. Width =	19'	43'	69'	23'	35'	23'	39'	
Reg'd Rm Length =	19.90'	7.76'	5.17½'	15.52'	9.70'	15.52'	8.52¾'	per ...
Vert. Life =		58.0526			36.1817		36.1817	yrs
Horz. Life =	72.5540	42.3845	29.4188	49.1909	42.2250	73.4683	49.1673	yrs
Entry Pillar =	60½'	60½'	65½'	73'	73'	75'	75'	width
Room Pillar =	81½'	117½'	163½'	87'	109'	90'	111'	width
Safety Factor =	2.00	2.00	2.07	2.00	2.00	2.00	2.00	
Slope Length =		61'-0"			43'-9"	43'-9"		at 15% grade
Tot. Stor. Length =	58,200'	23,280'	15,520'	36,560'	29,100'	36,560'	25,866⅔'	at 1950 ft³/day
Number Rooms =	156	64	42	110	72	110	64	
Number Panels =	12	8	6	10	8	10	8	
Room Length =	497.0769'	477.75'	483.5238'	500.7727'	481.6667'	500.7727'	481.6667'	
Daily Exc. Vol. =	8278.72	6286.38	6017.52	7188.41	6424.99	7541.74	6005.54	ft³
Tot. Stor. Area =	451.2829	257.3736	196.8710	238.7159	170.8402	217.5145	158.5978	acres
Tot. Vol. Mined =	40,089,013	28,696,983	27,131,841	34,708,726	31,989,491	38,800,483	30,399,706	ft³
Allo. Width for 15 yr Life =	5'-9 11/16"	2'-9 3/16"	3'-11 1/16"	4'-7⅝"	4'-11 7/16"	5'-11⅛"	2'-11¼"	

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90030049

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 = entry width

F = pillar width between entries

J = cross-sectional area of rooms

K = cross-sectional area of entries

M = overall width of storage area

N = overall length of storage area

S = total length of rooms available for waste storage

T = total length of entries

U = total length of rooms required for ramping

V = total volume of material mined in storage area

THEN

$M = 2(A + D)x + 4(E + F) - D$

$N = (2B + 4C + D + 2E + F - 4C)\frac{y}{4} - \frac{D}{2} - \frac{F}{2}$

$S = Bxy$

$T = (M - 4E)y + 4N$

$U = 2(C - E)xy$

$V = \left(S + \frac{U}{2}\right)J + \left(T + \frac{U}{2}\right)K$

TOTAL AREA REQUIRED FOR STORAGE = MN

AND THIS [illegible]

CASE I, $M = 214.5x + 363.5$

$N = (0.5B + 118.25)y - 71$

CASE II, $M = 331x + 227.5$

$N = (0.5B + 127.25)y - 89$

CASE III, $M = 467.5x + 201.5$

$N = (0.5B + 140)y - 119.5$

CASE IV, $M = 259.25x + 325.5$

$N = (0.5B + 108.875)y - 80$

CASE V, $M = 303.875x + 303.5$

$N = (0.5B + 114.375)y - 91$

CASE VI, $M = 243x + 336$

$N = (0.5B + 111.5)y - 82.5$

CASE VII, $M = 312x + 315$

$N = (0.5B + 116.75)y - 93$

ASSUMING THAT

$B \leq 500 - 2(C \cdot K[illegible]y)$

$M \leq 3000$

y is even

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 $xy \geq 69$ 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

MODIFYING THE ASSUMPTIONS SLIGHTLY TO OBTAIN MORE PRACTICAL COMBINATIONS OF x AND y, THEN FOR

CASE I at x = 13 and y = 12; M = 3052 ft., N = 3586.4614 ft.,
T = 49,733.8456 ft., U = 17,784 ft., and V = 40,089,013 ft³

CASE II at x = 8 and y = 8; M = 3875.5 ft., N = 2384 ft.,
T = 31,776 ft., U = 7,596 ft., and V = 28,698,983 ft³

CASE III at x = 7 and y = [illegible]; M = 3474 ft., N = 1839.0714 ft.,
T = 27,[illegible].[illegible]856 ft., U = 4,788 ft., and V = 27,131,891 ft³

CASE IV at x = 11 and y = 10; M = 2902.25 ft., N = 3125.1136 ft.,
T = 40,3[illegible].9544 ft., U = 8,525 ft., and V = 36,702,726 ft³

CASE V at x = 9 and y = 8; M = 3138.375 ft., N = [illegible].6667 ft.,
T = 33,105.6667 ft., U = [illegible]580 ft., and V = 31,989,991 ft³

CASE VI at x = [illegible] and y = 10; M = [illegible] ft., N = 3148.8636 ft.,
T = [illegible].9544 ft., U = 8,525 ft., and V = 38,800,483 ft³

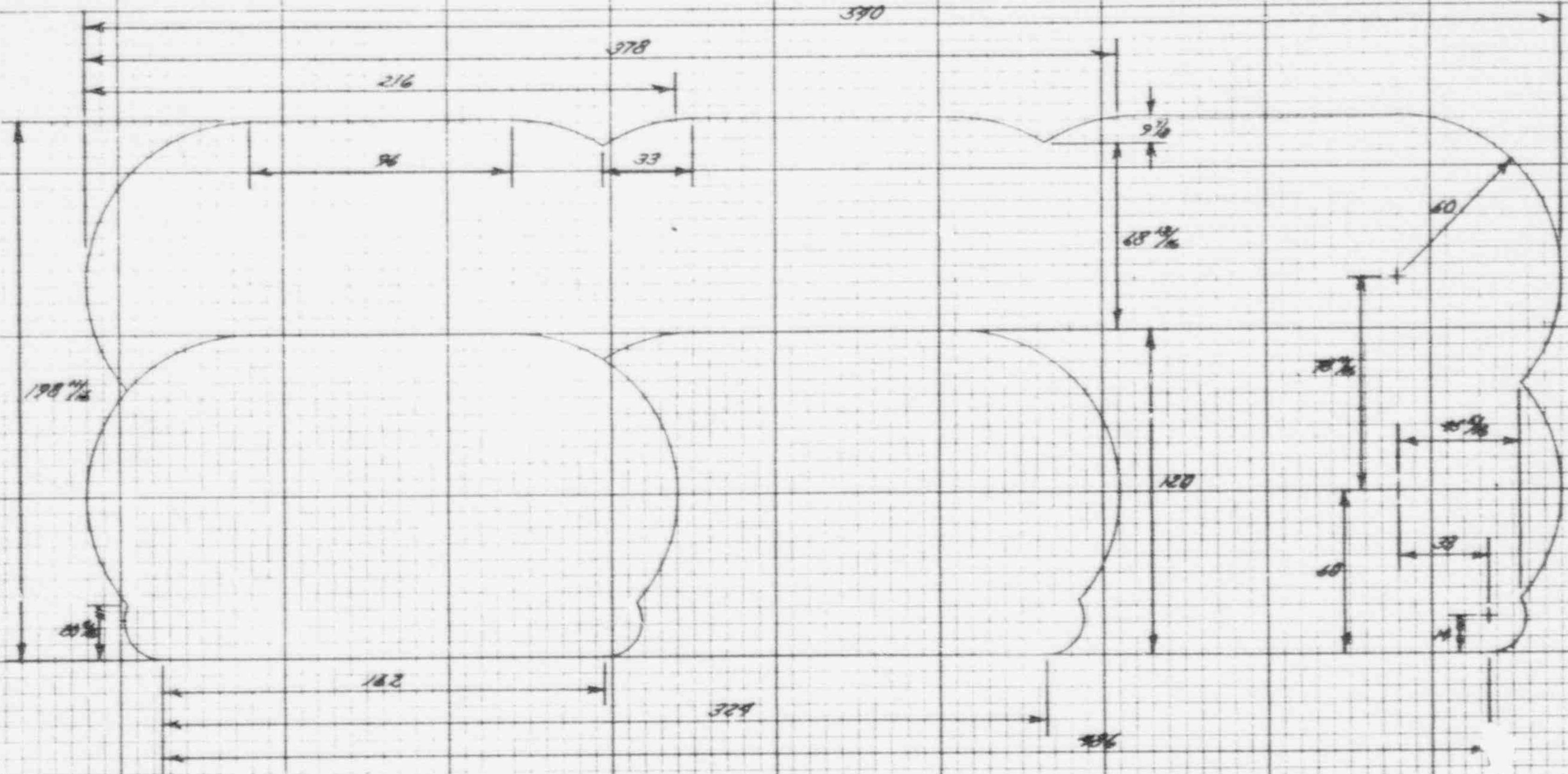
CASE VII at x = [illegible] and y = [illegible]; M = 2811 ft., N = 3957.6667 ft.,
T = [illegible].6667 ft., U = 4,960 ft., and V = 30,394,706 ft³

K+E 10 X 10 TO THE INCH 46 0702
KEUFFEL & ESSER CO.

395

Entry and Room Sizes and Shape for a Type 1012ACO Marietta Miner at ℄ = 5'-8"

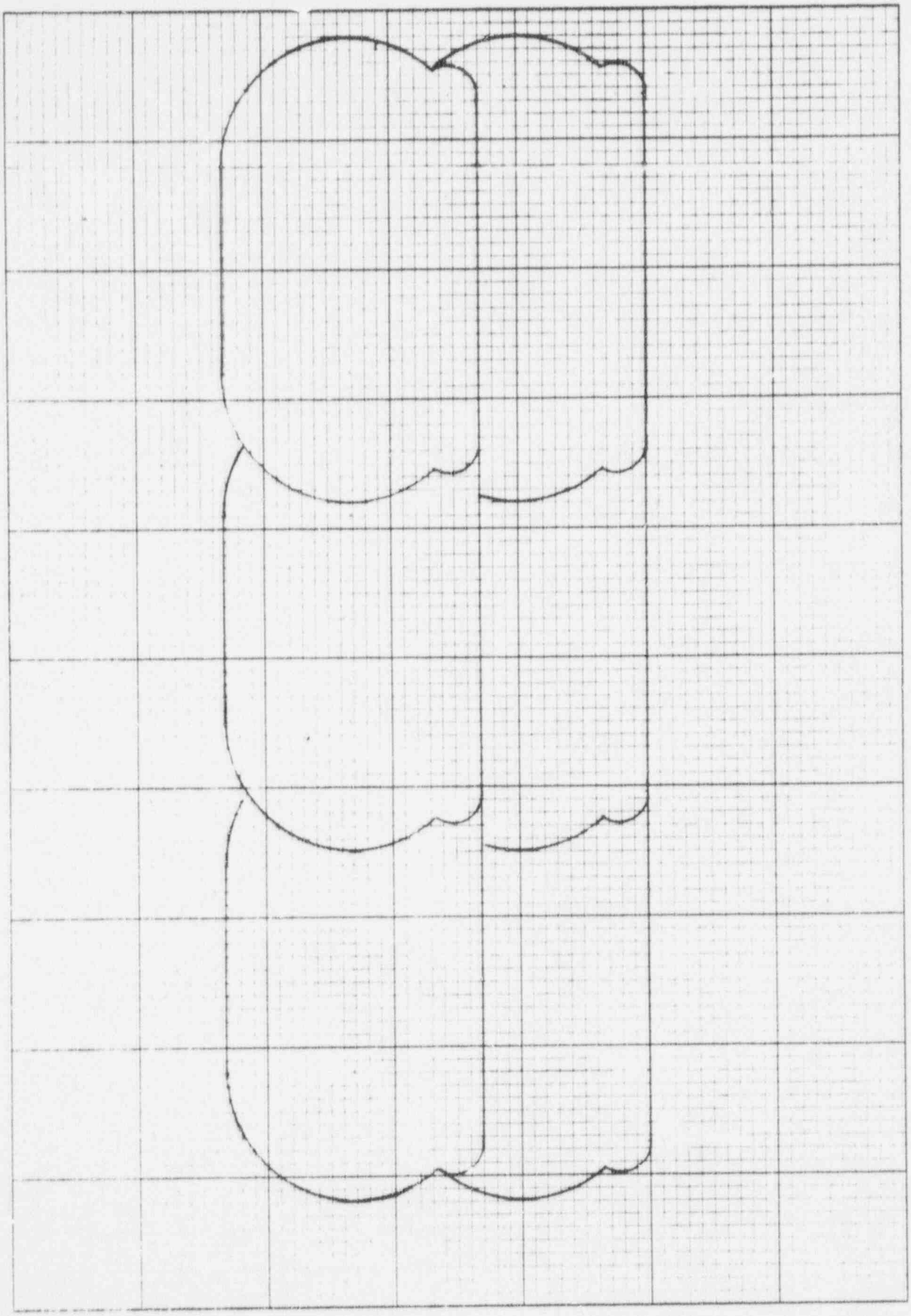
Dimensions are in inches



At 1 Vert. Pass and	1 Horiz. Pass,	W = 18'-0",	H = 10'-0",	L = 13'-6",	X-sect Area = 162.3079 ft²	and X-sect Perimeter = 53.1807 ft
1	2	31'-6"	10'-8"	27'-0"	295.9768	76.5899
2	3	45'-0"	16'-6 7/16"	40'-6"	719.9933	118.1800

J.L. Ash, Oct 20, 1976
Corrected: Oct 29, 1976

90030053



396

J. L. Ash

Proj. 288, 11-11-76

Mining Rates for Boring Machine

Goodman 426 Continuous Borer cuts a 72" high × 138" wide opening with two 250 hp motors. Under normal conditions, these machines can be expected to mine at an average rate of 1200 Tons/day or 400 Tons/shift for 2-pass openings. 1-pass = 87.122 ft² and 2-pass = 146.859 ft²

Type 1012 ACD Marietta Miner cuts a 120" high × 216" wide opening with two 600 hp motors. 1-pass = 162.3779 ft², 2-pass = 295.9240 ft², 3-pass = 429.4701 ft², Room = 719.4933 ft² and Room Entrance averages $\frac{429.4701 + 719.4933}{2} = 574.4817$ ft²

Take mining rate for the Marietta to be $\frac{2 \times 600}{2 \times 250} \times \frac{87.122}{162.3779} \times 400 = 515$ Tons/shift for all openings,

At 135 lbs/ft³, Entries = $\frac{295.9240 \times 135}{2000} = 19.9749$ Tons/foot for 25.78625 ft/shift advance

Room Entrance = $\frac{574.4817 \times 135}{2000} = 38.7775$ Tons/foot for 13.2829 ft/shift advance

Room = $\frac{719.4933 \times 135}{2000} = 48.5658$ Tons/foot for 10.6050 ft/shift advance

Room Exit = $\frac{429.4701 \times 135}{2000} = 28.9892$ Tons/foot for 17.7679 ft/shift advance

Use 20 Tons/foot, 500 Tons/shift and 25 ft/shift = 525 ft/month advance per Miner per shift for entries

Have $\frac{38.75(38.7775) + 426.25(48.5658) + 15.00(28.9892)}{38.75 + 426.25 + 15.00} = \frac{22,638.6389}{480} = 47.1638$ Tons/foot for 10.9210 ft/shift advance. Use 47.2 Tons/foot, 500 Tons/shift and 10.6 ft/shift = 222.6 ft/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 $64(45.283) + \frac{31,800}{25} = 4170$ 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

[illegible] LEVEL AREA = 3006.50(3409.63) + (3006.50 − 992.73)(333.56 + 532.10) + (2914.69 − 800.36)599.53 + 2914.69(932.15) + 0.5(992.73)333.56 + 0.5(532.10)50.56 + 0.5(599.[illegible])800.36 + 0.5$(532.10^2 + 50.56^2)^{1/2}\{1000^2 - [0.5(532.10^2 + 50.56^2)^{1/2}]^2\}^{1/2}$ + [illegible](40 + 84) + 360 = 10,251,052.60 + 1,786,523.1380 + 1,267,583.1200 + [illegible],116,928.[illegible] + [illegible],[illegible].5094 + 13,451.4880 + 239,915.9136 + 257,527.90[illegible] + [illegible],[illegible].8814 = 17,953,234.81 ft^2 = 413.65 acres

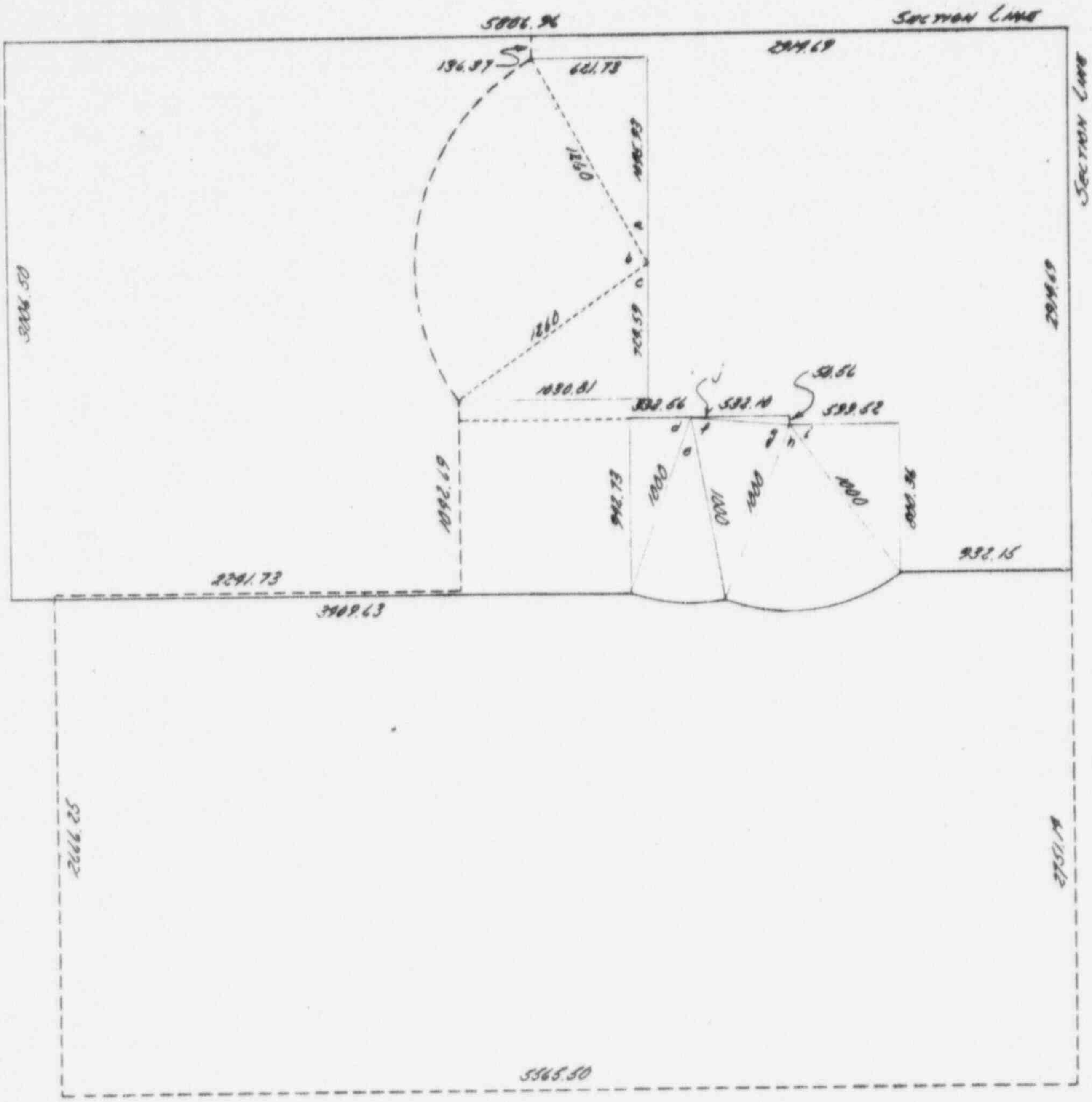
[illegible] LEVEL AREA USED FOR STORAGE = 2544(1239 + 1323.5) = 6,519,000 ft^2 = 149.66 acres or 37.[illegible] % OF THE TOTAL

[illegible] LEVEL AREA = [illegible](5565.50) + 1047.69(5565.50 − 2241.73) + (136.37 + 1095.95 + 724.59)([illegible] − [illegible]) + 136.37(621.73) + 0.5(621.73)1095.93 + 0.5(724.59)1030.81 + [illegible](46) + [illegible] = 14,829,018.38 + 3,465,661.[illegible] + 2,487,[illegible] + [illegible] + [illegible] + 372,[illegible] + 1,323,[illegible] = [illegible] ft^2 = 571.95 acres

[illegible] LEVEL AREA USED FOR STORAGE = 1455.5(2269.5) + 2836.0(19)115.0 + 2([illegible])115.0 = 3,226,363.75 + 6,196,[illegible] + 163,070.00 = 9,586,193.75 ft^2 = 220.11 acres or 38.4883 % OF THE TOTAL

[illegible] AREA = 552(1656) = 914,112 ft^2 = 20.9851 acres [illegible]
= 432(1536) = 663,552 ft^2 = 15.2331 acres
= 1437(2296) = 3,287,872 ft^2 = 75.4792 acres including [illegible]

[illegible]



∡a = 29.5667°

∡b = 95.5379°

∡c = 59.0959°

∡d = 70.5152°

∡e = 29.5575°

∡f = 74.9999°

∡g = 74.9999°

∡h = 57.7640°

∡i = 53.1695°

∡j = 5.9279°

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 - 729.59 - 800.36 - 50.56) + 136.37(621.73) + 942.73(3909.63 - 2291.73 - 5806.96 + 5565.50) + 0.5(621.73)1095.93 + 0.5(1030.81)729.59 + 0.5(333.56)942.73 + 0.5(532.10)50.56 + 0.5(599.52)800.36 + $0.5(532.10^2 + 50.56^2)^{1/2}\{1000^2 - [0.5(532.10^2 + 50.56^2)^{1/2}]^2\}^{1/2}$ + $1260^2\pi(\theta_b) \div 360 + 1000^2\pi(\theta_c + \theta_h) \div 360$ + 2291.73(3006.50 - 2914.69 - 2751.14 + 2666.25)

2,716,928.284 + 1,267,583.122 + 1,571,127.968 + 110,172.9728 + 84,785.32 + 873,382.7812 + 340,686.2795 + 373,957.309 + 157,228.5094 + 13,451.988 + 239,915.9136 + 257,527.9099 + 1,323,622.537 + 762,023.8914 + 15,512.7716 = 10,107,906.50 ft^2 = 232.03 acres

TOTAL AREA = 17,452,234.81 + 24,914,298.06 - 10,107,906.50 = 32,259,126.37 ft^2 = 740.57 acres

= 5565.50(2751.14 + 2914.69) + 3006.50(5806.96 - 5565.50) = 31,533,176.87 + 725,949.49 = 32,259,126.36 ft^2 = 740.57 acres

TOTAL AREA USED FOR STORAGE = 6,519,000 + 9,588,093.75 - 15,512.7716 = 16,091,580.98 ft^2 = 369.41 acres OR 49.8823% OF THE TOTAL

+ 914,112 ft^2 = 20.9851 acres OR 2.8337% OF THE TOTAL FOR THE EXPERIMENTAL AREA

= 17,005,692.98 ft^2 = 390.397 acres OR 52.7159% OF THE TOTAL FOR BOTH

Rexnord

RECEIVED

JAN 14 '77

FENIX & SCISSON, INC.

Process Machinery Division
P.O. Box 383
Milwaukee, WI 53201
414/744-2345
TELEX 2-6601

January 7, 1977

Fenix & Scisson, Inc.
Post Office Box 15609
Tulsa, Oklahoma 74115

ATTENTION: MR. GEORGE SCHAEFER

SUBJECT: Hoist Estimates

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) [illegible] (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)

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

RECEIVED
JAN [illegible]
[illegible] & SCISSON, INC.

WFB:AA

cc: Tom Armany

Enclosures

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Rexnord

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3 - 2 1977

FENIX & SCISSON, INC.

Process Machinery Division
P.O. Box 383
Milwaukee, WI 53201
TELEX 2 6601
My No. 414/643

February 28, 1977

Fenix & Scisson Inc.
5805 East Fifteenth Street
Tulsa, Oklahoma 74112

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

DESCRIPTION	SERVICE HOIST	TRU
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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Under paragraph TRU Shaft and in regard to your question, the hoist [illegible] 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:

HOIST DATA

DESCRIPTION	R.H. SHAFT	ESCAPE HOIST
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

404

90030062

Storage cycle for TRU Waste: Number of *14,000

the skid carrying 24 drums will require the most

Step 1. clamp Lift-O-Matics onto 4 drums and li

Step 2. tram the 4 drums from the skid a maximu
100 ft. @

step 3. position to unclamp drums at storage

step 4. lift load to maximum height and unclamp

step 5. lower mast

step 6. travel 100 ft. back to skid

step 7. position to clamp 4 drums

Skid load is 24 drums

*haulage times from "Haulage Cycle For TRU Waste"

A. Haulage vehicle unloads loaded skid in storage room within 100 ft.
B. Haulage vehicle trams empty skid out of room 1 min.
C. Haulage vehicle travels between storage room and TRU shaft @
D. Haulage vehicle unloads empty skid at TRU shaft and loads loaded
E. Haulage vehicle travels between TRU shaft and storage room @ 88
F. Haulage vehicle trams loaded skid from storage room entrance to placement

This figure, 1980 ft., means that entrance to the storage room is less the time the haulage vehicle is ready to wait. However it would make no sense to shaft is the bottleneck. If the haulage room, it would be waiting on the cage a all but the 3½ min. the haulage vehicle s fork lift time. Therefore as long as the is not upset. One 14,000# capacity fork the TRU level for back up.

900300 63

*see "Size of Fork Lift Required"

) lb. capacity fork lifts required 11/5/76 JHO

time to unload

ft off skid elapsed time 3 sec.

m distance of
7⅓ fps (5 mph) 14 sec.

site 10 sec.

drums 4 sec.

3 sec.

14 sec.

10 sec.

total time per 4 drums 58 sec.

to be conservative use 116 sec./4 drums

24 drums / 4 drums/trip = 6 trips

116 sec./trip × 6 trips = 696 sec. = 11.6 min.

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 drums / 2 drums/trip = 40 trips
30 min / 40 trips = .75 min/trip = 45 sec/trip

Consider 12 min. the maximum time to unload skid with one fork lift

f placement site, and loads empty skid 3½ min.

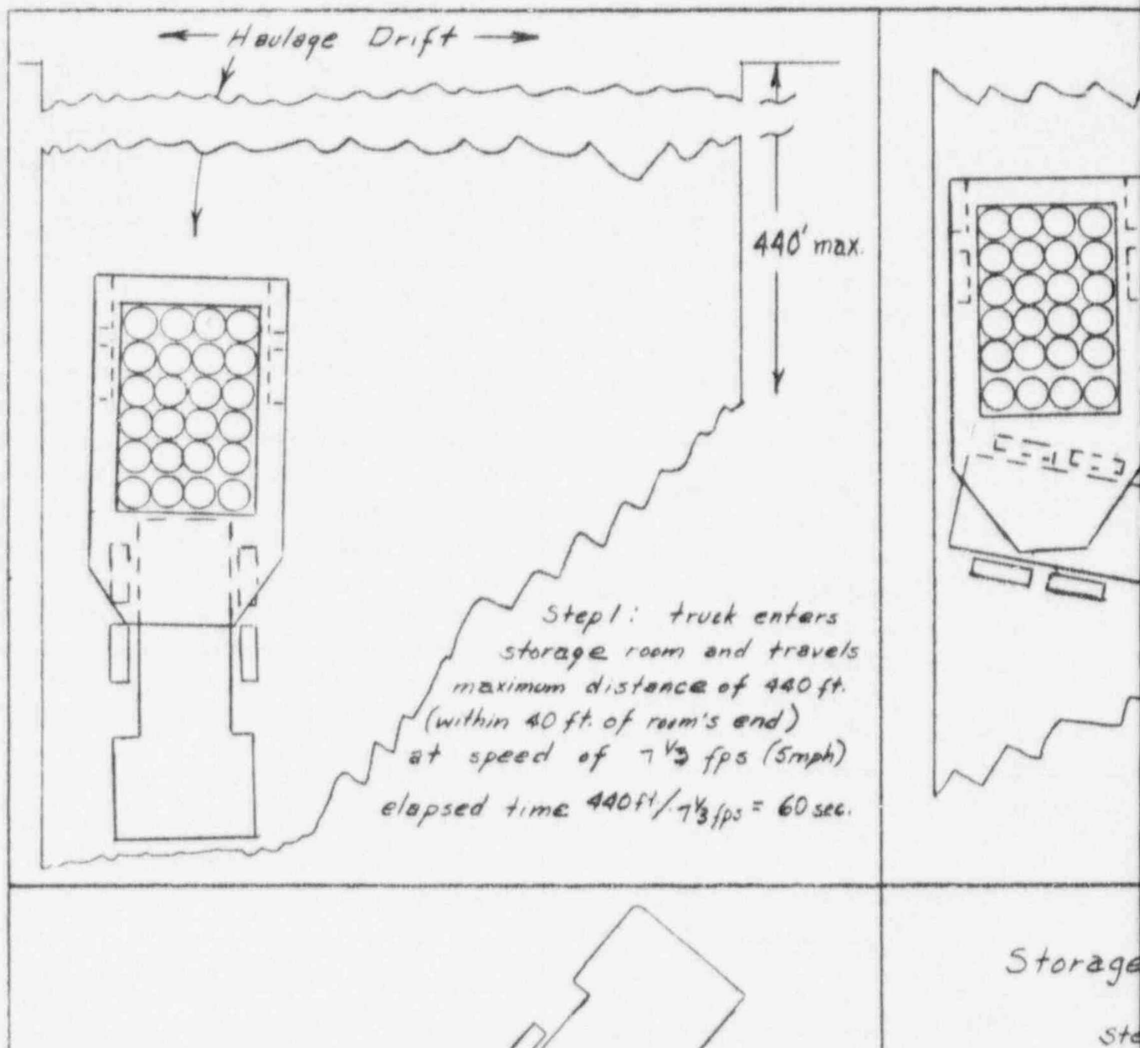
80 fpm X min.
skid 5½ min.
fpm X min.
site 1 min.

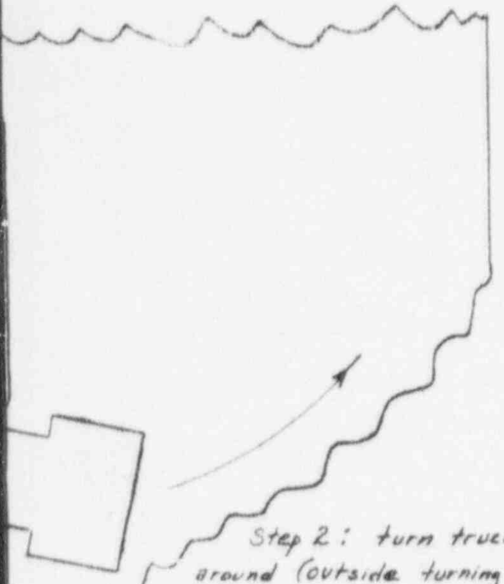
time fork lift has to unload skid

$2X + 7\frac{1}{2}$ min. $\leq$ 12 min.

$2X \leq 4.5$ min. → $X \leq 2.25$ min. 2.25 min × 880 fpm = 1,980 ft.

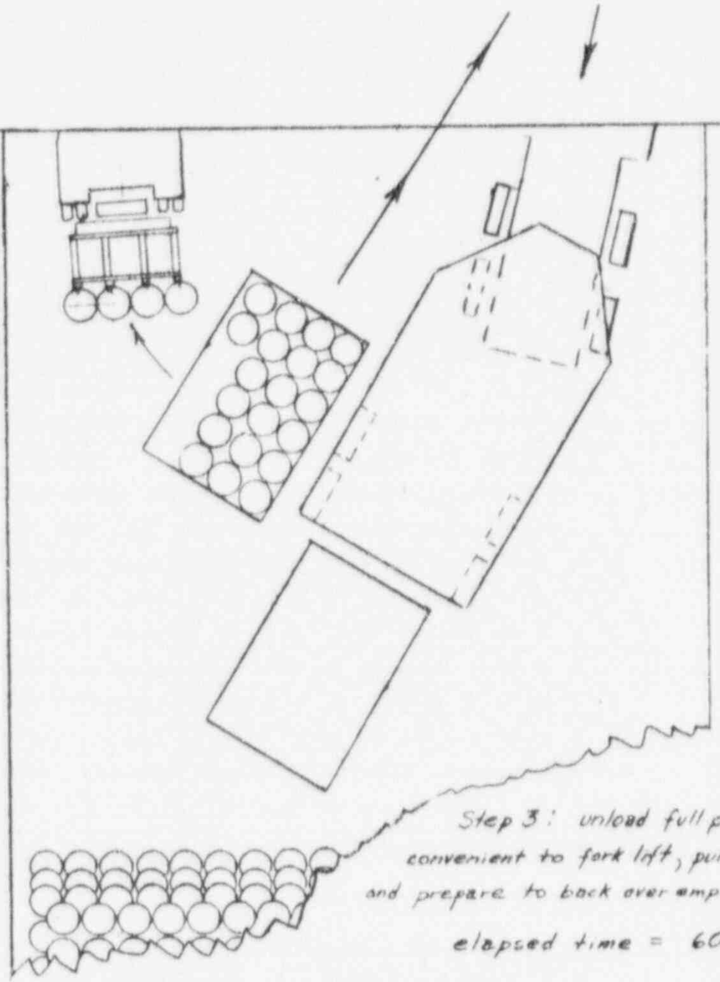
when the haulage distance between the TRU shaft and the
than 1980 ft., the fork lift will not have the skid unloaded by
return to the TRU shaft. The haulage vehicle would have to
add another fork lift to unload more quickly, because the
vehicle wasn't waiting on the fork lift in the storage
the TRU shaft. During the 28 min. hoist cycle time,
pends loading and unloading skids in the storage room is effective
fork lift can unload a skid in 24½ minutes, the cycle
ft is adequate. A second fork truck will be kept on


← Haulage Drift →
440' max.
Step 1: truck enters storage room and travels maximum distance of 440 ft. (within 40 ft. of room's end) at speed of 7 1/3 fps (5mph)
elapsed time 440ft/7 1/3 fps = 60 sec.
step 4: back over and load empty pallet
elapsed time = 90 sec.
step 5: travel back out of room at 7 1/3 fps
elapsed time 440ft/7 1/3 fps = 60 sec.
Storage



Step 2: turn truck around (outside turning radius should be about 17.5 ft., so no problem) and position to back up and unload full pallet

elapsed time = 60 sec.



Step 3: unload full pallet convenient to fork lift, pull ahead and prepare to back over empty pallet

elapsed time = 60 sec.

room cycle

p 1	60 sec.	
p 2	60 sec.	
3	60 sec.	
4	90 sec.	
5	60 sec.	
al	330 sec.	= 5.5 min.

Use 5.5 min.

ler the operation of unloading the t and loading a full one at the to require the same amount of nin.

10/29/76
JHO

Haulage Cycle For TRU Waste

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 10 mph = 880 ft/min

17 min × 880 ft/min = 14,960 ft. = 2.83 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.

90030066