New Folder Name LIGO STUDY SUMMARY REPORT VOLUME 1

FILE: T880080

P - IV - 9 - 3/16" wall x 4' spacers - Saves 1/2 million!

- Why 500 cfm blowers? when Not inhabited?

F Lansing - 1984 - 1.6×10^{-11} TL/sec m² in 900 hrs ($\sim 1.4 \times 10^{-8}$ @ 1 hr.)
~ 1/10 of Dayton!

LIGO STUDY

JPL SUMMARY REPORT

January 18, 1988

(VOLUME I)

LIGO STUDY - JPL SUMMARY REPORT

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIGO STUDY - JPL SUMMARY REPORT

INTRODUCTION

This report summarizes the JPL conceptual design effort for the Laser Interferometer Gravity Wave Observatory (LIGO) performed on behalf of the California Institute of Technology (CIT) and the Massachusetts Institute of Technology (MIT).

The JPL LIGO conceptual design effort began in April 1984 and has continued until the present time. During this period the Functional Requirements Document (FRD) was initiated by CIT/MIT with assistance from JPL. This FRD is still under development.

To present all the technical design and budgetary approaches that have been examined during this effort is beyond the scope of this document. This summary report organizes the results of the joint JPL/CIT/MIT efforts through December 1987 and reflects the facilities design status as of that date.

This report is comprised of two sections. Volume I outlines the December 1987 facilities design configuration of the LIGO. Volume II is an Appendix which incorporates materials and reports relevant to Volume I. Additional background information covering materials, design and associated cost estimates bearing on alternate LIGO configurations are maintained in JPL files.

LIGO STUDY - JPL SUMMARY REPORT

DESCRIPTION

This summary incorporates conceptual design approaches based on the following basic LIGO facilities configuration:

Two observatories, one each located in California and Maine.

Two four kilometer vacuum pipes per antenna.

Four foot diameter x 1/4 inch wall vacuum pipe.

Eight vacuum chambers.

1 x 10-8 Torr vacuum level.

Protective housings for the vacuum pipe and chambers.

BATCH START

STAPLE
OR
DIVIDER

SITE DATA (CALIFORNIA)

The following Section (II A) summarizes the site investigations and studies performed to date for the Edwards AFB LIGO site.

LIGO-EDWARDS

TOPOGRAPHIC SURVEY AND ALIGNMNENT

SUMMARY

Four plans (A, B, C, D) have been studied for the LIGO alignment at Edwards AFB, California. Future expansion requirements may alter these plans considerably.

ALIGNMENT CRITERIA

Criteria furnished by CIT on September 23, 1987, allowing $\pm 13^{\circ}$ variation in alignment from Plan A (submitted to Edwards) dictates further siting studies to determine the most efficient configuration. The allowable variation from 90° between the arms has not been finalized.

FOUR STUDIES CONSIDERED TO DATE

PLAN A

Submitted to Edwards early 1987 for approval.

Earthwork cost estimated at $2200K.

PLAN B

Leaves apex at same location as Plan A but rotates alignment to be symmetrical about N/S line. Earthwork costs are approximately same. This plan allows a greater distance to railroad and highway.

PLAN C

Utilizes natural berm on site and takes partial advantage of existing road.

ADVANTAGES

Maximizes the distance to railroad and highway and minimizes exposed berms to erosion. Earthwork costs approximately $1500K

POSSIBLE NEGATIVES

Berm may have been created by the Muroc Fault. CIT has checked this out and the fault is not considered active. An inactive fault, however, may incorporate gouge material with poor foundation conditions.

PLAN D

Places the apex in 20 ft. of cut instead of on the lake bed and will provide better foundation conditions for the central station. This plan also minimizes overall construction on the lake bed but requires heavy cut at the N.E. end.

PROFILES

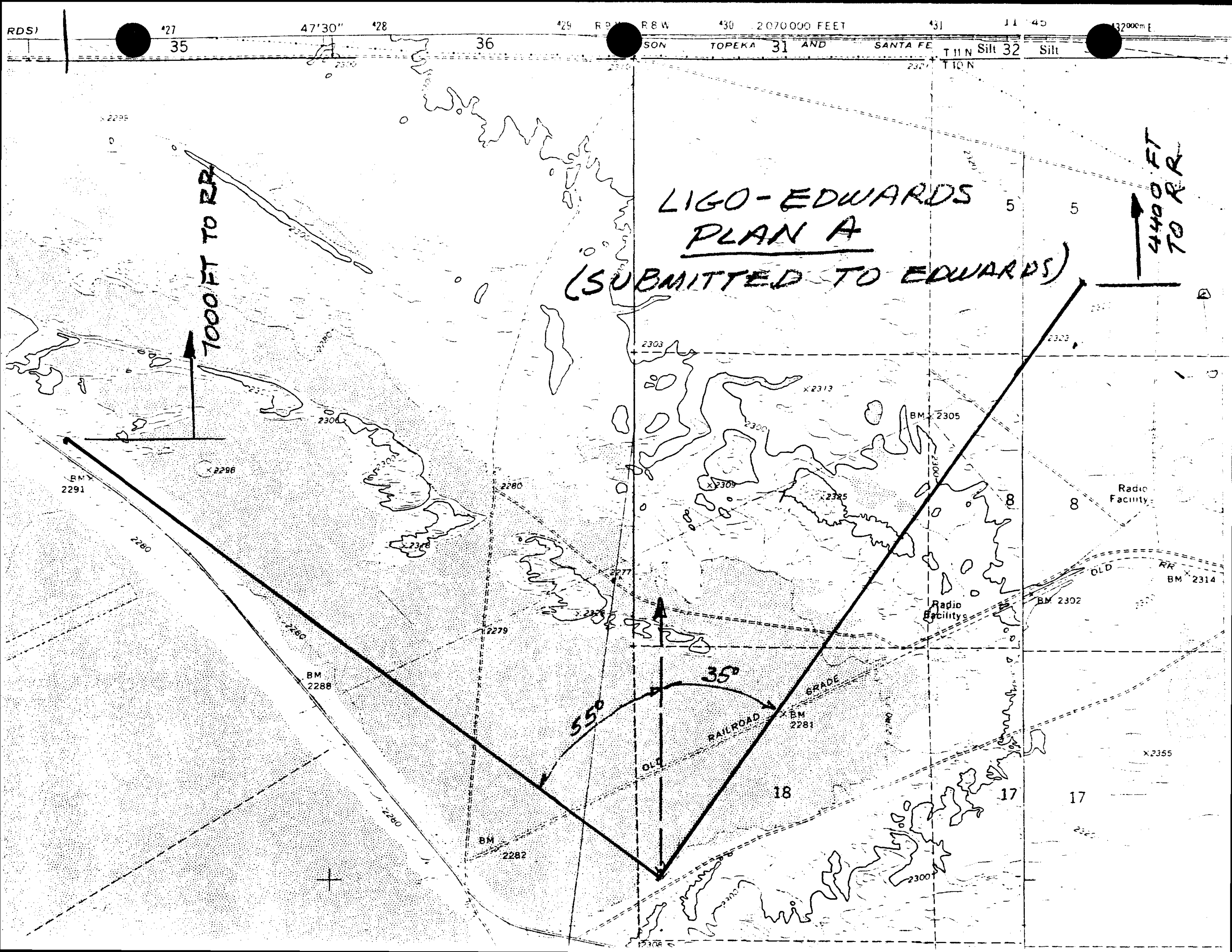
Preliminary profiles are available in the JPL files on the above four plans.

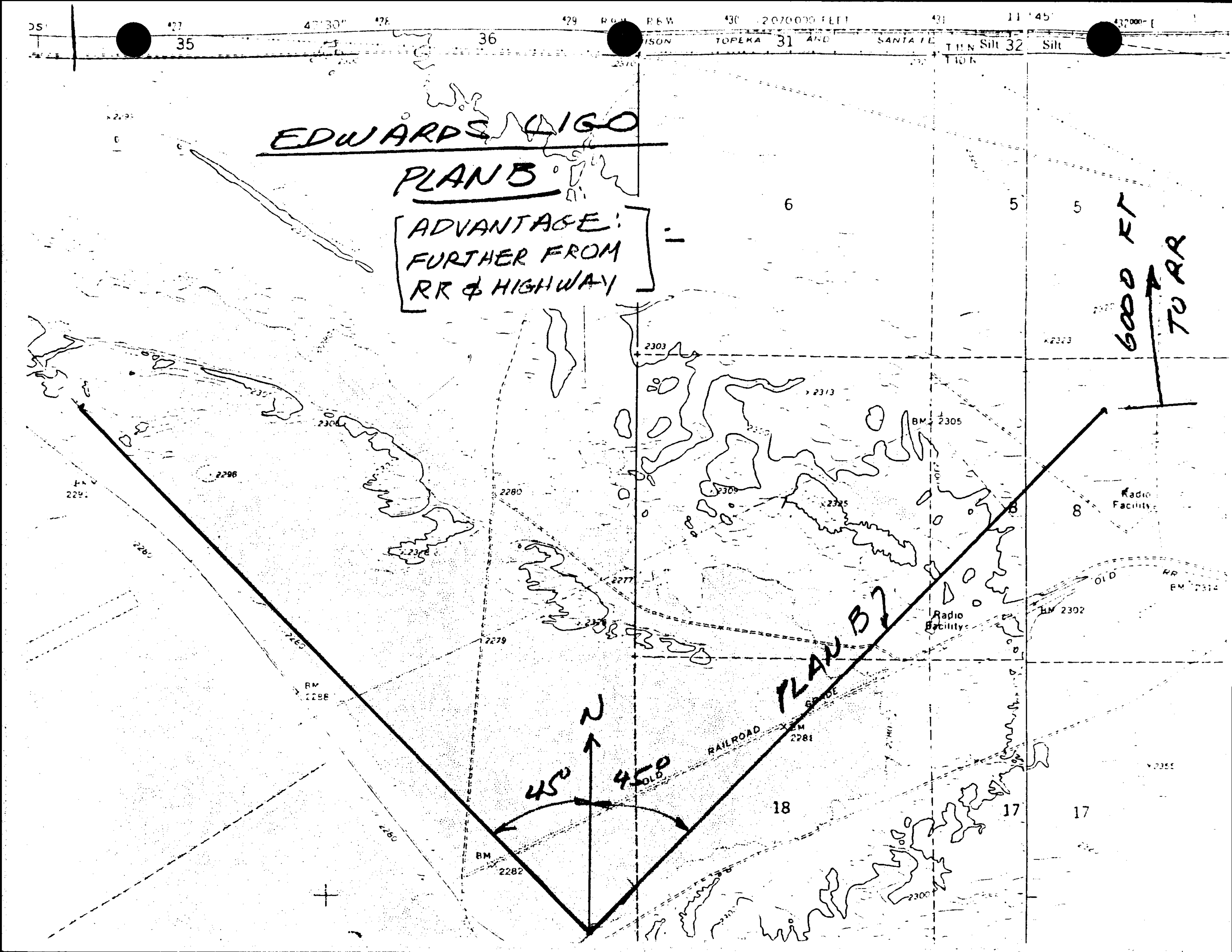
TOPOGRAPHICAL SURVEY STATUS

JPL has on hand a topographic survey prepared by Edwards AFB engineers which essentially covers the northeast leg only. The scale of this drawing is 1 inch equals 400 feet with 5 foot contours. Final design will require the area to be flown and maps produced at a scale of 1 inch equals 50 feet with 1 foot contours. A draft Statement of Work has been prepared for this effort.

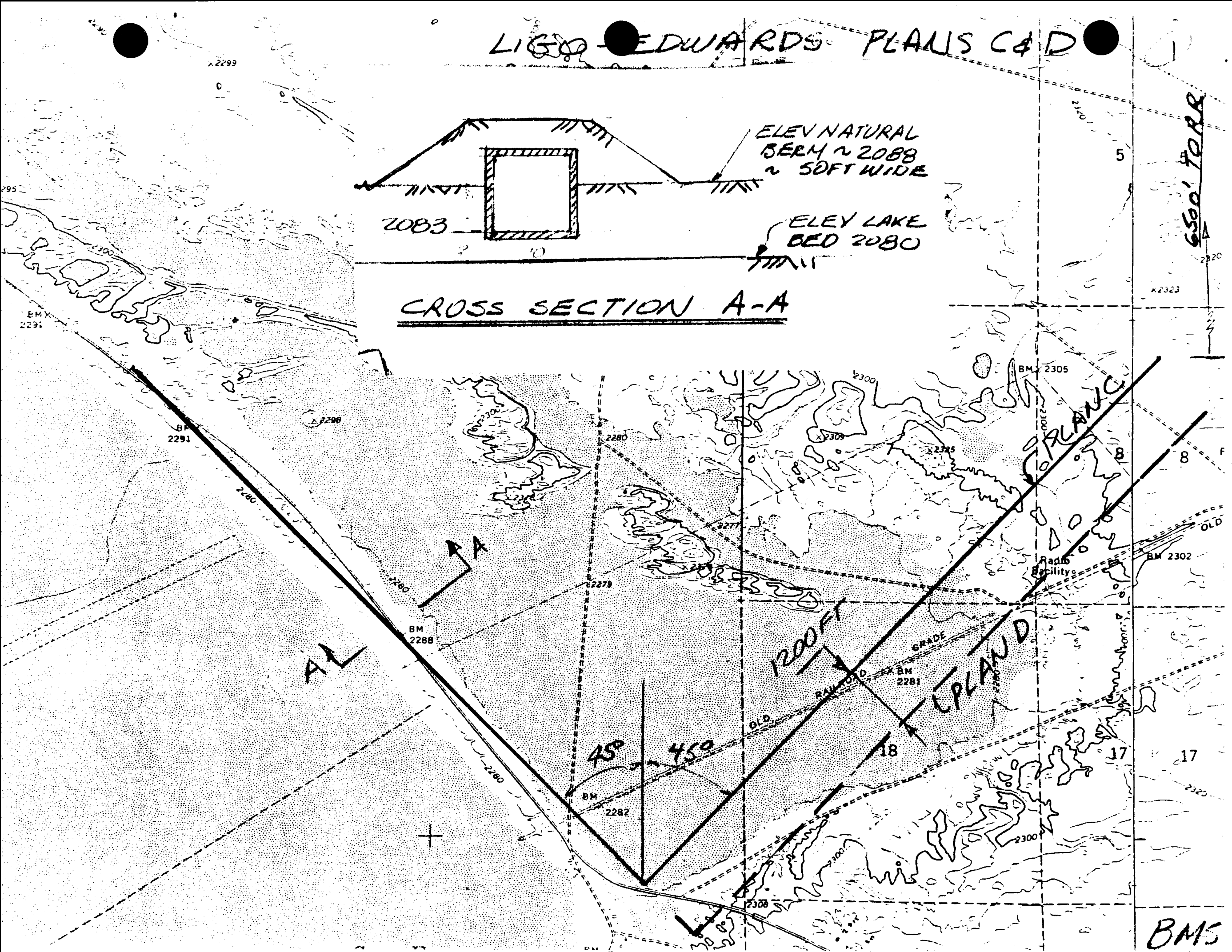
CONSIDERATIONS PRIOR TO FINALIZING SURVEY REQUIREMENTS

1. A new submittal to the Air Force will be required for a new alignment.
2. Should future expansion of LIGO be shown on the submittal?
3. Should topographic survey and geotechnical surveys include future expansion?


LIGO-EDWARDS
PLAN A
(SUBMITTED TO EDWARDS)
1000 FT TO RR
4400 FT TO RR
55°
35°
47'30"
2 070 000 FEET
TOPEKA
AND
SANTA FE
R 8 W
T 11 N
T 10 N
Silt
35
36
31
32
5
8
17
18
Radio Facility
OLD RAILROAD GRADE
OLD RR
BM 2305
BM 2302
BM 2314
BM 2291
BM 2288
BM 2281
BM 2282
2303
2313
2309
2325
2296
2277
2279
2280
2300
2355



EDWARDS LIGO
PLAN B
ADVANTAGE: FURTHER FROM RR & HIGHWAY
6000 FT TO RR
PLAN B?
N
45°
45°
TOPEKA
AND
SANTA FE
RAILROAD
GRADE
OLD
OLD RR
Radio Facility
Radio Facility
BM 2305
BM 2302
BM 2288
BM 2282
BM 2281
35
36
31
32
6
5
5
8
8
18
17
17
Silt
Silt


LIGO EDWARDS PLANS C&D
ELEV NATURAL BERM ~ 2088 ~ 50FT WIDE
2083
ELEV LAKE BED 2080
CROSS SECTION A-A
6500' TORR
PLAN C
PLAN D
1200 FT
45°
45°
A
A
BM 2305
BM 2302
BM 2288
BM 2282
BM 2281
Radio Facility
OLD
RAILROAD GRADE
2300
2280
BMS

XI

JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM
3326-85-004

4 January 1985

TO: V. Lobb

FROM: B. M. Sweetser BMS

SUBJECT: GWO - VBL-84-064 Item 10 - New Freeway Work Highway 58 - North of Edwards (Item 10)

The following contacts were made regarding the above.

A. CalTrans Office, Bishop, 619-873-8411 - Geo Nash (Kern Co. District)

Mr Nash stated they planned additional work within a mile of Mojave only. He furnished the following present traffic loadings.

		Total Number of Vehicles
1.	Annual daily average	8900
2.	Average daily peak month	9900
3.	Maximum peak hour	1050

B. CalTrans Office, San Bernardino, 714-383-4561 - William McKinney

Mr. McKinney stated they are going to upgrade the highway for 16 miles to a 4 lane expressway (not a freeway). This work will all be 3 1/2 miles east of Krammer junction. He stated he agreed with the traffic flow numbers above and saw no reason that there would be any significant increase in traffic due to this work.

BMS:rw

cc: A. Cantu
A. Riewe
F. Stoller
F. Menninger

XV

JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM
3556-84-122

23 October 1984

TO: F. Menninger

FROM: [redacted]

SUBJECT: Traffic Adjacent to Edwards AFB

A. East-West

1. Santa Fe RR - 16 Trains/day

one mile long (8 each way)

2. Highway 58

Average daily	11,400	vehicles
Peak hour	1,650	

B. North-South

1. Southern Pacific - 14 Trains/day

(7 each way)

2. Highway 14

Average daily	10,400
Peak hour	1,350

BMS:rw

cc: V. Lobb
F. Stoller
R. Elder
A. Riewe

JPL

LIGO - EDWARDS

WATER REQUIRED DURING CONSTRUCTION
(WATER TO BE HAULED)

- ASSUME 5000 YDS OF FILL PLACED / DAY WITH 2% DRY WEIGHT MOISTURE CONTENT & 11% REQUIRED FOR COMPACTION

- GALLONS REQ'D / DAY = (.11 - .02)(3250#) = 300#/YD
  300# = 36 GALLONS x 5000 = 18000 gal/day
- PERSONNEL USE = ~200 x 5 gals = 1000 gal/day

- TOTAL REQUIRED FOR COMPACTION (ENTIRE JOB)
  425,000 yd x 36 gal = 1.5 MILLION GALS
  (COST 1500 x $.45 = $675.00)
- WATER AVAILABILITY AT EDWARDS
  - STORAGE = 2.0 MILLION GALLONS
  - WELL CAPACITY = ~5 WELLS @ 1000 GPM

BMS 1 of 2
6-10-87

JPL

LIGO - EDWARDS

WATER REQUIRED DURING OPERATIONS

- ASSUME 10 PEOPLE USING TOILETS SHOWERS: 10 X 125 = 1250 GALLON/DAY

- COST OF 3" PVC SCHEDULE 80 PIPE CONNECTED TO CLOSEST SOURCE & TERMINATING AT APEX = $7.00/FT X 30,000 FT = $210,000

- COST OF DOMESTIC TYPE WELL* (20 GPM)

300 FT X $30/FT	= 9000
PUMP	2000
ELEC HOOK UP	1750
	$ 12,750

* [ESTIMATE FROM BRYAN PUMP & SUPPLY PALMDALE RECENTY COMPLETED 20 TEST WELLS AT EDWARDS CONTINOUS CHLORINATION EQUIP. ADD $1500.00]

BMS 2 of 2
6-10-87

ENVIRONMENTAL ASSESSMENT REQUIREMENTS

EDWARDS AFB

(IMPACT ANALYSIS)

The attached documents indicate the requirements for an environmental impact analysis of the LIGO at Edwards AFB to be prepared by CIT/JPL with technical assistance from the Base environmental coordinator.

Preliminary information on the LIGO was submitted to Edwards by George Root of JPL/Edwards in early 1985.

A biotic survey of the project as then planned was authorized by CIT/JPL and conducted by Westec Services of San Diego in 1985. The Westec report submitted in August 1985 indicates the LIGO construction will have negligible effect on the wild life and vegetation.

This report must be reviewed to assure that it is compatible with the final LIGO alignment and construction configuration. The biotic survey is only a portion of the assessment requirements as indicated on Form 814 enclosed.

REQUEST FOR ENVIRONMENTAL IMPACT ANALYSIS

FOR ENVIRONMENTAL PLANNING USE ONLY

I REQUEST

1. TO: (Environmental Planning Function)
6510 ABG/DEEV

2. FROM: (Organization and Office Symbol)
JPL/EF Stop#11

3. CONTROL NUMBER
850020

4. ESTIMATED COMP DATE

5. REQUESTOR (Name, Office Symbol and Phone No.)
George L. Root JPL/EF 277-7010

6. TYPE OF ANALYSIS NEEDED

	CATEX DETERMINATION	X	PRELIMINARY ENVIRONMENTAL SURVEY	X	ENVIRONMENTAL ASSESSMENT		ENVIRONMENTAL IMPACT STATEMENT

7. TITLE OF PROPOSED ACTION
GRAVITY WAVE DETECTION FACILITY

II DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES (DOPAA)

8. PURPOSE OF AND NEED FOR ACTION (Continued on Sheets) Construction to start July '87
Measure graviational signals from various sources. It is desireable to locate this facility near a JPL/CalTech Support Facility. Shops, storeroom and offices are established at the JPL/EF

9. DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES (Continued on Sheets)
Group II, Activity 28, 29, 74
Group III, Activity 73

See Attachment 1 - Geographical location
Attachment 2 - Basic construction details
Attachment 3 - Description of science activity

10. EPC MEMBER DOPAA REVIEW CERTIFICATION (Name and Grade)	SIGNATURE	DATE
George L. Root, Civilian	George L. Root	3-12-85
11. ORGANIZATIONAL APPROVAL (Name and Grade of Commander)	**SIGNATURE**	**DATE**
Floyd A. Anderson, Civ., Acting-Manager	Floyd A. Anderson	3-12-85

III ADDITIONAL APPROVAL (AS REQUIRED)

12. CONTRACT CONSULTANT APPROVAL AUTHORITY (Name and Grade)	SIGNATURE	DATE

IV ENVIRONMENTAL PLANNING RESPONSE

13. RESPONSES ATTACHED

☐	Preliminary Environmental survey (AF Form 814) attached
☐	Proposed action qualified for Catex (Appropriate Documentation attached)
☐	Proposed action does not qualify for Catex, assessment required

14. REMARKS This action has been reviewed IAW AFR 19-2. The PES conducted by DEEV established the requirement for further analyses in the areas of cultural resources, endangered species, and others. An Environmental Assessment (EA) will need to be prepared which analyses the potential adverse and positive impacts of the proposed project. Preparation of the EA is the proponent's responsibility with technical assistance provided by this office. Such analyses shall include the attributes listed under Item 4 on AF Form 814.

15. ENVIRONMENTAL PLANNER CERTIFICATION (Name and Grade)	SIGNATURE	DATE
TERRY YONKERS, GS-12 AFFTC Environmental Coordinator	Terry G. Yonkers	9 Apr 85
16. ENVIRONMENTAL PROTECTION COMMITTEE APPROVAL (Name and Grade)	**SIGNATURE**	**DATE**

AF FORM JUL 79 813

U.S. Government Printing Office: 1980—310-971/4053

PRELIMINARY ENVIRONMENTAL SURVEY

(CAUTION: This environmental survey is a preliminary document prepared to aid in the early development of your proposal. IT IS NOT AN ENVIRONMENTAL ASSESSMENT.)

1. TITLE OF PROPOSED ACTION
Gravity Wave Detection Facility

2. CONTROL NUMBER
850020

I

WORKSHEET

3. INSTRUCTIONS: *Indicate the effect either on or of each appropriate attribute listed below. Additional attributes may be listed in the "other" section.* + = Postive Effect; 0 = No Effect; - = Adverse Effect; U = Effect Unknown.

4. ATTRIBUTE

	Attribute	+	0	-	U
EARTH	EROSION (WIND/WATER)			X	
	SURFACE STABILITY				X
WATER	AQUATIC LIFE		X		
	FLOW VARIATION				X
	AESTHETIC PROPERTIES AND POTENTIAL USE OF WATER		X		
	AQUIFER YIELD		X		
	CHEMICAL QUALITY (DO, pH, DISSOLVED SOLIDS, NUTRIENTS, TOXICS)		X		
	PHYSICAL QUALITY (SUSPENDED SOLIDS, OIL, TEMPERATURE)		X		
AIR	ODORS		X		
	TOXIC SUBSTANCES		X		
	PARTICULATES			X	
	AIR MOVEMENT		X		
	OTHER (SULFUR OXIDES, HYDROCARBONS, NITROGEN OXIDES, CARBON MONOXIDE, PHOTOCHEMICAL OXIDANTS)		X		
BIOTIC	UNDISTURBED "NATURAL" AREAS			X	
	GAME ANIMALS AND FISH				X
	THREATENED AND ENDANGERED SPECIES				X
	SPECIES BALANCE				X
RESOURCES	FUEL RESOURCE CONSUMPTION/ CONSERVATION		?		X
	NON-FUEL RESOURCE CONSUMPTION/ CONSERVATION		X		
SPEC HAZARD	RADIOACTIVITY		X		
	ELECTROMAGNETIC				X

	Attribute	+	0	-	U
ACTIVITY SYSTEMS	TRANSPORTATION SUPPLY/DEMAND				X
	WATER		✓		X
	POWER/HEATING				X
	SOLID WASTE				X
	SEWER/STORM DRAINAGE				X
LAND USE	FLOOD PLAINS/				X
	OFF-BASE LAND USE		✓		X
	ON-BASE LAND USE	X			
	HISTORY/ARCHEOLOGICAL AREAS				X
	AESTHETICS				X
	ACCESS TO MINERALS		X		
SOCIO ECONOMICS	POPULATION		X		
	HOUSING SUPPLY/DEMAND		X		
	EMPLOYMENT	X	✓		X
	COMMERCIAL ACTIVITIES	X			
	INDUSTRIAL ACTIVITIES	X			
	CULTURAL PATTERNS		X		
NOISE	ON-BASE LEVELS (AIRCRAFT AND GROUND)		X		
	OFF-BASE LEVELS (AIRCRAFT AND GROUND)		X		
OTHER	HEALTH SAFETY				X

II

REMARKS

5. CONTINUE ON 3 **SHEETS**

See attached comments

6. NAME AND GRADE OF ENVIRONMENTAL PLANNER	7. SIGNATURE	DATE
Richard H. Norwood, GS-09	Richard H Norwood	9 April 85
Michael V. Phillips, GS-11	Michael V Phillips	9 April 85

AF FORM 814

PRELIMINARY ARCHAEOLOGICAL ASSESSMENT FOR THE GRAVITY WAVE DETECTION FACILITY

A. RECOMMENDATIONS

1. In accordance with pertinent federal laws and regulations (NHPA 1966, NEPA 1969, AHPA 1974, and ACHP regulations 36CFR 800) an intensive cultural resource survey should be conducted for the facility "right of way," access roads, or any other structures that could impact cultural resouces.

2. In the event cultural resources are found within the area of impact these should be evaluated in terms of National Register of Historic Places criteria.

3. Any cultural resource impact mitigation project should be coordinated with the appropriate state, and, if necessary, federal agencies.

4. A technical report should be prepared that presents findings, addresses impacts, and presents an impact mitigation plan.

5. An impact mitigation program should be carried out if appropriate to the circumstances.

B. RECORDS SEARCH

A record search was carried out for the right of way itself and for an area extending 1/2 mile out from the proposed facility. Records indicate that only small portions (5%) of the area have been studied previously

There are no previously recorded resources within the actual right of way. There are seven known cultural resources within 1/2 mile of the proposed facility (Ker 560, Ker 1754, Ker 1809H, Ker 1827H, Ker 1838, Ker 1839, Ker 1875). To date none of these sites have been formally evaluated.

The proposed facility location lies adjacent to Rogers Dry Lake. The National Park Service has recently nominated the lake bed as a National Historic Landmark. As of March 1985 the nomination had not been finalized. In our opinion the proposed facility will have no significant impact on the lake bed.

C. DISCUSSION

The project area lies in an area of moderate sensitivity. While sites may be expected to occur, their size and nature are not expected to be prohibitive in terms of project development. Should a large significant resource occur, impact mitigation can possibly be confined to a specified corridor along the right of way. An initial survey for the project could be accomplished in approximately 128 person hours following plane survey and staking of the centerline.

Costs and time frames will vary according to what is found. With the best case initial survey, analysis, and technical report could be completed for approximately $15,000 (negative report). The worst case involves discovery of resources that require work beyond the initial survey stage.

The proposed action, to site and construct a gravity wave detection facility on Edwards AFB, has the potential to impact the natural resources of the installation. Surface disturbance resulting from excavation of the vacumn chamber tunnel, construction of access roads, and equipment staging areas will create a potential for both wind and water erosion. Surface stability will be in a state of flux until completion of construction activities. Fugitive dust will be created and have to be controlled. A majority of the project area is contained within a playa sink. This area is subject to both sheet wash and periodic flooding as several watersheds to the north and north-east empty into this area before draining into Rogers Lake. The facility may have the potential to alter the flow patterns in this area. Design of the facility should strive to avoid concentrating excess storm flows into a small number of channels. This could alter the dynamics of sheetwash and sediment carrying capacity which maintains the integrity of the lakebed landing surface. The presence of candidate endangered plant species, Chorizanthe spinosa and Cymopterus deserticola, in the vicinity of the project area will require a surface survey conducted by a qualified botanist in the spring of the year to determine if any populations are likely to be impacted by the project's activities. While there is no legal requirement to mitigate impacts to a candidate species, it is incumbent upon the proponent to determine the presence of such species and plan for mitigation in the event of such species becoming officially listed. Habitat exists within the vicinity of the project area which could support the Mojave ground squirrel - a federally listed endangered species, and the desert tortoise - a state protected species and a candidated federal threatened species. A surface survey of areas subject to disturbance conducted by a qualified biologist will be required in the spring of the year to determine the presence or absence of such species in the project area. Should such species be encountered in or adjacent to areas which will be subject to disturbance, consultation with the appropiate agency (California Department of Fish and Game or the U.S. Fish and Wildlife Service) will be required to mitigate any impacts arising from the project's implementation. In addition, the project area contains scattered ocurrences of Joshua trees which are protected by Kern County. The vacumn chamber right-of-way should attempt to avoid populations of Joshua trees. In areas where this is not possible, disturbance should be restricted to a minimum so as to avoid impacting as few Joshua trees as possible. Cultural resources are known to occur adjacent to the vacumn chamber right-of-way. Only a small portion of the project area has been previously surveyed for cultural resources. An intensive surface survey conducted by a qualified archaeologist will be required to clear all areas which will be subject to disturbance. Refer to Atch. 1 - Preliminary Archaeological Assessment for specific items of concern. Based upon: 1) The potential for adverse impacts to natural and cultural resources which could result from the extensive ground disturbance required to construct the proposed facility, and 2) The national significance of this project, at a minimum an Environmental Assessment (EA) will be required to fulfill the environmental clearance process. The EA should address the significance of adverse and positive impacts of the project, including those physical attributes listed on the AF Form 814. Dependent upon the findings of the Environmental Assessment, an Environmental Impact Statement could be required. This process would require an additional nine months lead time before the project receives an approval to proceed.

Reasonable estimates of cost are not possible without initial survey data. It is probable that all cultural resource impact mitigation work could be accomplished well in advance of construction assuming a worst case and a start date prior to October 1985.

B. Sweetser
144/103
MAY 14 REC'D

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE FLIGHT TEST CENTER (AFSC)
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

13 MAY 1987

REPLY TO ATTN OF: XR

SUBJECT: Future Electrical Power Requirements

TO:

6510 TESTW/CC	AFAL/CC	AAEFA/CC
6520 TESTG/CC	JPL	
6510 ABG/CC	NASA DFRF/Code 0	

1. Recently approved major facilities at Edwards AFB have depleted the reserve capacity of the electrical transmission supply lines. In order for our supplier, Southern California Edison (SCE), to be able to plan for and meet our future requirements, we must identify these to them. The lead time for new electrical capacity is approximately 24 to 36 months.

2. In order to provide the necessary planning data to SCE, we need you to identify future requirements for major facilities and equipment (greater than 1 KW). This data should include projected IOC date, power load and type, i.e. inductive or capacitive. If the facility or project is classified or sensitive, the actual end use of the power is not required. Please identify both firm requirements as well as projected requirements for as far into the future as you have data.

3. Please provide the above data to our office by COB, 27 May 87. For additional information, please contact me or Mr Larry Plews at 7-3837,

J. P. Brady

J. P. BRADY, Chief
Plans and Programs Office

cc: AFFTC/CC
AFFTC/DE

BATCH
START

STAPLE
OR
DIVIDER

SITE DATA (MAINE)

The following Section (II B) summarizes the site investigations and studies performed to date for the Columbia (Cherryfield) LIGO site.

TOPOGRAPHIC SURVEY STATUS - MAINE

A ON HAND

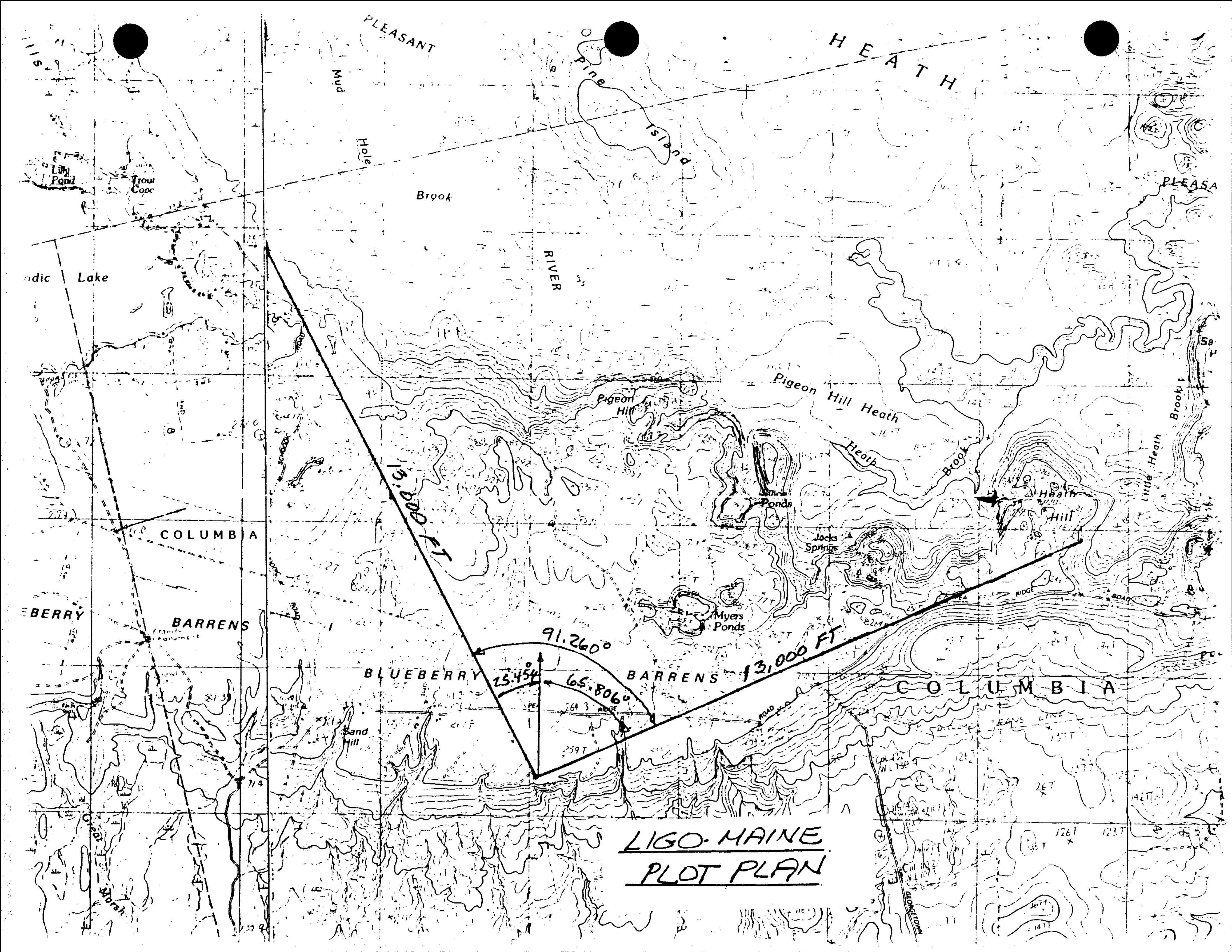
1. Aerial photos 1" = 800 ft.
2. Topography 1" = 500 ft., 2 ft. contours (preliminary)
3. Aerial photos 1" = 250 ft. with control survey data

B REQUIRED FOR FINAL DESIGN

1. Topography 1" = 50 ft. with 1 ft. contours. Cost $30,000 per James W. Sewall Co. letter of March 30, 1987

C ALIGNMENT

Present alignment is essentially fixed by terrain.


LIGO-MAINE
PLOT PLAN
13,000 FT
13,000 FT
91.260°
25.454°
65.806°
PLEASANT
HEATH
Pine Island
Mud Hole Brook
RIVER
Lake
Lily Pond
Trout Cove
Pigeon Hill
Pigeon Hill Heath
Heath Brook
Little Heath Brook
Heath Hill
Ponds
Jocks Springs
Myers Ponds
COLUMBIA
BARRENS
BLUEBERRY
BARRENS
Sand Hill
COLUMBIA
RIDGE
ROAD

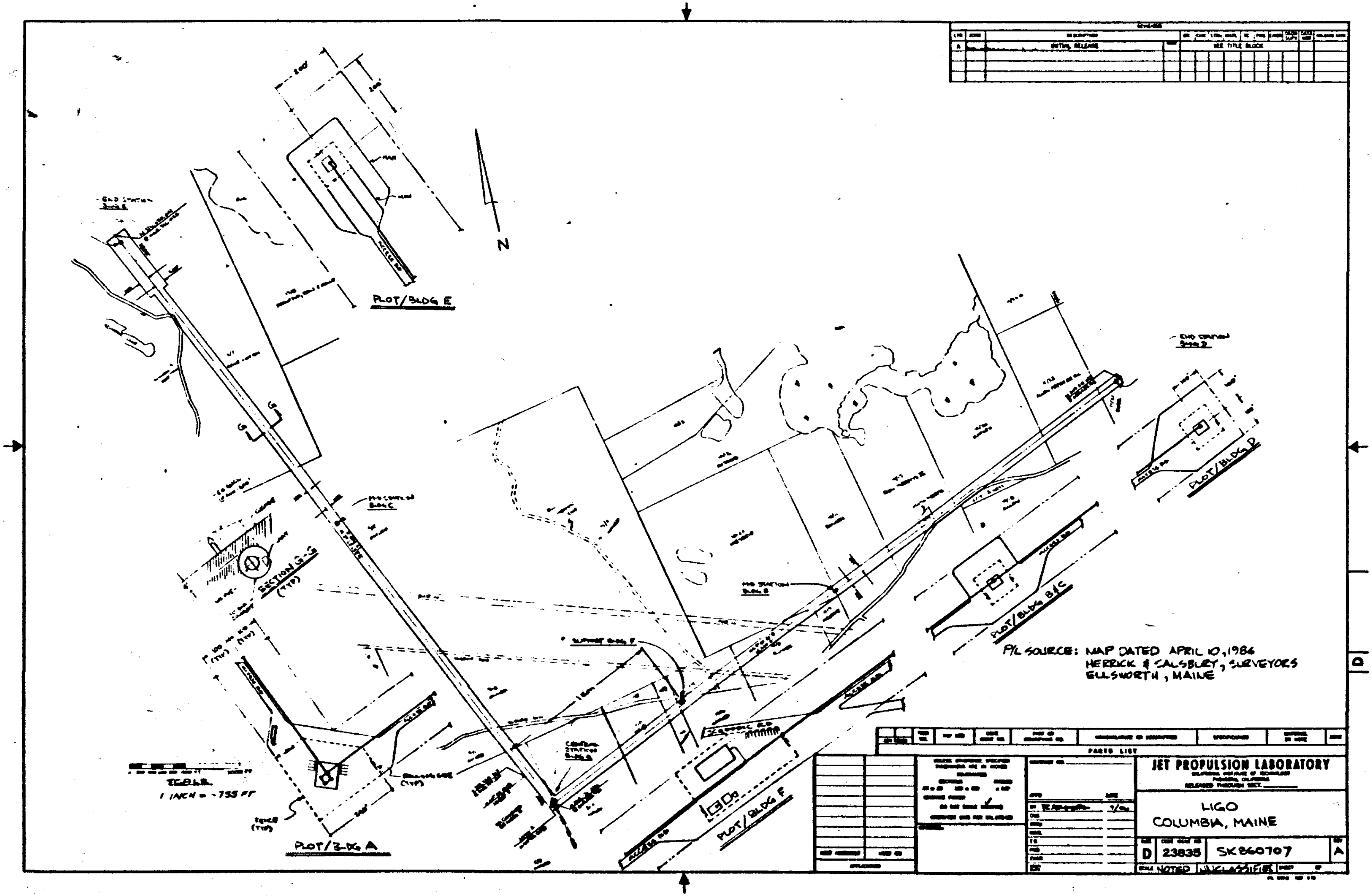

PLOT/BLDG E
N
PLOT/BLDG D
PLOT/BLDG B/C
PLOT/BLDG F
PLOT/BLDG A
SECTION G-G (TYP)
P/L SOURCE: MAP DATED APRIL 10, 1986
HERRICK & SALSBURY, SURVEYORS
ELLSWORTH, MAINE
JET PROPULSION LABORATORY
LIGO
COLUMBIA, MAINE
D 23835 SK860707 A
NOTED
UNCLASSIFIED
1 INCH = ~755 FT

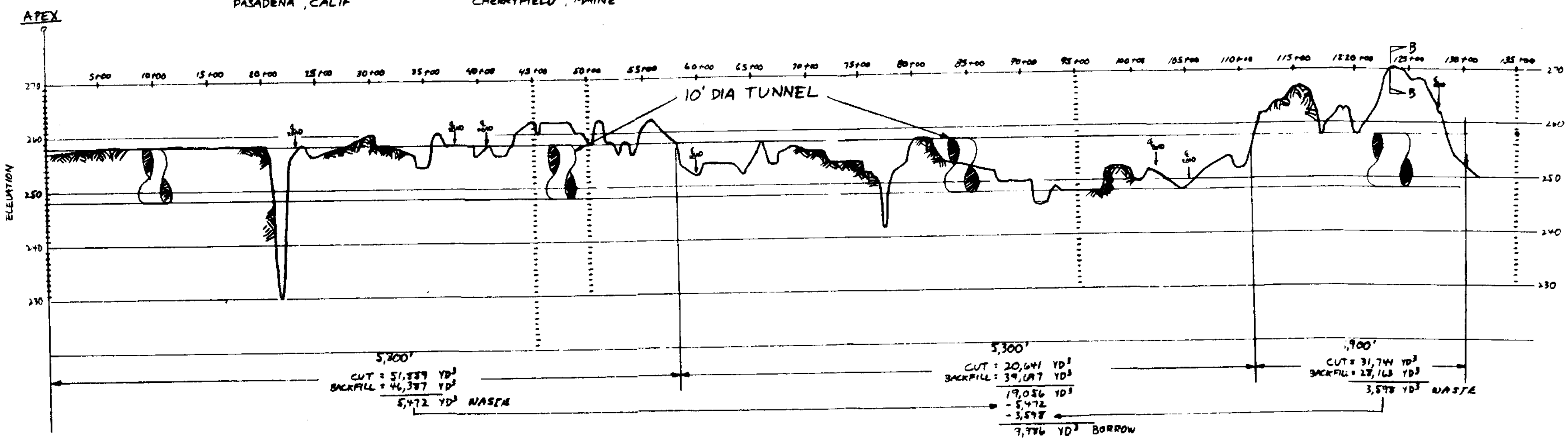
Figure IV-1

LIGO-MAINE

ELEVATION PROFILE OF EAST-WEST LEG

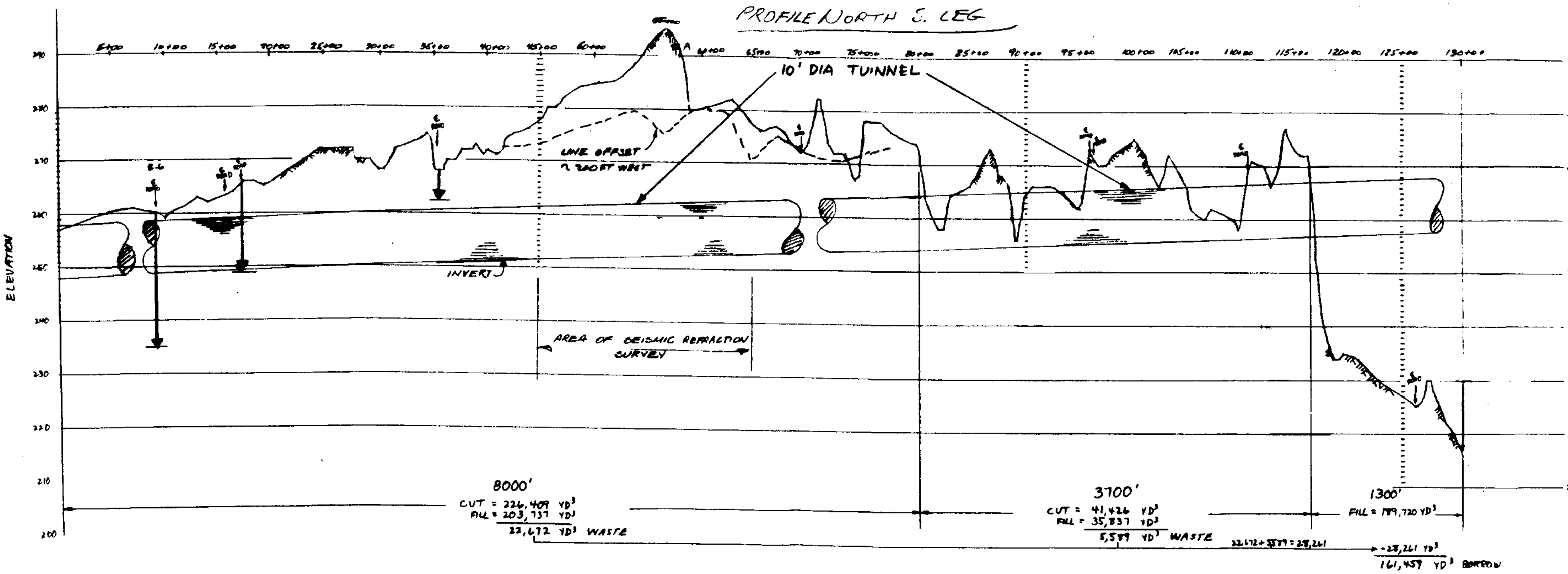
JET PROPULSION LAB
PASADENA, CALIF

GRAVITY WAVE PROJECT
CHERRYFIELD, MAINE



LIGO-MAINE

PROFILE NORTH S. LEG



JAMES W. SEWALL COMPANY
Consulting Foresters, Surveyors & Engineers

March 30, 1987

Mr. Burt Sweetser
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109

Re: Gravity Wave Project
Columbia, Maine

Dear Sir:

This priced proposal is based on the following work:

COMPLETE

1) Take new aerial photography of the 26, 400 feet of proposed baseline at a scale of 1" = 250'.

2) Pretarget the points set by Sewall in 1986 at approximately 500' interval along this line.

3) Perform additional horizontal and vertical control necessary to control the topographic mapping.

4) Digitally stereo compile a (1') one foot contour map at 1" = 50' for a band 200' wide centered on the proposed centerline.

5) Capture in a stereo digital format cross sections at 50 foot intervals and plot these sections along with a profile of the centerline.

Our price for the above work is as follows:

a) Pretarget and field work....................................$10,000.00

b) Stereo digital one foot contour mapping to include cross sections and profile..$30,000.00

STILL REQUIRED
NOV 2-87

147 Center Street · P.O. Box 433 · Old Town, Maine 04468 USA · 207/827-4456

JAMES W. SEWALL COMPANY
Consulting Foresters, Surveyors & Engineers

COMPLETED

The aerial photography has to be taken before the leaves come out on the bushes and brush this spring. If you can get approval for $3,300.00 the pre-targeting can be done and aerial photography can be taken.

Time is of the essence for the targeting and aerial photography.

Thank you for the opportunity to submit this proposal.

Very truly yours,

Earl W. Raymond

Earl W. Raymond
Vice President

EWR/bmw
cc: Marvin Toleson
Edwin Forsythe

Name of Station EOL 131 + 99.78

Line No. North B/L to

RECORD OF CONTROL SURVEY STATION

Horizontal control Third order accuracy	State Maine
Horizontal control NAD 1927 datum	Town-City Columbia
Vertical control Third order accuracy	Project Gravity Wave Detector
Vertical control SLD 1929 datum	Set by James W. Sewall Company
Elevation 201.33 feet	Year 1986

Coordinates X(East) 662916.22 Y(North) 316049.64

Maine East Zone State system of plane coordinates Projection TM

Distances and Direction to objects observed

Object	Distance (feet)	Grid Azimuth(from North)
Burntsen-monument with aluminum cap	127.59	239° 05' 14"

Detailed Description:

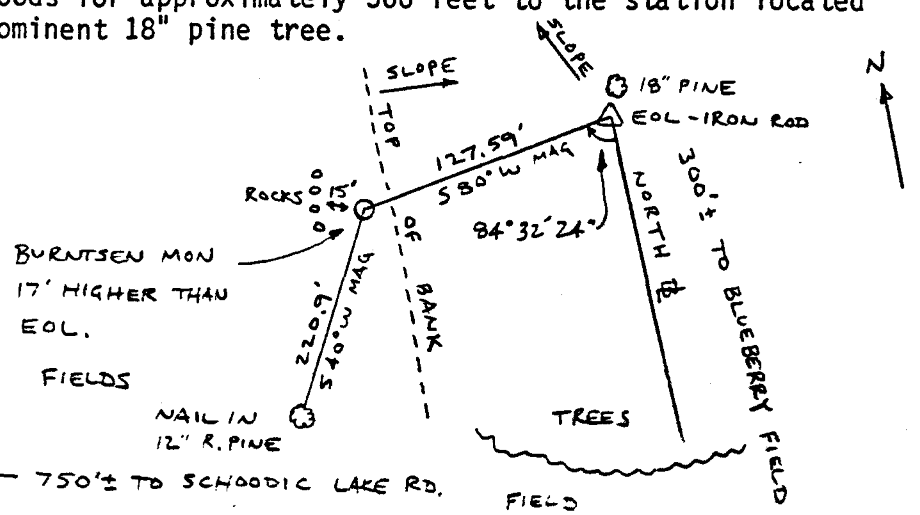
Sta. 131 + 99.78 (End of line - North Baseline)
To reach the station from the intersection of U.S. Route No. 1 and a long straight road in Harrington leading northerly, proceed in a north-northwesterly direction past an old school in town (now a wreath assembly facility) for 3.7 miles to Ridge Road and a "T" intersection.

Thence proceed in a westerly direction on Ridge Road for approximately 2.0 miles to a road leading northerly toward Schoodic Lake.

Thence proceed in a northerly direction on Schoodic Lake Road, so called, for approximately 2.0 miles to a field road leading to the northeast across a small barren sloping in that direction. The barren is bounded to the southeast by the bottom of a steep and abrupt down-slope.

Proceed in a northeasterly direction along road for approximately 0.1 mile to baseline thence proceed in a northwesterly direction along the baseline and a cut line through the woods for approximately 300 feet to the station located just southeast of a prominent 18" pine tree.

Sketch:



Name of Station EOL 132 + 02.24

Line No. East B/L to

RECORD OF CONTROL SURVEY STATION

Horizontal control	Third order accuracy	State	Maine
Horizontal control	NAD 1927 datum	Town-City	Columbia
Vertical control	Third order accuracy	Project	Gravity Wave Detector
Vertical control	SLD 1929 datum	Set by	James W. Sewall Company
Elevation	247.71 feet	Year	1986

Coordinates X(East) 680631.37 Y(North) 309542.40

Maine East Zone State system of plane coordinates Projection TM

Distances and Direction to objects observed

Object	Distance (feet)	Grid Azimuth(from North)
Burntsen monument with aluminum cap	118.19	114° 08' 14"

Detailed Description:

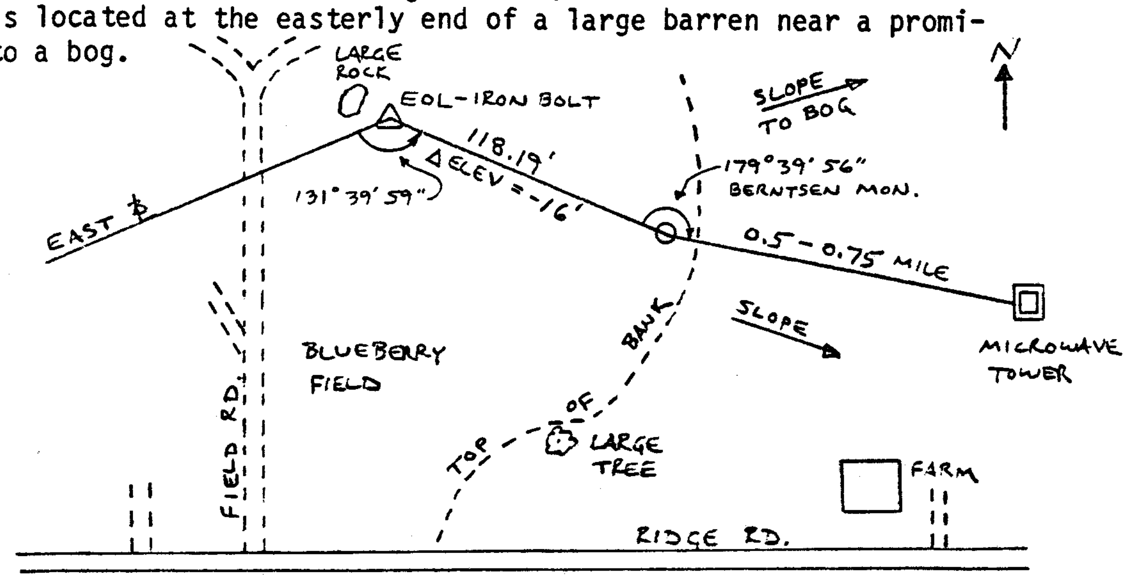
Sta. 132 + 02.24 (End of line - East Baseline)
To reach the station from the intersection of U.S. Route No. 1 and a long straight road in Harrington leading northerly, proceed in a north-northwesterly direction past an old school in town (now a wreath assembly facility) for 3.7 miles to Ridge Road and a "T" intersection.

Thence proceed in an easterly direction on Ridge Road for approximately 1.1 miles to a field road leading northerly across blueberry barrens.

Thence proceed north along this road (4-wheeled drive) for approximately 0.25 mile to the station located on the right (east).

The station is located at the easterly end of a large barren near a prominent down-slope to a bog.

Sketch:



JAMES W. SEWALL COMPANY
Consulting Foresters, Surveyors & Engineers

CHERRYFIELD-HARRINGTON

700 SERIES

EAST BASE LINE

Panel Number	Baseline Station	X	Y	Panel Elevation ✓	Panel Location ✓
500	0 + 00	668588.95	304131.24		
7001	0 + 00			199.23	705'+ Right of East Baseline
701	5 + 00	669045.31	304336.30	257.13	Baseline
702	10 + 00	669501.02	304541.07	258.83	Baseline
704	12 + 00			233.07	600' + Right of Baseline
703	12 + 00			261.77	600' + Left of Baseline
705	15 + 00	669957.53	304746.20	257.99	Baseline ✓
706	20 + 00	670413.15	304950.93	258.22	Baseline
709	25 + 00	670869.00	305155.76	256.22	Baseline
710	30 + 00	671325.69	305360.97	259.86	Baseline
711	35 + 00	671781.99	305566.00	253.60	Baseline
713	34 + 00			260.05	600'+ Left of Baseline
714	40 + 00	672238.11	305770.96	256.12	Baseline
712	36 + 00			254.52	600' + Right of Baseline
715	45 + 00	672693.84	305975.74	259.29	Baseline
717	48 + 00			266.64	600' + Left of Baseline
716	48 + 00			256.18	600' + Right of Baseline
718	50 + 00	673149.73	306180.58	257.17	Baseline
719	55 + 61.59	673661.96	306410.75	261.94	Baseline
7191	60 + 00			262.21	600' + Left of Baseline

JAMES W. SEWALL COMPANY
Consulting Foresters, Surveyors & Engineers

CHERRYFIELD-HARRINGTON

700 SERIES

EAST BASE LINE

Panel Number	Baseline Station	X	Y	Panel Elevation	Panel Location
7192	60 + 00			253.30	600' ± Right of Baseline
720	60 + 00	674062.07	306590.54	253.61	Baseline
721	65 + 00	674518.00	306795.41	254.36	Baseline
722	70 + 00	674973.69	307000.17	255.06	Baseline
724	73 + 10			254.05	387' ± Right of Baseline
723	73 + 10			Unknown	
725	75 + 00	675430.26	307205.33	252.02	Baseline
726	80 + 00	675886.03	307410.12	257.06	Baseline
728	84 + 00			229.94	600' ± Right "Y" of Baseline
727	84 + 00			Unknown	
729	85 + 00	676342.50	307615.23	253.10	Baseline
730	90 + 00	676798.37	307820.08	250.08	Baseline
731	95 + 00	677254.44	308025.00	248.97	Baseline
732	96 + 00			195.02	500' Right of Baseline
733	96 + 00			202.79	600' Left of Baseline
735	100 + 00	678167.08	308435.09	248.72	Baseline
734	105 + 00	677710.60	308229.98	248.54	Baseline
737	108 + 00			255.49	600' ± Left of Baseline
738	110 + 00	678622.70	308639.82	252.60	Baseline

JAMES W. SEWALL COMPANY
Consulting Foresters, Surveyors & Engineers

CHERRYFIELD-HARRINGTON

700 SERIES

EAST BASE LINE

Panel Number	Baseline Station	X	Y	Panel Elevation	Panel Location
736	108 + 00			245.62	600' Right of Baseline
739	115 + 00	679078.69	308844.72	266.64	Baseline
742	120 + 00			253.59	600' + Right of Baseline
740	120 + 00	679534.75	309049.64	258.35	Baseline
741	120 + 00			270.91	600' + Left of Baseline
743	125 + 00	679990.80	309254.57	267.03	Baseline
744	130 + 00	680446.90	309459.51	250.62	Baseline
747 EOL	132 + 02.24	680631.37	309542.40	247.71	Baseline (iron rod)
746	132 + 00			187.09	600' + Right of Baseline
745	132 + 00			262.22	600' Left of Baseline
709	25 + 00			256.22	Baseline
708	24 + 00			254.06	600' Right of Baseline
707	24 + 00			256.47	600' Left of Baseline
7181	51 + 67	673623.12	305389.67	254.52	915' Right of Baseline

CHERRYFIELD, MAINE

500 SERIES

NORTH BASELINE

Panel Number	Baseline Station	X	Y	Panel Elevation	Panel Location
500	0 + 00	668588.95	304131.24	257.50	Intersection of East & North Baseline
501	5 + 00	668373.90	304583.05	260.34	Baseline
502	10 + 00	668158.99	305034.57	259.28	Baseline
503	12 + 00			262.64	600'+ Left of Baseline
504	12 + 00			265.30	600' + Right of Baseline
505	15 + 00	667944.13	305486.00	263.08	Baseline
506	20 + 00	667729.56	305936.82	267.31	Baseline
507	24 + 00			265.04	600'+ Left of Baseline
508	24 + 00			271.47	600' + Right of Baseline
509	25 + 00	667514.52	306388.61	272.73	Baseline
510	30 + 00	667299.77	306839.79	268.14	Baseline
5111	36 + 00			273.02	600' + Left of Baseline
511	34 + 51.04	667105.83	307247.26	275.28	Baseline
5112	36 + 00			279.78	600'+ Right of Baseline
512	40 + 00	666869.87	307743.01	271.13	Baseline

Panel Number	Baseline Station	X	Y	Panel Elevation	Panel Location
513	45 + 00	666655.03	308194.40	278.24	Baseline
514	50 + 00	666440.15	308645.86	285.41	Baseline
515	55 + 00	666225.40	309097.05	292.31	Baseline
516	60 + 00	666010.24	309549.11	277.69	Baseline
519	65 + 00	665794.70	310001.94	275.70	Baseline
517	60 + 00			273.07	600' ± Left of Baseline
520	70 + 00	665580.60	310451.77	274.60	Baseline
521	75 + 00	665365.77	310903.12	277.20	Baseline
522	79 + 53.18	665170.99	311312.37	273.70	Baseline
523	84 + 00			274.06	600' ± Left of Baseline
525	85 + 00	664936.16	311805.74	268.10	Baseline
524	84 + 00			269.48	600' ± Right of Baseline
526	90 + 00	664721.15	312257.47	266.25	Baseline
529	95 + 00	664506.39	312708.69	266.55	Baseline
527	95 + 00			271.79	600' ± Left of Baseline
528	95 + 00			264.11	600' ± Right of Baseline
530	99 + 99.6	664291.52	313160.13	273.25	Baseline
532	106 + 00			240.25	600' ± Right of Baseline
534	110 + 00			267.79	Baseline
531	105 + 00	664076.51	313611.87	260.80	Baseline

Panel Number	Baseline Station	X	Y	Panel Elevation	Panel Location
533	106 + 00			276.49	600' + Left of Baseline
535	115 + 00	663861.48	314063.65	274.71	Baseline
536	118 + 00	663646.62	314515.07	233.56	600' + Right of Baseline
538	120 + 00			235.28	Baseline
537	118 + 00			267.76	600' + Left of Baseline
539	125 + 00	663431.85	314966.30	226.40	Baseline
540	130 + 00	663217.01	315417.68	216.77	Baseline
543	131 + 99.78	662916.22	316049.64	201.33	Baseline end of North baseline
541	132 + 00			235.32	600' + Left of Baseline
5001	0 + 00			232.38	600' + Left of Baseline
518	60 + 00			314.48	600' + Right of Baseline
542	131 + 00			169.39	500' + Right of Baseline

GEOTECHNICAL SURVEYS STATUS - MAINE

Seismic Work

1. Seismic Refraction Survey has been completed for 2000 lineal feet plus cross lines. See appendix for report by Weston Geophysical dated September 25, 1986.

2. Future geotechnical investigations must be conducted when the ground is not frozen. Approximately May - November.

3. Depth to groundwater and bedrock investigations (preliminary) see appendix for Geotechnical report dated November 18, 1986 by Robert Gerber, Inc.

4. Robert Gerber, Inc. has provided a verbal estimate of $270,000 to complete the full seismic refraction survey and borings for the 26,000 feet.

5. Monitoring of groundwater levels and measurement of radon gas continues.

ENVIRONMENTAL ASSESSMENT REQUIREMENTS

MAINE

(IMPACT ANALYSIS)

The attached documents indicate the requirements for an environmental impact analysis of the LIGO at the Maine site to be prepared by CIT/JPL.

Preliminary discussions have been conducted with the Director of Land Quality for the Department of Environmental Protection in Augusta, ME early in 1986.

An archeological survey of the project site was authorized by CIT/JPL and conducted by the University of Maine in the fall of 1986. The enclosed letter submitted November 1986 indicates that no cultural findings fall within the LIGO construction site.

Reference IOM04252 from F. Schutz indicates that a biotic survey will not be required based on discussions with the State Environmental office.

The application for project approval which outlines the total scope of the environmental assessment requirements is included in the appendix. A preliminary draft was prepared for in-house use by CIT/JPL in response to the above application based on information available in 1986 and is also included in the appendix.

5

UNIVERSITY OF MAINE *at Farmington*

Department of Social Sciences and Business

112 Main Street
Farmington, Maine 04938
207-778-3501

November 14, 1986

Dr. Frank L. Schutz
LIGO Project Manager
California Institute of
Technology
Mail Code 130-33
Pasadena, CA 91125

Dear Frank:

Enclosed please find an itemized budget for the additional funds you authorized us to spend in the conduct of the Columbia LIGO phase II archaeological field work. As you will see in the second attachment, we have completed this work and have recommended to Dr. A. E. Spiess of the Maine Historic Preservation Commission that no further archaeological work is necessary there. Furthermore, we will not need any additional funds beyond those that you authorized in your letter of 9/22/86.

I am very thankful that you were able to act quickly in our behalf in September since this enabled us to go back to the LIGO project area and make this needed assessment, which I am sure will come as good news to you. Please feel free to contact us if you have any additional questions at the present time. Good luck with the continuation of your planning!

Sincerely,

Jim Petersen

James B. Petersen, Director
UMF Archaeology Center

JBP/w

Enclosures

cc: Roger Spear
Mike Heckenberger

UNIVERSITY OF MAINE *at Farmington*

Department of Social Sciences and Business

112 Main Street
Farmington, Maine 04938
207-778-3501

November 10, 1986

Dr. Arthur E. Spiess
Maine Historical Preservation Commission
55 Capitol Street
Augusta, ME 04333

Dear Art:

This letter is to inform you of the results of the phase II archaeological survey conducted at the proposed location of the Laser Interferometer Gravity-wave Observatory (LIGO) in Columbia, Maine. A brief recap of the phase I findings and the salient details of the phase II testing will be presented below to summarize fieldwork to date.

During the course of the phase I testing, conducted in July 1986, one unequivocal prehistoric site (ME 60-10) and two possible prehistoric sites were encountered. Recommendations were made that suggested further investigation at all three sites. At that time, Frank Schutz communicated to us that all three localities lie well outside of the proposed project area as the site and possible sites were then defined. It was therefore considered unlikely that any were in danger of being impacted. However, phase II testing was deemed necessary to determine whether any of the sites extend into the project area; and also to delimit the actual extent of ME 60-10 to assure it would not be impacted by the proposed development of the LIGO facilities.

Phase II archaeological testing was initiated on October 15, 1986 by a crew of four under the joint supervision of Michael J. Heckenberger and Dr. Nathan D. Hamilton, both representing the UMF Archaeology Center. James B. Petersen, Director of the Archaeology Center at UMF, consulted with the field crew over all aspects of the field work. The field work was completed on October 25, 1986.

Field work proceeded in two stages: first, systematic excavations were conducted within the proposed LIGO corridor and second, we excavated select areas of the ME 60-10 locality. This two-fold approach was employed to determine the character of the cultural properties known to exist near the project area and to demonstrate with reasonable assurance that these properties will not be impacted. This work was done in compliance with the Historic Preservation Act of 1966, as amended.

Stage-one field testing proceeded with hand excavation of shovel test pits along select and systematic transects. These transects were placed in and immediately adjacent to the section of the study area closest to the sites encountered in the phase I survey. This section of the study area is located at the apex of the proposed facility's perpendicular arms and along the southern margin of East Pineo Ridge.

A total of 230 0.5 x 0.5m test pits were excavated during the first stage of the phase II testing. These were placed along 11 transects and all sediment was screened through 6mm (1/4") mesh hardware cloth. In all instances the test pits required only shallow excavation (30 - 40cm) due to the appearance of coarse grained sediments which were deposited by glacial ice prior to human entrance into the area. All transects were placed parallel to one of the two baselines and were spaced 10m apart. Transects were terminated either because they extended so far into the flat delta surface so as to eliminate the commanding view of the surrounding countryside, or if they extended over the margin of the delta. The test pits were spaced at a 5 or 10m interval along the transects. This pattern of testing was used so that all areas adjacent to the delta margin would get checked regardless of modern topograpic features. One possible prehistoric flake was recovered during this stage of testing. The specimen exhibited flake characteristics and was of a material (rhyolite) commonly used in aboriginal lithic industries here in Maine. The flake characteristics are dubious, however, and the material is not greatly weathered indicating that it may have been caused by more recent activities. Several historic artifacts, probably ca. 1850-1900, were also encountered, but due to their association with a modern dump are of little significance and will receive no further mention here.

The second stage of testing involved the excavation of 25 1x1m units at the known site, ME 60-10. These units were established on a metric grid placed over the surface around the previous finds and in alignment with the previously established positive transect (T22, W to E 108^{o}). The units were all hand excavated by 10cm arbitrary levels and all sediment was screened through 6mm (1/4") mesh hardware cloth. All units were labeled by their southeast corner (e.g. S10/E10) and tied into a datum point (S0/E0). Within each unit, excavation proceeded with removal of levels by 0.5 x 0.5 subunits. All artifacts were bagged by unit according to level and subunit. Each unit was excavated to a sterile depth and upon completion of the unit, stratographic profiles were recorded.

Test units were placed systematically across the grid so as to test the entire surface area associated with the phase I finds. This pattern yielded only one flake from the unit adjacent to the location of the flake surface collectedin the phase I. Subsequently seven additional 1x1m units were excavated adjoining the positive unit. The total yield of the 8m^2 block (including the phase I flake) was 29 flakes of various materials, two chert core fragments and one chopping tool clearly made from a modified rhyolite cobble. Some of the flakes may have been retouched and/or utilized but due to extensive weathering of the material this is hard to verify.

Although no diagnostic artifacts were retrieved during the phase II survey, the location and density of ME 60-10 suggests that it may have served as an early hunting station, possibly attributable to the Paleo-Indian period, ca. 9,000-7,000 b.c.. Located on the southern margin of a late prehistoric delta, ME 60-10 is situated so as to afford a commanding view of the surrounding area. This location would have been favored by early groups as a vantage point from which to watch movements of large game animals. At any rate, this level of archaeological reconnaisance has demonstrated that this is a significant and unusual find. We also determined that this cultural property lies outside area of impact for the LIGO project. Therefore, we recommend that while further investigation at ME 60-10 would benefit understanding of local and regional culture history it is <u>not</u> the responsibility of the LIGO project to conduct or fund such investigation. Further, due to the relatively small number of phase II finds, no additional laboratory or report preparation funds are required. A final combined phase I/phase II report can be expected no later than February 15, 1987. Please feel free to contact us if you have any unanswered questions.

Sincerely,

Michael J. Heckenberger

James B. Petersen

MJH/JBP:pj

cc: Frank Schutz
Roger Spear

Columbia LIGO

Phase I/II Archaeology Budget Addendum

<u>Field Work</u> (10 additional days)

1.	Salaries		
	Senior Crew (2) @ $70/day		$1,400.00
	Crew (2) @ $50/day		$1,000.00
			$2,400.00
2.	24.5% Fringe on Salaries		$588.00
3.	Per Diem @ $20/day for 40 days		$800.00
4.	Mileage @ $0.22/mile for 640 miles		$140.80
			$3,928.80
5.	Overhead (off-campus) @ 27.11%		$1,064.88
		Field Total	$4,993.68

<u>Lab Work</u> - supplemental funds to be allocated in 1987, <u>if</u> needed (per communication from Frank Schultz, September, 1986)

HIGHWAY AND HEAVY CONSTRUCTION
GRADING AND PAVING

February 4, 1986

T.I.W. Systems, Inc.
1284 Geneva Drive
Sunnyvale, CA 94089

Attn: Mr. Gary Young, Purchasing Manager

Subject: Gravity Wave Antenna
Cherryfield, Maine

Re: T.I.W. Purchase Order #23867
JPL Statement of Work 332-SW-870

Gentlemen:

Per your request and in accordance with the above referenced documents, we are enclosing a budget estimate for subject project. This estimate is based on the following assumptions.

1. A 1986 Construction Schedule.

2. Sufficient Right-of-Way is available for stockpile of trench excavation adjacent to trench limiting trucking of excavation and rehandling. Based on the information provided it appears that a maximum width of 200 feet will be needed. We estimate an extra cost of $686,000.00 if sufficient width cannot be obtained resulting in the trucking, stockpiling and rehandling of backfill material.

3. 95% compaction of native material as backfill to spring line. No processed bedding is included in cost.

4. Excavation does not involve any solid rock or boulders over two cubic yards.

5. Special Armco "Cynch Bands" are provided with pipe.

Consideration should be given to providing different gauge metal culvert for various incremental depths of bury. Also, significant transportation cost savings could result if one leg (13,000 feet) were reduced to a 9 foot diameter. This would allow two pieces of pipe to be shipped together, one inside the other.

ENCLOSURE "A'
Sheet 6 of 8

H. E. SARGENT, INC.
101 BENNOCH ROAD • STILLWATER, MAINE 04489 • TELEPHONE: 207/

BHS-1

We have extensive experience with the soils and other conditions in this area having moved in excess of 3,000,000 cubic yards for the OTH radar program with General Electric in Columbia Falls. Based on this experience, we anticipate the use of large hydraulic excavators and bucket loaders together with off-highway 35 to 50 ton trucks on this project.

This estimate specifically includes:

1. All field engineering/survey from an owner furnished benchmark and baseline.

2. Providing necessary water to obtain specified 95% compaction.

3. Stripping and respreading of loam and seeding.

4. Removal of vendor installed internal pipe stiffeners (spiders).

5. Labor to install special pipe connecting bands.

6. Unloading pipe from trucks and stringing pipe along work area.

7. Grading temporary construction access road along project.

Total Lump Sum Budget Estimate $4,601,942.00.

Included in the above is a $200,000.00 contingency.

The breakout of the final 1,300 feet of the North-South leg involves Budget Items 10, 16, 17 and 1,300 feet of Item 14 for a total of $570,377.00.

The 1,300 feet on the boulder end of the East-West leg totals $155,381.00.

Yours truly,

H. E. SARGENT, INC.

Dale Jellison

Dale L. Jellison

Enclosure
cc: Mr. Bert M. Sweetser (JPL)

PROJECT NAME: JPL CHERRYFIELD
BID DATE: JANUARY 28, 1986
TIME: 02:19 PM

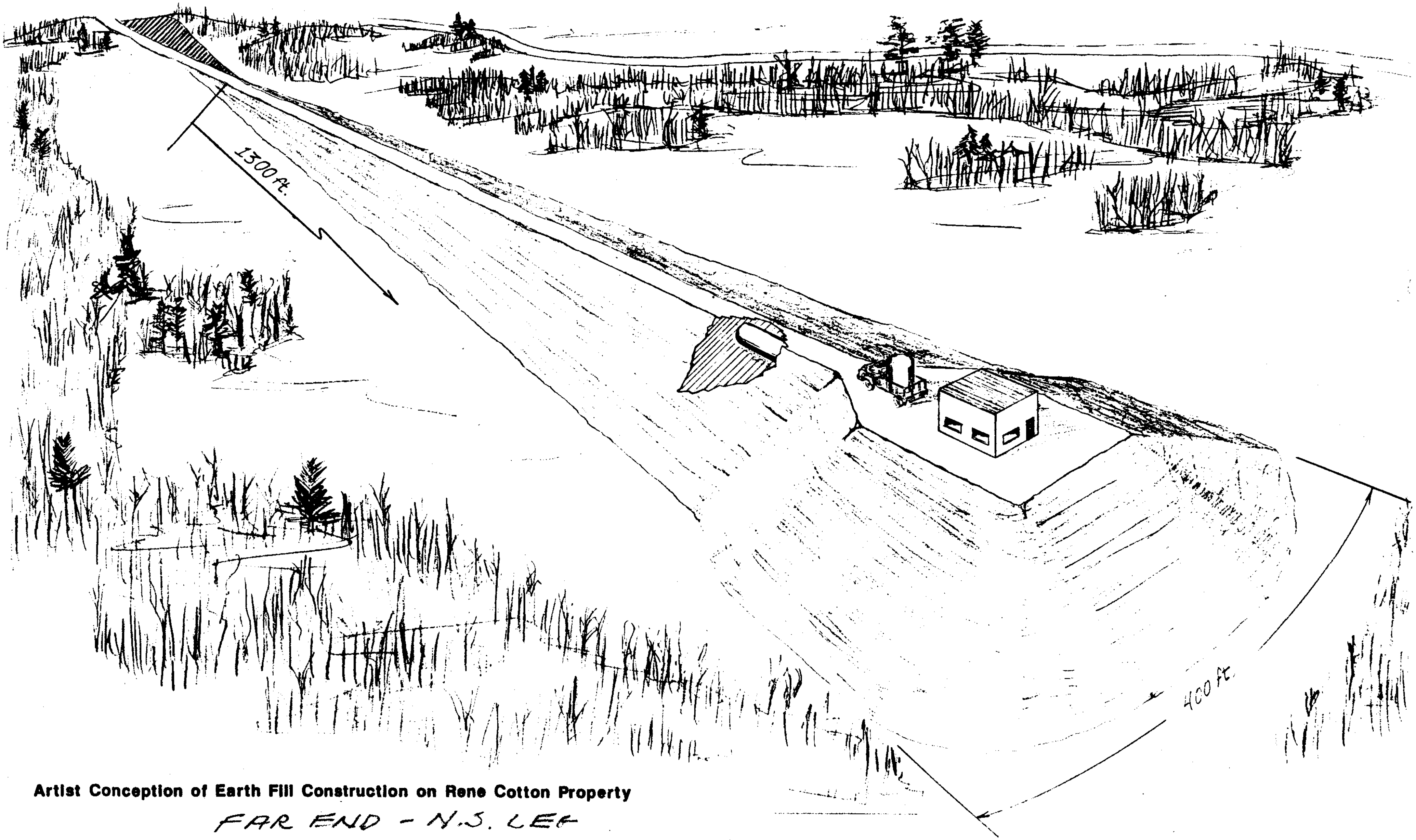
FILE NAME: "JPL--RJM" ESTIMATING #1

ITEM NO.	DESCRIPTION	BID EXTENSION
1.0000	CLEAR	3,000.00
2.0000	STRIP LOAM	50,000.00
3.0000	GRADE ACCESS ROAD	104,000.00
4.0000	UNLOAD PIPE TRUCKS	130,000.00
5.0000	CUT HOLES IN PIPE	78,000.00
6.0000	SEAL HOLES @ FOUNDATION	104,000.00
7.0000	REMOVE SPIDERS	78,000.00
8.0000	EXCAVATION N-S	535,670.00
9.0000	BACKFILL N-S	1,197,870.00
10.0000	BORROW PRECOMPACTED N-S	484,377.00
11.0000	EXCAVATION E-W	208,482.00
12.0000	BACKFILL E-W	521,205.00
13.0000	BORROW E-W	29,958.00
14.0000	LAY PIPE	312,000.00
15.0000	RESPREAD LOAM	150,000.00
16.0000	EXC IN N-S BORROW AREA	22,000.00
17.0000	BACKFILL N-S BORROW AREA	48,400.00
18.0000	SEED	44,980.00
19.00000	MOBILIZATION & GEN. CONDITIONS	300,000.00
20.00000	CONTINGENCY	200,000.00
		===============
		$4,601,942.00

ENCLOSURE "A'
Sheet 8 of 8

BMS-3

GRAVITY WAVE PROJECT



Artist Conception of Earth Fill Construction on Rene Cotton Property

FAR END - N.S. LEG

10

BANGOR HYDRO-ELECTRIC COMPANY

33 State Street, P.O. Box 932, Bangor, Maine 04401 Tel. 207-945-5621

August 5, 1986

Mr. Bert M. Sweetser
Jet Propulsion Laboratory
California Institute of Technology
Mail Stop 511-201
4800 Oak Grove Drive
Pasadena, California 91109

Subject: Proposed Major Research Facility
Columbia, Maine

Dear Mr. Sweetser:

This is in response to your letter dated July 1, 1986 to our Mr. James Logan, requesting a budget estimate for providing electric service to this location.

Based on the information available at this time, it will be necessary for us to construct approximately 4 miles of 34.5 KV. transmission line from Harrington, Maine to the closest point along the alignment.

Our preliminary estimated cost for providing a 2000 KW electric service to this facility is $300,000.

Yours very truly,

T. C. Ring

T. C. Ring
Manager - Engineering
& Construction

TCR:ec

cc: Lee
Logan

cc F. Schutz
V. Lord
J. Dorman
R. Elder
F. Henninger

BATCH START

STAPLE
OR
DIVIDER

VACUUM PIPE PROTECTIVE HOUSING CONFIGURATIONS

INTRODUCTION

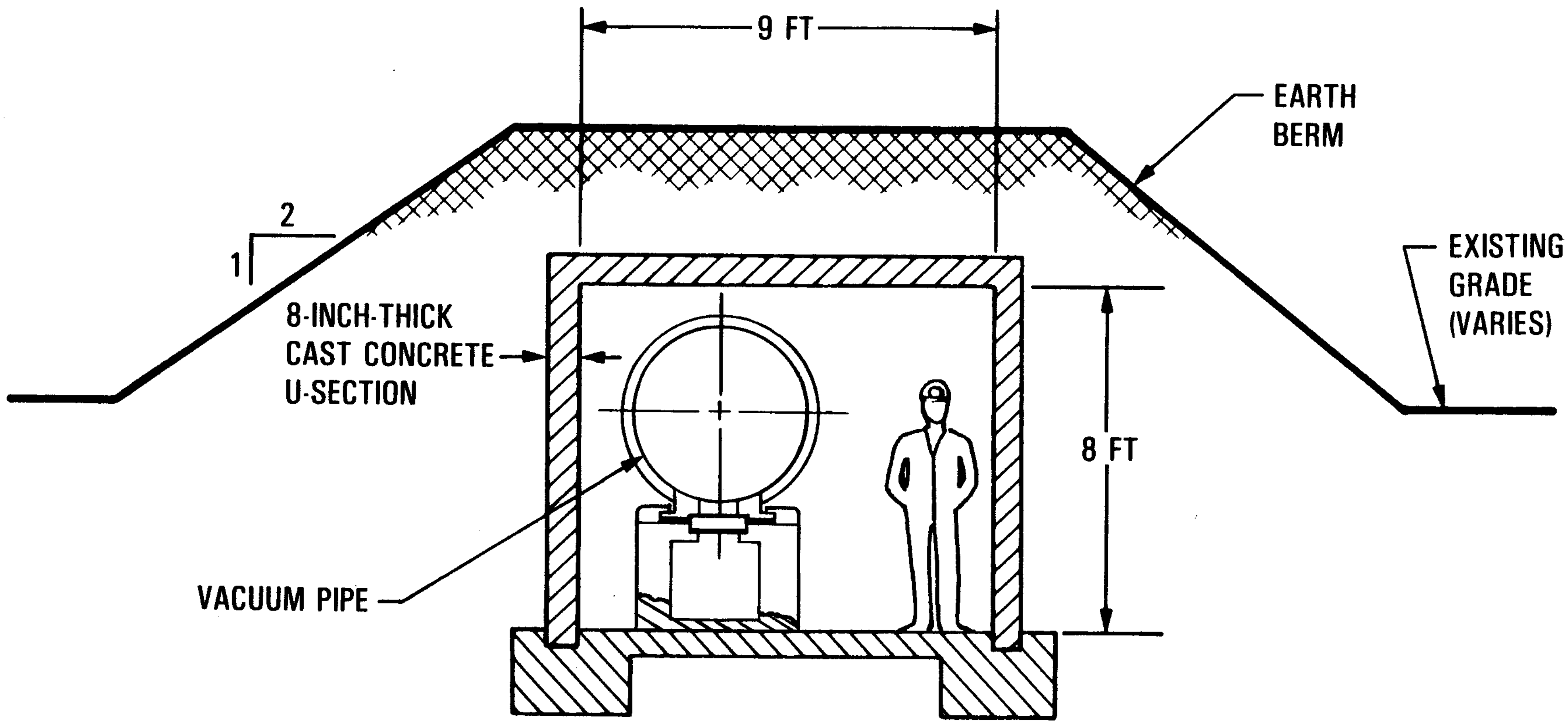
Two methods of thermally and socially insulating the LIGO Facility vacuum pipe have been proposed. The method best suited to the geological conditions and corrosive soil at the Edwards AFB site in California, is to build a concrete housing essentially above grade to be covered with bermed earth.

The proposed approach to the environmental constraints at the Columbia site in Maine is to bury, below grade, a galvanized steel corrugated housing.

Laser Interferometer Gravitational Wave Observatory (LIGO) Project

JPL

VACUUM PIPE AND HOUSING CROSS SECTION – CALIFORNIA SITE



C0091
A0023

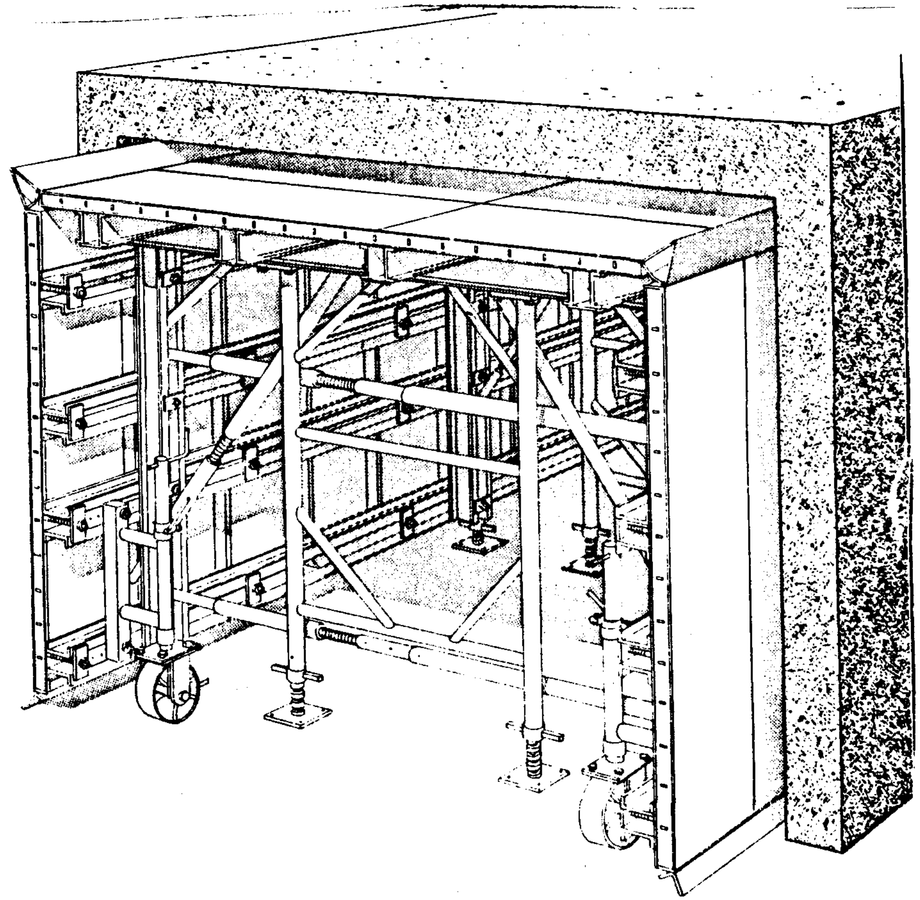
VBL-4
12-07-87

LIGO EDWARDS

CONCRETE HOUSING COSTS (8'x 9' WIDE)
(POURED IN PLACE)

• CONSTRUCTION METHOD:

USE TRAVELING CULVERT/TUNNEL FORMS SIMILIAR TO SYMONS SYSTEM SHOWN



BMS-1
Sept 11-87

LIGO EDWARDS

CONCRETE HOUSING COSTS (8' HIGH x 9' WIDE INSIDE)
(POURED-IN-PLACE)

- SOURCES OF ESTIMATES

	COST/FT $	COST $K 26,000 FT
• ASHLAND CONST. CO, CONTRACTOR TO EDWARDS, GOLDSTONE, BORON. OFFICES IN LANCASTER	$248	6450K
• SSC STRUCTURES. GENERAL CONTRACTOR USING SYMONS SYSTEM OFFICES IN LOS ANGELES	$243	6310K
• G. B COOKE INC, do OFFICES IN PASADENA	$225	5850K
• ASL, CIVIL ENGINEERS PER J. MANIFICO, CONTRACTOR OFFICES IN PASADENA	$207	5400K

BMS-2
Sept 11-87

LIGO - EDWARDS

CONCRETE HOUSING COSTS (PRECAST)

SOURCES

	COST/FT $	COST, 26000FT $ K
• BROOKS CONCRETE PRODUCTS PLANT IN EL MONTE	$250	6500K
• ASSOCIATED CONCRETE PROD. PLANT IN SANTA PAULA	$272	7072K

BMS-3
Sept 11-87

4

JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM

3322-86-003
6 January 1986

TO: F. Schutz

FROM: B. Sweetser

SUBJECT: LIGO -- Cost of Precast Tunnel Sections at Edwards

Fermilab indicated they are buying a precast tunnel section delivered on site for $103/ft. (7'-6 clear width x 8' high.)

I checked with Brooks Concrete Products of Baldwin Park. They make a standard section about the same size and quoted $164.00/ft. delivered to Edwards and $134/ft. if cast near the site in large quantities.

Costs do not include the slab on grade.

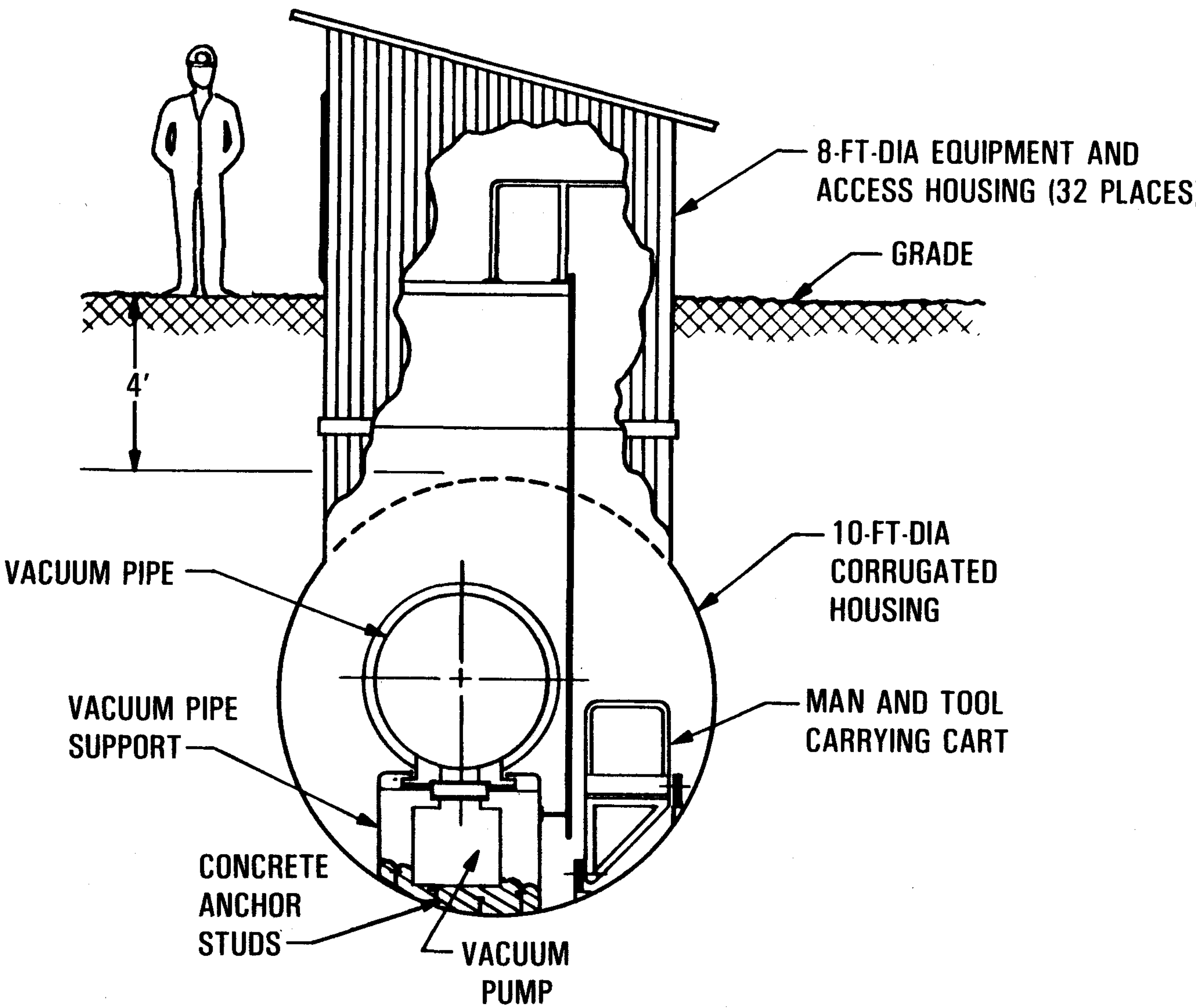
BMS:cd

cc: A. Cantu
R. Elder
V. Lobb
F. Menninger
A. Riewe
F. Stoller

Laser Interferometer Gravitational Wave Observatory (LIGO) Project

JPL

VACUUM PIPELINE AND HOUSING CROSS SECTION — MAINE SITE



C0092
A0023

VBL-3
12-07-87

PROPOSED BURIED VACUUM PIPE PROTECTIVE HOUSING/INSTALLATION (COLUMBIA SITE)

The buried housing for the vacuum pipe will consist of a 10 ft. diameter galvanized corrugated steel pipe. Nearly all this corrugated pipe will be installed as a complete tube manufactured with riveted seams. However, roughly 3% to 5% will be multiplate construction, which consists of arc segments bolted up in the field, to complete the full circumference. This multiplate construction will allow access to the 10 ft. housing at specific intervals since the sections would not be closed until the vacuum pipe is fully installed and welded.

With this construction approach, the vacuum pipe can be installed and welded at multiple locations along each leg of the alignment, permitting a flexible construction operation and optimize resources and scheduling.

Forty-foot sections of vacuum pipe will be lowered into the open sections of the multiplate pipe housing and towed into place. The vacuum pipe sections will be strapped to two dollies which roll on rubber tires. The dollies will be designed to straddle the concrete portion of the pipe supports so foundations can be placed without interference. Jacks on the dollies will permit lowering the vacuum pipe onto rigid alignment fixtures prior to welding.

After the vacuum pipe is installed and tested, the remaining segments of the multiplate pipe will be bolted in place to complete the 10 ft. diameter housing.

1. <u>Galvanizing versus Aluminum Type II Coatings</u>

Armco has submitted extensive data to JPL indicating the superiority of the aluminum Type II coatings over zinc galvanizing. Aluminum coated culverts have been in use for over 30 years. The Handbook of Steel Drainage and Highway Construction Projects published by the American Iron and Steel Institute (AISI), 1983, contains design recommendation for durability. The different coatings are covered on page 241 where zinc, aluminum, zinc alloy and aluminum Type II are treated as equivalent except that aluminum is not recommended where soil pH's above 9 are encountered. See Appendix A.

The California Division of Highways (CDH) has a culvert committee which is reviewing the same ARMCO data submitted to JPL for aluminum type II coating. In addition, CDH is conducting their own laboratory test program. The CDH report is to be issued early in 1986 and it will help guide JPL in the final culvert design.

2. <u>Cherryfield Soil</u>

JPL buried a seismometer at the apex of the LIGO. This pit was later dug to a depth of 13 feet to examine the soil conditions. One test pit in 26,000 ft. cannot be called a representative sample. However, as a matter of interest, samples were brought back to JPL and the material tested as follows:

pH (different depths) 5.1 and 5.3

Resistivity - 7,000 ohm/cm

Note: The sample was taken in July. Resistivity would be less in the wet season.

The University of Maine Blueberry Research Division stated the ideal pH for growing blueberries is 4.8 and the top six inches will vary from 4.5 to 5. They add sulfur to maintain this acidity if necessary.

Based on the above data it is likely that over the 26,000 foot length soils with a pH as low as 4.5 will be encountered. Resistivities in the 5,000 ohm range are also likely. (All to be confirmed by appropriate sampling and testing prior to final design.)

3. Estimated Culvert Life Due to Corrosion

The California Division of Highways has developed a chart to estimate the time in years to perforation for galvanized steel as shown as Appendix B. While a drainage culvert will still function with perforations, this does not appear to be an acceptable criteria for housing the LIGO. A conservative factor should be added in using this chart.

The AISI in their handbook establish useful life as double that time required for first perforation. This in our opinion is even less applicable.

Utilizing the properties of soil presented above and the California Highway design chart the number of years to <u>perforation</u> for <u>galvanized</u> steel are as follows:

14 gage -- 13x1.6 = 20.8 years

12 gage -- 13x.2.2 = 28.6 years

10 gage -- 13x2.8 = 36.4 years

4. <u>Incremental Costs of Heavier Gage Material</u>

The following appear to be essentially fixed costs in the overall installation of the corrugated pipe.

1. Coating of the metal
2. Manufacturing (approx.)
3. Shipping
4. Excavation
5. Installation (higher for lighter gage)

The following properties apply to a 10 ft. diameter pipe:

Gage	Thickness Inches	wt/ft lbs
14	.079	134
12	.109	183
10	.138	235

At 30 cents per pound material cost plus mark-up a heavier gage will cost approximately $15 per ft. more.

In using a 14 gage pipe the flexibility factor must be considered. See Appendix C. The requirements for a higher quality of backfill and care in placement may be partially or completely offset the cost of the greater wall thickness.

Once the physical and chemical characteristics of the soil are properly investigated it may be feasible to provide the contractor with bidding options with stricter requirements for handling and backfilling for lighter gage culverts.

5. Other Investigations

A. Brookhaven Laboratory Linear Accelerator

The contractor stated they are using a 10 ft. diameter aluminized 10 gage culvert. Armco in White Plains, New York, which supplied the material, also confirmed the thickness.

B. H. E. Sargent Construction Co.

This firm does considerable work for State Highway Dept. and others and have installed many culverts. They have not had experience with the large light gage culverts but indicated cost trade-offs are appropriate because of the quantity to be installed.

C. State of Maine -- Highway Dept.

They specify 8 gage (.168") for all culverts over 60 inches utilizing either galvanized or aluminum coatings to obtain a 50 year life.

D. Conclusions

The final selection of the culvert thickness and coating will depend on the detailed site investigations to be conducted at Cherryfield.

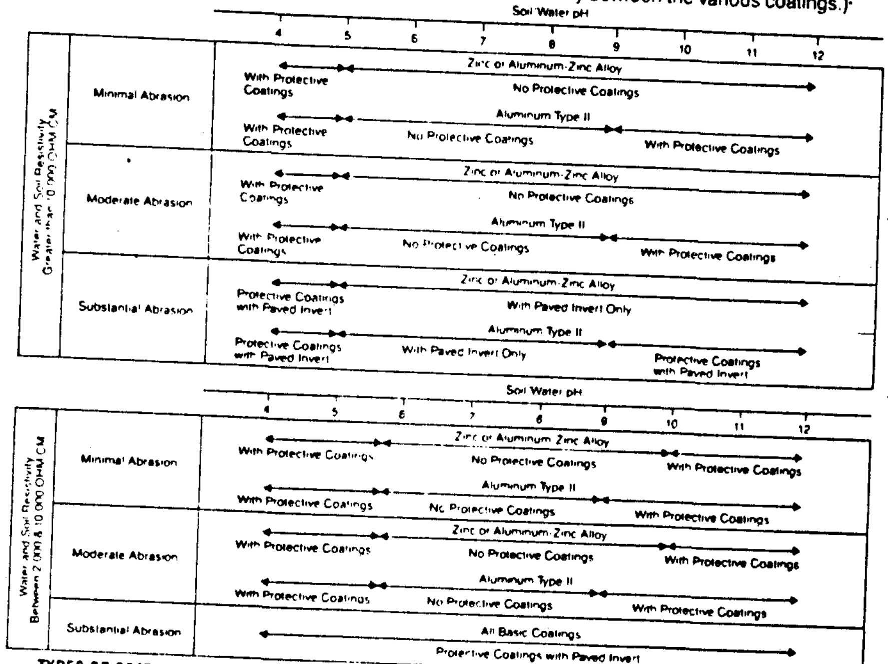
At present a 12 gage 10 ft. diameter is being considered for budget purposes.

APPENDIX A

NATIONAL CORRUGATED STEEL PIPE ASSOCIATION 24

Coating Selection Guide for Corrugated Steel Pipe

(This guide is not intended for the comparison of the durability between the various coatings.)



3/16/83

TYPES OF COATINGS

Basic Coatings

- Zinc AASHTO M218
- Aluminum Type II AASHTO M274
- Aluminum-Zinc Alloy AASHTO M289

Protective Coatings

Polymer Coated
- Zinc AASHTO M 246
- Aluminum Type II M 246
- Aluminum-Zinc Alloy M 246

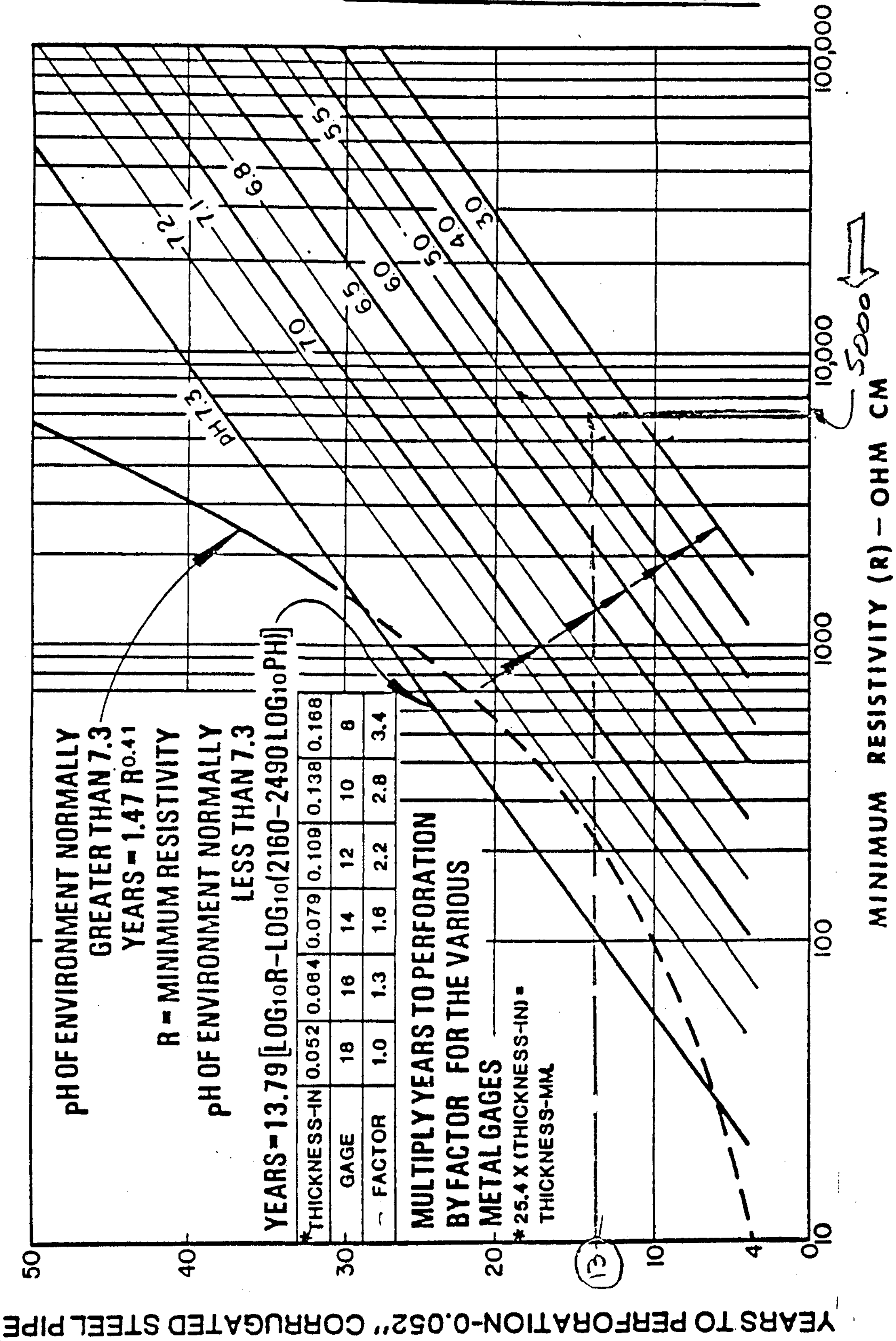
Bituminous Coated
- Zinc AASHTO M 190
- Aluminum Type II M 190
- Aluminum-Zinc Alloy M 190

Asbestos Bonded Coated
- Zinc Specification in preparation to replace WWP405

NOTES

1. Certain producers have indicated that their basic coatings can be used in a lower soil/water pH and/or resistivity range than that shown in the above chart. The producers should be contacted for their information.
2. Corrugated steel pipe with protective coatings have been used successfully below pH of 4 and above 12 and/or soil/water resistivities below 2,000 ohm-cm. Special design practices are recommended for these installations.
3. Abrasion is a combination of velocity and bed load. Each factor must be evaluated in selecting the appropriate abrasion condition.
4. Fabrication is covered in AASHTO M-36 and AASHTO M-245.
5. Information on durability and service life of corrugated steel pipe may be found in Chapter 7, Durability, of the AISI publication *Modern Sewer Design*, First Edition 1980; and Chapter 5, Durability, of the AISI publication *Handbook of Steel Drainage & Highway Construction Products*, Third Edition 1983.
6. The recommendations set forth in this Selection Guide are not a substitute for professional engineering advice and they are made without guarantee or representation as to results. Although every reasonable effort has been made to assure its accuracy, neither the National Corrugated Steel Pipe Association nor any of its members or representatives warrants or assumes liability or responsibility for its use or suitability for any given application.

APPENDIX B



*THICKNESS-IN	0.052	0.084	0.079	0.109	0.138	0.168
GAGE	18	16	14	12	10	8
FACTOR	1.0	1.3	1.8	2.2	2.8	3.4

REFERENCE: TEST METHOD NO. CALIF. 643

CHART FOR ESTIMATING YEARS TO PERFORATION OF CORRUGATED STEEL PIPE

APPENDIX C

ARMCO

ARMCO CONSTRUCTION PRODUCTS DIVISION

March 29, 1985

Dr. Edward Lin
Jet Propulsion Lab
4800 Oak Grove Drive
Pasadena, California 91109

Dear Dr. Lin:

I have discussed with our chief engineer the proposed installation of Armco AL-T-2 Corrugated Steel Pipe at Edwards Air Force Base as well as Cherry Field, Maine.

The consensus opinion is that for a buried trench installation with a minimum of two feet of cover, the 14 gage wall thickness with a 5 x 1 corrugation in 120" diameter, is structurally adequate. (This product incidentally, is available at our Riverside, California plant as well as Palmer, Massachusetts.) The pipe should be embedded in a native soil with a sand equivalency of 20 or better, and compacted to 90% proctor density. Sand equivalence is a Cal Trans description of soils that are free draining and non-plastic. Because handling and flexibility factor limits are being exceeded (see attachment para. 12.3.4) care must be exercised in installation. This means that during installation, inspectors must insure that proper structure shape is maintained.

Enclosed is a list of successfully installed structures in California, all of which exceed standard flexibility limits. More is available if you desire.

By copy of this letter, I am advising Art Taylor of our discussions, so that he will have this information should he talk to Ray Wise at MIT.

Sincerely,

Frederick H. Mayer
Account Manager

FHM/jmb
Enclosures

ENGINEERING APPROACH

AND

COST ANALYSIS

OF

AN HVAC SYSTEM

FOR THE 12 Ft BURIED

METAL CULVERT

ENCLOSURE "C"
Sheet 1 of 11

AGENDA

- ASSUMPTIONS
- VENTILATION REQUIREMENTS
- LOAD
- EQUIPMENT LAYOUT & SELECTION
- COST ANALYSIS

ASSUMPTIONS

- COMBINATION OF CRYOPUMPS AND ION PUMPS WILL BE USED AS THE MOST PROBABLE CONFIGURATION
- THE NUMBER OF CRYOPUMPS SERVING THE ENTIRE SYSTEM WILL BE APPROX. 60*
- THE NUMBER OF ION PUMPS SERVING THE ENTIRE SYSTEM WILL BE APPROX 250*

ENCLOSURE "C"
Sheet 3 of 11

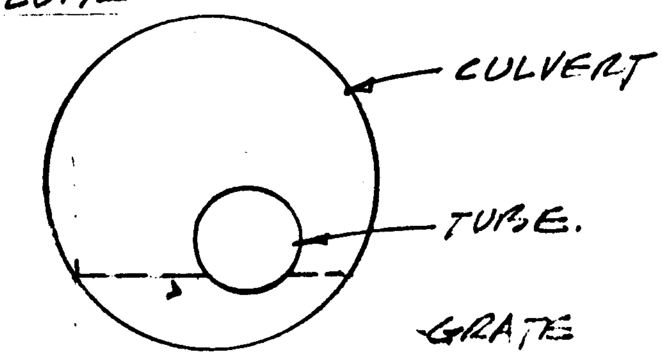
* FROM D.A. KILLIAN - HIGH VACUUM PUMP CONFIGURATION COST MATRIX - 10/31/84

VENTILATION REQUIREMENTS

1. DIMENSIONS, NET AREA & VOLUME

CULVERT - 12 ft DIA

TUBE - 4 ft DIA



NET AREA

$A = \pi(6^2 - 2^2) = 3.14 \times 32 \cong 100$ sq. ft

VOLUME

$V = 100$ sq. ft $\times$ 6 MILES $\times$ 5280 ft/M $\cong$ 3,200,000 ft^3

2. VENTILATION RATE

A SUGGESTED VENTILATION RATE WILL BE AROUND 2 AIR CHANGES PER HOUR (ONE CHANGE EVERY 30 MIN.) *

ENCLOSURE "C"
Sheet 4 of 11

IN OUR CASE THE TOTAL VENTILATION REQUIRED WILL BE

$$Q'_{AIR} = \frac{V \times \text{AIR CHANGE}}{60\text{min}}$$

$$Q_{AIR} = \frac{3{,}200{,}000 \times 2}{60\text{min}} = \underline{100{,}800 \text{ CFM}}$$

For each leg of the antenna the ventilation required will be 50,400 CFM

— · —

ENCLOSURE "C"
Sheet 5 of 11

* The suggested ventilation rate of 2 AIR CHANGES/Hr is comparable to a corridor which requires a min of 3 AIR CHANGES/Hr.

AH-11/25/84
Page 5 of 11

LOAD

- PUMPS

  CRYO PUMPS 60 X 5.2 kw X 3410 — 1,064,000

  ION PUMPS 250 X .2 kw X 3410 — 170,500

- LIGHTS

  1 W/sq.ft X 5 ft X 31600 ft X 3410 X .50 — 270,000

- PEOPLE

  1P/10 pumps X 210 pumps X 200 — 4200

RM SENS. — 1,508,700 BTU/HR

AIR FLOW @ 18°F ΔT

$$Q_c = \frac{1,508,700}{18°F \times 1.00} = 84,000 \text{ CFM}$$

IF WE INCREASE THE AIR FLOW TO EQUAL THE VENTILATION REQUIREMENTS THE ΔT WILL BE:

ENCLOSURE "C"
Sheet 6 of 11

$$\Delta T = \frac{1,508,700}{100,800 \times 1.00} \cong \underline{15°F}$$

THE TOTAL TONNAGE WILL BE.

RM SENS.	1,508,700
MOTORS	
SUPPLY 60 @ 1/3 HP } 35 HP	
EXH. 30 @ 1/2 HP }	
35 HP X 2545	89,000
OSA SENS. (30% OSA)*	
100,800 x .25 x (104-78)	655200
PEOPLE LAT 21 X 250	5250
TOTAL LOAD	2,258,150 BTU/HR or
	188 TONS

FOR EACH CRYO PUMP THE SUPPLY UNIT WILL HAVE TO HAVE A MIN. CAPACITY OF

$$T_{UNIT} = \frac{188 \text{ TONS}}{60 \text{ UNITS}} = 3.13 \text{ TONS / UNIT}$$

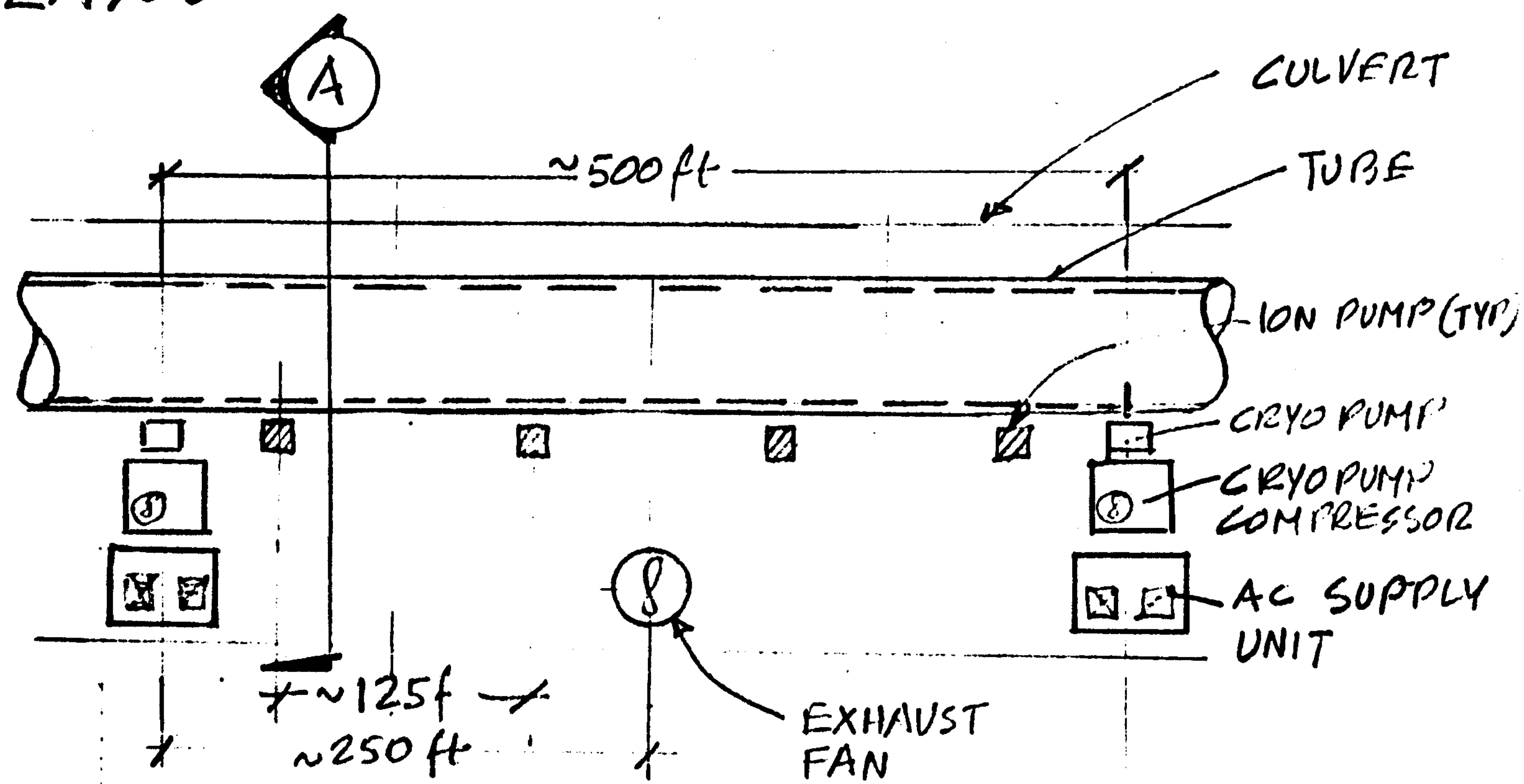
* OSA REQUIREMENT [illegible] 25 [illegible] AMOUNT IS FOR AIR COOLED CONDENSER AT CRYOPUMP & CULVERT VENTIL.

AH-11/25/[illegible]
Page 7 of 11

ENCLOSURE "C"
Sheet 7 of 11

EQUIPMENT LAYOUT & SELECTION

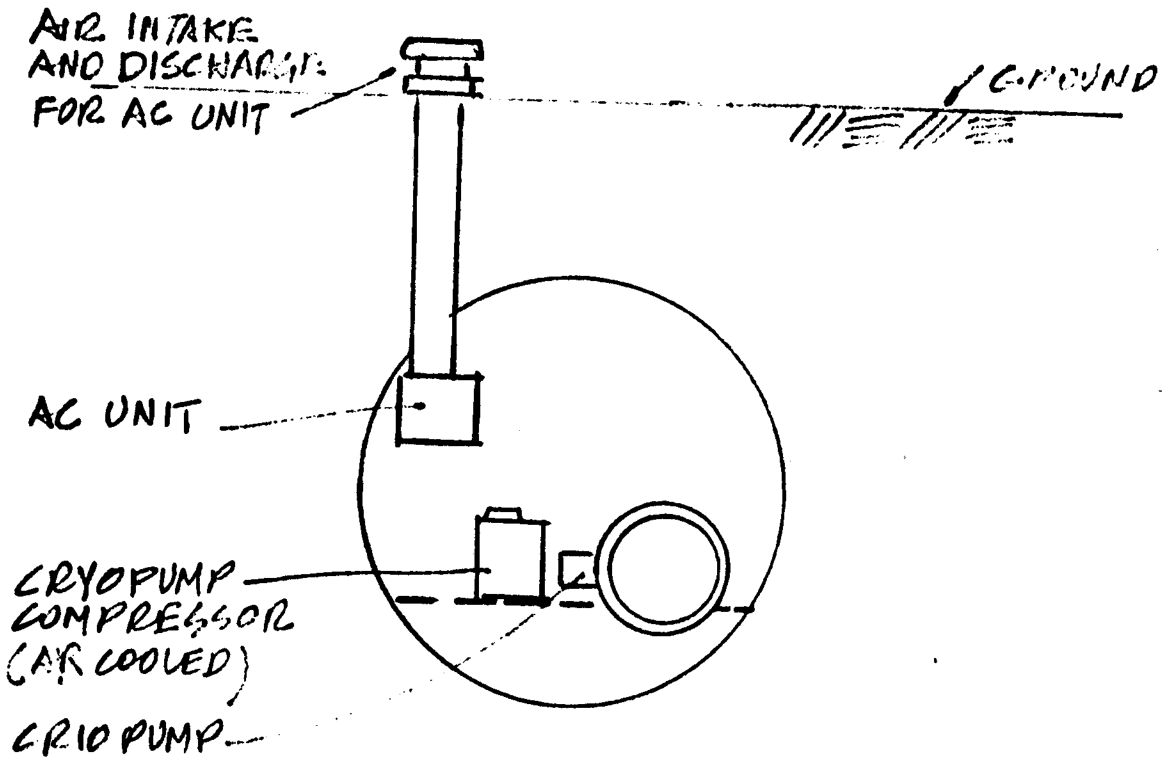
• LAYOUT



FLOOR PLAN
NOT TO SCALE

ENCLOSURE "C"
Sheet 8 of 11

AH - 11/25/95
Page 8 of 11



SECTION
NOT TO SCALE (A)

AH - 11/28/84

• SELECTION

AC UNIT

IT WILL BE AN HVAC UNIT, A COMPLETE PACKAGE WITH AN AIR COOLED CONDENSING UNIT, CONSISTING OF SUPPLY BLOWER (CENTRIF), CONDENSER BLOWER (CENTRIFUGAL), COILS, COMPRESSOR ELECTRIC HEATER & SELF CONTAINED CONTROLS. AIR INTAKE & DISCHARGE WILL REQUIRE A SERIES OF DUCTS TO THE GROUND ABOVE

EXHAUST UNIT

IT WILL BE AN INLINE FAN DUCTED TO THE OUTSIDE.

ENCLOSURE "C"
Sheet 10 of 11

COST ANALYSIS

- **AC UNIT**

UNIT (COMPLETE)	$ 3300
INSTALL W/DUCT	600
ELECT.	600
TOTAL PER UNIT	$ 4500

- **EXH. UNIT**

UNIT	600
INSTALL W/DUCT	300
ELECT.	300
TOTAL PER UNIT	$ 1200

TOTAL COST FOR ANTENNA

60 UNITS (AC) X 4500 + 30 UNITS X 1200 = $306,000

TOTAL COST = $306,000

ENCLOSURE "C"
Sheet 11 of 11

AH - 11/75/84
Page 11 of 11

BATCH
START

STAPLE
OR
DIVIDER

VACUUM PIPE FABRICATION AND PIPE SUPPORT STUDIES

JET PROPULSION LABORATORY INTEROFFICE MEMORANDUM

332k-87-184
18 December 1987

TO: B. Althouse

FROM: F. Stoller/R. Elder

SUBJECT: LIGO Vacuum Pipe Costing

Enclosed is a copy of B. Saldua's work sheet dated 4/29/87 regarding the cost breakdown of the vacuum pipe.

The WBS dated 8/3/87 shows Number 3051A (pipe) at $207/LF and Number 3051G (stiffner rings) with no dollar figure.

WBS Number 3051G should not be a separate item and should be included in the basic pipe cost. A stiffening ring cost of $8/LF should be added to 3051A for a total of $215/LF and 3051G should be deleted from the 8/03/87 WBS.

FWS/RE:vp

PAGE ____ OF ____

(PREPARED BY) E P Saldua	(DATE) 29 APR 87	(REPORT NO.)
(CHECKED BY)	(DATE)	(PROJECT) LIGO PROJECT

TITLE UP-TO-DATE ESTIMATE FOR STAINLESS STEEL PIPE AND FIELD WELDS

A. PIPE:

DIAMETER	=	48" I.D.
WALL THICKNESS	=	1/4"
MATERIAL	=	STAINLESS STL. 304L w/ Simul. No. 4 Finish
STIFFENERS	=	PL 1/2" x 2 1/2" @ 8'-0 O.C., Carbon Stl.
OLD 1985 ESTIMATE	=	$ 229./foot

NEW 1987 ESTIMATE (per foot)

Sources: NAYLOR PIPE CO., CHICAGO, ILL & C.E. HOWARD, INDUSTRY, CA

MATERIAL: 130 lbs. @ $0.90/lb (No. 2 FINISH)	$117.	–
@ $1.40/lb (No. 4 FINISH)	–	$182.
SPIRALLING/WELDING/HYDROTEST	73.	73.
MASS SPEC. VACUUM LEAK TEST	5.	5.
STIFFENERS / CLEANING / SEAL ENDS	20.	20.
	$215./ft	$280./ft.
	No. 2 finish	No. 4 finish

NOTES: 1. ACCORDING TO NAYLOR PIPE, ALLEGHENY STEEL MILLS RAISED THEIR PRICES ON No. 4 FINISH DUE TO LARGE REJECT FACTORS.

2. A SIMILAR VACUUM PIPE PROJECT FOR THE WHITE SANDS MISSILE RANGE, THAT NAYLOR and C.E. HOWARD ARE WORKING ON, is USING A No. 2 FINISH.

3. THESE NEW 1987 ESTIMATES INCLUDE SHIPPING TO WEST COAST.

B. FIELD BUTT WELD:

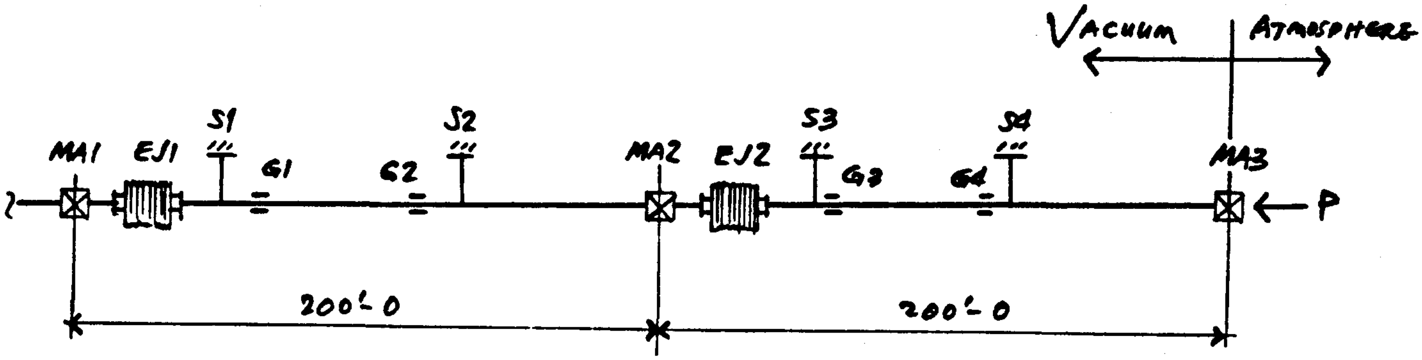
OLD 1985 ESTIMATE: $ 500. /joint   Source: PSF INDUSTRIES, Seattle

NEW 1987 ESTIMATE: $ 750. /joint   Source: C.E. Howard, Industry, CA

NOTE: NEW HEADING SHOULD READ: "INSTALL / ALIGN / WELD"

ENCLOSURE "C"
Sheet 1 of 1

GRAVITY WAVE ANTENNA PROJECT
PIPE ANCHORS, GUIDES and SUPPORTS

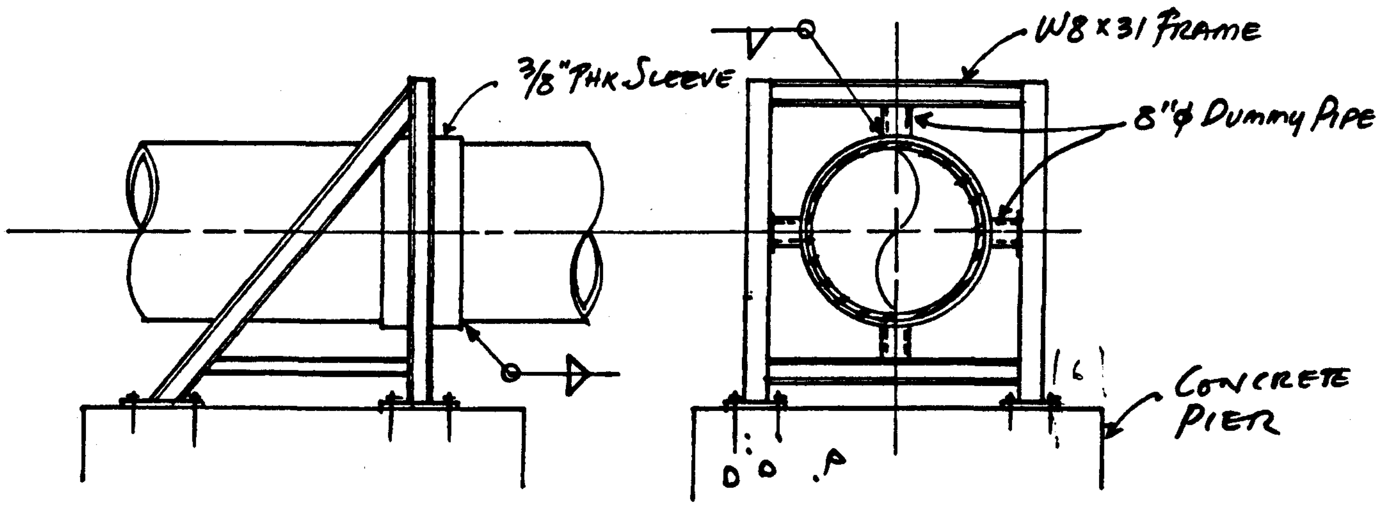


NOTE: EJ1 and EJ2 ARE SINGLE EXP. JTS.

48" DIAMETER PIPE:

AREA = 1,810 in^2

$P = 14.73\ psi\ (1810) = 26.7^K$



TYPICAL MAIN ANCHOR DETAIL

BPS-2
10-17-84

ENCLOSURE "A"
Sheet 2 of 6

GRAVITY WAVE ANTENNA PROJECT
DESIGN of PIPE and PIPE SUPPORTS

OVERVIEW

DESIGN of WALL THICKNESS

DESIGN of CIRCUMFERENTIAL STIFFENING RINGS

DESIGN of SPACING of SUPPORTS

DETAILS of SUSPENSION, ANCHORS and STIFFENERS

LAYOUT of PIPE SUPPORT SYSTEM
and SEISMIC CALCS

WALL THICKNESS REVIEWED

ENCLOSURE "D"
Sheet 1 of 10

BPS-1
10-3-84

GRAVITY WAVE ANTENNA PROJECT

DESIGN of WALL THICKNESS

Inside Diameter D_i = 48"
Internal Pressure = Vacuum
∴ Design Press P = 15 PSI (EXTERNAL)
Design Temp. T = 300°F
Material = SA-312 TP304L Stainless Steel
Assume : distance bet. stiffeners, L_s = 8'-0

Assume $t = .25$"
∴ Outside Diameter, D_o = 48.50"

$$\frac{L_s}{D_o} = \frac{8 \times 12}{48.50} = 1.98$$

$$\frac{D_o}{t} = \frac{48.50}{.25} = 194$$

from FIG. UGO-28.0
$A = .00025$
from FIG. UHA-28.1
$B = 3{,}400$

Max. allow. External Press, $P_a = \frac{4B}{3(D_o/t)}$

$$P_a = \frac{4(3400)}{3(194)} = 23.4 \text{ psi} > 15 \quad \text{OK.}$$

∴ Use 48"ø STAINLESS STEEL PIPE
1/4" wall
w/ STIFFENERS @ 8'-0

ENCLOSURE "D"
Sheet 2 of 10

BPS-2
10-3-84

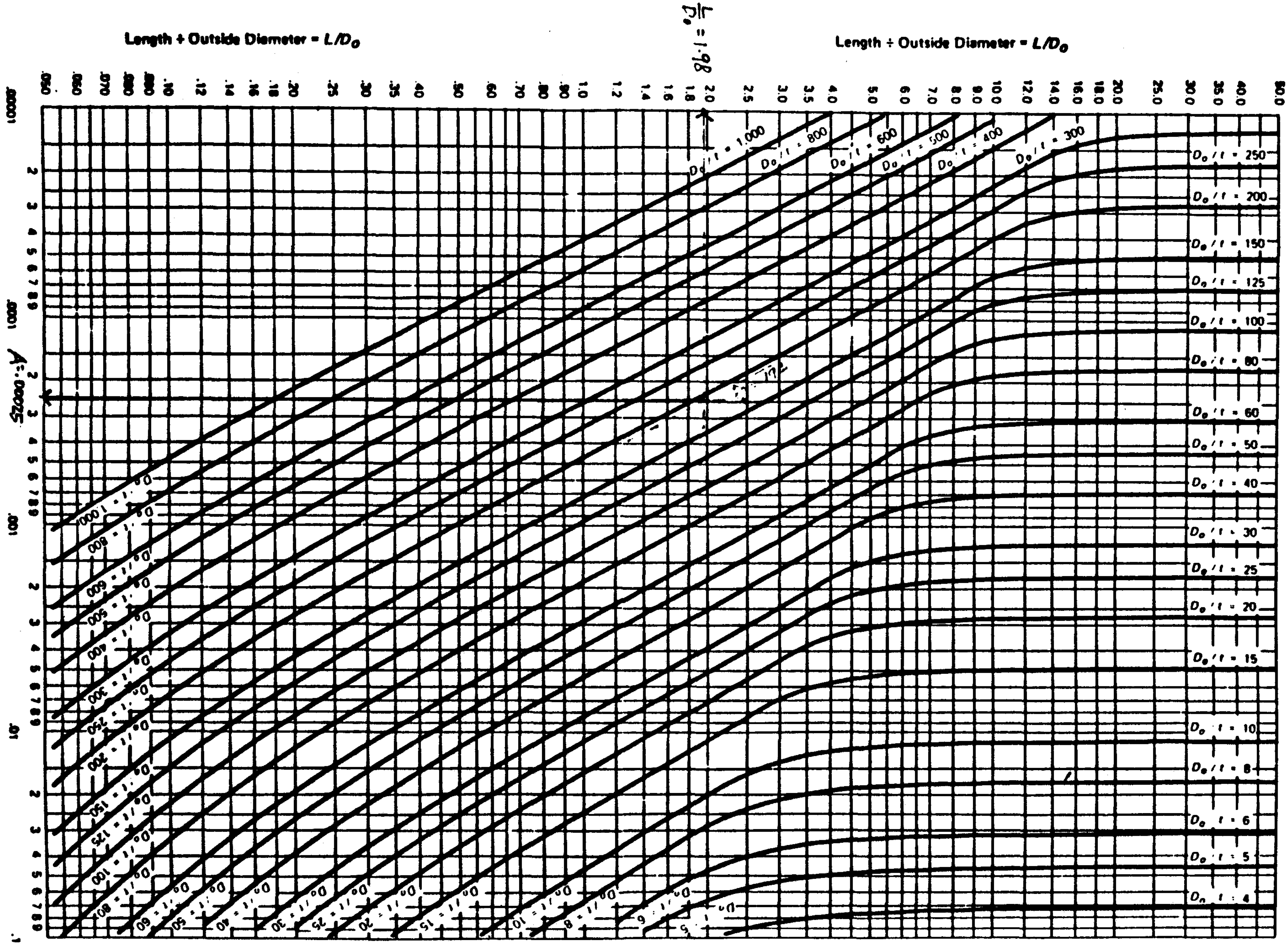


FIG. UGO-28.0 GEOMETRIC CHART FOR CYLINDRICAL VESSELS UNDER EXTERNAL OR COMPRESSIVE LOADING (FOR ALL MATERIALS)

ENCLOSURE "D"
Sheet 3 of 10

BPS-3
10-3-84

GRAVITY WAVE ANTENNA PROJECT

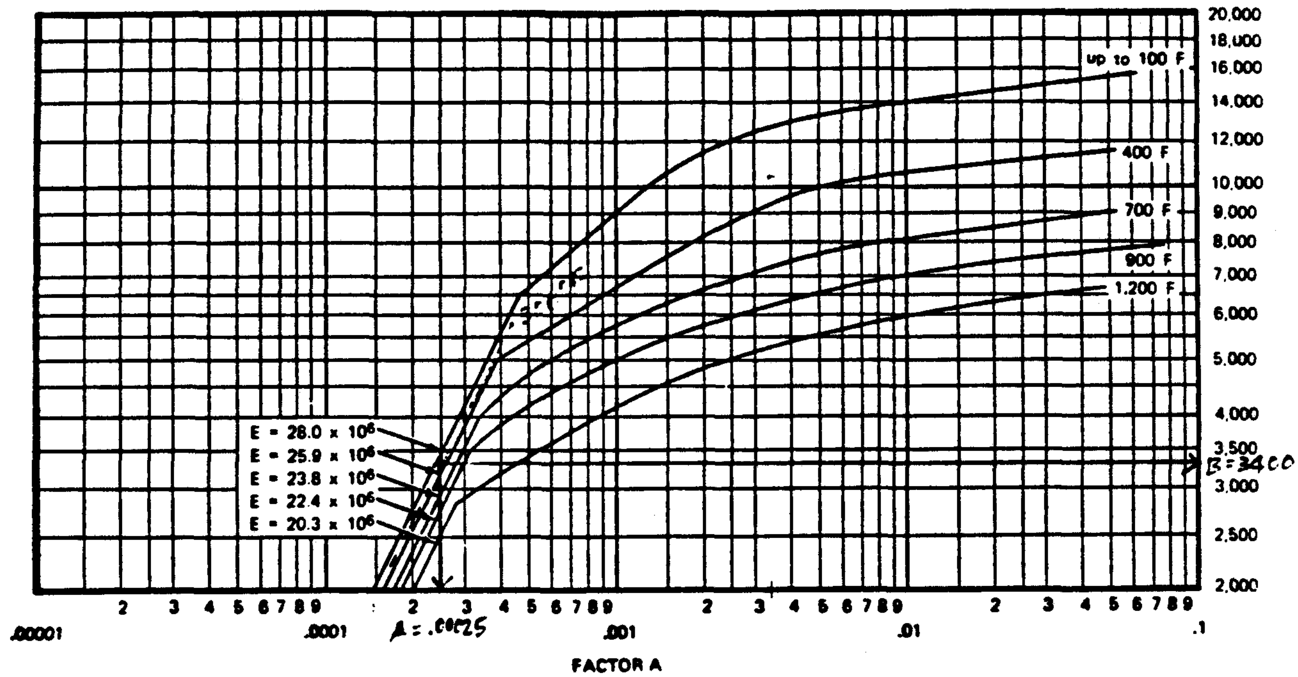


FIG. UHA-28.1 CHART FOR DETERMINING SHELL THICKNESS OF CYLINDRICAL AND SPHERICAL VESSELS UNDER EXTERNAL PRESSURE WHEN CONSTRUCTED OF AUSTENITIC STEEL (18 CR-8 NI, TYPE 304) (NOTE 8)

ENCLOSURE "D"
Sheet 4 of 10

BPS-4
10-3-84

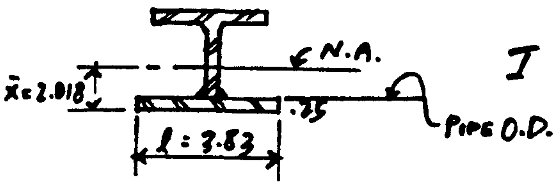
Gravity Wave Antenna Project

Design of Circumferential Stiffening Rings

Try. WT 4 × 5 $A = 1.48\ in^2$

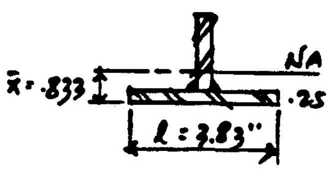
Effective length of shell

$$l = 1.10\sqrt{D_o t} = 1.10\sqrt{48.50(.25)} = 3.83''$$



$I = 12.045\ in^4$

Try PL 1/2" × 2 1/2" $A = 1.25\ in^2$



$I = 1.692\ in^4$

$$B = \frac{3}{4}\left[\frac{P D_o}{t + A_s/L_s}\right] = \frac{3}{4}\left[\frac{15(48.50)}{.25 + \frac{1.25}{96}}\right] = 2{,}074$$

from Fig. UHA-28.1

$A = .00016$

$$\text{Reqd } I_s' = \frac{D_o^2 L_s (t + A_s/L_s) A}{10.9}$$

$$= \frac{48.50^2 (96)(.25 + \frac{1.25}{96})(.00016)}{10.9} = .872\ in^4 < 1.692$$

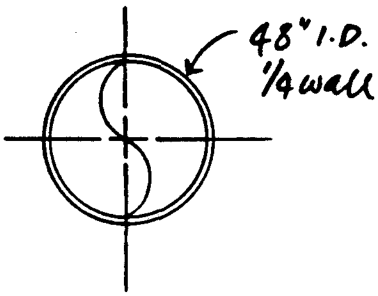
OK

Use PL 1/2" × 2 1/2" Stiffeners

ENCLOSURE ~~"D"~~ C 8L0
Sheet 5 of 10

BJS-5
10-3-84

Gravity Wave Antenna Project
Design of Spacing of Supports



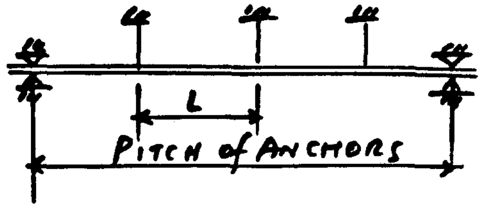
$I = 11{,}028 \text{ in}^4$

$S = 455 \text{ in}^3$

$A = 37.90 \text{ in}^2$

$w = 129 \text{ PLF}$

Use $W_t = 170$ PLF to include insul. etc



$$f = \frac{1.2 W_t L^2}{S}, \qquad \delta = \frac{17.1 W L^4}{EI}$$

Piping formulas based on $M = \frac{1}{10} wL^2$ as a compromise

Simply Supp. $M = \frac{1}{8} wL^2$

Fixed Ends $M = \frac{1}{12} wL^2$

Design "L" for Stress:

$$L = \sqrt{\frac{F_a S}{1.2 W_t}} = \sqrt{\frac{10{,}200(455)}{1.2(170)}} = 150'$$

Design "L" for Deflection:

Assume max. $\Delta = .25"$

$$L = \sqrt[4]{\frac{\Delta EI}{17.1 W_t}} = \sqrt[4]{\frac{.25(26{,}000{,}000)(11028)}{17.1(170)}} = 70' \quad \text{Governs}$$

Natural Frequency $f_n = \frac{3.13}{\sqrt{\delta_s}} = \frac{3.13}{\sqrt{.25}} = 6.26$ cps

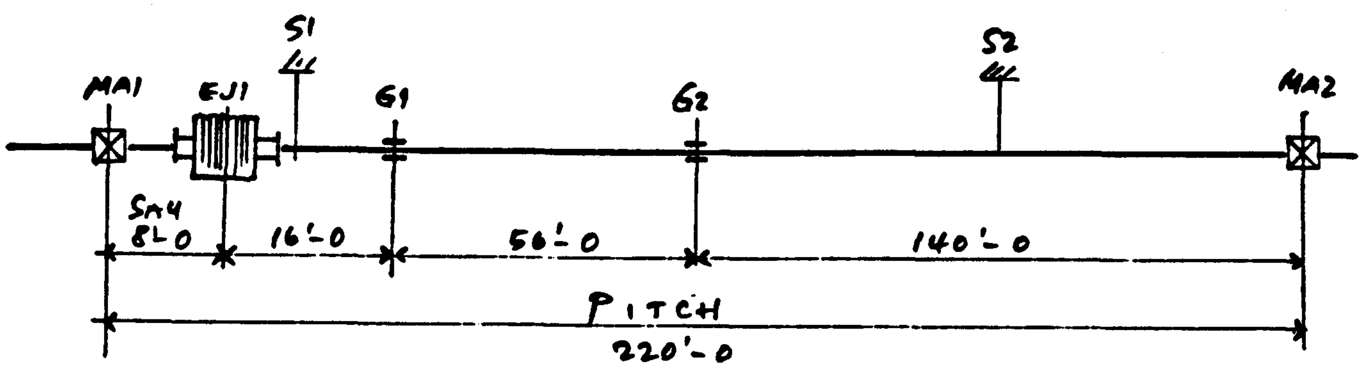
Actual Stress using $L = 70'$

$$f_b = \frac{1.2(170)(70)^2}{455} = 2{,}197 \text{ psi} < 10{,}200 \quad \text{OK}$$

RPS-6
10-3-84

GRAVITY WAVE ANTENNA PROJECT

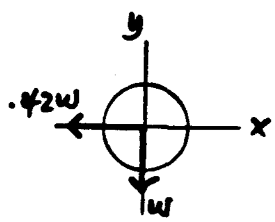
LAYOUT of PIPE SUPPORT SYSTEM:



SEISMIC ANALYSIS:

$V = ZIKCSW$

$= 1.0 \times 1.5 \times 2.0 \times .14 \times W = .42W$



$l_{ux} = 140'$ SEISMIC

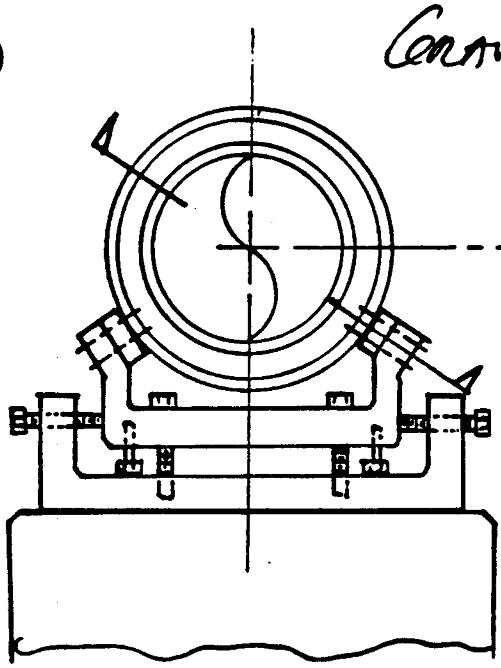
$l_{uy} = 70'$ GRAVITY

$f_y = 2{,}197$ psi

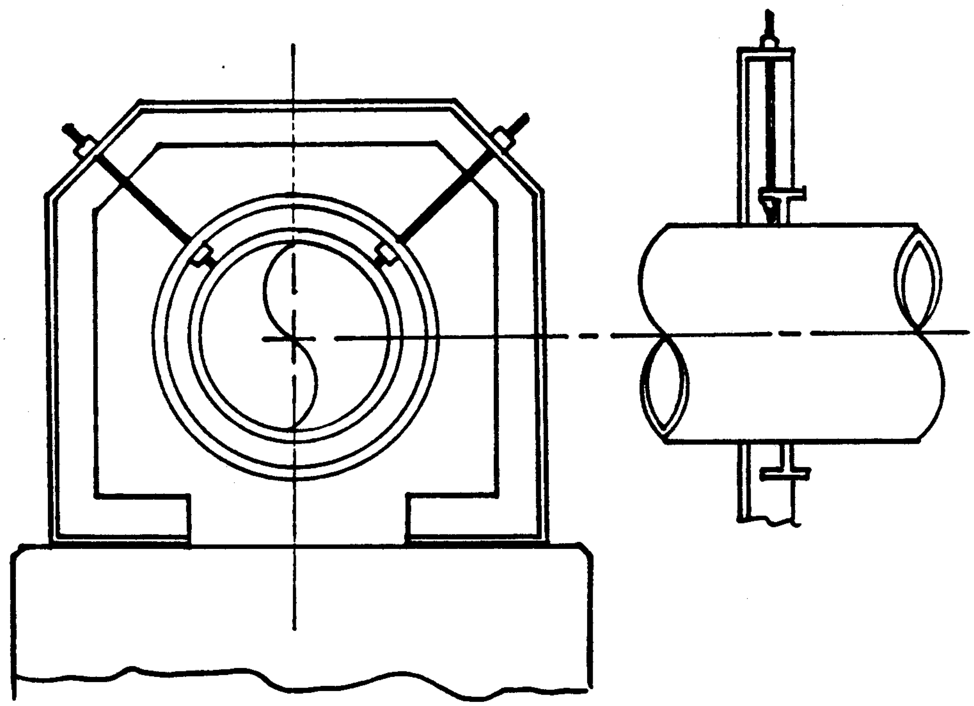
$$f_x = \frac{1.2\,(.42 \times 170)\,(140)^2}{455} = 3{,}691 \text{ psi}$$

$$f = \sqrt{f_x^2 + f_y^2} = 4{,}295 \text{ psi} < 19{,}200 \quad \text{OK}$$

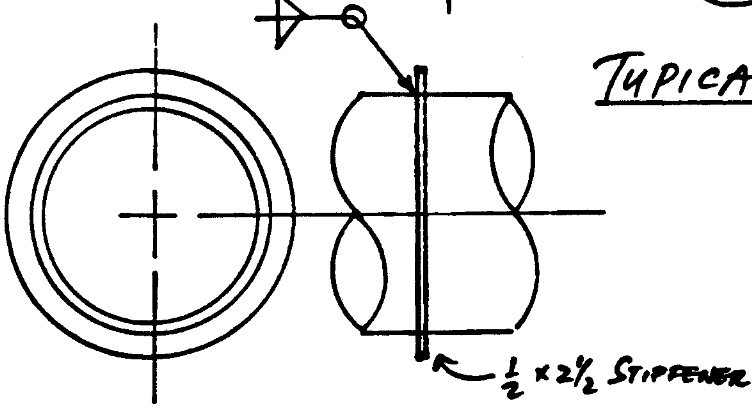
GRAVITY WAVE ANTENNA PROJECT



TYPICAL ANCHOR



TYPICAL SUSPENSION



TYPICAL STIFFENER

GRAVITY WAVE PROJECT
OTHER WALL THICKNESSES and COST COMPARISON

48'Φ 304 STAINLESS

32,810 ft TOTAL PROJECT

3/8" wall without STIFFENERS	$310/ft	: $ 10.17 M
1/4" wall with STF 8'-0	$251/ft	: $ 8.24 M
3/16" wall w/STF. @ 4'-0	$236/ft	: $ 7.74 M

BPS-9

ENCLOSURE "D"

Sheet 9 of 18 -84

ALUMINUM VS. STAINLESS STEEL

48" Inside Diameter

1. Raw Pipe Prices:

1/4" wall 304 Stainless Steel	$226/ft
1/4" wall Aluminum 6061-T6	$190/ft.

2. Stiffener Price:

1/2" X 2 1/2" Plate-Ring Stiffener	$200/each

3. Pipe W/Stiffeners:

1/4" wall Stainless w/Stf @ 8'-0	$251/ft
1/4" wall Aluminum w/Stf @ 3'-0	$257/ft

Although aluminum is cheaper than stainless steel, that price advantage is lost due to the fact that the aluminum pipe must have closer spaced ring stiffeners.

The only advantage left for aluminum then would be cheaper shipping and handling costs because steel weighs three (3) times heavier.

GRAVITY WAVE OBSERVATORY PROJECT

- WHAT HAPPENS IF BELLOWS WERE ELIMINATED ?
- PIPE STRESSES at CARBON STEEL & STAINLESS STEEL STIFFENERS
- DEPTH of CHAMBER FOUNDATIONS EXCEED 50 CM ?
- WELDING of STAINLESS STEEL PIPES

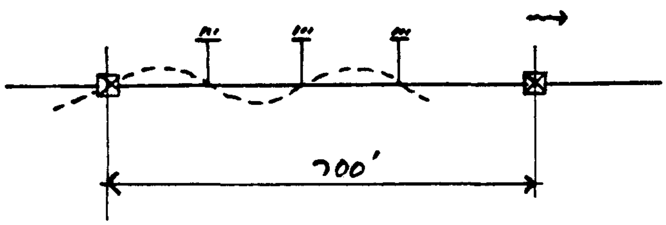
SOME REFERENCES USED :

1. ANSI B31.1 - 1977 ED. POWER PIPING by ASME
2. MODERN WELDING TECHNOLOGY by HOWARD GRAY 1979

BPS-1
2-20-85

Gravity Wave Observatory Project
Question: Can Bellows Be Eliminated?

1. No Bake, $\Delta T = 50°F$



Matl: AISI 304L

$\alpha_T = 9.9 \times 10^{-6}$

$E = 28 \times 10^{6}$ psi

$D = 48"$

$t = 1/4"$

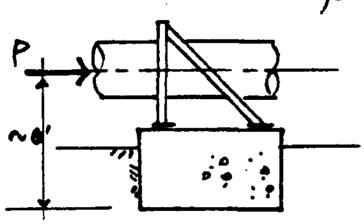
$A = 37.9\ in^2$

$$\Delta L = 9.9 \times 10^{-6} \times 50° \times 700 \times 12 = 4.16"$$

$$P = \frac{\Delta A E}{L} = \frac{4.16 \times 37.9 \times 28 \times 10^{6}}{700 \times 12} = 525,484 \text{ lbs.}$$

$$f = \frac{525,484}{37.9} = 13,865 \text{ psi}$$

for a 6'x8' Footing:



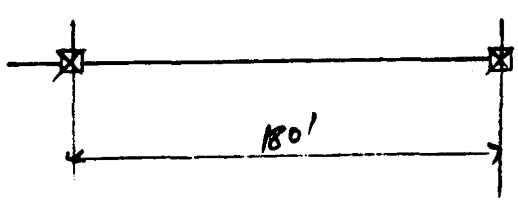
$$f = \frac{P}{A} \pm \frac{M}{S}$$

$$= 0 \pm \frac{525.5 \times 6}{53} = 59 \text{ KSF}$$

allow. = 3.0 to 6.0 KSF

Size of Footing Reqd = 12' x 20'

2. Bake Out, $\Delta T = 265°F$



$\Delta L = 5.67"$

$P = 2,784,058$ lbs.

$f = 73,458$ psi

Conclusion: Bellows Can Not Be Eliminated

? Can # Bellows be reduced for lower temps?

ENCLOSURE "C"
Sheet 2 of 7

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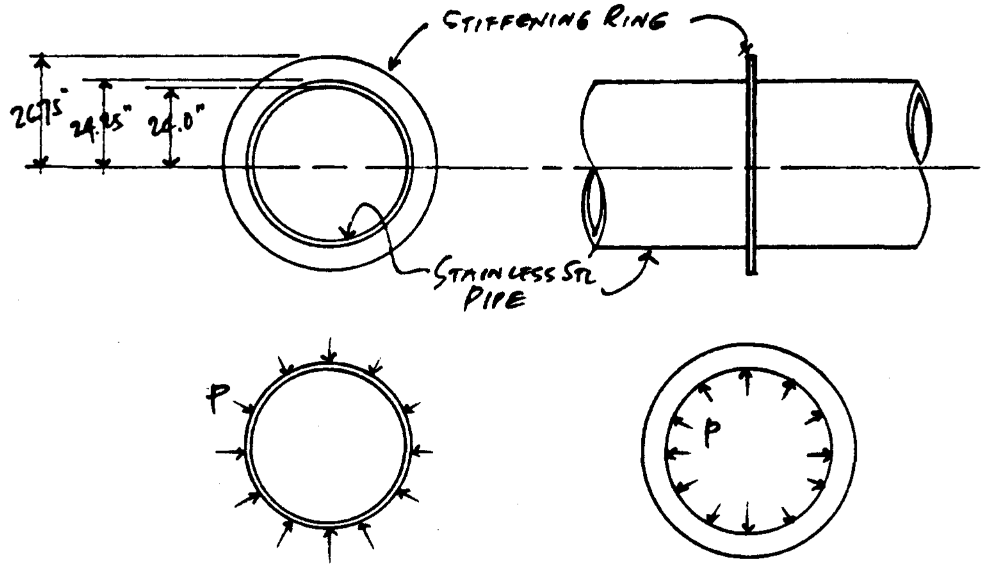
2-20-85

GRAVITY WAVE OBSERVATORY PROJECT
RADIAL EXPANSION of PIPE and STIFFENERS



FBD of PIPE FBD of STIFFENER

1. CARBON STEEL STIFFENING RINGS

$E_{CS} = 29 \times 10^6$ psi $\alpha_{CS} = 6.5 \times 10^{-6}$ in/in/°F

$E_{SS} = 26.6 \times 10^6$ psi $\alpha_{SS} = 9.9 \times 10^{-6}$ in/in/°F

$\Delta T = 300°F - 70°F = 230°F$

STIFFENER: $\Delta_{CIRCUMF.} = 2\pi(25.5)(230)(6.5 \times 10^{-6}) = .2395"$

PIPE: $\Delta_{CIRCUMF} = 2\pi(24.125)(230)(9.9 \times 10^{-6}) = .3452"$

DIFFERENCE in RADII due to BAKE-OUT $= \dfrac{.3452 - .2395}{2\pi} = .0168$

$$\Delta RADIUS = \frac{pr^2}{Eh} = \frac{p(25.5)^2}{29 \times 10^6 (2.5)} - \frac{-p(24.125)^2}{26.6 \times 10^6 (.25)} = .0168$$

$p = 174$ psi

TANGENTIAL STRESSES:

$$\sigma_{STF} = \frac{pr}{h} = \frac{174(25.5)}{2.5} = 1{,}745 \text{ psi}$$

$$\sigma_{pipe} = \frac{174(24.125)}{.25} = 16{,}791 \text{ psi}$$

BPS-3
2-20-85

GRAVITY WAVE OBSERVATORY PROJECT
RADIAL EXPANSION of PIPE and STIFFENERS contd

2. STAINLESS STEEL STIFFENERS

Δ_{RADIUS} = .00312"
p = 32 psi

TANGENTIAL STRESSES
σ_{STF} = 356 psi
σ_{pipe} = 3,088 psi

3. ANSI B31.1 POWER PIPING CODE

ALLOWABLE PRIMARY STRESS = S_H = for sustained loads
" SECONDARY STRESS = S_A = for thermal

$S_A = f(1.25 S_c + .25 S_H)$

TOTAL ALLOW. STRESS RANGE = $S_A + S_H$

for AISI 304L :
S_c = 13,300 psi
S_h = 10,100 psi @ 300°F
f = 1.0 for < 700 cycles

$S_A = 1.0\ (1.25 \times 13300 + .25 \times 10{,}100)$
= 19,150 psi > 16,791 psi for C.S. STIFFENERS

CONCLUSION: MAY USE CARBON STEEL STIFFENERS

BPS-4
2-20-85

ENCLOSURE "C"
Sheet 4 of 7

GRAVITY WAVE OBSERVATORY PROJECT
DEPTH OF CHAMBER FOUNDATIONS

QUESTION:

WOULD THE DEPTH OF VACUUM CHAMBER FOUNDATIONS EXCEED 50 CM? (19.7")

DISCUSSION:

DEPENDING ON THE WEIGHT OF VACUUM CHAMBER AND OTHER EQUIPMENT, THE DEPTH OF FOUNDATIONS SHALL BE IN EXCESS OF 2'-0 (61 CM).

FOR STANDARD LIGHT RESIDENTIAL CONSTRUCTION, MINIMUM DEPTH OF FOUNDATION IS 2'-0.

BPS-5
2-20-85

Gravity Wave Observatory Project
Welding of Stainless Steel Pipes

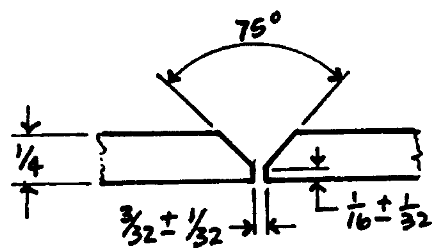
Stainless Steel

- Iron : Main Element
- Chromium : 11 to 30% : + Oxygen in Air produces Chromium Oxides That Serves as a Barrier To Oxidation, Rust
- Nickel : 8 to 12% : Reduces Thermal and Electrical Conductivity
- Carbon : Undesirable
  - Combines with Chromium To Produce Chromium Carbide (Carbide Precipitation) at 800° to 1600°F
  - Limit to .03%

Ideal Material : AISI 304L

18% Chromium
8% Nickel
.03% Carbon

Joint Design :



Performed By Oxygen Flame Cutting, Utilizing A Torch That Revolves Around The Pipe Circumference.

Pipe Joint. Alignment and Fit-Up :

Utilize An Internal Line Up Clamp That Is Inserted In The End Of The Last Section Of The Pipeline. Air Pressure Clamps The Internal Lineup Clamp To The Section Already Welded To The Pipeline And Then As The New Section Is Being Placed In Position It Clamps, Locates And Spaces The New Section.

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2-20-85

ENCLOSURE "C"
Sheet 6 of 7

GRAVITY WAVE OBSERVATORY PROJECT
WELDING of STAINLESS STEEL PIPES

RECOMMENDED FIELD WELDING PROCESS:
GAS METAL ARC WELDING (GMAW)

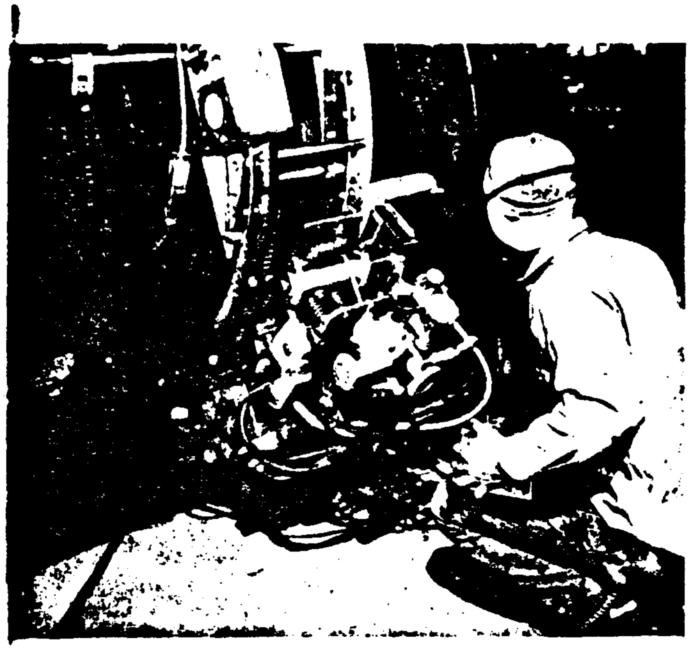

FIGURE 20-10 *Automatic GMAW welding machine for large pipe.*

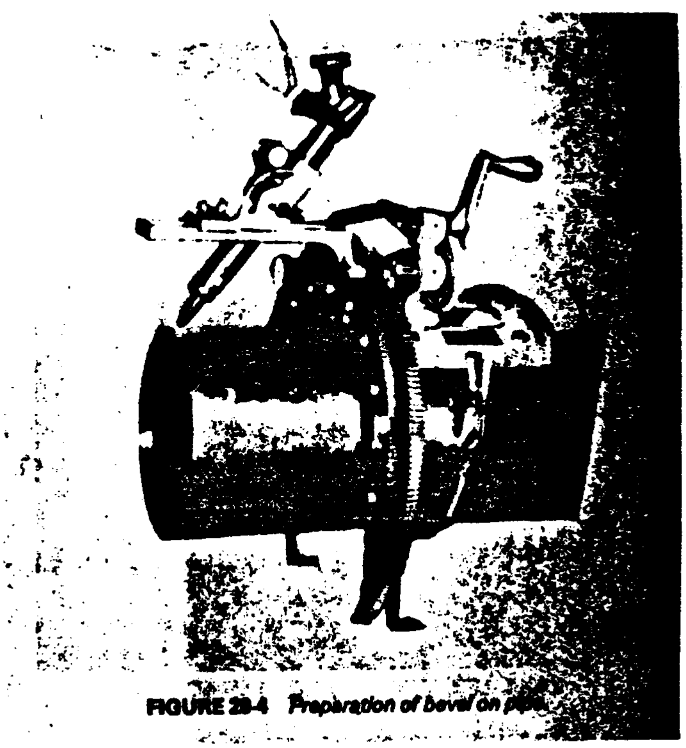

FIGURE 20-4 *Preparation of bevel on pipe.*

BPS-7
2-20-85

ENCLOSURE "C"
Sheet 7 of 7

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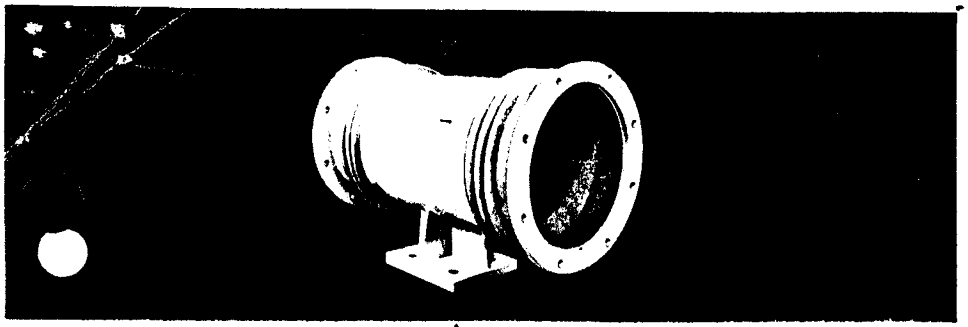
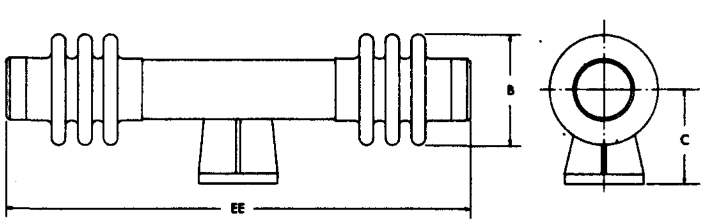
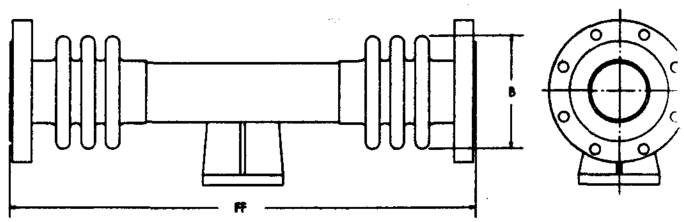
NON-EQUALIZING DOUBLE TYPE



Size Ins.	Axial Traverse Only Inches	No. of Corru-gations	Flanged Ends FF* Inches	Flanged Ends Weight Pounds	Welding Ends EE Inches	Welding Ends Weight Pounds	Internal Sleeves Pounds Add	Anchor Base Pounds Add	B O.D. of Corru-gations in Inches
	1	2	29¾	1316	27	480	60		
	2	4	34¼	1350	31½	514	76		
	3	6	38¾	1384	36	548	92		
	4	8	43¼	1418	40½	582	108		
48	5	10	47¾	1452	45■	616	124	295	52⅞
	6	12	52¼	1486	49½■	650	140		
	7	14	56¾‡	1520	54■	684	156		
	8	16	61¼‡	1554	58½■	718	172		
	9	18	65¾‡	1588	63■	752	188		
	10	20	70¼‡	1622	67½■	786	204		
	1	2	30¾	1788	27	543	74		
	2	4	35¼	1826	31½	581	92		
	3	6	39¾	1864	36	619	110		
	4	8	44¼	1902	40½	657	128		
54	5	10	48¾	1940	45■	695	146	351	58⅞
	6	12	53¼	1978	49½■	733	164		
	7	14	57¾‡	2016	54■	771	182		
	8	16	62¼‡	2054	58½■	809	200		
	9	18	66¾‡	2092	63■	847	218		
	10	20	71¼‡	2130	67½■	885	236		
	1	2	31	2032	27	604	88		
	2	4	35½	2074	31½	646	108		
	3	6	40	2116	36	688	128		
	4	8	44½	2158	40½	730	148		
60	5	10	49	2200	45■	772	168	420	64⅞
	6	12	53½	2242	49½■	814	188		
	7	14	58‡	2284	54■	856	208		
	8	16	62½‡	2326	58½■	898	228		
	9	18	67‡	2368	63■	940	248		
	10	20	71½‡	2410	67½■	982	268		
	1	2	31½	2681	27	665	102		
	2	4	36	2727	31½	711	124		
	3	6	40½	2773	36	757	146		
	4	8	45	2819	40½	803	168		
66	5	10	49½	2865	45■	849	190	479	70
	6	12	54	2911	49½■	895	212		
	7	14	58½‡	2957	54■	941	234		
	8	16	63‡	3003	58½■	987	256		
	9	18	67½‡	3049	63■	1033	278		
	10	20	72‡	3095	67½■	1079	300		
	1	2	31¾	3601	27	730	116		
	2	4	36¼	3651	31½	780	140		
	3	6	40¾	3701	36	830	164		
	4	8	45¼	3751	40½	880	188		
72	5	10	49¾	3801	45■	930	212	550	76
	6	12	54¼	3851	49½■	980	236		
	7	14	58¾‡	3901	54■	1030	260		
	8	16	63¼‡	3951	58½■	1080	284		
	9	18	67¾‡	4001	63■	1130	308		
	10	20	72¼‡	4051	67½■	1180	332		





The "C" dimension for double non equalizing expansion joints is the same as that for self equalizing double type expansion joints. See pages 52 through 57.

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NON-EQUALIZING DOUBLE TYPE

Size Ins.	Axial Traverse Only Inches	No. of Corru-gations	Flanged Ends FF* Inches	Flanged Ends Weight Pounds	Welding Ends EE Inches	Welding Ends Weight Pounds	Internal Sleeves Pounds Add	Anchor Base Pounds Add	B O.D. of Corru-gations in Inches
32	1	2	28⅝	625	27	310	36		
	2	4	33⅛	645	31½	330	44		
	3	6	37⅝	665	36	350	52		
	4	8	42⅛	685	40½	370	60		
	5	10	46⅝	705	45■	390	68	171	36⅞
	6	12	51⅛	725	49½■	410	76		
	7	14	55⅝‡	745	54■	430	84		
	8	16	60⅛‡	765	58½■	450	92		
	9	18	64⅝‡	785	63■	470	100		
	10	20	69⅛‡	805	67½■	490	108		
34	1	2	28¾	705	27	338	38		
	2	4	33¼	725	31½	358	48		
	3	6	37¾	745	36	379	58		
	4	8	42¼	765	40½	398	68		
	5	10	46¾	785	45■	418	78	182	38⅞
	6	12	51¼	805	49½■	438	88		
	7	14	55¾‡	825	54■	458	98		
	8	16	60¼‡	845	58½■	478	108		
	9	18	64¾‡	865	63■	498	118		
	10	20	69¼‡	885	67½■	518	128		
36	1	2	28⅞	753	27	352	40		
	2	4	33⅜	775	31½	374	50		
	3	6	37⅞	797	36	396	60		
	4	8	42⅜	819	40½	418	70		
	5	10	46⅞	841	45■	440	80	194	40⅞
	6	12	51⅜	863	49½■	462	90		
	7	14	55⅞‡	885	54■	484	100		
	8	16	60⅜‡	907	58½■	506	110		
	9	18	64⅞‡	929	63■	528	120		
	10	20	69⅜‡	951	67½■	550	130		
38	1	2	29	869	27	371	42		
	2	4	33½	891	31½	393	52		
	3	6	38	913	36	415	62		
	4	8	42½	935	40½	437	72		
	5	10	47	957	45■	459	82	210	42⅞
	6	12	51½	979	49½■	481	92		
	7	14	56‡	1001	54■	503	102		
	8	16	60½‡	1023	58½■	525	112		
	9	18	65‡	1045	63■	547	122		
	10	20	69½‡	1067	67½■	569	132		

Size Ins.	Axial Traverse Only Inches	No. of Corru-gations	Flanged Ends FF* Inches	Flanged Ends Weight Pounds	Welding Ends EE Inches	Welding Ends Weight Pounds	Internal Sleeves Pounds Add	Anchor Base Pounds Add	O.D. of Corru-gations in Inches
40	1	2	29¼	998	27	393	44		
	2	4	33¾	1022	31½	417	56		
	3	6	38¼	1046	36	441	68		
	4	8	42¾	1070	40½	465	80		
	5	10	47¼	1094	45■	489	92	225	44⅞
	6	12	51¾	1118	49½■	513	104		
	7	14	56¼‡	1142	54■	537	116		
	8	16	60¾‡	1166	58½■	561	128		
	9	18	65¼‡	1190	63■	585	140		
	10	20	69¾‡	1214	67½■	609	152		
42	1	2	29½	1124	27	413	46		
	2	4	34	1148	31½	437	60		
	3	6	38½	1172	36	461	74		
	4	8	43	1196	40½	485	88		
	5	10	47½	1220	45■	509	102	240	46⅞
	6	12	52	1244	49½■	533	116		
	7	14	56½‡	1268	54■	557	130		
	8	16	61‡	1292	58½■	581	144		
	9	18	65½‡	1316	63■	605	158		
	10	20	70‡	1340	67½■	629	172		
44	1	2	29½	1188	27	434	50		
	2	4	34	1214	31½	460	64		
	3	6	38½	1240	36	486	78		
	4	8	43	1266	40½	512	92		
	5	10	47½	1292	45■	538	106	258	48⅞
	6	12	52	1318	49½■	564	120		
	7	14	56½‡	1344	54■	590	134		
	8	16	61‡	1370	58½■	616	148		
	9	18	65½‡	1396	63■	642	162		
	10	20	70‡	1422	67½■	668	176		
46	1	2	29⅝	1246	27	453	54		
	2	4	34⅛	1276	31½	483	70		
	3	6	38⅝	1306	36	513	86		
	4	8	43⅛	1336	40½	543	102		
	5	10	47⅝	1366	45■	573	118	276	50⅞
	6	12	52⅛	1396	49½■	603	134		
	7	14	56⅝‡	1426	54■	633	150		
	8	16	61⅛‡	1456	58½■	663	166		
	9	18	65⅝‡	1486	63■	693	182		
	10	20	70⅛‡	1516	67½■	723	198		

*For 6″ diameter and larger, add ¼″ to the face to face dimension of flanged units when internal sleeves are required in bellows of 6 corrugations or less each end. This includes 1/16″ thick gasket between flange and sleeve face.

‡Add 4¼″ to the face to face dimension of 6″ to 72″ diameter flanged end double unit when sleeves are required in bellows of seven corrugations or more each end.

■Add 6½″ to the end to end dimension of 14″ to 72″ diameter weld end expansion joint when sleeves are required in bellows of five corrugations or more each end.

The maximum operating pressure for all expansion joints shown in the dark shaded area is 50 psi, in the lighter shaded area 30 psi, and in the unshaded area 15 psi.

FOUNDATION DESIGN FOR SUPPORT OF VACUUM PIPE

In reviewing the requirements for support of the 4-ft. diameter vacuum pipe, it appears feasible to support the foundation on the invert of the 10-ft. diameter corrugated metal (CMP) pipe housing and not penetrate the housing.

This design approach saves the cost of cutting openings in the invert of the CMP plus the difficult task of sealing the opening against ground water.

The following criteria would apply to this approach:

1. Compaction under the invert of the culvert housing shall be 95% of maximum density as determined by the ASTM D1557-78, Method C.
2. Allowable design pressures on the base of the foundation shall be in the 2000 PSF range.
3. Adjustment mechanisms shall be incorporated into the pipe supports to compensate for any long term settlement which should be minor under these conditions.
4. The foundation shall be anchored to the corrugated pipe housing by Nelson studs.

JPL

GRAVITY WAVE PIPE ENVIRONMENTAL LOADING DEFLECTIONS

- CONDITIONS EXAMINED
  - GRAVITY LOADING (WEIGHT OF PIPE, INSULATION, MISC.)
  - WIND LOADING
  - THERMAL LOADING
  - SELF-INDUCED VIBRATIONS (AEROLASTIC VORTEX SHEDDING)
- PIPE - PHYSICAL DESCRIPTION
  - 72' MAXIMUM SPAN BETWEEN "SIMPLE" SUPPORTS
  - 48 INCH DIAMETER, ¼ INCH WALL
  - STAINLESS STEEL TYPE 304L

    E= 28 + 06 PSI

    COEFFICIENT OF EXPANSION 9.6 - 06 / °F

    DENSITY 0.29 LBS/CU. IN.

    YIELD STRENGTH 30 + 03 PSI

R.Levy -1
4/29/86

JPL

PIPE MIDSPAN DEFLECTIONS

- o PIPE COMPLIANCE CONSTANT

  d = 0.0239 w — d IN INCHES

  w LBS/INCH OF SPAN

- o GRAVITY DEFLECTION

  w = 13 LBS/INCH — PIPE + STIFFINERS = 11.2

  INSULATION + MISC = 1.8

  d = 0.3 INS

- o WIND DEFLECTION

  w = 9.6 LBS/INCH — 100 MPH

  C_D = 1.0 (COULD BE LESS)

  d = .23 INS — H = 4.5 FEET

- o GRAVITY AND WIND VECTOR SUM

  d = 0.38 INS

- o THERMAL DEFLECTION

  $d = T\ A_T\ L^2 / (8D)$

  d = .0186 T/°F

  (d = .93 INS FOR 50°)

  T = TEMPERATURE DIFFERENCE ACROSS A DIAMETER

  D = DIAMETER

  L = SPAN

  A_T = COEFFICIENT OF EXPANSION

R.Levy -2
4/29/86

JPL PIPE VORTEX SHEDDING

o DEFINITIONS

$S = f\,H / U$

S = STROUHAL NUMBER
f = FREQUENCY, hz
H = PROJECTED SIDE, FEET
U = WIND SPEED, FEET/SEC

$R = 6380\,UH$

R = REYNOLDS NUMBER

o S DEPENDS ON R

o FOR THIS CONFIGURATION, ESTIMATE:

S = 0.40
R = 2.1 + 06 (SUPERCRITICAL)
f = 6.44 hz (48 IN DIA, 72 FT SPAN)
U = 72.5 FT/SEC (49 MPH)
C_L = 0.3 = LIFT COEFFICIENT

o VORTEX SHEDDING IS NOT LIKELY TO BE SIGNIFICANT HERE *REYNOLDS NUMBER IS TOO HIGH. *VORTICES WILL HAVE RANDOM AMPLITUDE AND FREQUENCY - THUS NON RESONANT.

o CONSIDER HYPOTHETICAL BUT UNLIKELY, CASE OF SHEDDING.

w = 6.14 x 4.5 x 0.3/12 = .69 LBS/INCH
(q) (H) (C_L)

d = .0239 x .69 = .0165 (FOR STATIC LOAD)

d = .0165 x 50 (IF RESONANT WITH 1% DAMPING)
= 0.83 INCHES

JPL **PIPE WALL STRESSES**

o STRESS COEFFICIENT

BENDING MOMENT = $wL^2/8$

STRESS = MOMENT/Z

Z = I/R
L = 72 x 12
R = 24
t = 0.25

STRESS = 206 PSI x w

LOAD		STRESS, PSI
DEAD	13 x 206	2,678
WIND	9.6 x 206	1,978
THERMAL - NONE IF SIMPLY SUPPORTED		
VORTEX SHEDDING (ONLY HYPOTHETICAL, NOT LIKELY)		
	0.69 x 50 x 206	7,107

NOTE: YIELD STRESS IS 30,000 PSI

R. Levy -4
4/29/86

BATCH START

STAPLE
OR
DIVIDER

VACUUM PIPE ALIGNMENT TECHNIQUES

VACUUM PIPE ALIGNMENT STRATEGY

Plan and profile of the LIGO vacuum pipes will be established to provide the minimum amount of earthwork associated costs consistent with operational requirements.

For construction layout of the vacuum pipe supporting piers and the adjustable pipe mounting saddles a detailed survey will be conducted along the location of the LIGO to establish horizontal and vertical control. A construction control line will be established in close proximity to the center line of the vacuum pipe. Offsets, both horizontal and vertical, between the control line and the designed position of the mounting saddle will be calculated for each pipe foundation pier cap. The top of concrete for each pier cap will be on the order of two inches below the undersurface of the mounting saddles to provide grout space. The saddles will be mounted to anchor bolts embedded in the piers, surveyed into position and grouted.

The placement of the vacuum pipe segments on the mounting saddles will be as follows. Each pipe segment end will be scribed on its exterior surface at the pipe's crown and one spring line. Brackets will be welded on at these points for the support of surveyor's tablets. The horizontal and vertical offsets of each tablet from the pipe's centerline will be measured and recorded. These operations will be accomplished at the point of fabrication using jigs.

Setting of each vacuum tube segment will be done by first-order leveling techniques, augmented, as required, by use of the Global Positioning System. Line-of-sight will be used on targets placed on the crown and spring line tablets and the mounting saddles will be adjusted accordingly to achieve alignment. Sightings will be adjusted for effects of atmospheric refraction. The specification for variation of the actual tube centerline from a true straight line is plus or minus 3 cm. along the longitudinal center line. This variation includes dead load deflection, manufacturing tolerance and field setting of the tube.

Foundations for the tube supporting piers will be designed so that total settlement will not exceed 0.125 inches. This will minimize or eliminate the need for realignment of the tube.

BATCH START

STAPLE
OR
DIVIDER

SEISMIC AND ACOUSTIC NOISE CONTROL

GWA

SEISMIC ISOLATION OF TANK UNITS

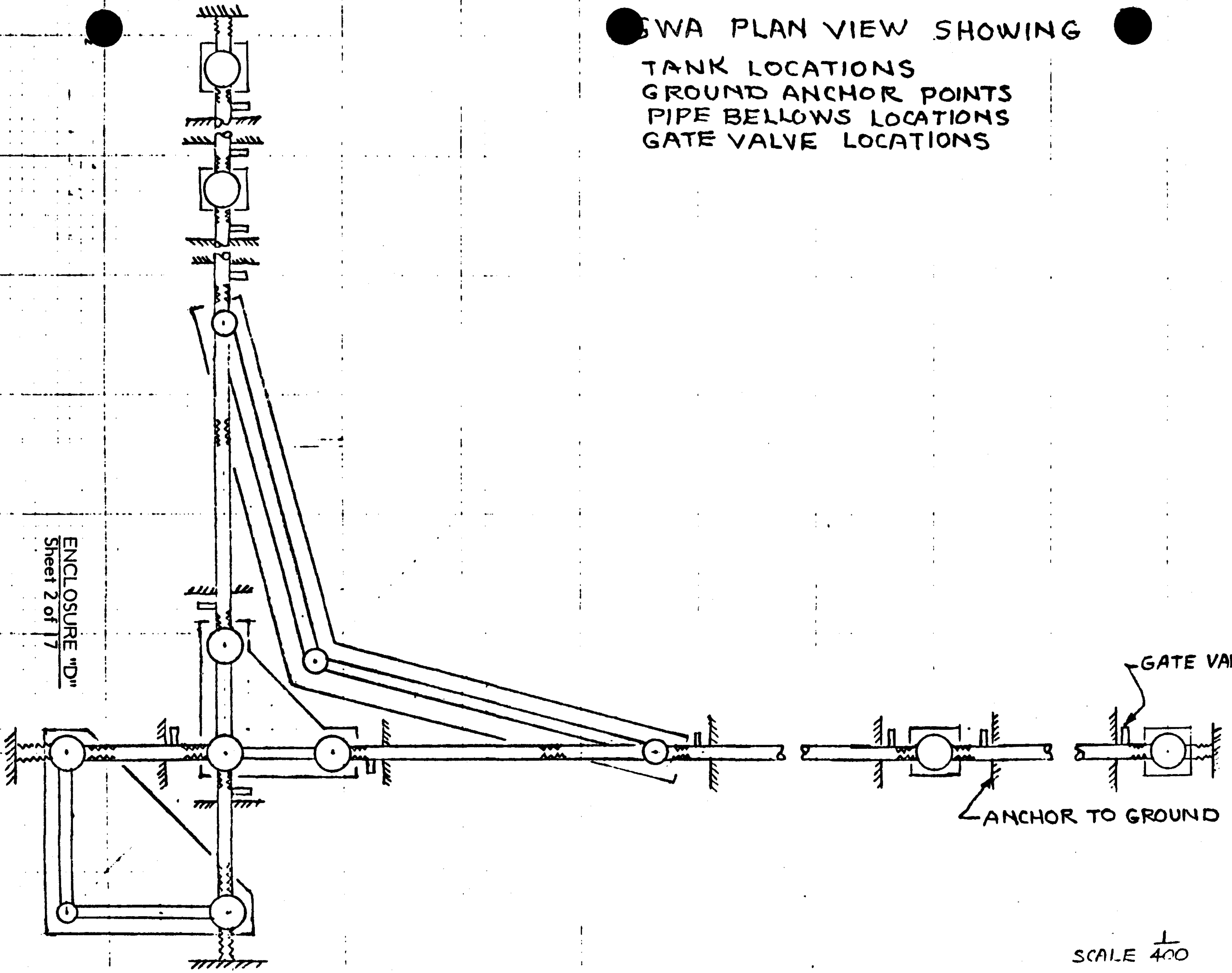
SEPT. 19, 1984

H. MCGINNESS

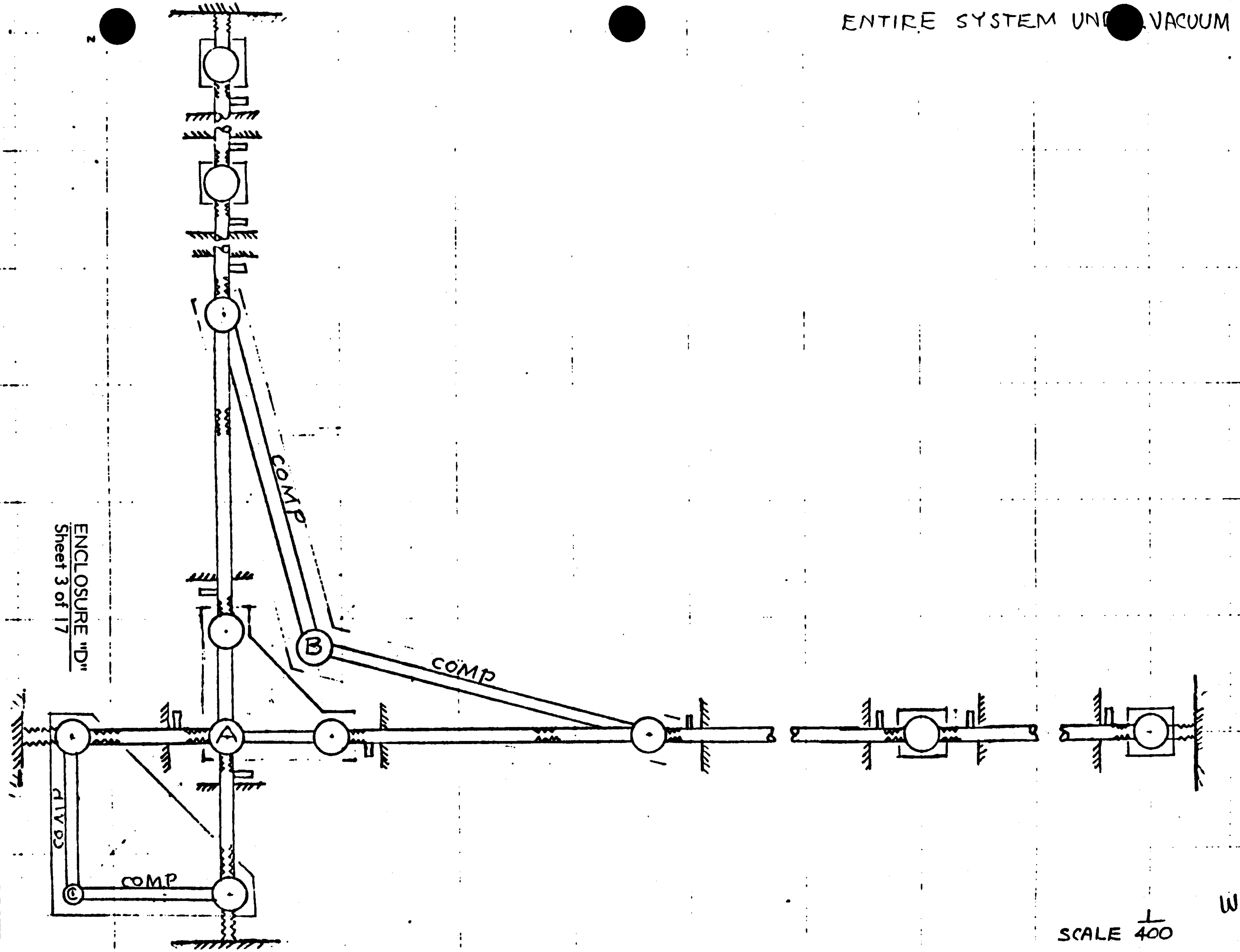
ENCLOSURE "D"
Sheet 1 of 17

GWA PLAN VIEW SHOWING

TANK LOCATIONS
GROUND ANCHOR POINTS
PIPE BELLOWS LOCATIONS
GATE VALVE LOCATIONS

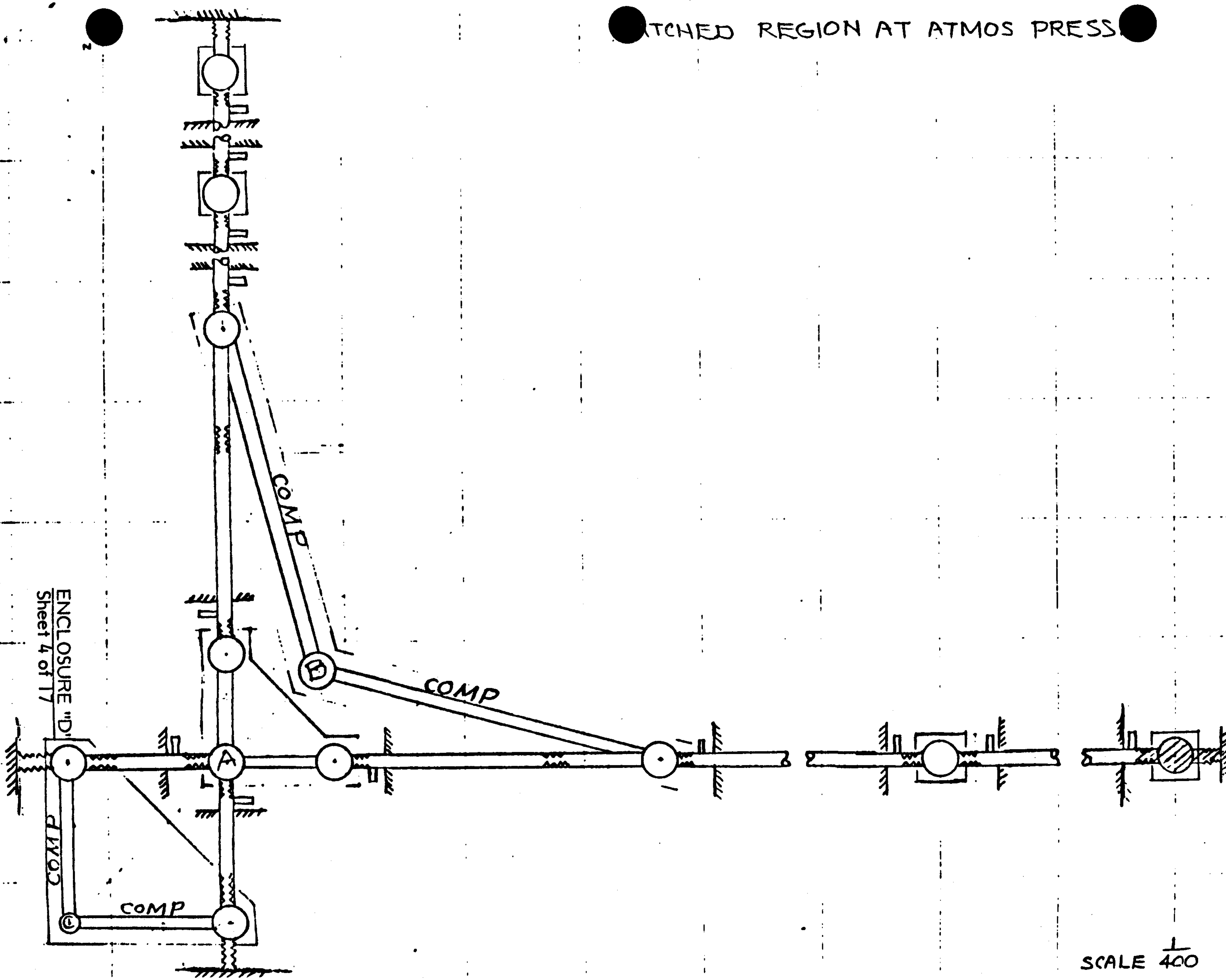


ENCLOSURE "D"
Sheet 2 of 17



ENTIRE SYSTEM UND VACUUM
COMP
COMP
COMP
B
A
C
SCALE 1/400
W

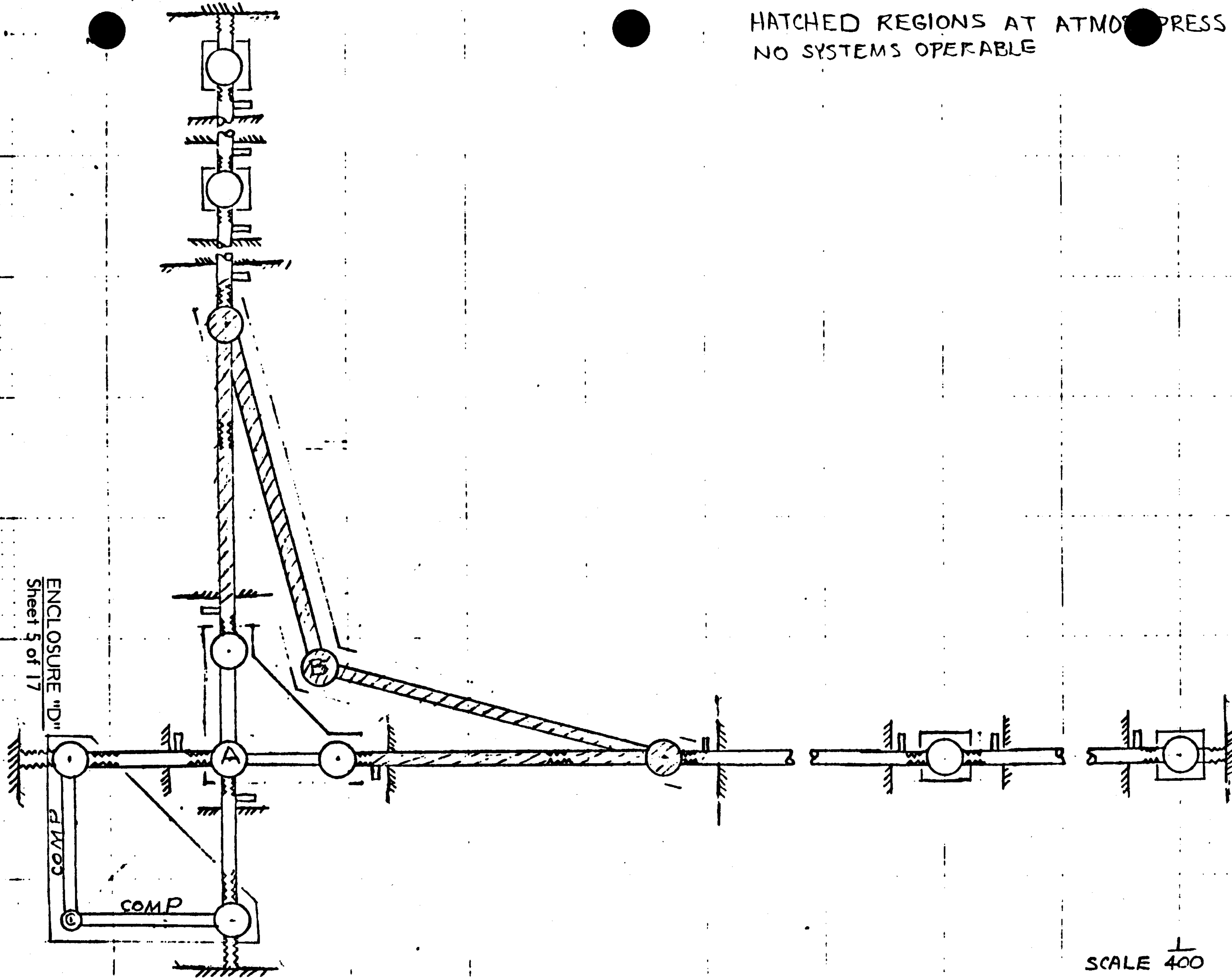
ATCHED REGION AT ATMOS PRESS



ENCLOSURE "D"
Sheet 4 of 17

SCALE 1/400

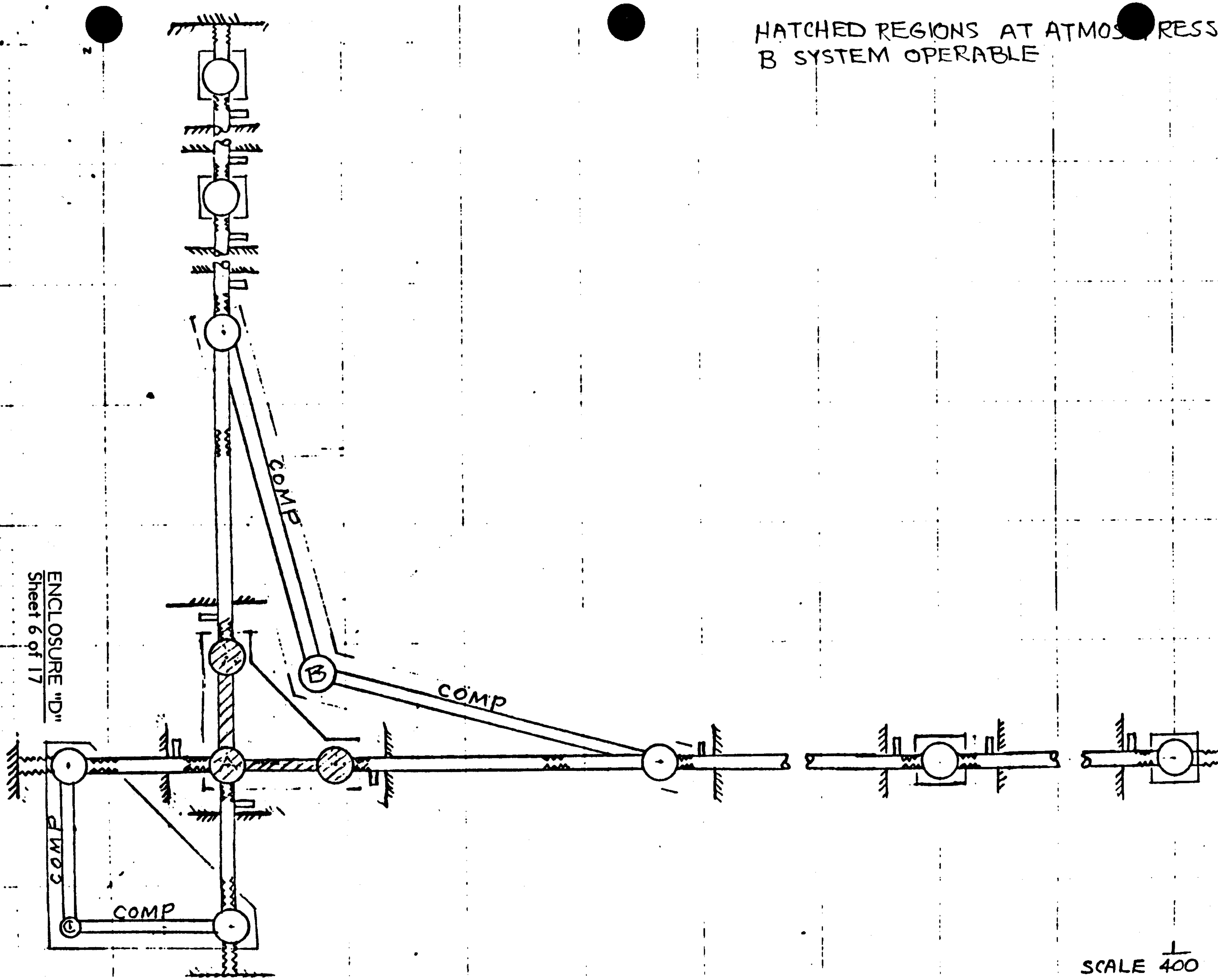
HATCHED REGIONS AT ATMOS PRESS
NO SYSTEMS OPERABLE



ENCLOSURE "D"
Sheet 5 of 17

5

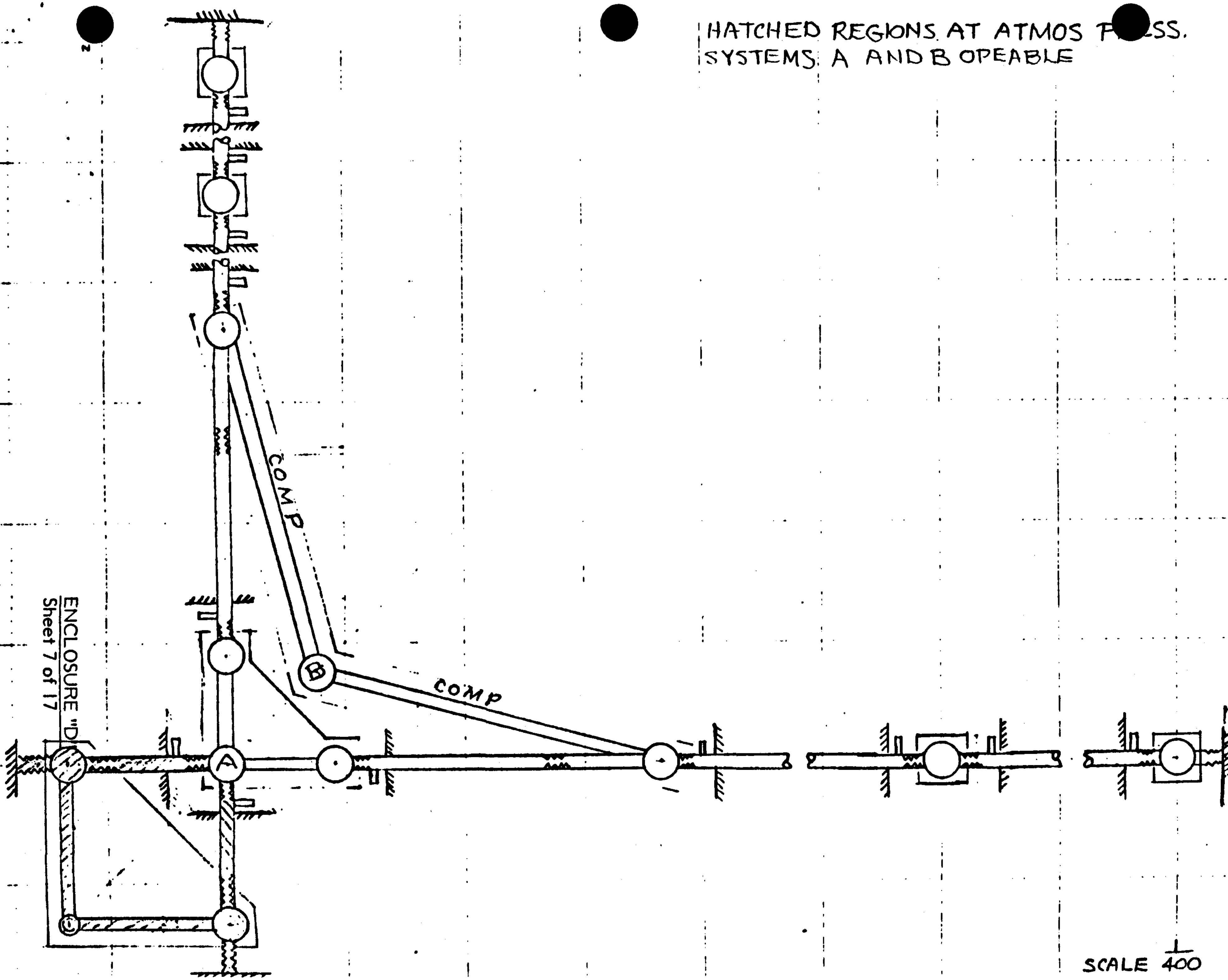
HATCHED REGIONS AT ATMOS. PRESS.
B SYSTEM OPERABLE



SCALE $\frac{1}{400}$

ENCLOSURE "D"
Sheet 6 of 17

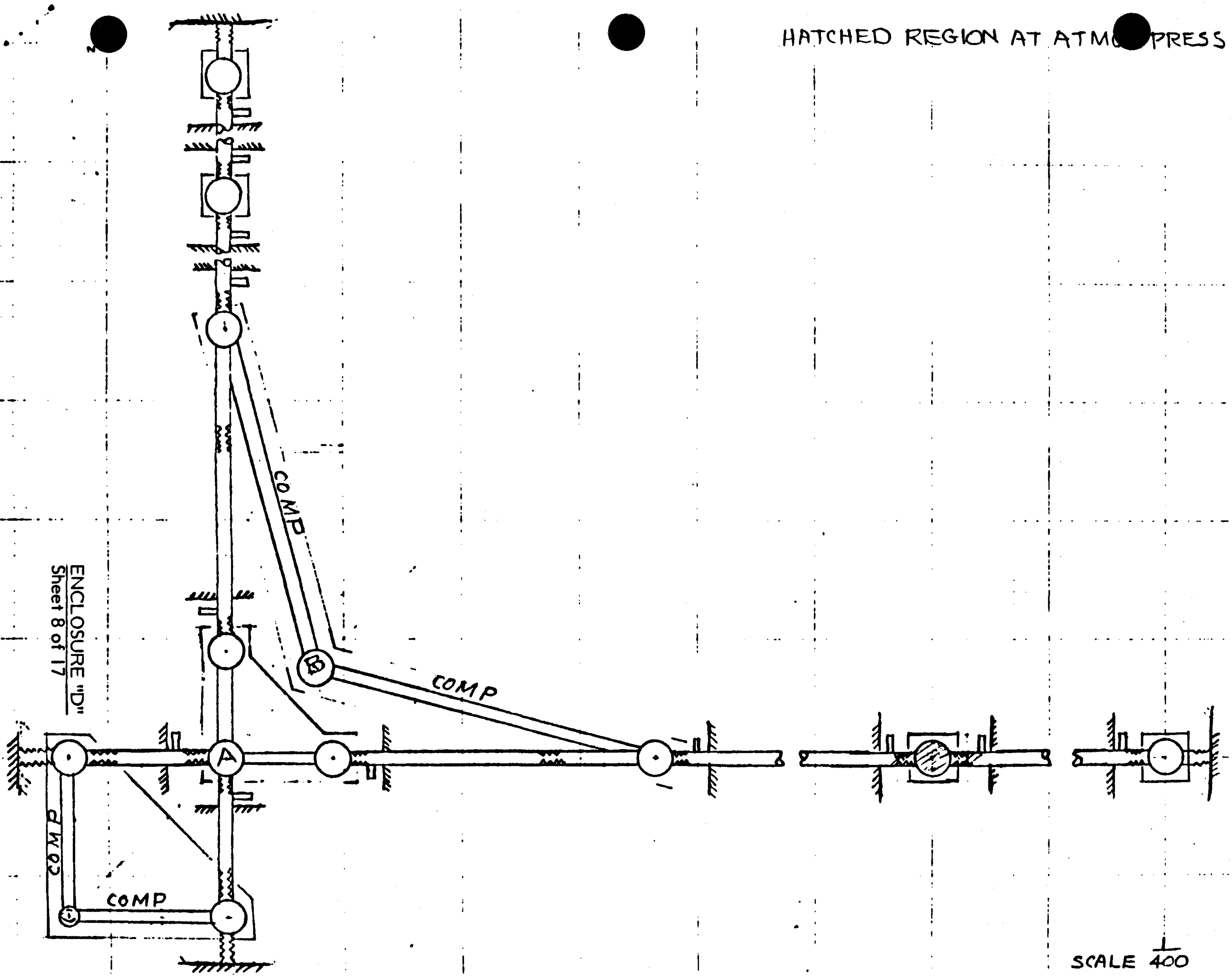
HATCHED REGIONS AT ATMOS PRESS.
SYSTEMS A AND B OPEABLE



SCALE $\frac{1}{400}$

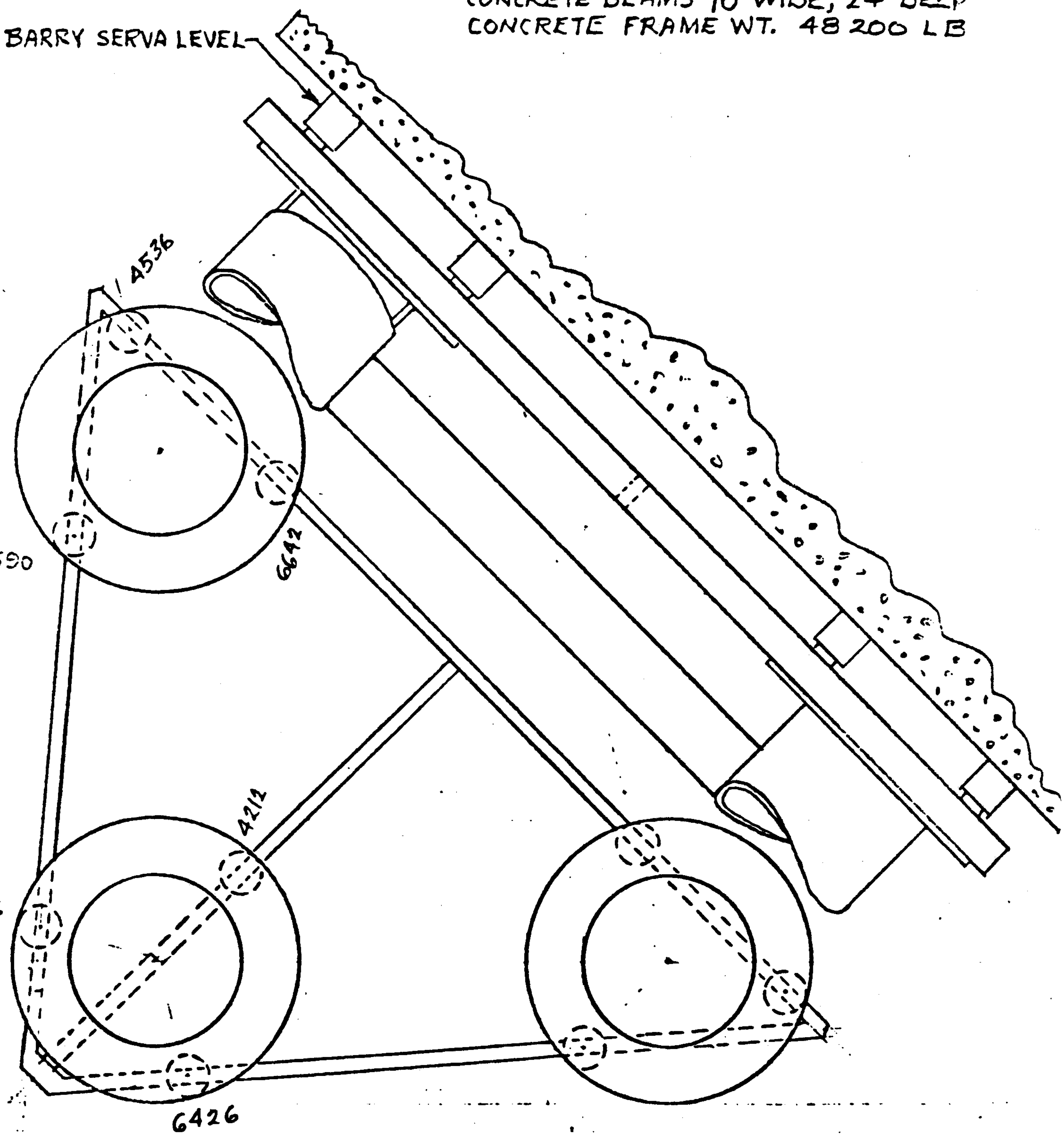
ENCLOSURE "D"
Sheet 7 of 17

ENCLOSURE "D"
Sheet 8 of 17



"A" SYSTEM SUPPORT FRAME
SCALE 1/100

CONCRETE BEAMS 10" WIDE, 24" DEEP
CONCRETE FRAME WT. 48 200 LB



"C" SYSTEM SUPPORT FRAME
SCALE 1/100

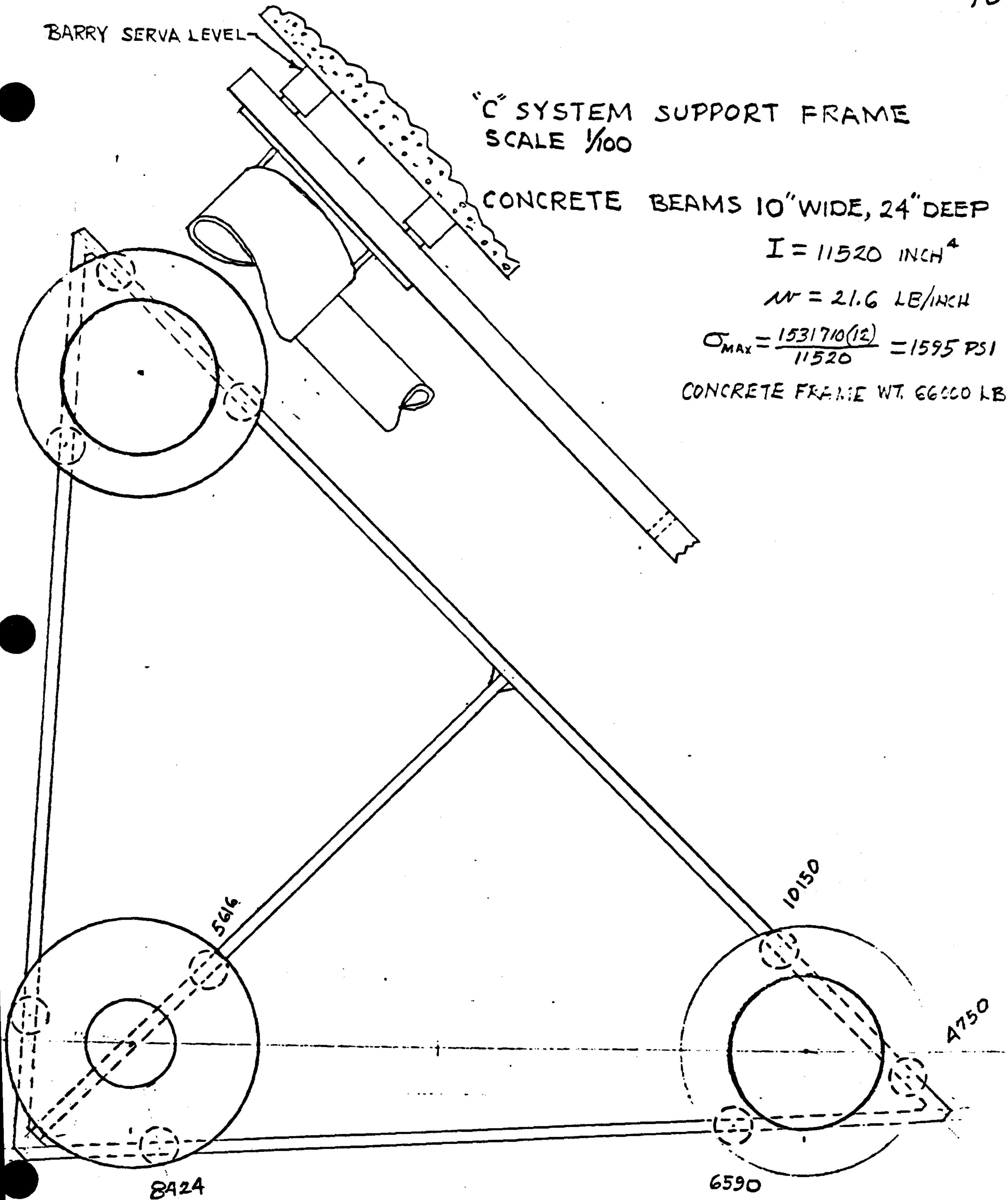
CONCRETE BEAMS 10" WIDE, 24" DEEP

$I = 11520 \text{ INCH}^4$

$w = 21.6$ LB/INCH

$\sigma_{MAX} = \frac{1531710(12)}{11520} = 1595$ PSI

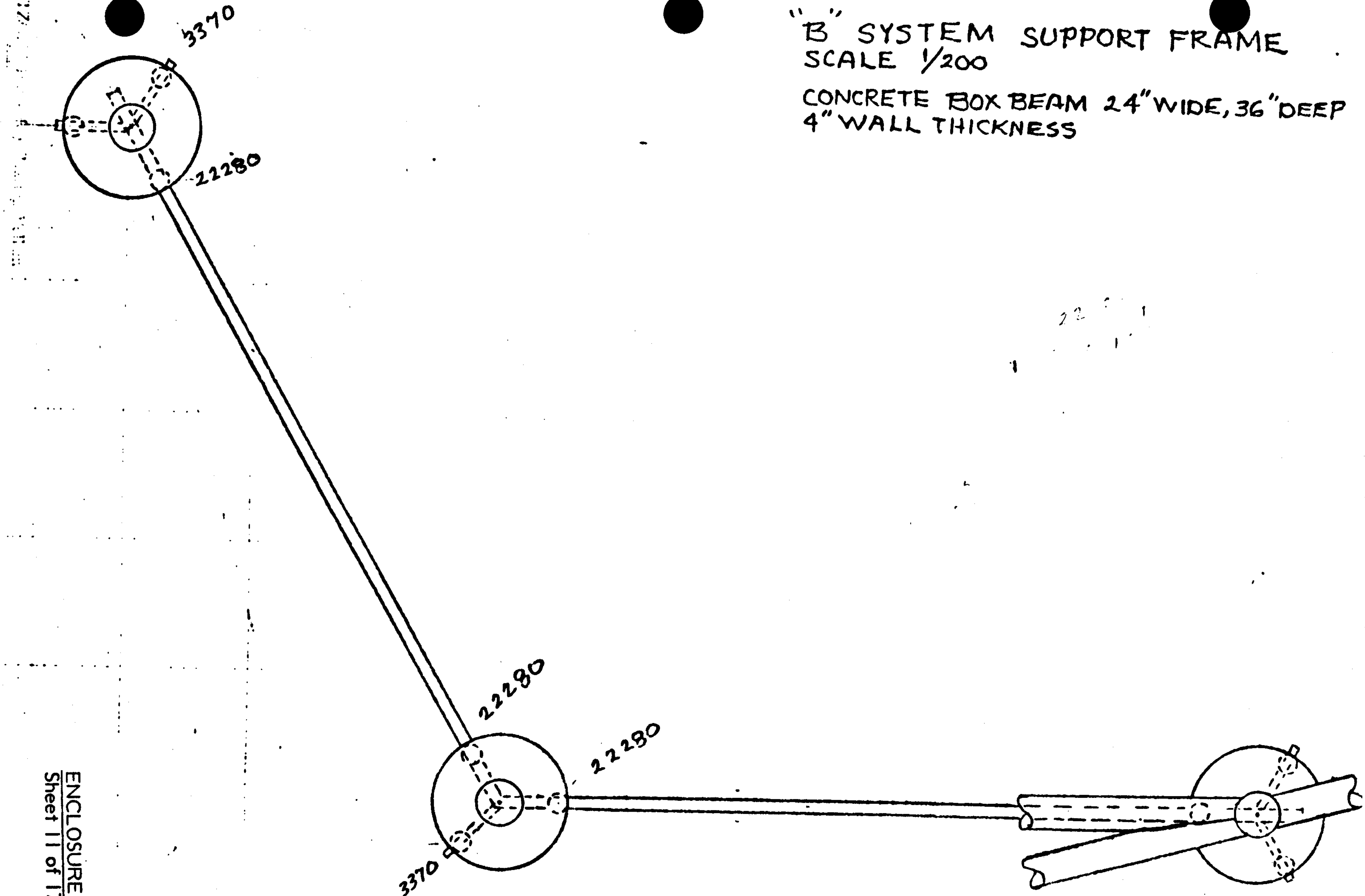
CONCRETE FRAME WT. 66000 LB



ENCLOSURE "D"
Sheet 10 of 17

"B" SYSTEM SUPPORT FRAME
SCALE 1/200

CONCRETE BOX BEAM 24" WIDE, 36" DEEP
4" WALL THICKNESS

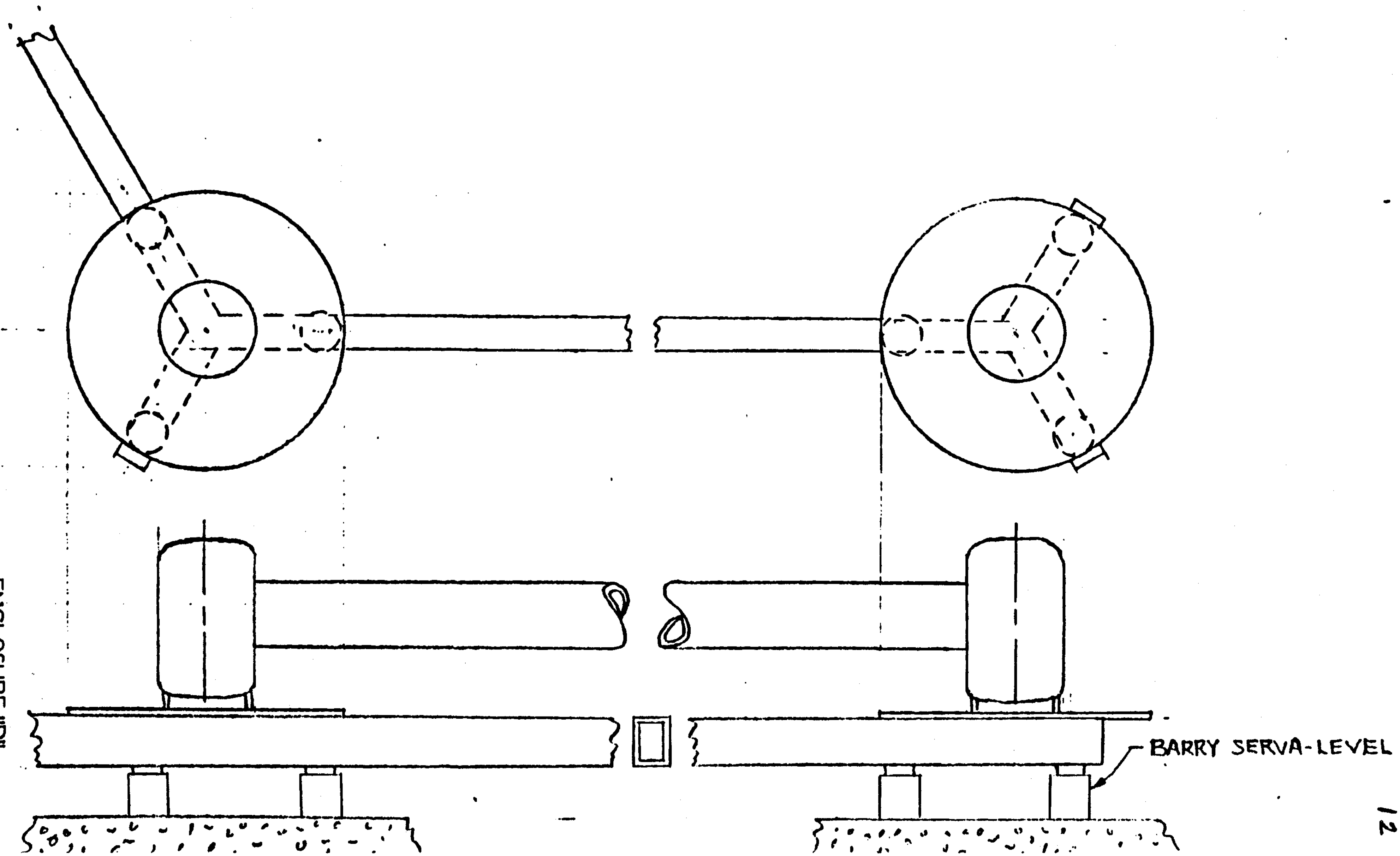


ENCLOSURE "D"
Sheet 11 of 17

"B" SYSTEM SUPPORT FRAME

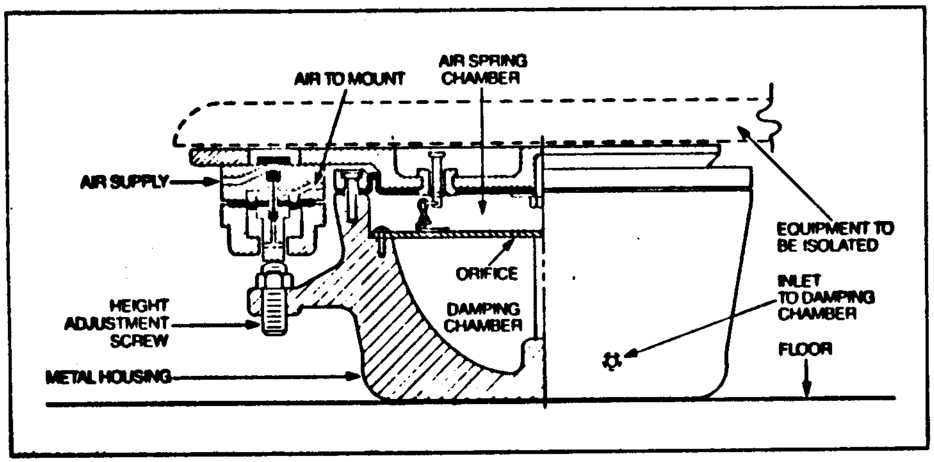
SCALE 1/100

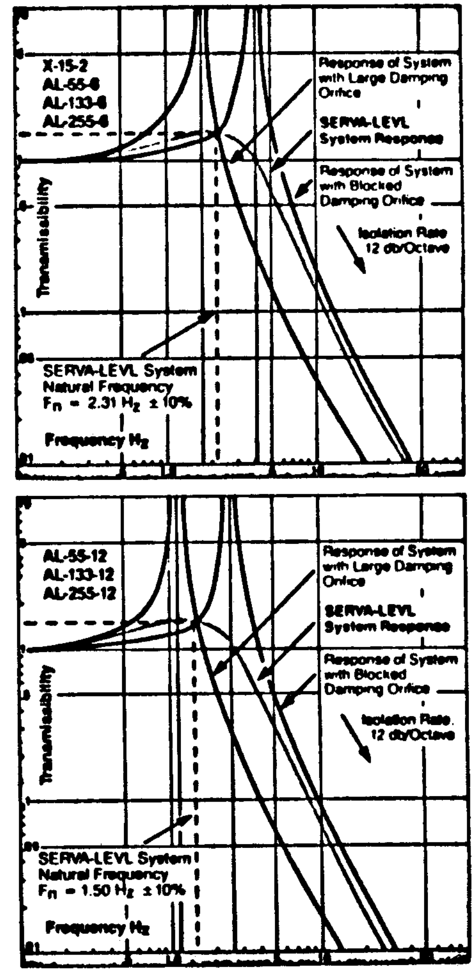
CONCRETE BOX BEAM 24" WIDE, 36" DEEP
4" WALL TIHCKNESS



ENCLOSURE "D"
Sheet 12 of 17

BASIC SERVA-LEVL UNIT
by BARRY CONTROLS

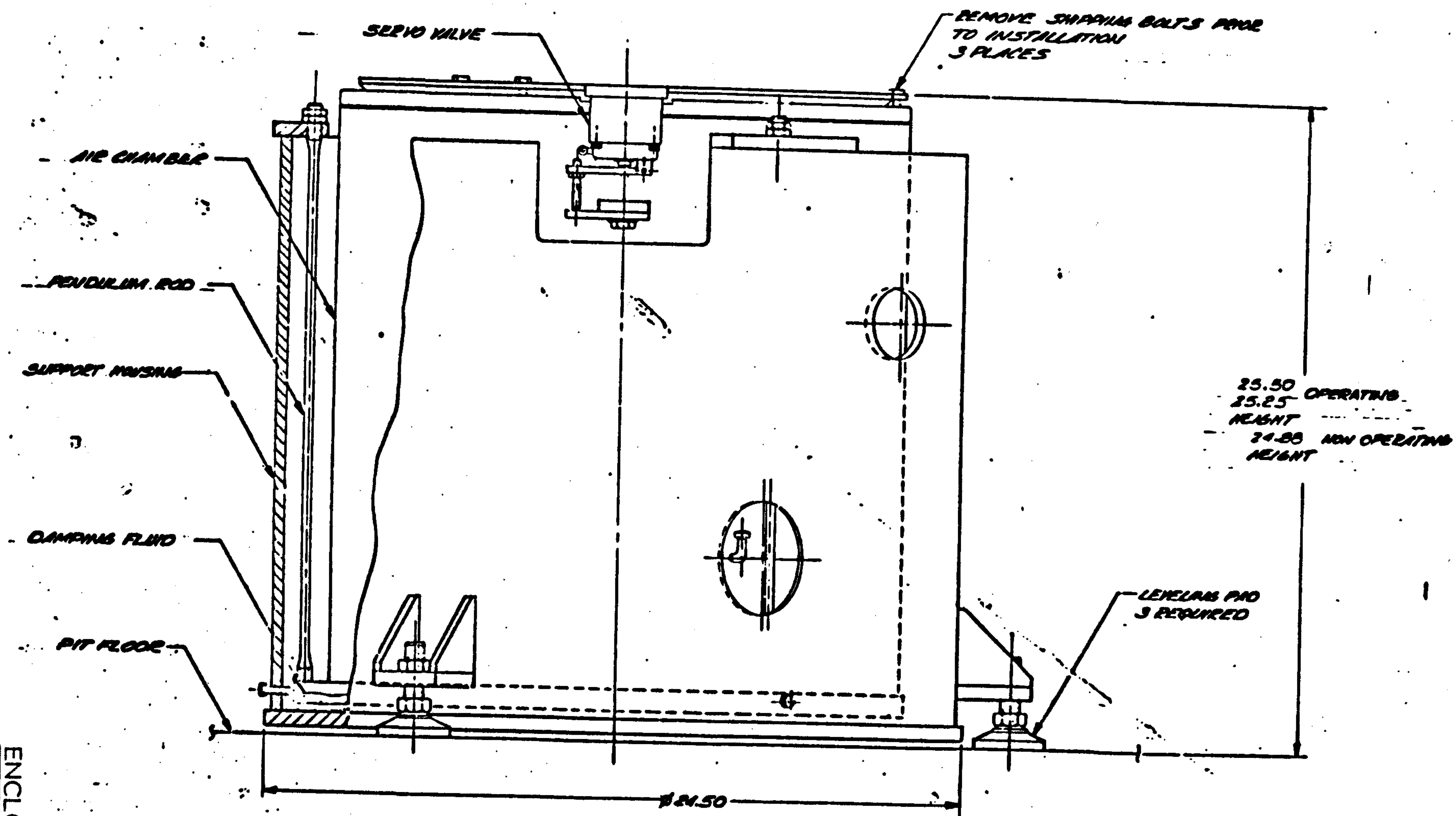




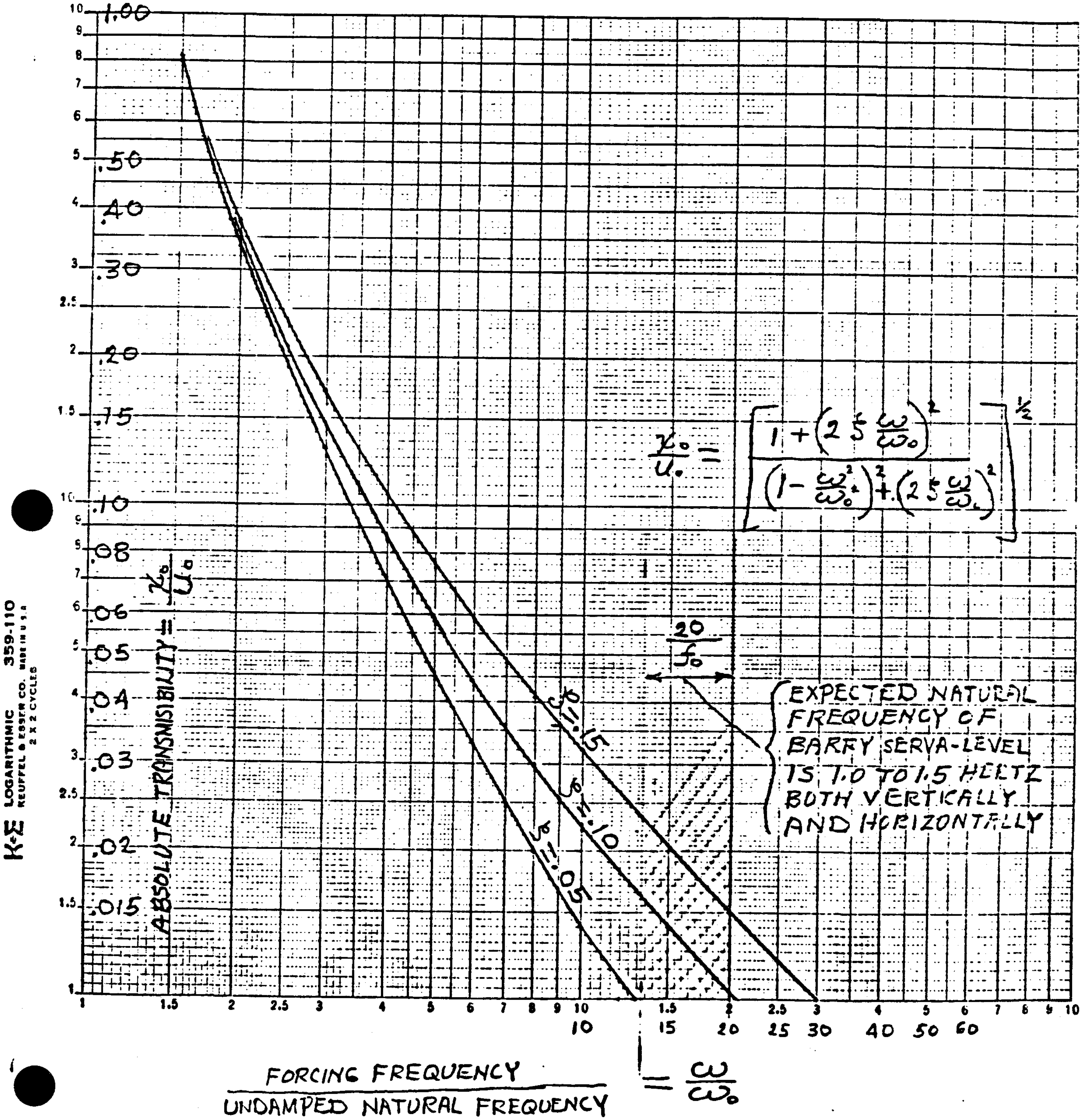
TRANSMISSIBILITY vs. FREQUENCY (vertical)

ENCLOSURE "D"
Sheet 13 of 17

BARRY CONTROLS SERVA-LEVL PENDULOUS MOUNT ACHIEVES HORIZONTAL ISOLATION AS WELL AS VERTICAL ISOLATION.



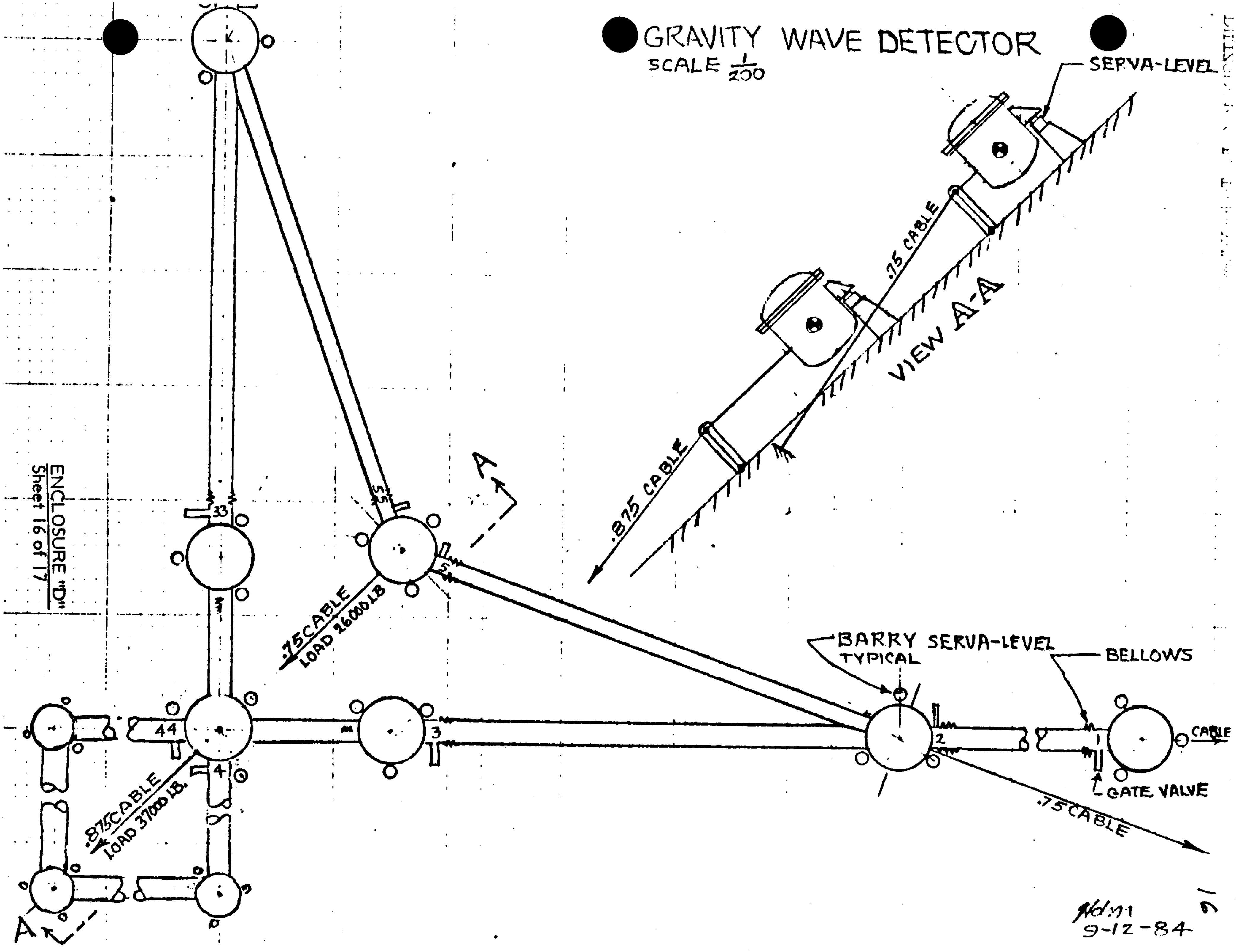
ENCLOSURE "D"
Sheet 14 of 17



FORCING FREQUENCY / UNDAMPED NATURAL FREQUENCY $= \frac{\omega}{\omega_0}$

GRAVITY WAVE DETECTOR

SCALE 1/200



ENCLOSURE "D"
Sheet 16 of 17

9-12-84

	REACTION ON SERVA LEVELS	TOTAL NO. OF SERVA LEVEL REQ
END STA 10' TANK —	21000 LB	6
MID STA. 10' TANK	21000	6
"B" SYSTEM 6' TANK	35600 2	4
	16700	5
"C" SYSTEM 6' TANK ONE 10' TANK TWO	21750	2
	19950	1
	26800 2	2
	21400	2
	23250	2
"A" SYSTEM 10' TANK	20900	1
	23100	2
	23300	2
	21200	2
	21250	2
		39

TEN SETS OF 3 AT $21000/SET = 210000
THRE SETS OF 4 AT $28000/SET = 112000

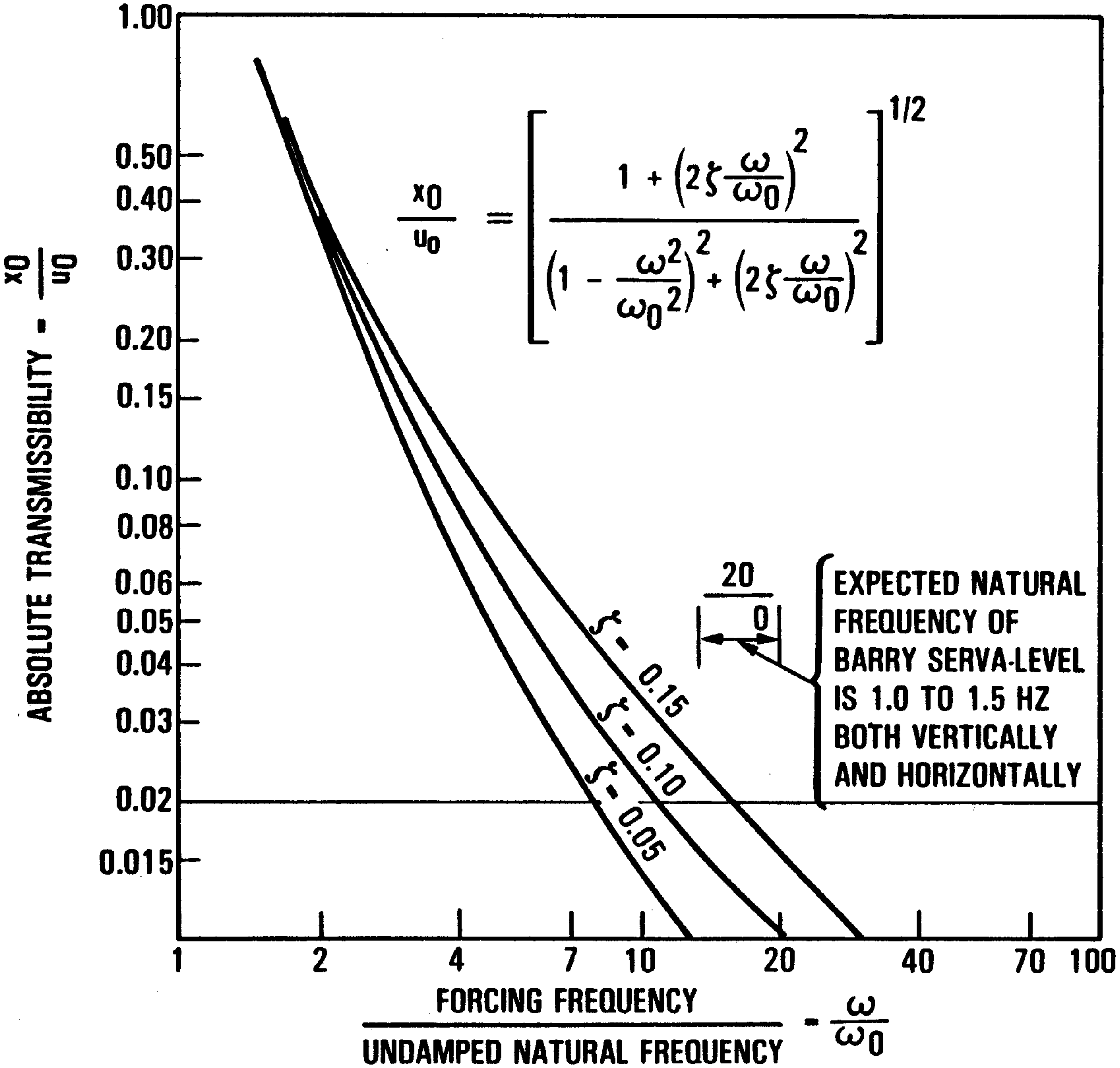
$322000

ENCLOSURE "D"
Sheet 17 of 17

JPL

Gravity Wave Observatory

RESPONSE OF DAMPED SINGLE SPRING-MASS SYSTEM

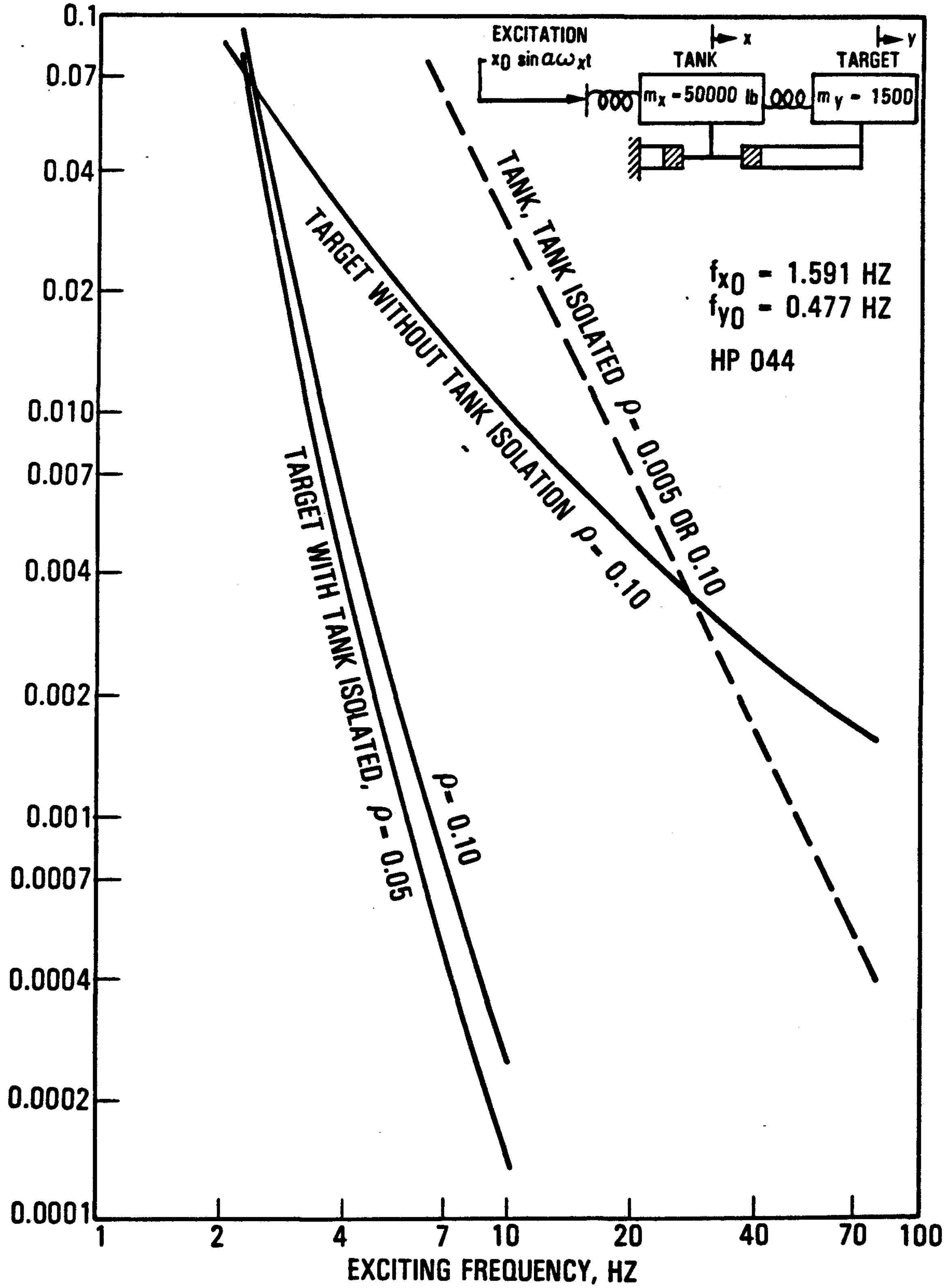


HM-4
12/12/84

Gravity Wave Observatory

JPL

RESPONSE OF DAMPED DOUBLE SPRING-MASS SYSTEM



V0132
CS002

HM-5
12/12/84

GRAVITY WAVE OBSERVATORY
ROTATING MACHINERY VIBRATION FREQUENCY

HVAC UNIT

• COMPRESSOR	57.5 Hz
• CONDENSER FAN	13.8 Hz *
• BLOWER	17.1 Hz *
• EXHAUST FAN	22.0 Hz *

CRYOGENIC PUMP

• CRYOGENIC PUMP	1.5 - 2.0 Hz *
• CRYOGENIC COMPRESSOR	50 - 60 Hz
• CONDENSER FAN	20 - 30 Hz

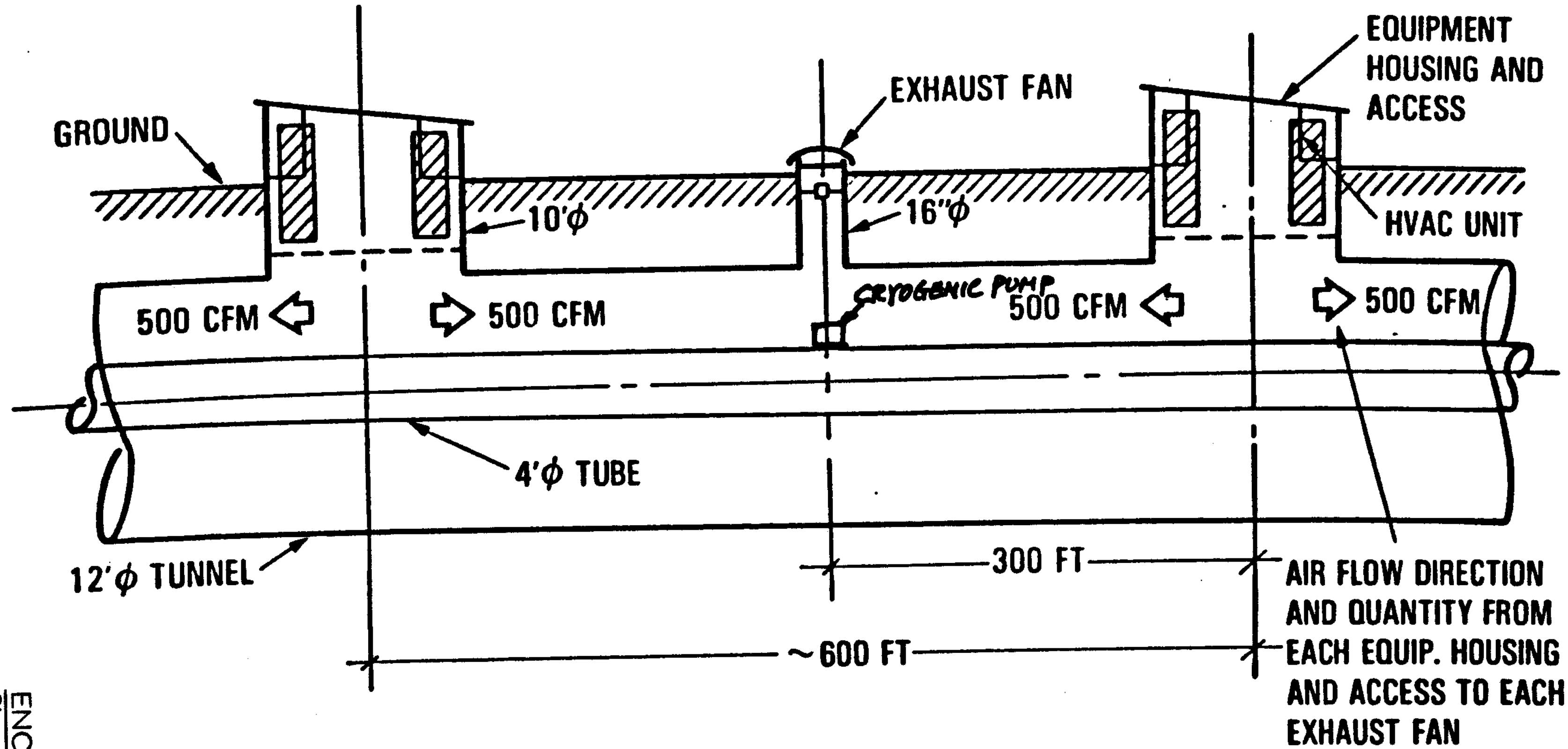
ENCLOSURE "G"
Sheet 1 of 2

* DISTURBANCE FREQUENCY IS LOWER THAN THE DESIGN REQUIREMENT OF 20 Hz

JPL

Gravity Wave Observatory

EQUIPMENT LAYOUT



ENCLOSURE "G"
Sheet 2 of 2

V0132
CS015

AH-5
12/12/84

CY-2

GRAVITY WAVE OBSERVATORY

SOUND AND VIBRATION CONTROL

BY

CHRISTOPHER S. YUNG

FEBRUARY 20, 1985

GRAVITY WAVE OBSERVATORY

Table 7 . . . . Ranges of Indoor Design Goals for Air-Conditioning System Sound Control
(Note: These are for unoccupied spaces, with all systems operating)

Type of Area	*Range of A-Sound Levels, Decibels*	*Range of NC Criteria Curves*
RESIDENCES		
Private homes (rural and suburban)	25–35	20–30
Private homes (urban)	30–40	25–35
Apartment houses, 2- and 3-family units	35–45	30–40
HOTELS		
Individual rooms or suites	35–45	30–40
Ballrooms, banquet rooms	35–45	30–40
Halls and corridors, lobbies	40–50	35–45
Garages	45–55	40–50
Kitchens and laundries	45–55	40–50
HOSPITALS AND CLINICS		
Private rooms	30–40	25–35
Operating rooms, wards	35–45	30–40
Laboratories, halls and corridors		
Lobbies and waiting rooms	40–50	35–45
Washrooms and toilets	45–55	40–50
OFFICES		
Board room	25–35	20–30
Conference rooms	30–40	25–35
DESIGN → Executive office	35–45	30–40
Supervisor office, reception room	35–50	30–45
General open offices, drafting rooms	40–50	35–45
Halls and corridors	40–55	35–50
Tabulation and computation	45–65	40–60
	40–55	40–50
AUDITORIUMS AND MUSIC HALLS		
Concert and opera halls		
Studios for sound reproduction	20–30	15–25
Legitimate theaters, multi-purpose halls	30–35	25–30
Movie theaters, TV audience studios		
Semi-outdoor amphitheaters	35–45	30–35
Lecture halls, planetarium		
Lobbies	40–50	35–45
CHURCHES AND SCHOOLS		
Sanctuaries	25–35	20–30
Libraries	35–45	30–40
Schools and classrooms	35–45	30–40
CHURCHES AND SCHOOLS (Cont'd)		
Laboratories	40–50	35–45
Recreation halls	40–55	35–50
Corridors and halls	40–55	35–50
Kitchens	45–55	40–50
PUBLIC BUILDINGS		
Public libraries, museums, court rooms	35–45	30–40
Post offices, general banking areas, lobbies	40–50	35–45
Washrooms and toilets	45–55	40–50
RESTAURANTS, CAFETERIAS, LOUNGES		
Restaurants	40–50	35–45
Cocktail lounges	40–55	35–50
Night clubs	40–50	35–45
Cafeterias	45–55	40–50
STORES, RETAIL		
Clothing stores } Department stores (upper floors) }	40–50	35–45
Department stores (main floor) } Small retail stores }	45–55	40–50
Supermarkets	45–55	40–50
SPORTS ACTIVITIES, INDOOR		
Coliseums	35–45	30–40
Bowling alleys, gymnasiums	40–50	35–45
Swimming pools	45–60	40–55
TRANSPORTATION (RAIL, BUS, PLANE)		
Ticket sales offices	35–45	30–40
Lounges and waiting rooms	40–55	35–50
EQUIPMENT ROOMS		
8 hr/day exposure	<90	
3 hr/day exposure	<97	
(or per OSHA requirement)		

Note: NC curves are shown in Fig. 5. For a discussion of the relations between NC curves and A-weighted sound level, see Chapter 6, 1972 HANDBOOK OF FUNDAMENTALS

EXTRACTED FROM ASHRAE 1976

CSY-2

GRAVITY WAVE OBSERVATORY

Table 5 . . . . Typical Sound Pressure Levels

	150dB		Short exposure can cause hearing loss
	140	Jet plane takeoff	
	130	Artillery fire Machine gun Riveting	
Deafening	120	Siren at 100 ft. Jet plane (passenger ramp) Thunder—Sonic boom	Threshold of pain
	110	Woodworking shop Accelerating motorcycle Hard rock band	Threshold of discomfort
	100	Subway (steel wheels) Loud street noise Power lawnmower Outboard motor	
Very loud	90	Truck unmuffled Train whistle Kitchen blender Pneumatic jackhammer	
	80	Printing press Subway (rubber wheels) Noisy office Average factory	Intolerable for phone use
Loud	70	Average street noise Quiet typewriter Freight train at 100 ft. Average radio	
	60	Noisy home Average office Normal conversation	
Moderate	50	General office Quiet radio Aberage home Quiet street	
	40	Private office Quiet home	←
Faint	39	Quiet conversation Broadcast studio	
	20	Empty auditorium Whisper	
Very faint	10	Rustling leaves Soundproof room Human breathing	
	0db		Threshold of Audibility

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CSY-3

GRAVITY WAVE OBSERVATORY

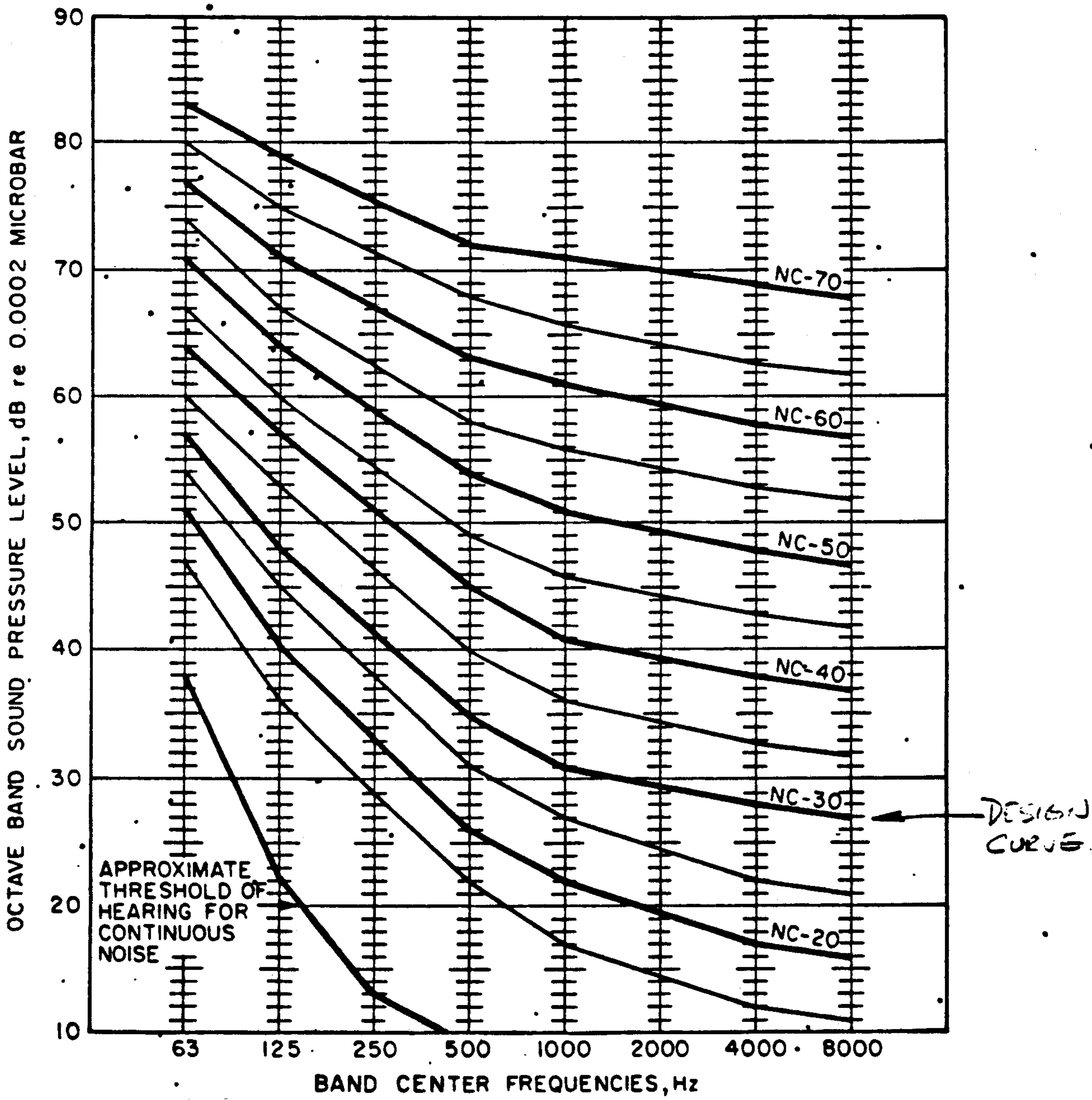

Fig. 5. . . . Noise Criterion Curves for Specifying the Design Level in Terms of the Maximum Permissible Sound Pressure Level for Each Frequency Band

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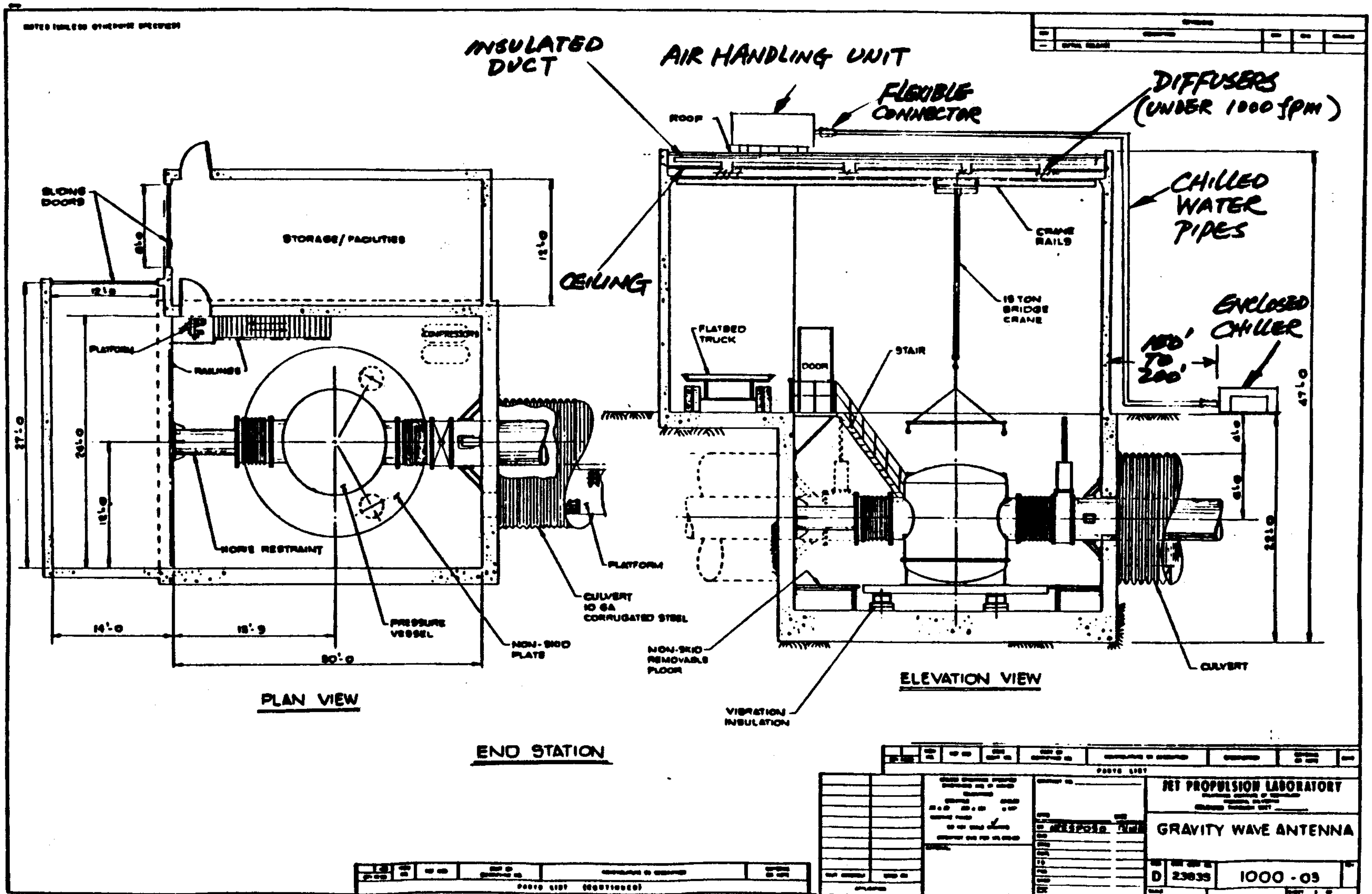
Gravity Wave Observatory

END AND INTERMEDIATE BUILDING



V0132
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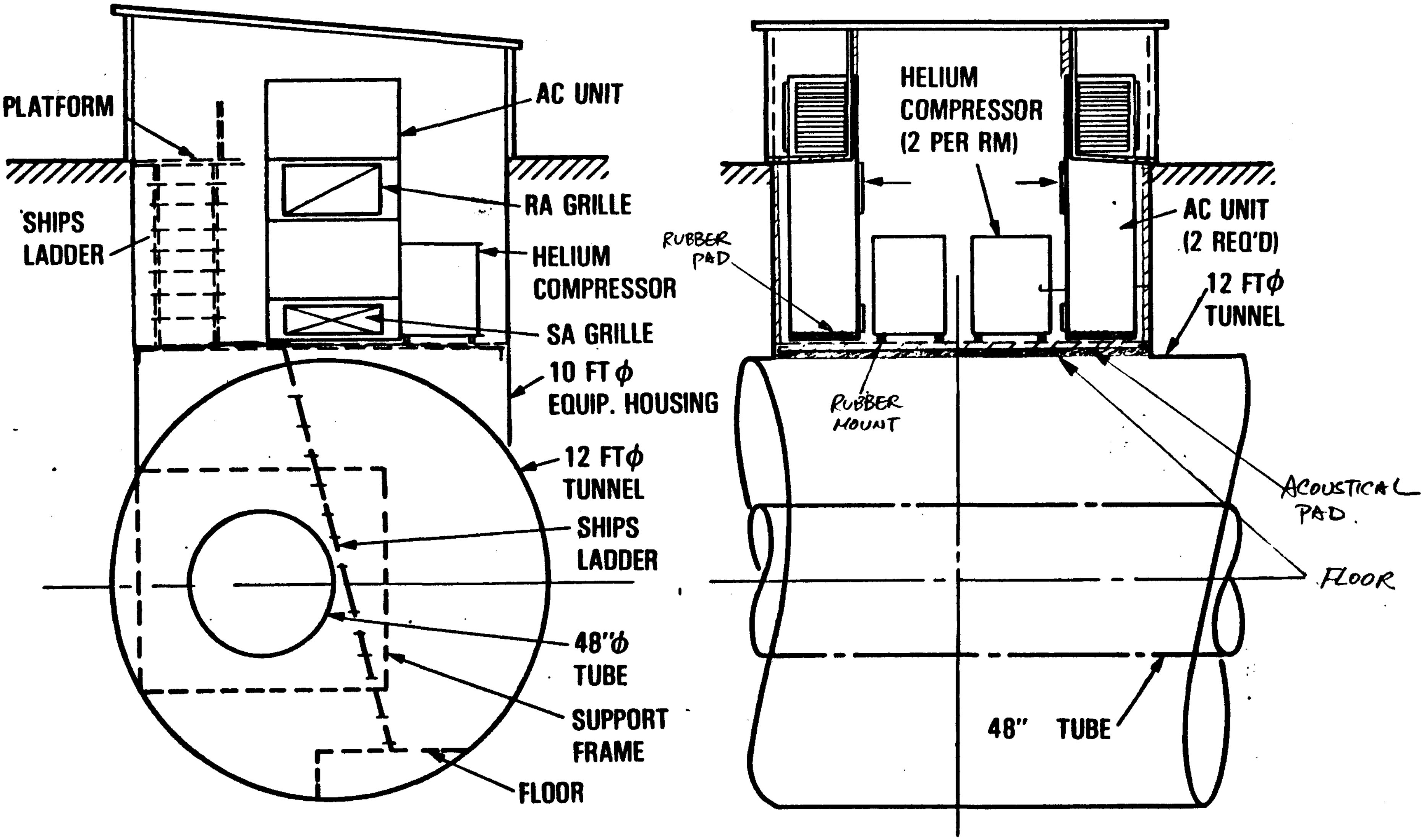
12/12/84

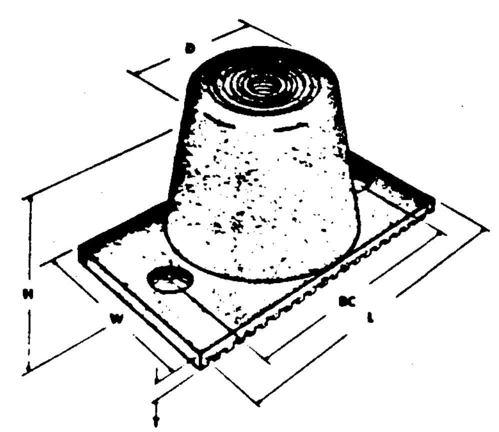
CSY-5

Gravity Wave Observatory

EQUIPMENT HOUSING AND ACCESS (Cont'd)



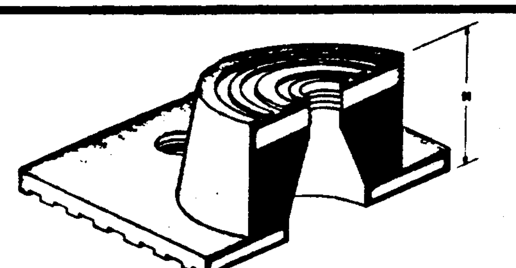
SECTION VIEWS



TYPE ND

ENGINEERING DATA

Type and Size	Recommended Load Range	Max. Static Deflection		Length L	Width W	Height H		Tapped Hole TH	Bolt Centers BC	Base T	Top Dia. D
	Pounds	Type N	Type ND			Type N	Type ND				
NA Black Green Red	15-35 25-55 40-90	0.11	–	3 3/16	1 11/16	7/8	1 1/2	5/16-18	2 3/8	3/16	1 1/4
NDA Black Green Red	15-45 30-75 60-125	–	0.35								
NB or NDB Black Green Red White	50-100 75-150 110-235 180-380	0.20	0.40	3 7/8	2 5/16	1 1/8	1 7/8	3/8-16	3	1/4	1 3/4
NC or NDC Green Red White Yellow	140-260 200-400 310-600 520-1000	0.25	0.50	5 1/2	3 5/16	1 5/8	2 3/4	1/2-13	4 1/8	1/4	2 9/16
NDD Yellow	900-2200	–	0.50	6 1/4	4	–	2 3/4	1/2-13	5	1/4	3 3/8
NDE Yellow	2000-4300	–	0.50	7 3/8	5 1/8	–	2 3/4	1/2-13	6 1/8	1/4	4 1/2

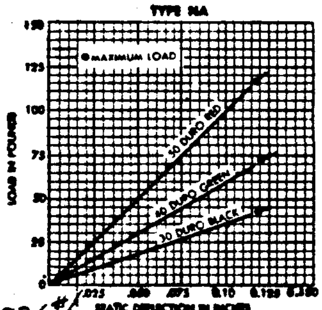


TYPE N

SIZE	BASE PLATE HOLES
NA or NDA	11/32 D
NB or NDB	11/32 D
NC or NDC	9/16 D
NDD	9/16 D
NDE	9/16 D

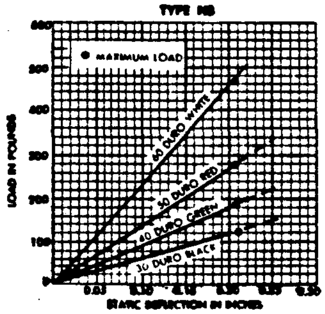
LOAD DEFLECTION CURVES

TYPE NA

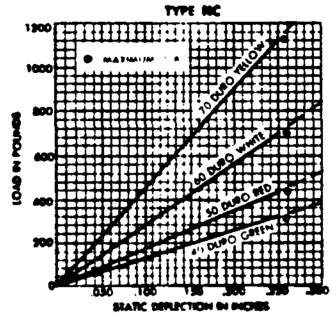


x 236#/in

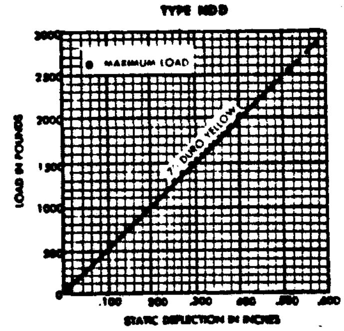
TYPE NB



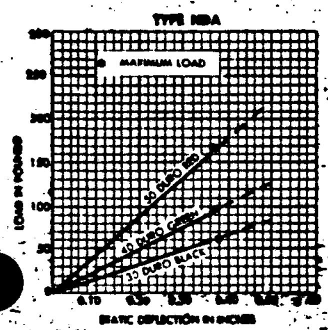
TYPE NC



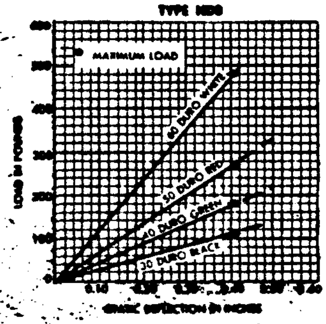
TYPE NDD



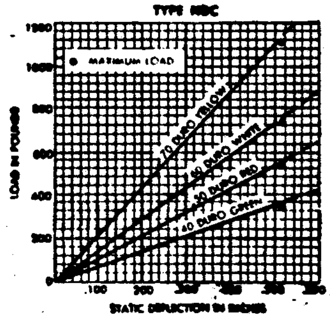
TYPE NDA



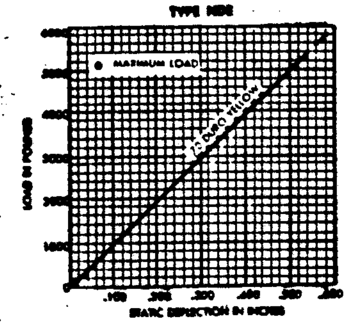
TYPE NDB



TYPE NDC

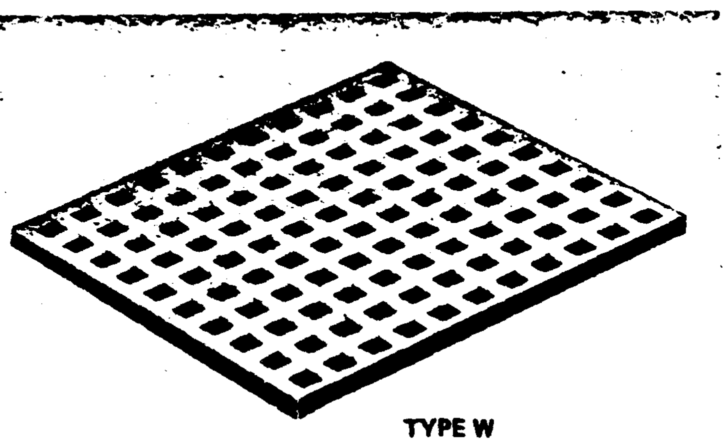


TYPE NDE

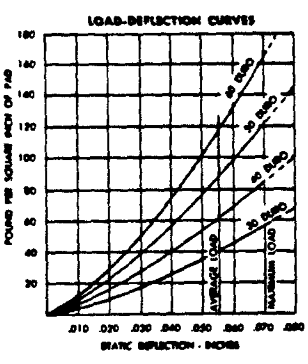


CSY-7

Vibration Pads are used to reduce noise and vibration and to eliminate the need for bolting down. The flat configuration hardly elevates the machine to be isolated and in many cases this low cost method conveniently solves or prevents a problem that does not warrant the use of either rubber or spring mountings. As a general rule, pads are recommended to eliminate bolting, for minor vibration problems in upper stories or for ground floor and non critical applications.



TYPE W
NEOPRENE WAFFLE PAD



Other oil-resistant stocks may be substituted for Neoprene as new elastomers are developed.

Durometer or Hardness	Recommended Loading PSI	Max. Load PSI	Apx. Ratio Dynamic Modulus / Static Modulus
			1.00
30	40	55	1.00
40	60	85	1.24
50	90	120	1.51
60	120	170	1.82

Low durometer pads are preferable for noise and vibration isolation. Select the harder materials for economy or concentrated loads. Pad life is extended by light loading the selected durometer.

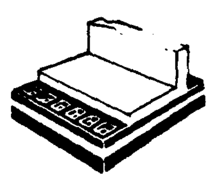
Pads may be stacked to increase deflection. Multiply the single layer deflections shown by the number of pads used to determine the overall deflection.

THE TYPE "W" Neoprene Waffle has greater carrying capacity per square inch, increased holding power and a built in contamination seal. Identical rubber grids are molded back to back for maximum rubber contact area and resistance to rib collapse or hinging. The interconnections form suction pockets for gripping smooth steel as well as rough surfaces and also act as dirt and oil dams at the perimeter regardless of how the pad is cut. The square waffle pattern is layed out on ½" centers to facilitate cutting pads to size in the field without the need for measuring.

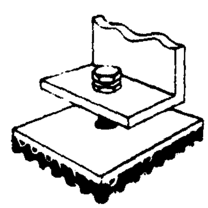
While there is no need for bolting or cementing on most installations, Type "W" Adhesive may be used for securing machines that have exceptionally large horizontal forces. The adhesive is also useful when the pad is made part of an assembly or shipped cemented to machinery legs.

The Waffle Pad is stocked in both 40 and 50 durometer Neoprene. The high tensile black stock has been selected for its oil resistance and physical specifications. Colored stocks, Natural Rubber, Hycar, Butyll, Silicone or other of the Elastomers can be furnished for special conditions. Pricing would be dependent on material and quantity. Standard pads are 5/16" thick and may be purchased 18" x 36", 18" x 18" or cut to size.

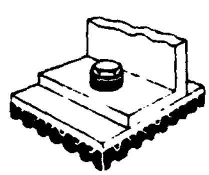
Waffle Mounts are made by cold bonding a type "W" pad to a steel plate. They are used when a machine leg has too small a bearing area to be placed directly on the pad and there is need for a steel load distributing plate.



STYLE WMW has a Waffle gripping surface both top and bottom. No bolting is required.



STYLE WML can be used under equipment that already has built in leveling bolts. The steel plate is extra heavy and counter bored to position the leveling bolt.



STYLE WM is recommended when the equipment must be anchored. The mounting is drilled for ¾" D. or smaller bolts.

Type and Size		Rated Load Lbs.	Length Inches	Width Inches	Height Inches
WMW WML WM	200	200	2	2	½
	450	450	3	3	½
	800	800	4	4	5/8
	1250	1250	5	5	5/8
	1800	1800	6	6	5/8
	2400	2400	6	8	5/8
	3000	3000	6	10	¾
	4000	4000	8	10	¾
	4800	4800	8	12	¾
	5600	5600	8	14	1

Note: Height varies with type. Listed heights are average.
Loadings based on 40 Durometer "W" pad loaded 50 psi. 50 Duro pads may be used for heavier capacities.
Mounts can be furnished with type "NK" pads on request.

CSY-8

GRAVITY WAVE OBSERVATORY

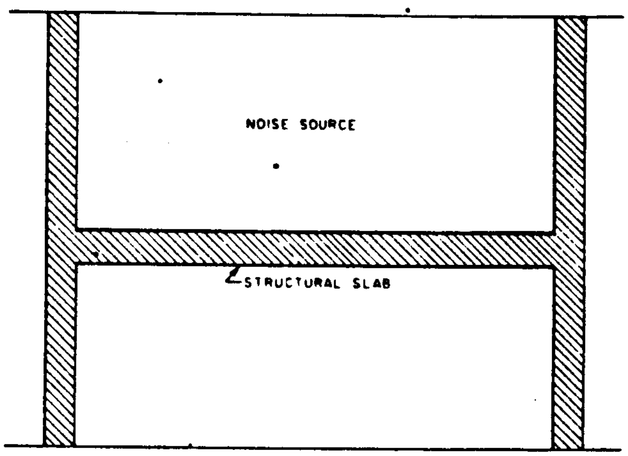
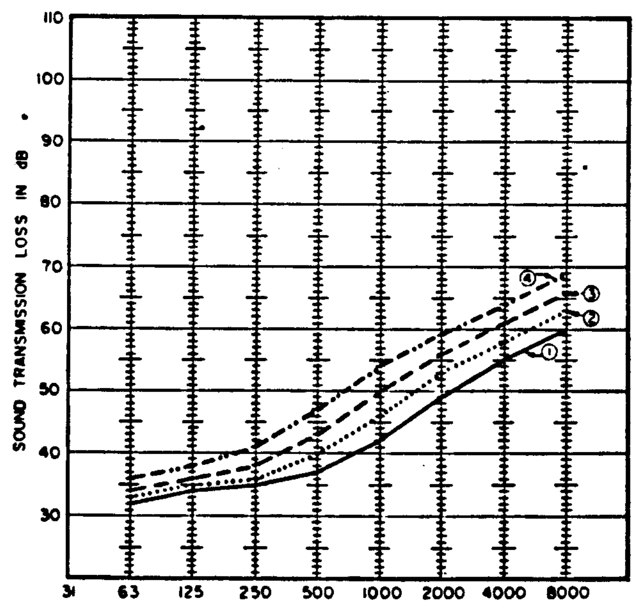


Fig. 34A. . . . Structural Slab with Noise Impinging Directly



1. 3-in. and 4-in. thick structural slab.
2. 6-in. thick structural slab.
3. 8-in. thick structural slab.
4. 12-in. thick structural slab.

Fig. 34B. . . . Anticipated Sound Transmission Loss for Flat Plate Structural Slabs

EXTRACTED FROM ASHRAE 1976

CSS-9

GRAVITY WAVE OBSERVATORY

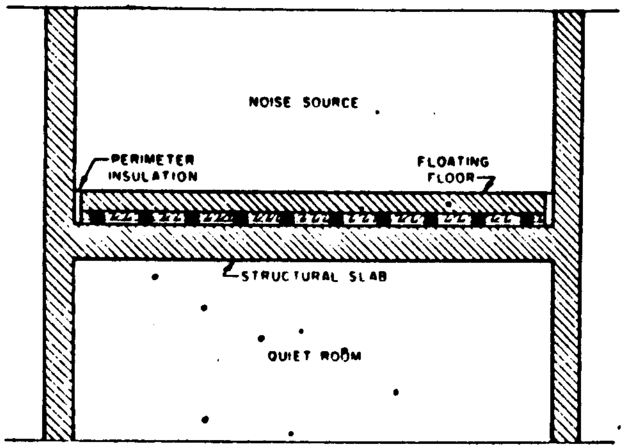


Fig. 35A. . . . Floating Floor with Noise Source Unshielded, so that Flanking Around the Floating Floor May Occur

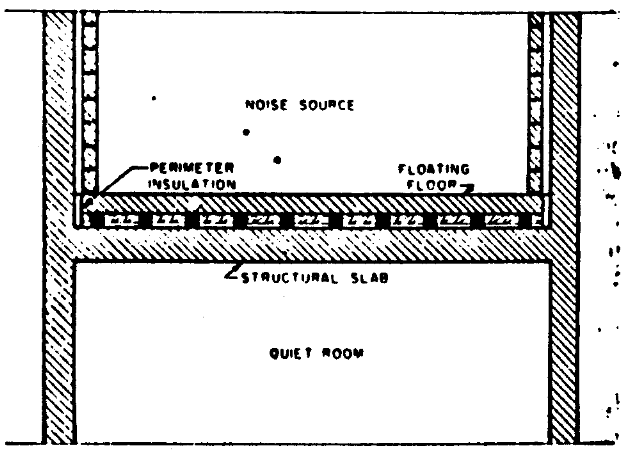
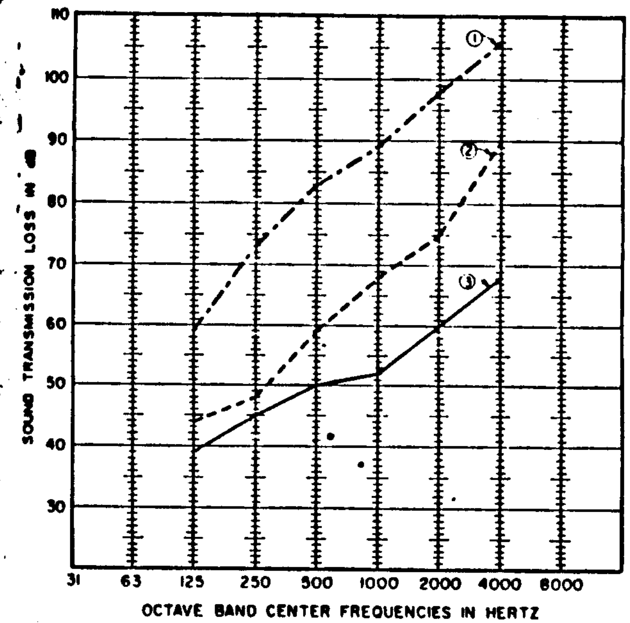


Fig. 35B. . . . Floating Floor with Noise Source Shielded to Prevent Flanking, or Short Circuiting of the Noise Around the Floating Floor



1. Transmission loss for 4-in. floating floor, 2-in. glass fiber filled air cavity over structural floor with source noise shielded to prevent flanking.
2. Transmission loss for 4-in. floating floor, 2-in. air cavity over structural floor, noise source unshielded, resulting in some flanking.
3. Transmission loss for structural floor only.

Fig. 35C. . . . Floating Floor Sound Transmission Loss

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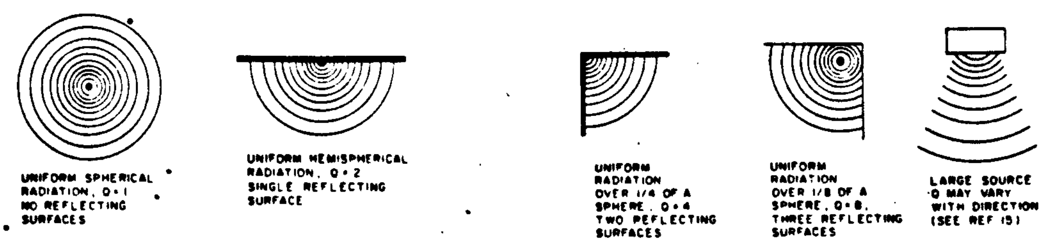
GRAVITY WAVE OBSERVATORY

Table 3 . . . . Decibel Difference Between Power Level of Outdoor Equipment Noise and Corresponding Sound Pressure Level at Any Distance, *r*[a]

Distance, r, in Feet	10	15	20	30	40	60	80	120	200	500	1000[b]
$(L_w - L_p)$ for $Q = 2$	18	21	24	27	30	33	36	39	43	51	57–62
$(L_w - L_p)$ for $Q = 4$	15	18	21	24	27	30	33	36	40	48	54–59
$(L_w - L_p)$ for $Q = 8$	12	15	18	21	24	27	30	33	37	45	51–56

[a] Table does not apply when *r* is less than twice the maximum dimension of the equipment. Values may be up to 5 dB low for distances between 2 and 5 times maximum equipment dimension.
[b] At distances above 1000 ft, air absorption and atmospheric conditions become important.



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L_w = POINT OF NOISE GENERATION
L_p = POINT OF MEASUREMENT.

Table 4. Sound-Transmission Loss in Building Partitions

Wall	Thickness, in.	Weight, lb per sq ft	Transmission loss, db
Wood	0.2	0.45	18.5
Plate glass	0.25	3.2	27.0
Hollow gypsum tile, unplastered	3	11.1	27.2
Brick wall, unplastered	....	22.0	33
Brick wall, plastered	6	46	43
Brick wall, plastered	10.5	93	49
Double wall; metal lath, ½ in. gypsum plaster, on staggered 2 × 4 in. wood studs	7.5	19.8	44
Double 3 in. hollow gypsum tile, unplastered, 3 in. air space	9	22.0	42.6
1 in. Thermax nailed over building paper to 3 in. Thermax laid up in mortar, ½ in. plaster on both sides	5	15	47
Double 2 in. solid-gypsum tile, unplastered, completely isolated structurally by separate foundations, 4 in. air space	8	20.4	59

Based on Sabine, "Acoustics and Architecture," McGraw-Hill.

EXTRACTED FROM MARKS MECHANICAL ENGINEERING HANDBOOK

CSY-11

GRAVITY WAVE OBSERVATORY

Table 8 . . . . Sound Pressure Levels of Typical Noise Sources*

Source	*dBA*	*NC*
Air Compressors	80–100	75–115
Boilers	80–110	75–105
Chillers	80–110	75–105
Air-Cooled Condensers	80–110	75–100
Cooling Towers	60–80	55–75
Centrifugal Fans (Medium to Large over 300 rpm)	80–110	75–105
Inline Fans	90–110	85–105
Pumps	60–80	55–75
Fan-Coil Units	40–60	35–55
Induction Units (function of Nozzle Pressure)	40–70	35–65
Diffusers over 1000 fpm	40–60	35–55
Diffusers under 1000 fpm	15–35	15–35

*Figures as developed by testing engineer based on field measurements and catalog data. Should be used as approximate guide only as actual sound pressure level can vary from indicated ranges.

Table 6 . . . . Background Correction

Decibel difference between sound level when air-conditioning equipment is operating (total level) and when it is not operating (background level)	*0*	*1*	*2*	*3*	*4*	*7*	*10*
Decibels to be subtracted from total sound level in order to get the sound level due to airconditioning equipment alone	over 10	7	4	3	2	1	0.5

Table 7 . . . . Combining Two Sound Levels

Difference Between Two Levels To Be Combined, dB	*0–1*	*2–4*	*2–9*	*10 and more*
Number of Decibels to be Added to Higher Level to Obtain Combined Level	3	2	1	0

EXTRACTED FROM ASHARE 1976

GRAVITY WAVE OBSERVATORY

Table 25. . . . Vibration Criteria

Equipment	*Maximum Allowable Vibration* Peak-to-Peak Displacement, Mils (0.001 in.)*
Pumps	
1800 RPM	2
3600 RPM	1
Centrifugal Compressors	1
Fans (Vent Sets, Centrifugal, Axial)	
Under 600 RPM	4
600–1000 RPM	3
1000–2000 RPM	2
Over 2000 RPM	1

*For equipment installed on inertia blocks: reduce allowable vibration by ratio of weight of equipment to total weight of equipment and inertia block. For example, 700 RPM fan weighing 1000 lb on 2000 lb inertia block. Allowable vibration is (1000/3000) × 3 = 1 mil.

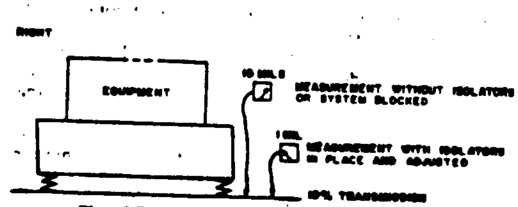

Fig. 15. . . . Testing Isolation Efficiency

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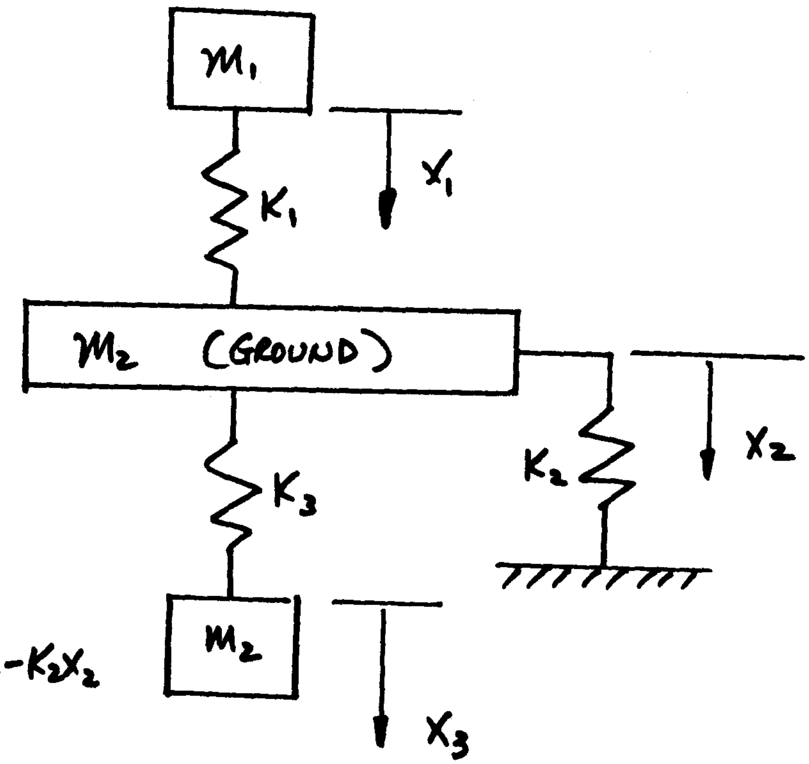
REFERENCE · ASHRAE HANDBOOK 1976.

THE MAXIMUM ALLOWABLE VIBRATION LEVELS SHOWN IN ABOVE TABLE ARE BASED ON EQUIPMENT INSTALLED ON REASONABLY EFFECTIVE ISOLATORS ($f_d/f_n \geq 3:1$ OR AT LEAST 1-IN DEFLECTION SYSTEMS FOR EQUIPMENT OPERATING ABOVE 600 RPM)

CSY-13

GRAVITY WAVE OBSERVATORY

SIMPLIFIED VIBRATION MODEL



$$m_1\ddot{x}_1 = -K_1(x_1 - x_2)$$

$$m_2\ddot{x}_2 = -K_1(x_2 - x_1) - K_3(x_2 - x_3) - K_2 x_2$$

$$m_3\ddot{x}_3 = -K_3(x_3 - x_2)$$

BATCH START

STAPLE
OR
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BUILDINGS

The following information describes the major equipment layout and square footage for the six primary buildings required for the LIGO. Detail elements and associated costs are described in the WBS and in the Functional Requirements Document.

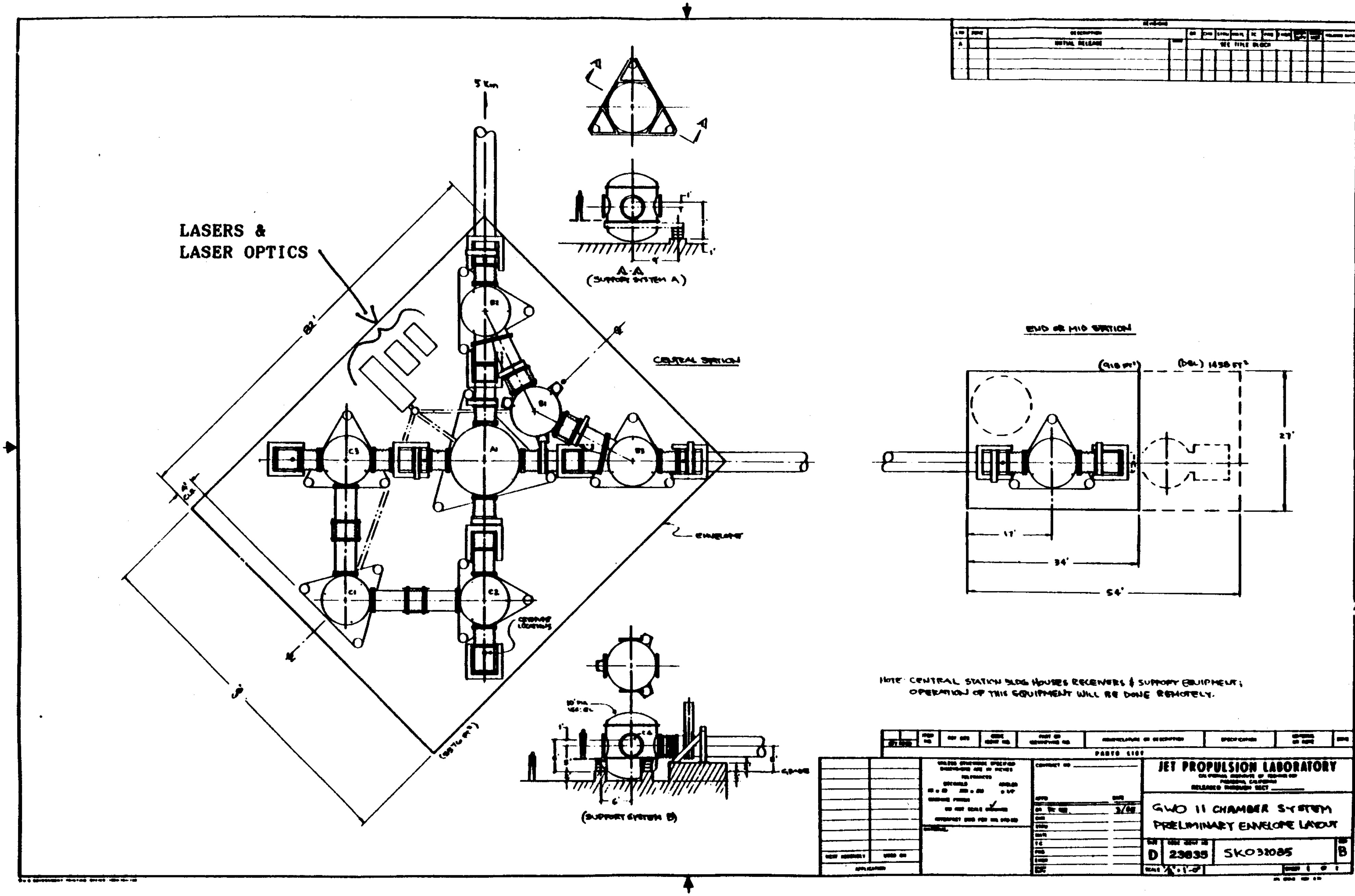


Figure 4.1-1

The corner, mid, and end stations of the LIGO shown at a later date, after the addition of three more chambers.

TOP RIDING SINGLE GIRDER CRANE

3/8/85

WPL

10 ton rating

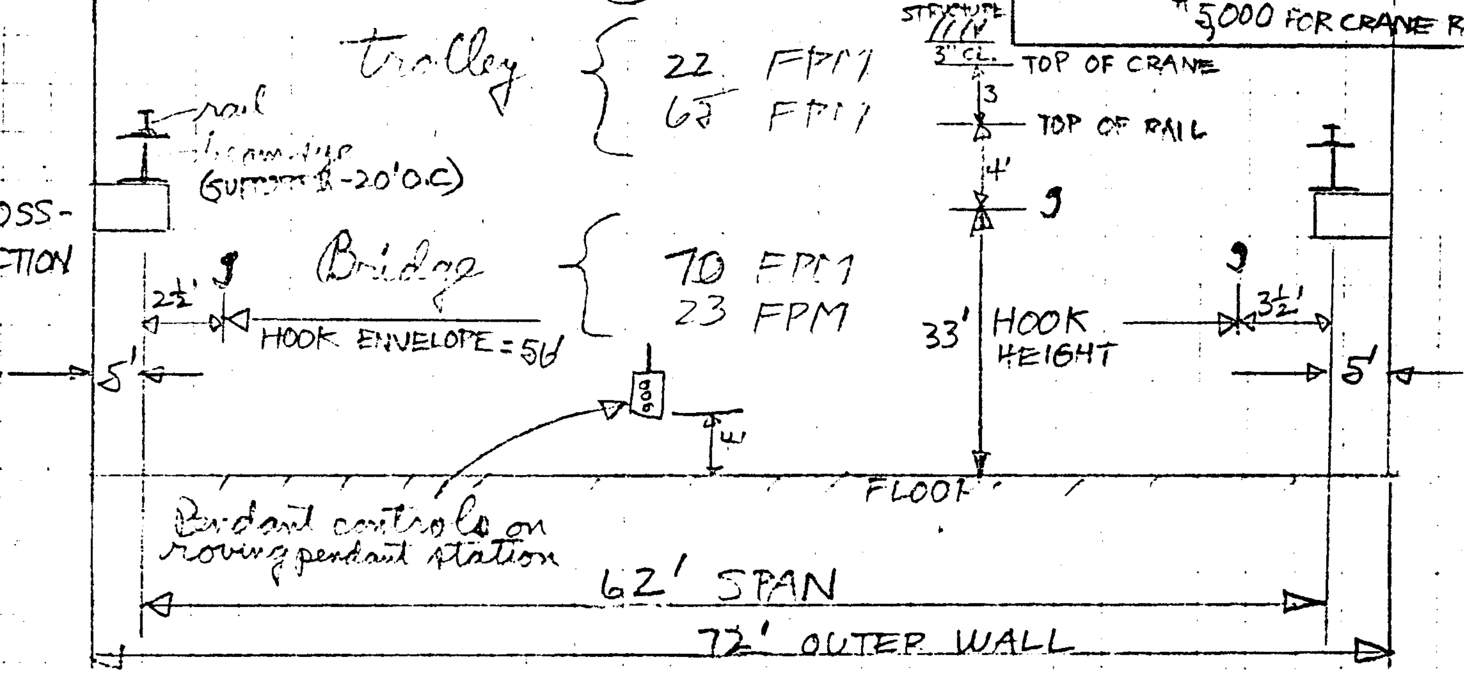
hoist { 2.2 FPM, 7.0 FPM, 22.0 }

Per DICK GATES of ACCO Babcock, Downey, Cal.

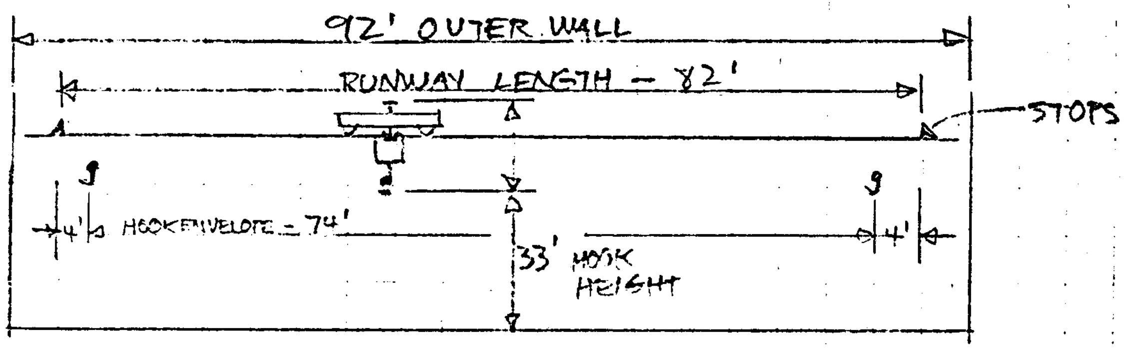
CRANE ONLY $35,745 F.O.B. Down[ey]

$5,000 FOR CRANE RA[IL]

CROSS-SECTION

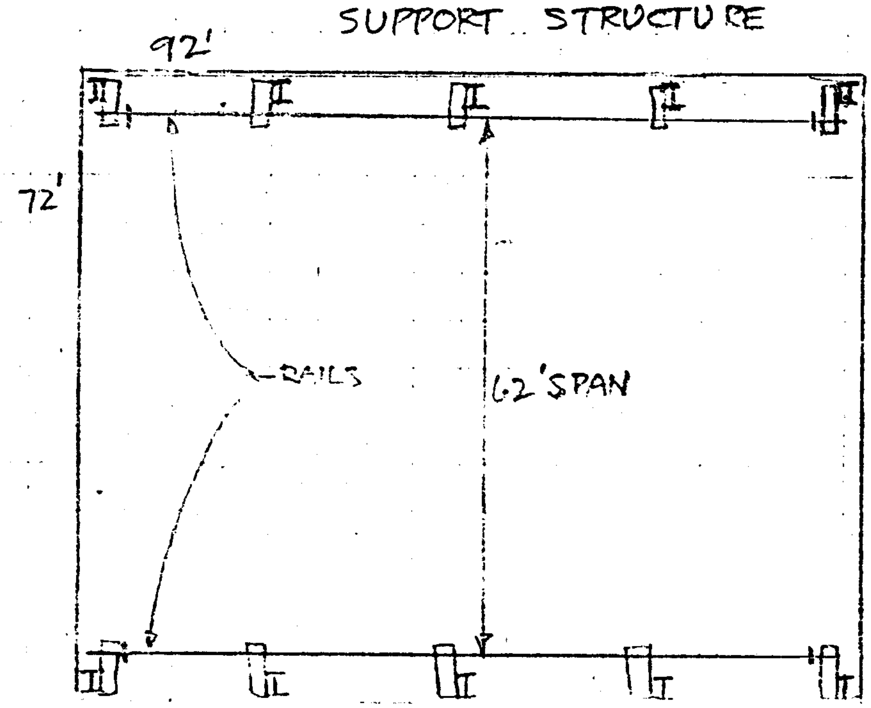


SIDE-VIEW



SUPPORT STRUCTURE

PLAN-VIEW



STRUCTURE COST
(self supporting runway system, utilizing columns & A frame)
$66,000 – material
$75,000 inclusi[ve]

WMS

SERVICE BUILDING

It is planned to construct a central service building to accommodate the maintenance and operations requirements of the LIGO. This building will be located 1000 meters distant from the central station.

An approximate area allotment for this facility is as follows:

Sq. ft.	Function
1000	Machine shop electronic repair 31.6²
1000	Data acquisition, storage, analysis
2700	Offices
600	Garage for 3 vehicles
800	Spare parts and supplies
400	Lunch room/recreation
200	Toilets, janitor closet
300	HVAC/equipment/elec.
Total 5000	

Construction

Butler bldg?

The building will be of the prefabricated type with structural steel framing, footings, and floor slab which will be reinforced concrete over compacted earth fill. Wall panels will be high efficiency-insulated factory finish metal panels. Roof construction will be standing seam factory-finished 20-year-rated roof insulated below.

Interior finish will include carpet floor covering in office areas, and resilient floor covering in lunch room and support areas. Interior partitions will be metal studs with painted gypsum board.

The building will be air-conditioned and heated by electric duct heaters.

BATCH START

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VACUUM PUMPING CONFIGURATION STUDIES

INTRODUCTION

The JPL effort towards the design of a High-Vacuum system for the LIGO focused on utilizing existing vacuum industry standard practices, components, configurations and methods. Costs of the vacuum pumping equipment associated with this approach were substantial.

In an effort to reduce these costs the CIT/MIT staff, beginning late in 1985, began an extensive investigation of outgassing rates, conductance losses and pumping speeds.

The results of the CIT/MIT high vacuum investigation for the LIGO are not presented in this JPL report; however, background information on the earlier JPL design approach is included in the appendix.

BATCH START

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OUTGASSING AND CLEANING TECHNIQUES

L I G O PROJECT
VACUUM PIPE CLEANING, ALTERNATES AND COSTS

METAL CLEANING: removal of undesirable soils

PIPE FABRICATION processes:
machining, forming, grinding, stamping, drawing, buffing, welding

* all necessary operations
* but they all deposit soils on metal

COMPOUNDS THAT REMOVE SOILS:

1. **ALKALINE** detergents: remove oils and grease
2. **ACIDIC** detergents : remove oils, grease, weld scale, heat discoloration, flux, rust, metal particles, yet does not disturb the passive oxide film. For this reason, this is the preferred choice over abrasives on stainless steel.

CONVENTIONAL STAINLESS STEEL CLEANING PROCEDURE:

1. Dry-abrasive blast with glass beads, aluminun oxide, or garnet, or hand-clean using steel wire brush or Scotch Brite.
2. Vapor-degrease or solvent-rinse with tricholoro-ethylene
3. Clean with hot-alkaline cleanser
4. Rinse with tap water
5. Clean with HCl
6. Clean with nitric-hydrofluoric acid
7. Rinse with cold tap water
8. Rinse with hot deionized water
9. Rinse with methanol
10. dry

CLEANING METHOD USED BY C. E. HOWARD FOR WHITE SANDS

1. Steam clean
2. Flush with warm deionized water
3. Brush with acidic detergent OAKITE 33 at 120-140F
   1 part Oakite 33 and 2 parts water
4. Rinse with hot water
5. dry

COST ESTIMATE FROM C. E. HOWARD : $ 10.00 per foot

bpsaldua
16Dec87

products and processes for cleaning, sanitizing, metal conditioning, water treatment

oakite. service bulletin

-vs Alconox

Proven Oakite. procedure passivates stainless steel in two simple steps

- **No lung-irritating nitrous fumes to inhale**
- **No need to preclean or change solution strength**

Before describing Oakite's foolproof, short-cut procedure for passivating stainless steel, some background facts seem appropriate.

First of all, all grades (series) of stainless steel have the unique property of forming a thin, transparent, corrosion-resisting film on exposure to air or other oxidizing conditions. Chromium is the alloy metal most responsible for this property. Nickel can be added as a second alloy to increase the corrosion resistance of the surfaces.

Secondly, to achieve maximum corrosion resistance, stainless steel is usually *passivated* after it's been thoroughly cleaned and pickled to remove surface scale. The *passivation* procedure consists of immersing the cleaned and pickled stainless steel parts into an acidic solution that removes any residual contamination. This contamination — usually minute iron particles — can cause discoloration or invite corrosion.

Removing the residues allows the complete formation of an invisible, protective oxide film that makes the surfaces highly passive and corrosion-resistant. The impervious coating is quickly formed on exposure of the surfaces to the oxygen in air or other sources.

Now here's Oakite's two-step passivation procedure. . .

1. Remove embedded iron particles by immersing stainless steel parts in a 15 to 25% by volume solution of Oakite 33 for 15 to 30 minutes. Or, remove lighter contamination by immersing parts in a similar strength solution of Oakite Liquacid for a similar length of time. Both solutions pickle as they clean to assure thorough passivation.
2. Rinse.

OAKITE

Oakite's passivation procedure — proven successful many times over — is replacing the usual 4-step method. This requires: (1) precleaning; (2) rinsing; (3) pickling parts by immersing them in a highly corrosive nitric acid solution — often containing sodium dichromate; (4) rinsing.

The nitrous fumes given off in this procedure are highly irritating to the lungs. What's more, the solution strength must be changed for different series of stainless steel. In addition, the nitric acid could passivate the free iron particles and prevent their desired removal.

Why put up with fumes?

If you're still passivating stainless the old-fashioned, lung-irritating way, give your local Oakite Technical Sales Representative a call. Let your rep demonstrate how much easier and pleasant it is to passivate with Oakite 33 or Liquacid. It could be like a breath of fresh air in your operation.

FR:cl
No. 10C
3/84

OAKITE PRODUCTS, INC., 50 VALLEY ROAD, BERKELEY HEIGHTS, N.J. 07922
OAKITE PRODUCTS OF CANADA, LTD., 115 EAST DR., BRAMALEA, ONT. L6T 1B7
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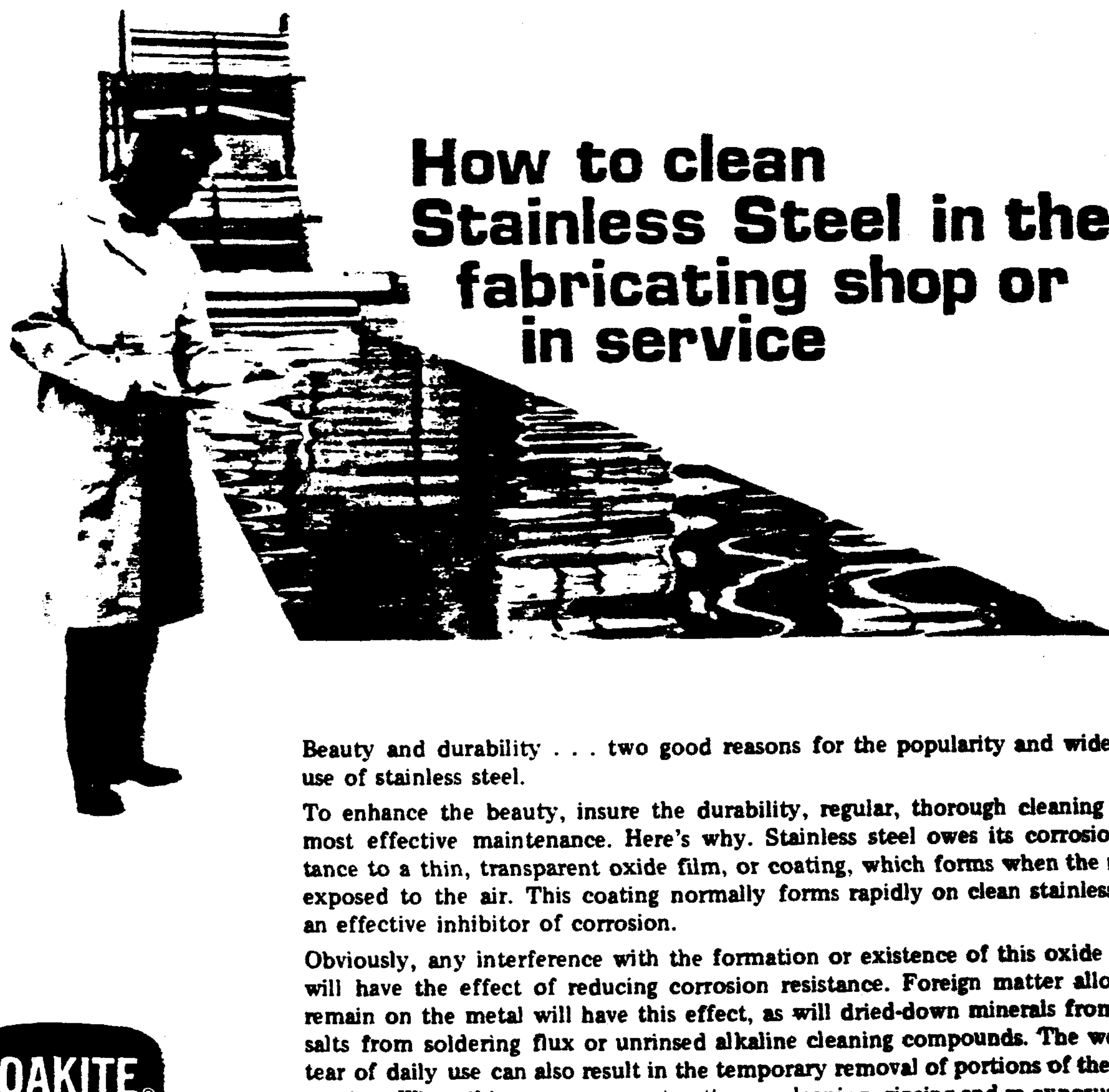
products and processes for cleaning, sanitizing, metal conditioning, water treatment

oakite® service bulletin

How to clean Stainless Steel in the fabricating shop or in service



Beauty and durability . . . two good reasons for the popularity and wide-spread use of stainless steel.

To enhance the beauty, insure the durability, regular, thorough cleaning is your most effective maintenance. Here's why. Stainless steel owes its corrosion resistance to a thin, transparent oxide film, or coating, which forms when the metal is exposed to the air. This coating normally forms rapidly on clean stainless and is an effective inhibitor of corrosion.

Obviously, any interference with the formation or existence of this oxide coating will have the effect of reducing corrosion resistance. Foreign matter allowed to remain on the metal will have this effect, as will dried-down minerals from water, salts from soldering flux or unrinsed alkaline cleaning compounds. The wear-and-tear of daily use can also result in the temporary removal of portions of the passive coating. When this occurs prompt action — cleaning, rinsing and re-exposure to air — is beneficial.

OAKITE®

CLEANING THE KEY

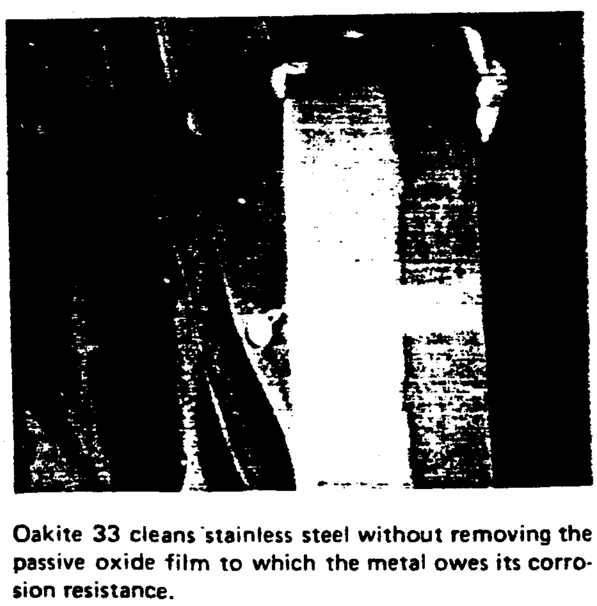
From the foregoing it should be obvious that the way to keep stainless steel truly stainless is to clean it whenever and wherever necessary. This means in the fabricating shop, where the metal is worked, as well as in the field where it serves.

Ordinarily, stainless steel responds in very satisfactory fashion to cleaning. However, for best results, in terms of both effort expended and final appearance, cleaning materials used should be suited to the unique character of the metal.

The following specialized Oakite materials are recommended for safe, efficient cleaning of stainless steel. Keeping in mind the needs of both the custom fabricator and ultimate user of stainless steel equipment, the materials recommended are suited to hand application.

OAKITE HIGHLITE: This product combines acidic detergents with compatible surface active agents and an inert abrasive powder base for coarse cleaning. The powder, applied on a damp sponge to surfaces previously wet down with water, removes difficult stains from, and brightens, stainless steel. It is particularly useful in removing heavier welding discoloration not readily eliminated with non-abrasive cleaners. Though only mildly abrasive, Oakite Highlite or any other "scouring" type product should be applied with the grain of the metal. Application of abrasive type materials to bright polished stainless is not recommended, unless the satin finish characteristic of abrasive action is acceptable and preferable to the existing discoloration.

OAKITE 33: A phosphoric acid, with wetting and solvent properties, this material is ideal for use on stainless steel because it removes most of the soils encountered on this metal, yet does not normally disturb the passive oxide film. For this reason it is a favorite choice of those who avoid the use of abrasives on stainless. Oakite 33 is effective removing discoloration, rust, weld scale, metal particles, soldering flux, grease, oil, most of the foreign matter likely to be encountered. Because it prepares stainless steel for repassivation, Oakite 33, in addition to being a preferred stainless steel cleaner, is also recommended as a follow-up to scouring with abrasive type products.



Oakite 33 cleans stainless steel without removing the passive oxide film to which the metal owes its corrosion resistance.

This product is used with water, normally 1 part Oakite 33 to 2 parts water. Solutions should be mixed in a stainless steel, glass or wooden container. Flush surface to be cleaned with fresh water, then swab Oakite solution over area with sponge or cloth. While solutions of Oakite 33 are relatively safe to use, in keeping with good practice for handling any acidic material, rubber gloves, goggles and an apron should be worn.

Note: Because of its solvent content, Oakite 33 is not recommended for use on or around food process or preparation equipment. Substitute Oakite 31 which, though similar in action and application to Oakite 33, is specially formulated for use on food contact surfaces.

OAKITE 117: A hydrocarbon type solvent material recommended for both its cleaning ability and safety. Removes stencil, grease pencil marks, wax, fingerprints, oil and dust deposits. Cleaning action is faster and more thorough than attainable with ordinary petroleum distillates, such as kerosene. From the safety standpoint, Oakite 117 features a flashpoint of 57°C (135°F) (Tag Open Cup) and is much less toxic than carbon tetrachloride. For example, the threshold limit value or exposure tolerance for Oakite 117 is about 200 ppm compared with 10 ppm for carbon tetrachloride. It is applied full strength. Application by non-atomizing spray is recommended, but may also be brushed or wiped on. Blow off surfaces with pressure air. No water rinsing needed.

OAKITE LIQUI-DET 2: Concentrated, mildly alkaline liquid detergent specially suited for use on stainless steel food contact surfaces. It contains no solvent. Synthetic surface active agents provide fast wetting of the most stubborn residues. Rinsability is excellent. Use at from 4 to 16 m/ℓ (½ to 2 fl oz/gal) of water. Regular use enhances the appearance of stainless steel.

CLEANING STAINLESS STEEL DURING SPECIFIC STEPS OF FABRICATION

It is important that stainless steel surfaces not be neglected — from a cleaning standpoint — while the metal is in the shop being fabricated. This is important not only to prevent corrosion and maintain the appearance of the metal but also to insure the quality of welded or soldered joints.

Cleaning Before Joining. Before welding or soldering, areas around the point of juncture must be free of oil, grease, oxide or other shop soils. To remove oily type soils, dust, fingermarks and the like, apply Oakite 117. See previous description and application instructions. If oxide is present, substitute Oakite 33 which will remove both types of soil. Application is as noted in product description.

Cleaning After Welding. Weld scale, heat discoloration, flux may be the source of future corrosion and should be removed. Oakite 33 is effective for dealing with all three. When welding discoloration is so heavy as to suggest the scouring action of an abrasive, substitute Oakite Highlite. Follow with Oakite 33 to help speed reformation of passive oxide film.

Descaling, Deoxidizing, During Fabrication. To remove oxidation, heat scale, smut and or discolorations during fabrication, immerse in a 10 to 30% by volume of water solution of Oakite Deoxidizer SS. Limit immersion time to that required to remove oxidation and/or heat scale. Use at room temperature.

REMOVING GENERAL SHOP SOILS

After fabrication, stainless steel is likely to contain one or more of a variety of residues, including tiny bits of metal, oil, grease, wax, stencil marks, fingerprints or dust.

Oakite 33, with its built-in solvent and detergent properties, is an ideal choice for removing all of these soils, before equipment leaves the shop. Use as recommended.

When only oily type soils, such as fingerprints, grease, tar, pencil markings, light oil or wax residues are to be removed, Oakite 117 will be found highly satisfactory. Apply undiluted, as previously outlined and blow off with pressure air.

RECOMMENDED PROCEDURES FOR CLEANING STAINLESS STEEL IN SERVICE

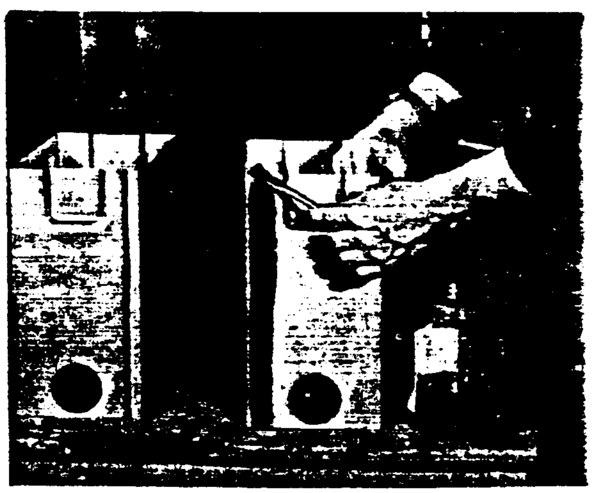
The wide use of stainless steel in restaurants, hospitals, institutions, pharmaceutical companies, food processing plants and in many architectural applications, demands the availability of cleaning materials suited to hand application under in-service conditions.

The products below meet this requirement.

Light Cleaning: For regular maintenance cleaning of equipment such as in the above applications, powdered Oakite Versadet, Liqui-Det 2 or Oakite FiSan-Det (their liquid) are recommended. Dilute water solutions remove most oily type soils, fingerprints and residues. These detergents rinse freely, and when used regularly, greatly enhance the appearance of stainless . . . and are well suited for frequent application to stainless steel food contact surfaces under in-use conditions as are encountered in the institutional kitchen.

For general duty cleaning and brightening in one operation, Oakite Chlor-Tergent or FiSan-Chlor are excellent choices. To remove dulling mineral film, Oakite 31 or FiSan-SR (both liquid acidic detergents) are widely and effectively used.

Heavy-Duty Cleaning: Where tenacious burned-on soils like fatty deposits or protein residues are found



Testing Oakite 33 for heat discoloration removal after welding stainless steel beverage containers.

Oakite Highlite cleans and brightens stainless steel doors of freezer locker.

on equipment surfaces, the powerful cleaning action of Oakite 62, or Oakite FiSan-HD can do a thorough removal job, leaving surfaces clean and streak-free. For spots or dulled surfaces, the slightly abrasive action of Oakite Highlite will be effective. It cleans and brightens. Do not use it on highly polished finishes.

Neglected surfaces or those that contain rust, discoloration or other soils that resist the previously recommended methods should be treated with Oakite 33 or, on food contact surfaces, Oakite 31. This latter material, applied as described on page 2, is very effective on the straw-colored film that sometimes forms on stainless kitchen equipment as a result of long service and repeated applications of water and detergents. Common to many surfaces, this film is more readily discernible on stainless, particularly when splotched with white spots caused by the spillage of acidic foods.

Outdoors. Stainless steel employed in outdoor architectural applications should be cleaned frequently to inhibit pitting and discoloration. Any of the materials already described may be used, depending upon surface condition and application circumstances.

FREE ADVISORY SERVICE

The Oakite materials recommended in this bulletin are available through your local Oakite Technical Sales Representative who is an experienced industrial cleaning specialist, capable of advising you on the cleaning of any stainless steel equipment or surface. Take advantage of this advisory service. It is free and involves no obligation. Give your local Oakite representative a call today.

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No. 61B
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Chemical products may be hazardous if improperly or carelessly used. Apply Oakite materials only as directed by your Oakite representative and observe handling precautions indicated on labels.

OAKITE
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OAKITE PRODUCTS, INC., 50 VALLEY ROAD, BERKELEY HEIGHTS, N. J. 07922
OAKITE PRODUCTS OF CANADA, LTD., 115 EAST DR., BRAMALEA, ONT. L6T 1B7
Subsidiaries and Distributors World-wide Cable: OAKITE, BerkeleyHeights

Conventional Cleaning of SS

TABLE V-1

GENERAL CLEANING GUIDE

Instructions	MATERIALS		
	Titanium	300 Series Stainless Steel	Ceramic
1. Mechanical cleaning: Mask-off seal area on all flanges. Dry-abrasive blast with glass beads, very fine aluminum oxide, or garnet[a]. Use low pressure and blast sparingly to minimize material loss and damage to welds. Use clean abrasives and equipment to prevent surface contamination. Alternate procedure - if abrasive blasting is not possible: Hand-clean with a fine stainless steel wire brush or with Scotch Brite[b]. Be careful to remove residual dust during this and subsequent cleaning steps by vacuuming or blowing.	X	X	
2. Vapor-degrease or solvent-rinse with trichloro-ethylene or equivalent.	X	X	X
3. Hot-alkali clean with Oakite compound No. 27, 5-ounces per gallon of water at 80 or 90°C. Immerse 2 minutes or longer, depending on condition. Use steam-cleaner for large parts.	X	X	X

Instructions	MATERIALS		
	Titanium	[redacted]	Ceramic
[redacted]. Rinse throughly with hot tap-water.	X	[redacted]	X
[redacted]. Clean with hydrochloric acid. (Optional) — use in place of Step 6 for stainless steel if desired. Use solution of 1:1 HCl (Tech grade) in water at 70°C. Immerse 2 to 8 minutes. Avoid over-etching to protect welds and sealing edges.		[redacted]	
[redacted]. Clean with nitric-hydrofluoric acid. Use 20 to 30% by volume concentrated HNO_3 and 2 to 3% by volume concentrated HF at room temperature. Immerse for time shown, or until oxide is removed. Handle with all caution required by hydrofluoric acid. Avoid over-etching to protect welds and sealing edges.	X 5 to 15 minutes	[redacted]	X[d]
[redacted]. Rinse throughly with cold tap-water.	X	[redacted]	X
8. Clean with nitric-hydrofluoric acid. Use 20 to 30% by volume concentrated HNO_3 and less than 1% by volume concentrated HF at room temperature. Immerse for 5 to 15 minutes until smut is removed. Handle with all caution required by hydrofluoric acid.	X		

Instructions		MATERIALS		
		Titanium	300 Series Stainless Steel	Ceramic
9.	Rinse throughly with cold tap-water	X		
10.	Rinse throughly with hot deionized water. (Water resistivity of 500,000 ohms-cm or higher.)	X	X	X
11.	Methanol rinse: Use electronic-grade methanol. Change when water content is more than 80% by volume.	X	X	X
12.	Dry in warm air. Use clean, filtered, fume-free air at approximately 65°C.	X	X	X

a) Glass beads may be obtained from:

Dry Honing Corporation
P.O. Box 302
Belmont, California
Specify: MS-XL Glas-Shot Beads (U.S. sieve size 270 plus 1000; nominal size 0.0021 to 0.0005-inch).

b) Scotch Brite is a product of Minnesota Mining and Manufacturing Co.; Size No. 448 recommended.

c) **Do not use on Type 303 Stainless Steel.** Receivers on rotatable ConFlat Flanges (such as on demountable feedthroughs) are composed of this material.

d) For non-glazed ceramic only. Clean glazed ceramic with concentrated nitric acid.

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HIGH VACUUM ENVIRONMENTAL CONSTRAINTS

F. Lansing

December 12, 1984

Gravity Wave Observatory

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OUTGASSING RATES

- Extensive HV literature, equipment manufacturers, and technology centers search was conducted including
  - ✓ The Rutherford Lab., Chilton, England
  - ✓ Stanford Linear Accel. Center (SLAC), CA,
  - ✓ Lawrence Livermore National Lab., CA
  - ✓ Los Alamos National Lab, NM
  - CERN, Geneva, Switzerland
  - ✓ National Lab for HE Physics, Japan
  - Varian Asso., Palo Alto, CA
  - Rockwell International,, Golden Co.
  - Institute for Experimental Physics, Vienna, Austria

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OUTGASSING RATES (Cont'd)

- Consolidated Vac. Corp, NY
- GE Co., NY
- Sandia Lab, Albuquerque, NM
- Institute for Nuclear Research, Amsterdam
- AD Little, Mass.
- Several vacuum pump manufacturers (Balzers, CVI, ...)

- Outgassing rate of 1.6×10^{-11} torr $\ell/(cm^2 s)$ is practically achievable for stainless steel-304, with special cleaning and either 900 hr on-site pumpdown time or 300-500 hr pumpdown plus factory bakeout

? 9000 hrs for $\frac{1}{t}$ O. G.

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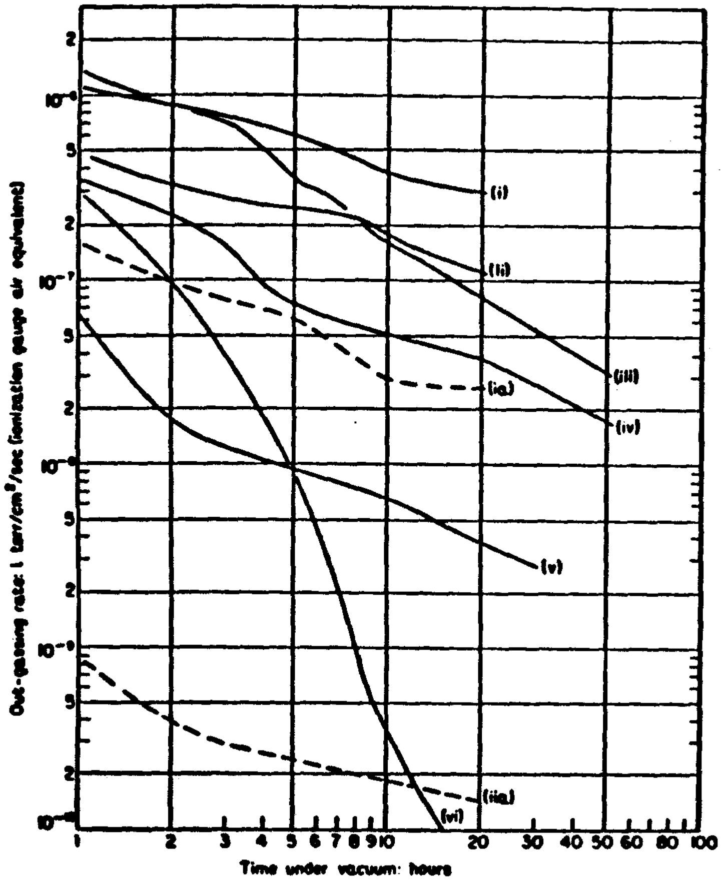
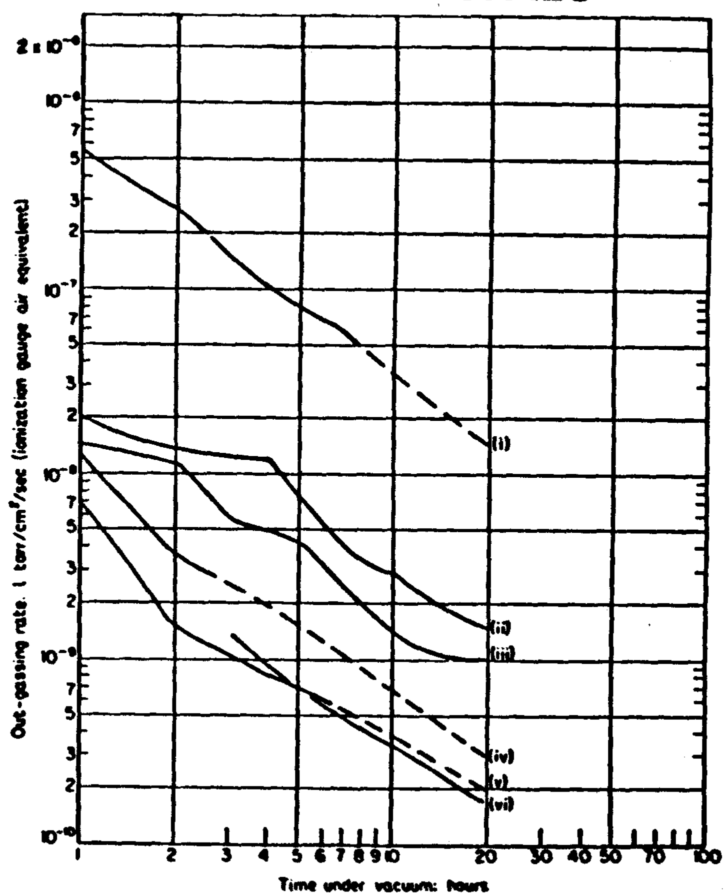
OUTGASSING OF METALS vs SEAL MATERIALS



(i) Nitrile, 60° shore, (Edwards High Vacuum O-ring material), $\frac{1}{2}$ h exposure
(ii) Viton-A, 60° shore, (Edwards High Vacuum O-ring material), $\frac{1}{2}$ h exposure
(iii) Silastic, white, 50° shore, 1 h exposure
(iv) Picien wax (spread on copper), 1 h exposure
(v) Silicone high vacuum grease, 1 h exposure
(vi) Mylar, 1 h exposure
(ia) Nitrile (as above) after $\frac{1}{2}$ h exposure, followed by 4 h 100°C bake under vacuum
(iia) Viton-A (as above) after $\frac{1}{2}$ h exposure, followed by 4 h 150°C bake under vacuum

UNBAKED METALS



Ref? Strausser?

(i) Mild steel sheet, slightly rusting, 1h exposure ?
(ii) Stainless steel EN58F, fully-machined shell casting, $\frac{1}{2}$ h exposure ?– after prior pump?
(iii) Aluminium alloy LM8M(A), gravity casting, finish as cast, $\frac{1}{2}$ h exposure
(iv) Chromium-plated mild steel, 1 to 2 microinch polished surface, 1h exposure
(v) Mild steel sheet, 5 to 7 microinch smooth surface, 1h exposure
(vi) Aluminium sheet, smooth surface, 1 h exposure

TOTAL OUTGASSING FROM A VESSEL $= \sum_i \text{AREA}_i \times \text{OUTGASSING RATE}_i$

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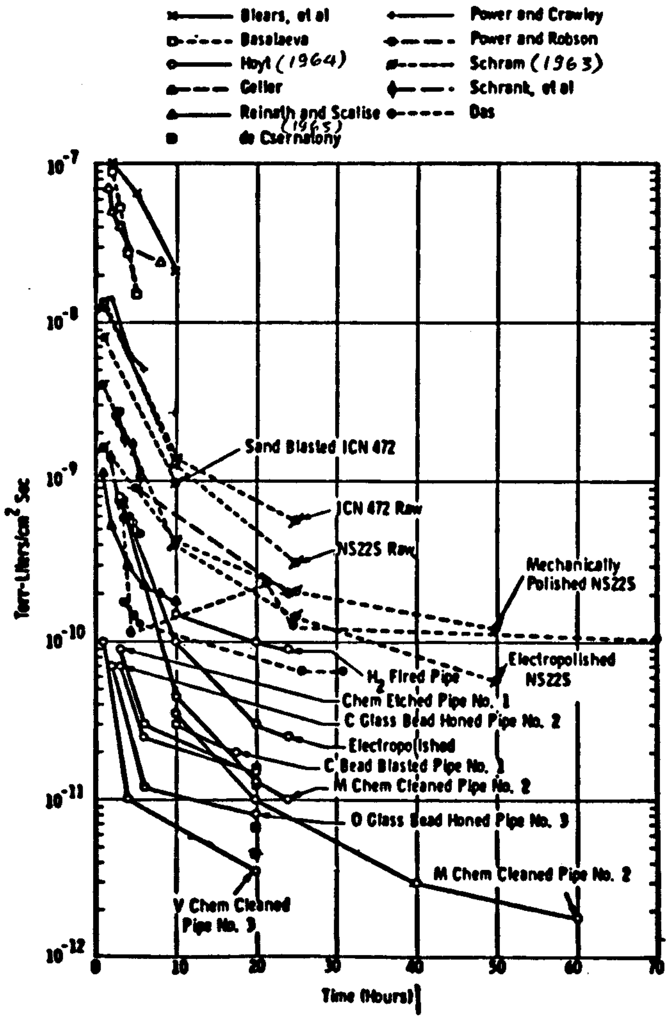
STAINLESS STEEL OUTGASSING RATE

UNBAKED, DIFFERENT CLEANING METHODS

? Straussen ?



- ELECTROPOLISHING AND CHEMICAL CLEANING ARE SUPERIOR SURFACE PRETREATMENTS
- RANGE IS WIDE (1→1000) FOR DIFFERENT SURFACE TREATMENTS

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PREDICTED OUTGASSING RATES

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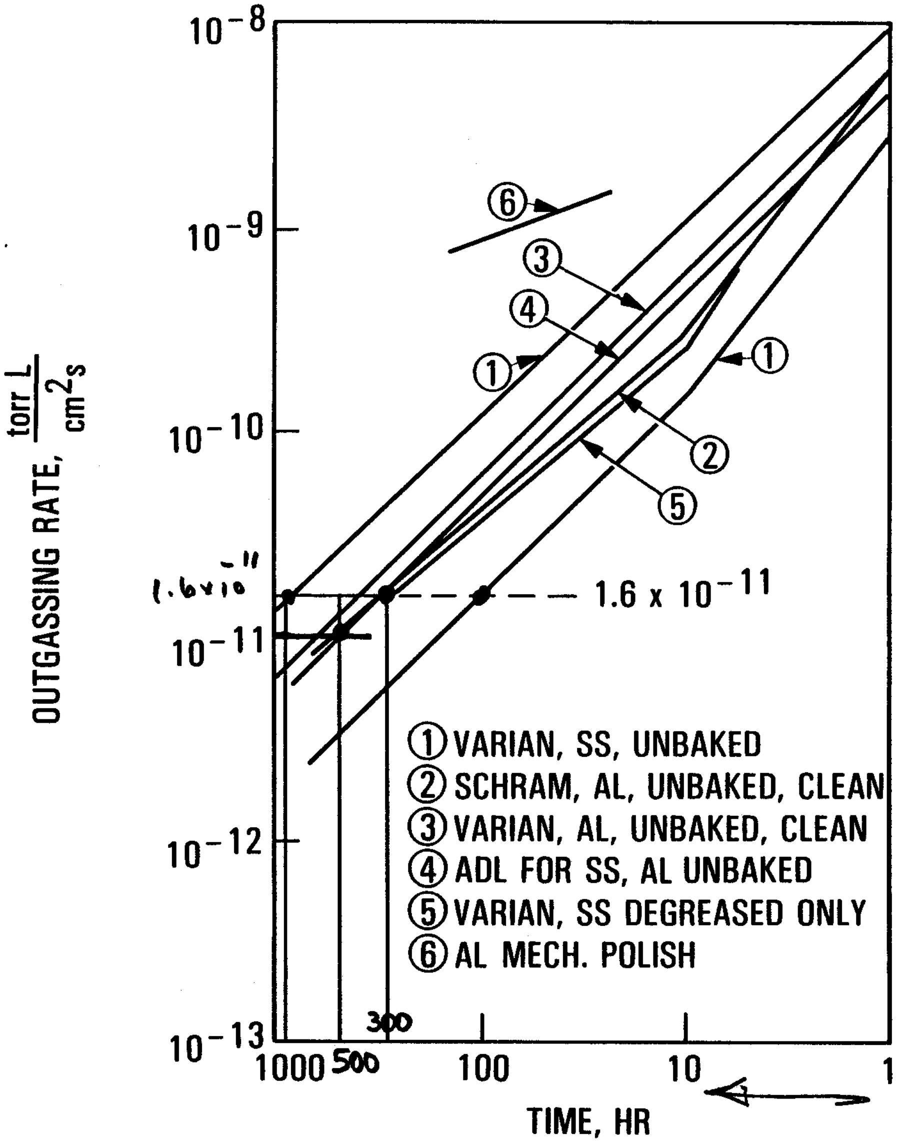

- RECOMMENDED RATE 1.6×10^{-11} torr L/sec cm^2 AFTER EITHER 900 HR PUMPING OR 300-500 HR PLUS BAKEOUT

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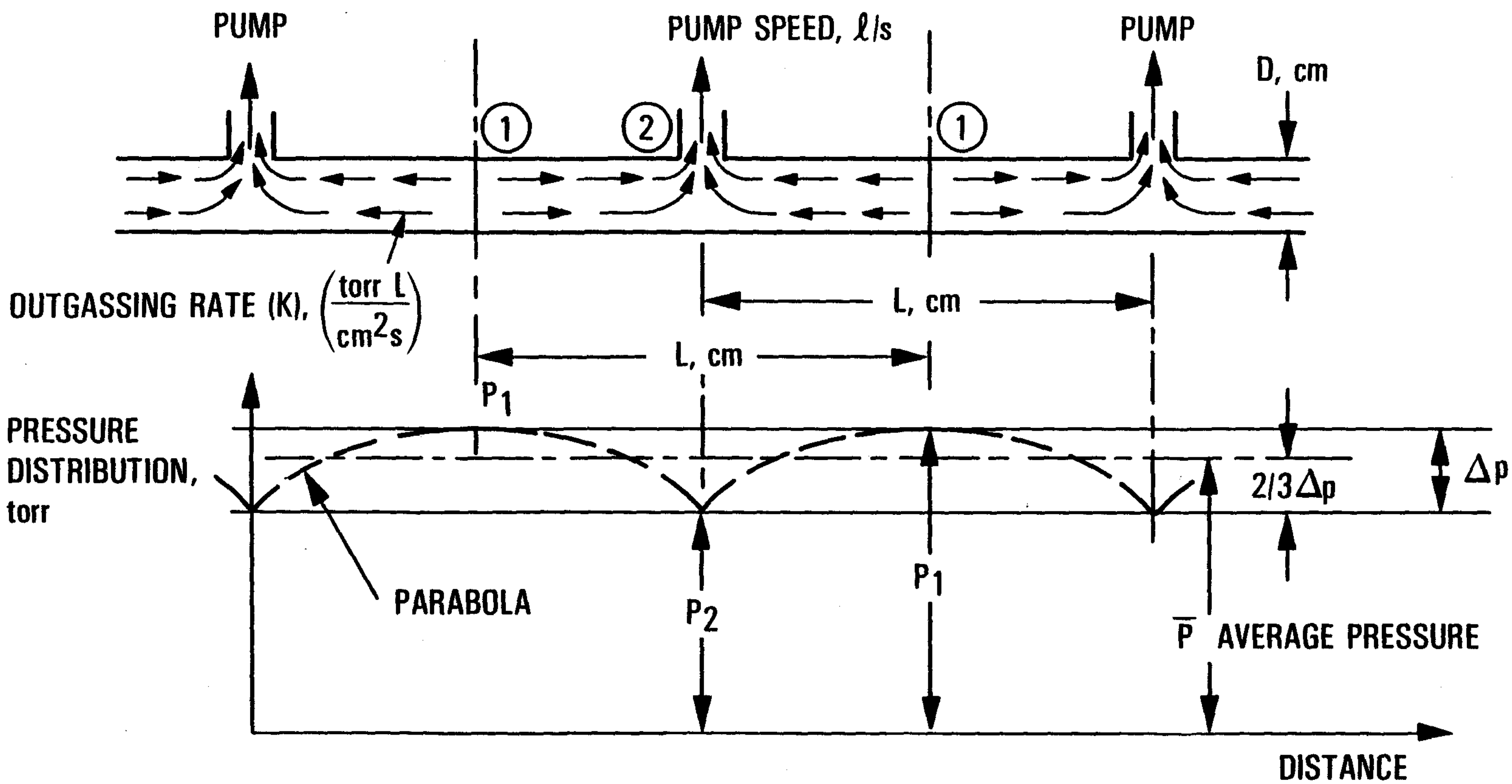
FLOW AND PRESSURE DISTRIBUTION



- OUTGASSING FLOW IS NON UNIFORM WHICH GENERATES A PARABOLIC RATHER THAN LINEAR PRESSURE CURVE

$\overline{P} = K(\pi DL)[1/c + 1/s]$, $c = 145.2\ D^3/L$, $P_1 - P_2 = \pi K (L/D)^2/96.8$

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CLEANING PROCEDURE FOR STAINLESS STEEL

- Steam degrease
- Clean with alkaline
- Rinse with hot tap water
- Clean with acid (Ecolite) 20-25% HNO_3 2-3% HF 10 min at 50-60°C
- Rinse with cold tap water
- Hydrowash (air + water mix at 5.45 atm)
- Rinse with cold tap water
- Rinse with deionized water at 80°C
- Rinse with deionized water at 95°C
- Blow off and dry with clean air

- Adopted by SLAC, LLNL, for stainless steel - (to be baked?)
- Duration of each step will be designed subject to material selection

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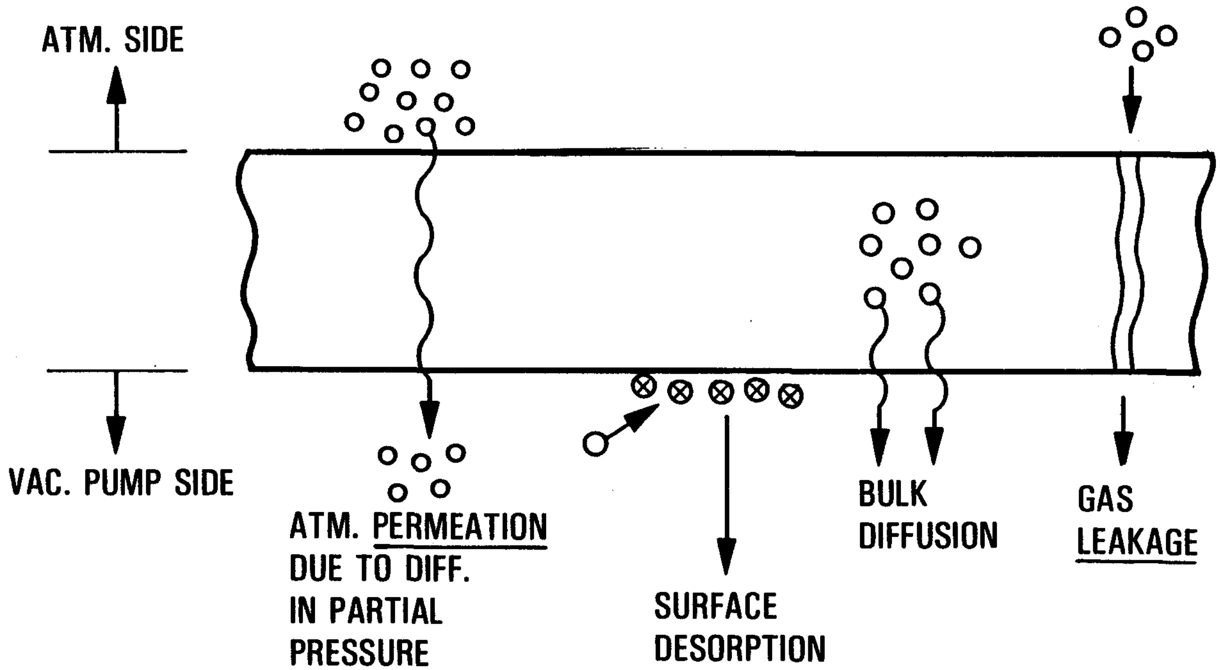
OUTGASSING MECHANISM



- **Outgassing does not include gas leakage**
- **Bulk diffusion (mostly hydrogen) is enhanced by bakeout**
- **Surface desorption occurs at room-low temp (mostly H_2O, CO)**
- **Below 10^{-4} torr, gas load in vessel is negligible compared to wall outgassing**

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NON-LINEAR EFFECT ON HIGH VACUUM PUMP DESIGN

Press, torr	Pump Speed, ℓ/s	Spacing, m	No. of Pumps*	Total Speed, ℓ/s
10^{-8}	500	8	1228	614,000
	1,000	16	616	616,000
	5,000	72	139	695,000
	10,000	115	87	870,000
10^{-7}	500	81	124	62,000
	1,000	156	64	64,000
	5,000	454	22	110,000
	10,000	555	18	180,000
10^{-6}	500	769	13	6,500
	1,000	1250	8	8,000
	5,000	2000	5	25,000
	10,000	2000	5	50,000

*For outgassing rate 1.6×10^{-11} torr ℓ/s cm^{-2}, 4 ft diam pipe, 10 km long, excluding end stations

*Gas load/end station ≅ 53×10^{-6} torr ℓ/s

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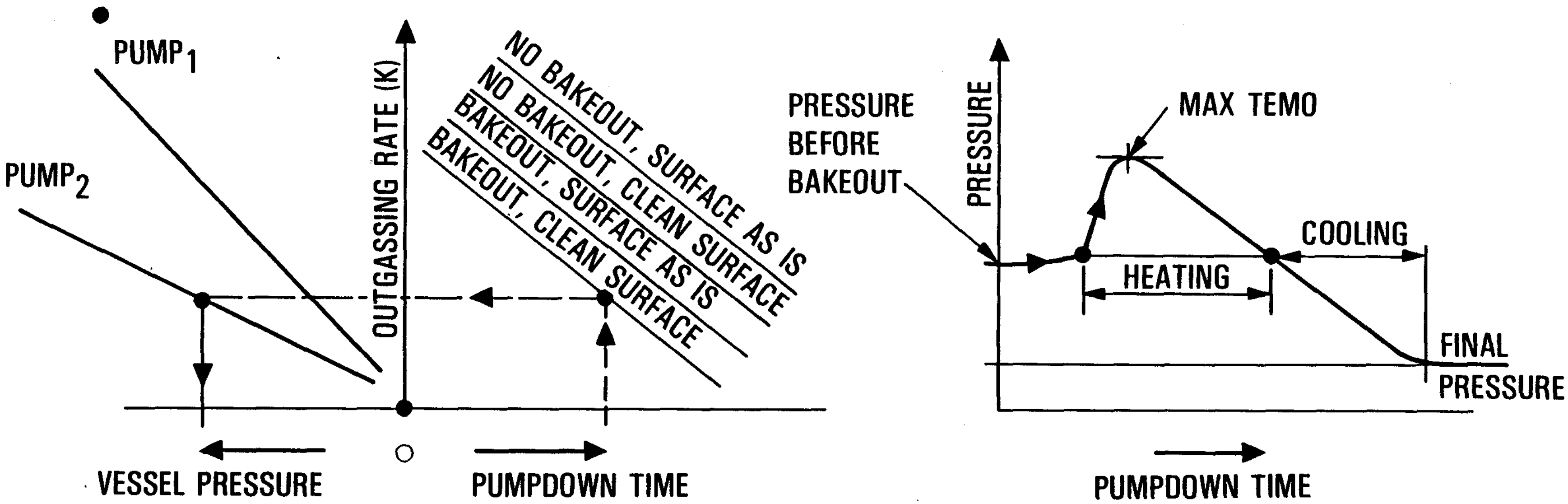
BAKEOUT CHARACTERISTICS



- Bakeout reduces time (same pumps, pressure)
- Bakeout reduces pressure (same time, pump)
- Bakeout reduces pump size required (same time, pressure)

} A factor of 10-100

- 98% of gas after bakeout is H_2. Before bakeout, H_2O and CO desorb
- Bakeout is performed while pumping either in factory or in situ

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BAKEOUT REQUIREMENTS

• Bakeout temp.	~400°C (for 1/4 in, SS-304)
• Type of heating	elect. strip heaters or gas-fired
• Bakeout duration	20-24 hrs
• Time constant (t_{63})	7-8 hrs
• Steady state time (t99)	30-40-hrs

Notes:

- Bakeout time is proportional to $(\text{thickness})^2$
- Diffusion coefficient increases exponentially with temp. Doubling the temp reduces by much less than one-half the bakeout time ??
- Critical bakeout time (tc) depends on temperature, type of material, surface pretreatment and thickness - time should be $> t_c$

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OUTGASSING OF VACUUM MATERIALS* (K)

A — UNBAKED MATERIALS

Material	K (torr l. s^{-1} cm^{-2}) x 10^{10}	a_1	K_{10} (torr l. s^{-1} cm^{-2}) x 10^{10}	a_{10}
Aluminium (fresh)	63	1.0	6.0	1.0
Aluminium (degassed 24 h)	41.4	3.2	3.06	0.9
Aluminium (3 h in air)	66.5	1.9	4.75	0.9
Aluminium (fresh)	62	1.0	5.25	0.9
Aluminium (anodised-2 μm pores)	2760	0.9	322	0.9
Aluminium (bright rolled)	—	—	75	1
Duralumin	1700	0.75	350	0.75
Brass (wave-guide)	4000	2.0	100	1.2
Copper (fresh)	400	1.0	41.5	1.0
Copper (mech. polished)	35	1.0	3.56	1.0
OFHC copper (fresh)	188	1.3	12.6	1.3
OFHC copper (mech. polished)	19	1.1	1.63	1.1
Gold (wire fresh)	1580	2.1	5.1	1
Mild steel	5400	1	500	1
Mild steel (slightly rusty)	6000	3.1	130	1
Mild steel (chromium plated polished)	100	1	9.0	—
Mild steel (aluminium spray coated)	600	0.75	100	0.75
Steel (chromium plated fresh)	70.5	1	5.8	1
Steel (chromium plated polished)	91	1	8.0	1
Steel (nickel plated fresh)	42.4	0.9	4.94	0.9
Steel (nickel plated)	27.6	1.1	2.33	1.1
Steel (chemically nickel plated fresh)	83	1	7.05	1
Steel (chemically nickel plated polished)	52.2	1	4.6	1
Steel (descaled)	3070	0.6	2950	0.7
Molybdenum	52	1.0	3.67	1
Stainless Steel EN58B	—	—	14	1.6
Stainless Steel 18/9/1 (electro polished)	—	—	2	—
(vapour degreased)	—	—	1	—
(diversey cleaned)	—	—	3	—
Stainless steel	1750	1.1	210	0.75
Stainless steel	900	0.7	200	0.75
Stainless steel ICN 472 (fresh)	135	0.9	14.7	0.9
Stainless steel ICN 472 (sanded)	82.8	1.2	10.4	0.8
Stainless Steel NS22S (mech. polished)	17.1	0.5	4.6	0.7
Stainless Steel NS22S (electro polished)	42.8	1.0	4.28	1.0
Stainless Steel NS22S	144	1.3	13.5	1.9
Zinc	2210	1.4	322	0.8
Titanium	113	0.6	18.4	1.1
Titanium	40	1.0	3.68	1

*FROM R.J. ELSEY, RUTHERFORD LAB. ENGLAND, 1975

$$\left(K_1 = \text{AFTER 1 HR},\ K_{10} = \text{AFTER 10 HRS},\ K = \frac{\text{CONSTANT}}{(\text{TIME})^{a}} \right)$$

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OUTGASSING OF VACUUM MATERIALS (Cont'd)

B — POLYMERS

Material	K_1 torr l. s^{-1} cm^{-2} × 10^9	α_1	K_{10} torr l. s^{-1} cm^{-2} × 10^9	α_{10}
Araldite (moulded)	116	0.8	35.2	0.8
Araldite D	800	0.8	220	0.78
Araldite D	190	0.3	125	0.5
Araldite F	150	0.5	73	0.5
Celluloid	860	0.5	430	0.5
Gaflon (PTFE) (fresh)	16.6	0.8	3.31	0.9
Kel-F	4	0.57	1.7	0.53
Methyl methacrylate	420	0.9	140	0.57
Mylar (24 h at 95% RH)	230	0.75	40	—
Nylon	1200	0.5	600	0.5
Pertinax	620	0.18	290	0.5
Plexiglas	72	0.44	27	0.44
Plexiglas	310	0.4	180	0.4
Polyamid	460	0.5	230	0.5
Polyester-glass laminate	250	0.84	80	0.81
Polyethylene	23	0.5	11.5	0.5
Polystyrene	2000	1.6	200	1.6
Polystyrol	56	0.6	12	0.61
Polyvinylcarbazol	160	0.5	80	0.5
PTFE	30	0.45	15	0.56
PVC (24 h at 95% RH)	85	1.0	2	—
Teflon	6.5	0.5	2.5	0.2
Terephenil (fresh)	62.2	0.5	16.8	0.5

K_1 = AFTER 1 HR
K_4 = AFTER 4 HRS
K_{10} = AFTER 10 HRS.

C — RUBBERS

Material	K_1 torr l. s^{-1} cm^{-2} × 10^9	α_1	K_4 torr l. s^{-1} cm^{-2} × 10^9	α_4
Butyl DR41	150	0.68	40	0.64
Convaseal	100	0.5	49	0.6
Natural crepe	730	0.7	310	0.65
Natural gum	120	0.5	60	0.5
Neoprene	3000	0.4	1800	0.4
Neoprene	300	0.5	145	0.5
Nygon	1300	0.5	650	0.6
Perbunan	350	0.3	220	0.5
Poliosocyanate	2800	0.45	1270	0.57
Polyurethane	50	0.5	25	0.5
Silicone	1800	1.0	440	1.2
→ Viton A (fresh)	114	0.8	—	—

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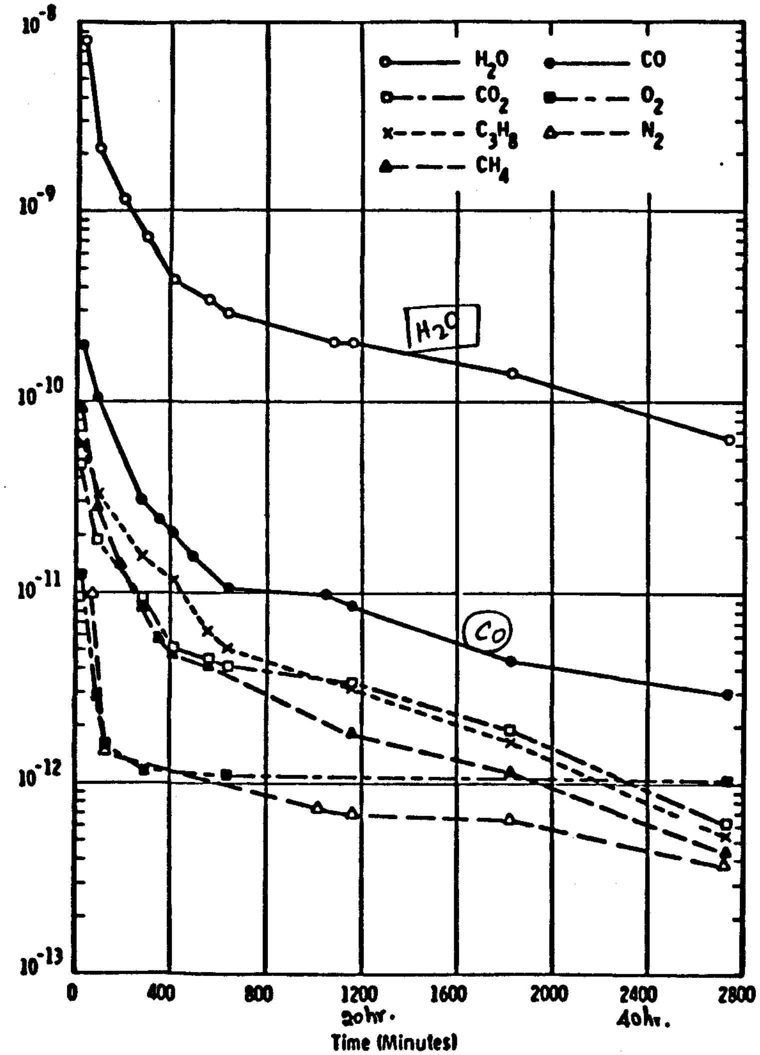
JPL OUTGASSING COMPOSITION FOR SS SAMPLE

(UNBAKED)



Source? Elsey?

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- H_2O IS THE MAJOR GAS DESORBED FOR PREBAKED SAMPLES

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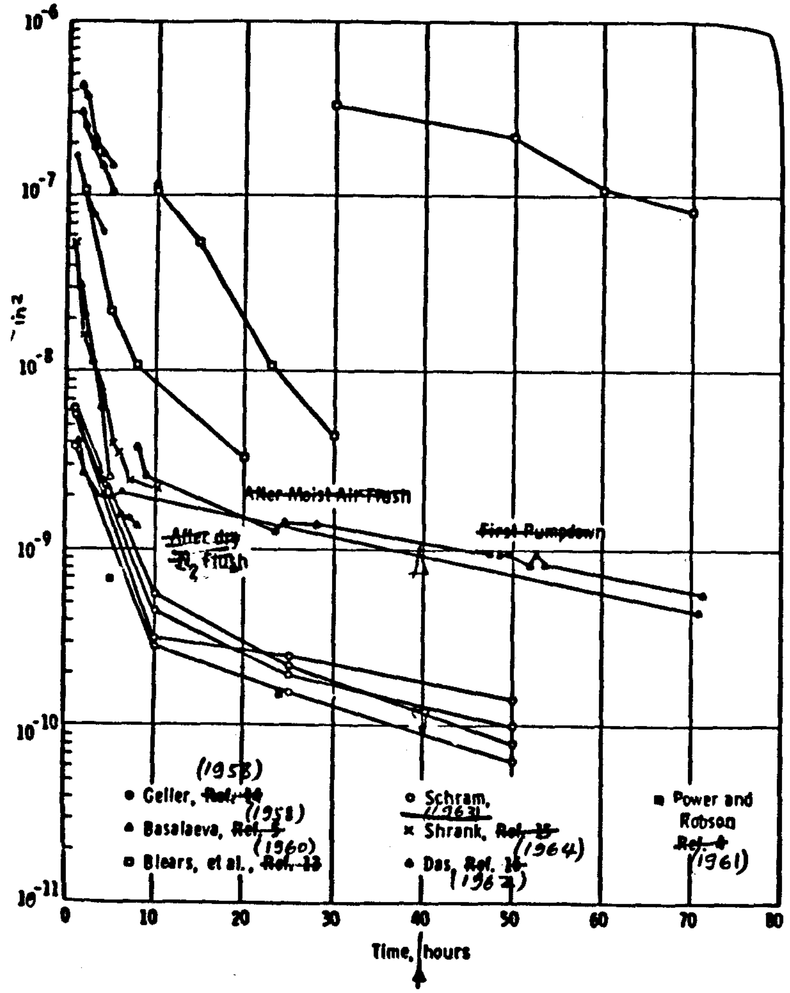
ALUMINUM OUTGASSING RATE

UNBAKED, DIFFERENT CLEANING METHODS



- SHOW WIDE RANGE OF RATES (1→1000) OBTAINED WITH DIFFERENT PRETREATMENTS
- RATE DEPENDS ON THICKNESS OF OXIDE LAYER; REDUCED BY POLISHING OR GRINDING AND INCREASED BY ANODIZING

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CS003

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12/12/84

DIVERSEY WYANDOTTE DS-9-314

MICROFINISH FOR STAINLESS STEEL, KOVAR & OTHER NICKEL ALLOYS

DESCRIPTION

DIVERSEY WYANDOTTE DS-9-314 is a unique, patented, premixed composition for brightening and passivating stainless steel. It produces a bright, specular finish on AISI 300 series stainless steel, and visually pleasing surfaces on 200 series and 400 series alloys by means of a simple immersion process. Close tolerances can be maintained and uniform finishes are obtained without the use of current. It is also used to descale a wide variety of (stainless) steels and exotic corrosion resistant alloys such as Inconel and Kovar. Regardless of the shape of the work, all surfaces (inside and out) exposed to the working solution are processed with equal effectiveness.

UNIQUE CHARACTERISTICS

1. Surface Passivation

DS-9-314 produces a true nickel rich stainless grain structure, capable of forming an adherent non-reactive nickel-chrome oxide surface. This passive surface resists rust formation in the salt spray cabinet and shows no copper formation when tested with copper sulfate solution. This is truly a chemically passive surface.

By contrast, stainless steels mechanically polished produce a grainy surface and leave pure iron and foreign particles on the surface. Nitric-hydrofluoric acid and similar baths roughen the surface, developing inclusions with iron contaminates. Both surfaces produce rust in the salt spray cabinet and in the presence of high humidity, and copper specks are produced with copper sulfate solution. Although the surface appears clean, it is not chemically passive and rapidly deteriorates.

2. Minimum Metal Loss

A minimum removal of metal occurs during processing in the Diversey Wyandotte DS-9-314 bath. This is an advantage where close tolerances must be maintained. An average loss of 0.05 mils per minute per side occurs under recommended conditions when a 302 series stainless steel is processed from a 2B finish to a specular finish. This removal will not affect metallurgical properties of the stainless steel.

3. Minimum Hydrogen Absorption

Stainless steel alloys treated by DS-9-314 show minimum hydrogen absorption, less than 2 ppm, greatly reducing possible structural failures due to hydrogen embrittlement.

Industrial Products Group • 1532 Biddle Ave. • Wyandotte, Michigan 48192 • (313) 281-0930

4. High Vacuum and Cryogenic Application

The DS-9-314 produces an extremely fine microfinish, free of inclusions. This microfinish minimizes outgassing and produces a very high vacuum using standard bake-out procedures.

Organic material trapped on a hydrofluoric acid roughened surface can cause very dangerous impact detonation if the parts are used in liquid oxygen.

The DS-9-314 in contrast produces a clean surface free from organic material and particulate matter on stainless steel parts. These are necessary conditions for cryogenic and high vacuum applications.

5. Preparation of Stainless Steel for Brazing, Soldering and Glass Joints

Stainless steel surfaces treated in the DS-9-314 are chemically clean providing rapid wettability and complete penetration by the solder and brazing material. This results in adherent vacuum tight joints, capable of leak-proof applications. The DS-9-314 is ideally suited for polishing prior to controlled atmosphere (dry hydrogen) brazing.

6. Scale Removal and Solder Cleaning

The Diversey Wyandotte DS-9-314 effectively removes heat treatment scale and welding scale. Silver and brass solder are cleaned in the DS-9-314 bath without detrimental effect. The process should not be used, however, on tin or lead soldered work.

HANDLING INSTRUCTIONS

DS-9-314 is a strong acidic product. Personnel handling this product should wear protective clothing including eye protection and exercise precautions associated with strong, corrosive acids. OSHA Material Safety Data Sheets are available on request from your local Diversey Wyandotte representative.

EQUIPMENT RECOMMENDATIONS

Tanks: Lining materials inert to the Diversey Wyandotte DS-9-314 solution are polyethylene, polypropylene, unplasticized polyvinyl chloride, Teflon, polyester bonded fiberglasses and glass.

Heaters: Normally, quartz heaters are used. However, heaters coated with Teflon can be used. Indirect heating (such as steam) or steam passed through protected tubing in the solution is not recommended because temperatures generally are difficult to control. Pure titanium plate coils are satisfactory heaters.

Ventilation: Diversey Wyandotte DS-9-314 solution forms a foam blanket over the bath when in use. This slows down dispersion of exhaust gasses, but does not eliminate them entirely. Adequate ventilation will be necessary to remove any and all fumes formed during processing.

OPERATING INSTRUCTIONS

Diversey Wyandotte DS-9-314 is used only in immersion applications.

Conditions

Concentration:	100% by volume
Temperature:	170-175°F (75-80°C)
Time:	5-15 minutes or until scale-free and bright as desired.
Agitation:	Gentle agitation by "rocking" of the parts, a method often used in electroplating, is the preferred and most effective manner of agitation. For small parts, agitation by slowly rotating in a perforated barrel is acceptable.

Sometimes it is necessary to mask off or tape parts so that certain areas will not be affected by the DS-9-314 bath. Contact your local Diversey Wyandotte representative for suppliers of these materials.

Typical Processing Cycle

A general process for descaling and brightening stainless steel is given below. The sequence may vary slightly depending on the condition of the stainless steel and on the degree of brightness desired.

1. Clean with DIVERSEY WYANDOTTE 909, 6-8 oz/gal (45-60 g/l), 160-180°F (70-82°C), 5-10 minutes.
2. Cold water rinse.
3. Scale/Oxide Conditioning with DIVERSCALE 299, 16-32 oz/gal (120-240 g/l), 180-200°F (82-95°C), 15-30 minutes.
4. Cold water rinse.
5. Scale/Oxide Removal and neutralization of residual alkalinity with DIVERSEY WYANDOTTE EVERITE II, 50% by volume, 70-75°F (20-25°C), 5-15 minutes.
6. Cold water rinse.
7. Brighten and Passivate with DIVERSEY WYANDOTTE DS-9-314.
8. Cold water rinse.
9. Hot water rinse and dry.

If a smut is generated on the surface following Step #7, process parts through Steps #2, #3 (5 minutes), #4, #5 (1 minute), #8 and #9. The surface will regain its brightness and retain its passivity.

An alternate method for removing smut is by immersion in 30-50% by volume nitric acid (42°Be') for 3 to 5 minutes at room temperature with a gentle rocking of parts. To obtain complete passivation of the 400 series stainless steel, immersion time should be increased to 30 minutes.

SOLUTION CONTROL

Controls for the Diversey Wyandotte DS-9-314 are detailed in Technical and Operating Data Bulletin IM-36-1, "Chemical Control DS-9 Solutions".

SERVICE HINTS

1. Racking and position of the part in the chemical bright dip bath is very important. Avoid gas pockets on cup shaped articles. Foam collects in these areas and prevents fresh solution from coming in contact with the metal surface. The foam does no harm if the position is changed regularly so that fresh solution is present for brightening action.

2. Small parts that do not nest together can be processed in a slowly rotating perforated polypropylene finishing barrel.

3. Do not overload the bright dip tank. Too much work being processed causes too much foam and excessive heat build-up. About 50 square feet (4.6 sq. meters) of stainless steel being processed at one time is the limit in a 100 gallon (378 liter) tank.

4. Keep the solution covered when not in use.

5. It is very important to maintain close temperature control. The best operating range is 170-175°F (76-79°C). At higher temperatures the brightening action and metal removal is faster. There is danger of breakdown of the brightening agents over 180°F (82°C). Remember the temperature tends to rise during the chemical brightening.

6. The quality of the stainless steel itself makes a difference as to the final quality of the brightened surface. Improper treatment (forming) of the stainless steel, irregular heat treating, etc., can cause differences in the final outcome of the processed steel.

7. There is no harm in removing a part from the bright dip bath to observe the brightening action as long as the foam is not allowed to dry on the part and the part is immediately put back in the bright dip bath. This type of agitation actually helps to increase brightness. Do not rinse the part to examine for brightness. If the part is rinsed, the bright dip process must be started over again. Condition in Diversey Wyandotte DIVERSCALE 299, rinse and neutralize in EVERITE II before going back to the DS-9 bright dip bath.

8. Black oily or colloidal substance in the foam of DS-9-314 bath indicates poor cleaning and scale removal. Check the DIVERSEY WYANDOTTE 909, DIVERSCALE 299, and EVERITE II baths and subsequent rinses.

PACKAGING

DIVERSEY WYANDOTTE DS-9-314 is packaged in a 55 gallon, non-returnable polyethylene drum with steel overpack.

STORAGE

DIVERSEY WYANDOTTE DS-9-314 should be stored indoors in a cool dry area and away from direct heat and sunlight. Avoid storage at temperatures above 100°F (38°C) for any extended time. If product freezes, it should be allowed to come to room temperature before using. DS-9-314 should be stored away from alkaline materials such as caustic soda and oxidizable material. Contact with either could produce a strong reaction and splattering could occur.

WASTE DISPOSAL

DIVERSEY WYANDOTTE DS-9-314 contains no chromates, fluorides or cyanides. The spent bath will contain metal ions such as iron, nickel, chromium, etc. Treatment and disposal of the spent DS-9-314 bath will depend on the local ordinances. Waste disposal methods are available on request from your Diversey Wyandotte representative.

PRECAUTIONS

DANGER: CAUSES SEVERE BURNS TO SKIN AND EYES.
HARMFUL IF SWALLOWED OR INHALED.

Contains hydrochloric acid. Product is corrosive to human tissues. Avoid contact with skin, eyes or clothing. Do not breath vapor or mist. Use adequate ventilation. Wash contaminated clothing and shoes before reuse. Wash thoroughly after handling product.

In case of eye or skin contact, flush with plenty of water for at least 15 minutes. Call a physician immediately. If inhaled, remove to fresh air. If breathing difficulty persists, get medical attention.

DO NOT TAKE INTERNALLY. If swallowed, give large amounts of water, milk or diluted milk of magnesia. DO NOT INDUCE VOMITING. Call a physician immediately.

KEEP OUT OF REACH OF CHILDREN.

HANDLING AND STORAGE: Keep container tightly closed.
Before moving container be sure closure is securely fastened.
Store in a cool area out of sunlight.
Loosen closure carefully.
In case of spill, flush area with water.

DIVERSEY WYANDOTTE

EVERITE® II

INHIBITED ACID FOR RUST AND SCALE REMOVAL

DESCRIPTION

EVERITE II is a special blend of a mineral acid and inhibitors in a concentrated easy to use liquid form. It is safe for removal of rust and scale from ferrous metals without attacking the base metal.

HANDLING INSTRUCTIONS

EVERITE II contains a strong acid and is a corrosive material. Contact with the skin or eyes may cause irritation and burns. The same safety precautions should be observed as when handling muriatic acid products. Personnel should wear face shield, safety glasses, rubber gloves and apron when working with EVERITE II. OSHA Material Safety Data Sheets are available on request from your Diversey Wyandotte representative.

EQUIPMENT RECOMMENDATIONS

Processing tanks for EVERITE II should be constructed of Koroseal, polyethylene, PVC, acid resistant brick or similar acid resistant materials. Mild steel tanks are not recommended for holding EVERITE II solutions.

OPERATING INSTRUCTIONS

Typical Process Cycles

A. Descaling Heat Treated Steel Parts

1. To remove oxides from the surfaces of heat treated parts, immerse in solution of EVERITE II at a concentration of 5-50% by volume at room temperature, depending upon the amount of oxide present and the time necessary for completing the work.
2. Rinse in cold water.
3. Neutralize using an appropriate Diversey Wyandotte product.
4. Rinse in cold water.
5. Dip in an appropriate Diversey Wyandotte rust preventive.

Typical Process Cycles (continued)

B. Removing Rust and Scale From Engine Radiators

1. Flush out system to remove loose particles.
2. Fill with clean hot water. Add appropriate Diversey Wyandotte cleaner and pump this solution through system for about an hour.
3. Drain while still warm and flush with clean water.
4. Fill the system about 3/4 full with cold water and introduce enough EVERITE II to completely fill the system. Idle the engine to circulate and titrate every ten minutes. When necessary, add material to replenish that dissipated by the scale. When two successive titrations are the same, drain and flush the system with clean water.
5. Fill with warm water and add appropriate Diversey Wyandotte neutralizer. Recirculate this solution 10 to 20 minutes to neutralize the EVERITE II and then drain.
6. Rinse with clean water by recirculating and drain. The system is then ready for filling with water and operation.

C. Removing Heat Scale From Forgings & Castings

1. Soak in a 50% by volume solution of EVERITE II for time sufficient to remove scale. Temperature should not be above 100°F (40°C). The container should be acid-proof.
2. Rinse in clear water.
3. Neutralize with an appropriate Diversey Wyandotte product.
4. Rinse.

D. Preparing Metal Surfaces For Repainting

1. Strip the paint and rinse the surface thoroughly.
2. Allow to dry down.
3. Apply 25% by volume EVERITE II to the surfaces by brushing or soaking.
4. Repeat applications until the rust has all been removed.
5. Rinse thoroughly.
6. Apply the recommended LOCKOTE treatment, rinse and dry. The surface is now ready for painting.

E. Removing Scale & Rust From Water Cooling System & Pipe Lines

(Dynamometers, air conditioning systems, water cooling towers, compressors and condensers.)

1. If there is slime or oil in the water, circulate a solution of appropriate Diversey Wyandotte cleaner for a sufficient period of time to remove the slime and oil.
2. Rinse the system thoroughly with cold water.

Typical Process Cycles (continued)

E. Removing Scale & Rust From Water Cooling System & Pipe Lines (continued)

3. Recirculate a solution of EVERITE II in the system. Use a concentration of 5-25% by volume, depending on accumulation of rust and scale. Time required will depend on extent of accumulation, but temperature should not be above 100°F (40°C).

4. Rinse thoroughly with cold water.

5. Recirculate a solution of appropriate Diversey Wyandotte neutralizer in cold water for 1/2 hour.

6. Rinse.

SOLUTION CONTROL

Overloading of EVERITE II solutions with dissolved iron is often the cause for dissatisfaction; the work, for example, failing to be cleaned in the required time and appearing dirty and rusty following immersion. Although this rust coat is easily rinsed off, the condition is indicative of loss in activity of the EVERITE II bath. For this reason, proper control of EVERITE II solutions should be maintained.

Steps should be taken to see that the dissolved iron content does not reach more than 6-8 oz/gal (45-60 g/l), and when this concentration is reached, the bath is dumped and a new solution made up.

Field control of EVERITE II solutions is accomplished simply by use of specific gravity readings. The hydrometer provides immediate readings as to the condition of the EVERITE II solution. For example, a fresh 50% by volume solution of EVERITE II will have a Baume reading of 9.0 as indicated on the graph. After a number of days, the Baume reading is 19. Using the equation:

Dissolved Iron = (Baume of Used EVERITE II Solution) - (Baume of Fresh EVERITE II Solution)

= (19) - (9)

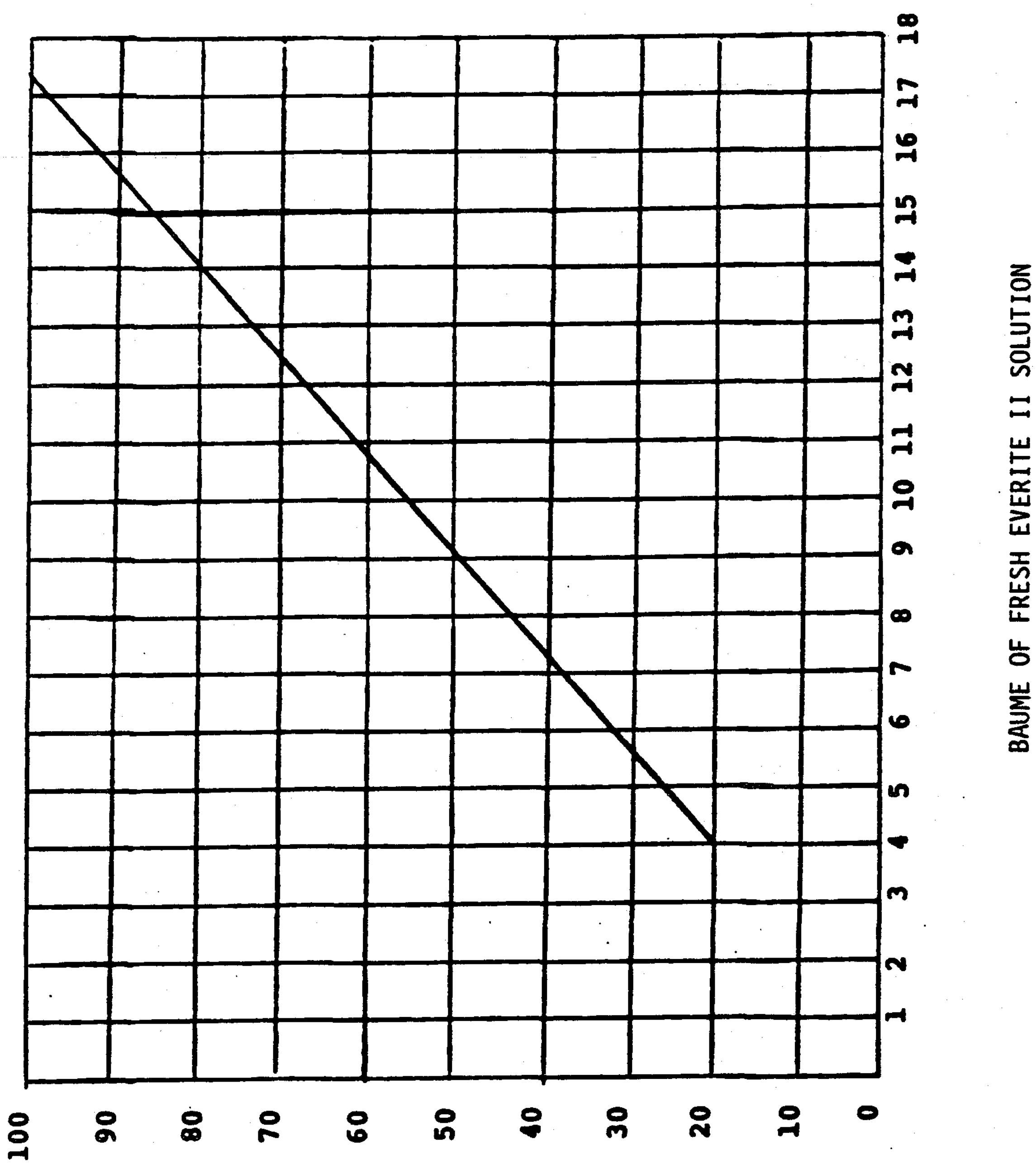
= 10 oz/gal (75 g/l)

This EVERITE II bath should be dumped.

If a chemical titration is desired, the following chart applies:

% EVERITE II	SAMPLE SIZE	ml 0.1N NaOH to pH (8.1) or Phenolphthalein End Point (Pink Coloration)
100%	1 ml	87.0 ± 1.5 ml
90%	1 ml	78.3 ± 1.5 ml
75%	1 ml	65.3 ± 1.5 ml
50%	1 ml	43.5 ± 1.5 ml
25%	1 ml	21.8 ± 1.5 ml
10%	1 ml	8.7 ± 1.5 ml
0%	1 ml	0.0 ± 0.2 ml

PERCENT BY VOLUME, EVERITE II



PACKAGING

EVERITE II is a brown liquid supplied in non-returnable fiber or lined steel drums.

STORAGE

EVERITE II should be stored in sealed containers in a cool, dry area away from alkaline products.

WASTE DISPOSAL

EVERITE II may require neutralization to a specified pH range prior to disposal depending on local ordinances. Disposal instructions are available on request from your Diversey Wyandotte representative.

PRECAUTIONS

DANGER: CAUSES SEVERE BURNS TO SKIN AND EYES.
HARMFUL IF SWALLOWED OR INHALED.

Contains hydrochloric acid. Product is corrosive to human tissues. Avoid contact with skin, eyes or clothing. Do not breath vapor or mist. Use adequate ventilation. Wash contaminated clothing and shoes before reuse. Wash thoroughly after handling product.

In case of eye or skin contact, flush with plenty of water for at least 15 minutes. Call a physician immediately. If inhaled, remove to fresh air. If breathing difficulty persists, get medical attention.

DO NOT TAKE INTERNALLY. If swallowed, give large amounts of water, milk or diluted milk of magnesia. DO NOT INDUCE VOMITING. Call a physician immediately.

KEEP OUT OF REACH OF CHILDREN.

HANDLING AND STORAGE: Keep container tightly closed.
Before moving container, be sure closure is securely fastened.
Store in a cool area out of sunlight.
Loosen closure carefully.
In case of spill, flush area with water.

DIVERSEY WYANDOTTE

DIVERSCALE® 299

SCALE AND OXIDE CONDITIONER FOR STAINLESS STEEL AND OTHER HEAT RESISTANT ALLOYS

DESCRIPTION

DIVERSCALE 299 is a highly alkaline product used to oxidize complex heat scales on stainless steel, heat resistant alloys and jet engine components rendering them more soluble in subsequent baths. It conditions complex heat scales rapidly and without corrosion of the base metals, ferrous and high temperature alloys.

DIVERSCALE 299 permits descaling without drastic and harmful acid pickles which may cause embrittlement and intergranular corrosion especially on heat sensitive components. Certain types of heat scale resulting from the combustion process in jet engines are directly dissolved in DIVERSCALE 299 solutions.

DIVERSCALE 299 exhibits long solution life.

HANDLING INSTRUCTIONS

DIVERSCALE 299 is a highly alkaline and oxidizing material. The same safety precautions should be observed as when handling caustic soda. Contact of the material with skin or eyes will cause burns and irritations. Personnel should wear rubber gloves, apron and face shield when working with DIVERSCALE 299.

When making up new solutions of DIVERSCALE 299, the material should be slowly added to cold water with constant stirring. Large amounts of heat are generated as DIVERSCALE 299 is dissolved in water. NEVER MAKE UP NEW SOLUTIONS OF DIVERSCALE 299 BY ADDING TO HOT OR WARM WATER.

If it is necessary to make additions of DIVERSCALE 299 to heated existing DIVERSCALE 299 baths, the material should be added very slowly over the surface of the solutions with constant stirring.

OSHA Material Safety Data Sheets for DIVERSCALE 299 are available on request from your local Diversey Wyandotte representative.

EQUIPMENT RECOMMENDATIONS

DIVERSCALE 299 can be used with 300 series stainless steel or mild steel tanks and heaters. However, a DIVERSCALE 299 solution is most efficiently heated with gas burners placed underneath the tank. Racks and baskets are almost always constructed of 300 series stainless steel.

DIVERSCALE 299 tanks require proper ventilation to control fumes. Use metal duct-work. Do not use ducts made of aluminum, organic materials or with organic linings such as wood, plastics or paint.

OPERATING INSTRUCTIONS

Concentration:	16-32 oz/gal (120-240 g/l)
Temperature:	180-240°F (80-115°C)
Time:	Normally 15-30 minutes

Typical Descaling Cycle

1. Pre-clean in appropriate Diversey Wyandotte cleaner.
2. Water rinse.
3. Condition scale in DIVERSCALE 299.
4. Water rinse.
5. Scale removal in 50% Diversey Wyandotte EVERITE II.
6. Water rinse.

Upon prolonged immersion in EVERITE II, stainless steel may become slightly stained although no attack on the surface has occurred. This stain is removed easily by immersing work in DIVERSCALE 299, followed by a rinse, a one minute dip in EVERITE II, and a thorough final rinse.

Some heat scales require a second treatment. In extreme cases, the descaling sequence may have to be repeated two or three times. (Steps 1 and 2 then are omitted.)

When work is known to be completely free of oils, shop dirt, etc., Step 1 sometimes can be eliminated.

Smut Removal

For parts with smut after processing in DS-9, the sequence is as follows:

1. Immerse in DIVERSCALE 299: 14-20 oz/gal (105-150 g/l), 180-200°F (80-95°C), 2-4 minutes.
2. Rinse.
3. Immerse in EVERITE II: 30-50% (by volume), room temperature (70°F or 20°C), 1-2 minutes.
4. Rinse thoroughly with fresh water.

SOLUTION CONTROL

Test Kit Method

Concentration Range - - - - All
Test Kit- - - - - - - - - - Type B plus 250 ml beaker or 8 oz glass
Testing Solution- - - - - - 18
Indicator Solution- - - - - Phenolphthalein
Sample Size - - - - - - - - - 1 dropper
Color Change- - - - - - - - Dark wine red to dark brown

Procedure

1. Place dropper (to line) of DIVERSCALE 299 solution sample in beaker.
2. Fill the test bottle to line with water, then transfer the water to the sample in the beaker.
3. Add 2 to 5 droppers of 20% Sodium Gluconate to the beaker (purple color will change through green to dark brown).
4. Add 5 drops of Phenolphthalein to give a dark wine red color.
5. Titrate dropwise with TS18. Watch for a color change from dark wine red to dark brown while titrating against a white background.

Calculation

Ounces DIVERSCALE 299 per gallon = 1.07 x Drops TS18
Grams DIVERSCALE 299 per liter = 8.0 x Drops TS18

Laboratory Method

1. Filter about 25 mls of solution through a tight pad of glass wool to remove suspended material.
2. Carefully pipette 2 mls of the filtered sample into a 250 ml Erlenmeyer flask. Add about 50 mls of water.
3. Add 5 heaping spoonsful (about 1 gm) of starch iodide mixture (Reagent A) and about 5 mls of 50% Sulfuric Acid, mix, and allow to stand for 1 to 2 minutes.
4. Titrate with 0.1N Sodium Thiosulfate to the disappearance of the dark starch iodide color.
5. Calculations
   Factor = 8.36
   Metric Factor = 62.7
   Ounces DIVERSCALE 299 per gallon = 8.36 x mls Reagent C x Normality
   Grams DIVERSCALE 299 per liter = 62.7 x mls Reagent C x Normality

PACKAGING

DIVERSCALE 299 is a free flowing granular compound that may range from purple-gray to blue-green in color depending upon age and storage conditions. It is supplied in non-returnable fiber drums.

STORAGE

DIVERSCALE 299 should be stored in a sealed container in a cool indoor area away from acids and oxidizable (flammable) material. Contact with oxidizable material may cause combustion.

WASTE DISPOSAL

DIVERSCALE 299 may require neutralization to a specified pH range in accordance with local ordinances. Waste disposal procedures are available on request from your local Diversey Wyandotte representative.

PRECAUTIONS

DANGER: CAUSES SEVERE BURNS. MAY BE FATAL IF SWALLOWED. HARMFUL IF INHALED.

Contains sodium hydroxide. Do not get in eyes, on skin, on clothing. Avoid breathing dust or mist. Keep container closed. Use with adequate ventilation. Wash thoroughly after handling.
PRECAUTION: When handling, wear goggles, face shield and rubber gloves. While making solutions, add slowly to surface of solution to avoid violent spattering.

KEEP OUT OF REACH OF CHILDREN.

FIRST AID: CALL A PHYSICIAN IMMEDIATELY.
In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes, while removing contaminated clothing and shoes. Wash clothing before reuse, discard contaminated shoes. If swallowed, dilute by drinking large quantities of water or milk. DO NOT INDUCE VOMITING. If inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen.

ATTENTION: When empty, this container may still be hazardous. Because containers, even after they have been emptied, still retain product residues (vapor, liquid or solid), all labeled hazard precautions must be observed.

WESTERN PNEUMATIC TUBE COMPANY
P. O. Box 909 – KIRKLAND, WASHINGTON 98083 TELEPHONE (206) 822-8271

July 25, 1985

Jet Propulsion Lab
4800 Oak Grove Drive
Pasadena, California 91109

Attention: Mr. S. Ghosh
Mail Code - 511-203
Phone: (818) 577-9825

Dear Mr. Ghosh:

Per our telephone conversation on July 25, 1985, please find enclosed copies of our pickle and degreaser procedures. If you have any additional questions, please feel free to contact me.

Very truly yours,

John Titland
Technical Director

JT:jp

Enclosures

WESTERN PNEUMATIC TUBE COMPANY
P.O. BOX W—KIRKLAND, WASHINGTON 98033 TELEPHONE (206) 822-8271

VAPOR DEGREASING PROCEDURE

1.0 SCOPE

1.1 This procedure describes the requirement for vapor degreasing of tubing in trichloroethylene.

2.0 REFERENCED DOCUMENTS

2.1 The following documenta was used as a reference for preparing this specification:

"Modern Vapor Degreasing and DOW Chlorinated Solvents" -- Dow Chemical -- 1977

3.0 PERSONNEL

3.1 Personnel to be qualified shall receive training consisting of practical experience and personal instruction.

3.2 Personnel shall have a minimum of sixty days work experience at Western Pneumatic Tube and shall exhibit good work performance.

3.3 Any evidence of failure to follow required safety procedures or poor work performance will result in a withdrawal of personnel from vapor degreaser operations.

4.0 METHOD

4.1 The degreaser solvent shall be trichloroethylene.

4.2 No titanium, aluminum, or magnesium shall be degreased without prior approval by the Technical Director.

4.3 Tubing shall be dry and free of any extraneous materials such as shop towels, paper, etc. Tubing coming from pressure test, abrasive cut-off, or which has been rained on, shall remain in a warm area until dry to avoid unnecessary moisture being introduced into the solvent.

Q.A. APPROVAL ____________ MFG. APPROVAL ____________

4.0 METHOD (CONTINUED)

4.4 Tubing shall be contained in approved stainless steel baskets or bundled using approved 3" wide degreasing slings.

4.5 Position load over vapor chamber, remove cover, lower one end of load several inches to assure drainage, then lower at lowest speed range into vapor area, stopping above liquid surface of the boiling sump. Avoid creation of any turbulence in the vapor degreaser.

4.6 Hold load in vapor phase until condensate is running freely from lower end of tubes, then lower into liquid phase of boiling sump.

4.7 Leave load in liquid phase several minutes, until fast boiling is resumed.

4.8 At low speed, raise, from boiling sump, allow to drain well, and rinse in liquid phase in the cold (condensate) sump. Raise to vapor phase and leave several minutes.

4.9 Raise, drain, then raise above freeboard at lowest speed before leveling load.

4.10 Replace cover.

4.11 Work orders shall be signed upon completion of the degreasing operation by the operator.

5.0 EQUIPMENT AND FACILITIES

5.1 Maintenance of liquid degreaser tanks, lines, and auxiliary equipment shall be the responsibility of the Maintenance Foreman and the Maintenance Shop.

5.2 Vapor degreasing facilities shall consist of an open top degreaser, steam heat lines, condenser lines, water separator, re-distilling tanks, storage tank and control equipment necessary for operation.

5.3 Annual inspections shall be conducted by the Maintenance Foreman for purposes of maintaining degreaser functions, cleaning distribution lines, and conducting safety inspections.

5.4 Biannually cleaning and inspection shall be conducted by maintenance personnel.

6.0 SAFETY

6.1 Personnel operating the degreaser shall receive from the area foreman sufficient instruction to observe appropriate safety measures.

6.2 Adequate ventilation shall be maintained in vapor degreaser operations and during any exposure to solvent materials.

6.3 Prolonged or repeated contact of degreaser solvent with the skin should be avoided by use of protective gear.

6.4 Disposal of used solvent shall be the responsibility of the Maintenance Foreman.

7.0 PERIODIC TESTS

7.1 Testing of degreaser solvent for acid acceptance, water content, and any other tests necessary for operation shall be the responsibility of the Technical Director or a designated representative.

7.2 Vapor degreasing operation shall be subject to control by the Technical Director in issuing safe operating guidelines.

WESTERN PNEUMATIC TUBE COMPANY
P.O. BOX W—KIRKLAND, WASHINGTON 98033 TELEPHONE (206) 822-8271

PICKLE HOUSE PROCEDURE

1.0 SCOPE

1.1 This specification describes the standard pickling procedures used by Western Pneumatic Tube Company. Any special pickling operations will be conducted under the supervision of the Technical Director.

2.0 PERSONNEL

2.1 The pickle tank operator shall receive training consisting of personal instruction and practical experience.

2.2 Any evidence of failure to follow required safety procedures or of poor work performance will result in removal from pickle house operations.

3.0 PICKLE HOUSE SOLUTIONS

3.1 Stainless Steel Pickle

3.1.1 The stainless steel pickle shall be mixed with an approximate concentration of 10% HNO_3, 4% HF, and the remainder water.

3.1.2 The charge for the main pickle tank shall be:

HNO_3 = 4 drums (350 lbs X 65% acid per drum)

= 910 lbs acid

HF = 2 drums (242 lbs X 70% acid per drum)

= 339 lbs acid

water = solution to 22 inches deep

= approximately 1100 gallons solution

Q.A. APPROVAL ____________ MFG APPROVAL ____________

3.0 PICKLE HOUSE SOLUTIONS (CONTINUED)

3.1 3.1.3 The charge for the small pickle tank shall be:

HNO_3 = 2 drums (350 lbs X 65% acid per drum)

= 455 lbs acid

HF = 1 drum (242 lbs X 70% acid per drum)

= 170 lbs

water = solution to 18" deep

= approximately 550 gallons solution

3.1.4 The condition of the stainless steel pickle shall be determined by the Bench Foreman based on the time required to achieve an adequate pickle. The stainless steel pickle may be spiked by the Bench Foreman according to the following schedule:

a. Main pickle tank

first spike: 1 drum HF maximum

second spike: 1 drum HF maximum

1 drum HNO_3 maximum

third spike: 1 drum HF maximum

b. Small pickle tank

first spike: 1/2 drum HF maximum

second spike: 1/2 drum HF maximum

1/2 drum HNO_3 maximum

third spike: 1/2 drum HF maximum

Additional spikes or spikes not in accordance with the above schedule shall be approved by the Technical Director.

3.1.5 The Bench Foreman shall report all charges and all spikes to the Technical Director in writing.

3.0 PICKLE HOUSE SOLUTIONS (CONTINUED)

3.2 Nickel Pickle

3.2.1 The nickel pickle shall be mixed with an approximate concentration of 20% HNO_3, 2% HF, and the remainder water.

3.2.2 The charge for the main pickle tank shall be:

HNO_3 = 4 drums (350 lbs X 65% acid per drum)

= 910 lbs acid

HF = 91 lbs acid solution (70% acid)

water = solution to 11 inches deep

= approximately 455 gallons of solution

3.2.3 The charge for the small tank shall be:

HNO_3 = 2 drums (350 lbs X 65% acid per drum)

= 455 lbs acid

HF = 45 lbs acid (70% acid)

water = solution to make 10 inches deep

= approximately 227 gallons of solution

3.2.4 The condition of the nickel pickle shall be determined by the Bench Foreman based on the time required to achieve an adequate pickle. The nickel pickle may be spiked by the Bench Foreman as follows:

a. Main pickle tank

first spike: 2 drums HNO_3 maximum

90 lbs HF maximum

b. Small pickle tank

first spike: 1 drum HNO_3 maximum

45 lbs HF maximum

3.0 PICKLE HOUSE SOLUTIONS (CONTINUED)

3.2.4 (Continued)

Additional spikes or spikes with more acid than stated above shall be approved by the Technical Director.

3.2.5 The Bench Foreman shall report all charges and all spikes to the Technical Director in writing.

3.3 Potassium Permanganate Solution

3.3.1 The potassium permanganate solution shall be mixed with an approximate concentration of 36 oz./gallon NaOH and 9 oz./gallon $KMnO_4$ in water.

3.3.2 The charge for the permanganate tank shall be:

NaOH = 4 drums

= 1688 lbs

$KMnO_4$ = 4 drums

= 440 lbs

water = solution to 24" deep

= approximately 720 gallons of solution

3.3.3 The condition of the potassium permanganate solution shall be determined by testing performed by the Lab. The solution shall be spiked only under the direction of the Technical Director.

4.0 METHOD

4.1 Pickle tanks

4.1.1 The work order will be checked for any special instructions prior to beginning any pickle operations.

4.1.2 Tubes shall be free of oils or surface soils which could act to mask surface contact with pickle solution.

4.1.3 Tubes shall be placed in a corrosion resistant basket or bundled, using 5" wide nylon slings.

4.1.4 Position bundle or basket of tubes above assigned pickle tank. Lower one end several inches to prevent air entrapment. Slowly lower load into solution until all tubes are submerged.

4.0 METHOD (CONTINUED)

4.1.5 After 10 minutes in solution, raise bundle or basket and drain to exchange stagnant solution and release entrapped air pockets, then slowly lower until submerged.

4.1.6 Check frequently to avoid over pickling. Pickling is complete when smut and scale becomes loose to the touch, or can be removed by wiping with a mild abrasive or a stiff brush. The tube surface shall show no evidence of etching or intergranular attack.

4.1.7 When pickling is complete, the bundle or basket of tubes shall be raised above the pickle solution, drained well, rinsed with the hose from the rinse water tank, and again allowed to drain.

4.1.8 The bundle or basket will then be moved to above the sump grate and each tube washed both inside and outside with the high pressure sump water hose to remove all smut and scale. Tubes not cleaned by flushing will be hand wiped, brushed, or abrasively scrubbed as required.

4.1.9 When all tubes have been cleaned, the tubes shall be rinsed with the hose from the rinse water tank. The bundle or basket of tubes shall then be submerged in the rinse water tank and rinsed for a minimum of 15 minutes. Following this final rinse, the tubes shall be drained and allowed to dry in ambient shop air.

4.2 Potassium Permanganate Tank

4.2.1 The work order shall be checked for any special instructions prior to beginning any pickle operations.

4.2.2 Tube shall be free of oil or surface soil which could act to mask contact with the potassium permanganate solution.

4.2.3 Tubes shall be placed in a corrosion resistant basket or bundled, using polyethylene rope.

4.2.4 Position basket or bundle of tubes above the potassium permanganate tank. Lower one end several inches to prevent air entrapment. Slowly lower load into the potassium permanganate solution until all tubes are submerged. Allow tubes to remain in solution for the required time.

4.0 METHOD (CONTINUED)

4.2.5 When potassium permanganate treatment is complete, the bundle or basket of tubes shall be raised above the solution, drained well, rinsed with the hose from the rinse water tank, moved to above the sump grate, and rinsed with the high pressure sump water hose. After the potassium permanganate treatment, the tubes shall be pickled or dried in ambient shop air for pickling at a later time.

4.3 Temperatures and Times

4.3.1 Stainless Steel Pickle

a. Maximum temperature: 145°F

b. Maximum time:

-- Stainless steel with furnace scale -- approximately 1 hour

-- Stainless steel without scale -- approximately 30 minutes

NOTE: Maximum time dependent on condition of acid.

-- Alloys other than stainless steel shall not be pickled in this bath without the approval of the Technical Director.

4.3.2 Nickel Pickle

a. Maximum temperature: 140°F

b. Maximum time:

-- Nickel and cobalt alloys with black furnace scale -- 15 minutes

NOTE: All nickel and cobalt alloy tubes with furnace scale shall have had a potassium permanganate solution treatment prior to pickling.

-- Nickel and cobalt alloys without furnace scale -- 5 minutes

4.0 METHOD (CONTINUED)

4.3.3 Potassium Permanganate Solution

a. Maximum temperature: 210^{o}F

b. Minimum time: 1 hour

4.3.4 The use of temperatures or times not in accordance with those stated above shall be approved by the Technical Director.

4.4 Solution Mixing

4.4.1 The mixing of pickle house solutions shall be carried out with the utmost care under the supervision of the area foreman. The pickle tank operator shall be clothed with a complete protective outfit including face protection when mixing solutions.

4.4.2 Tanks shall be filled to approximately half capacity with water prior to adding any chemicals. The chemicals shall be added in a controlled manner to avoid any spilling or splashing. Spills or splashes shall immediately be rinsed into the sump with any of the available water hoses. When all the chemicals have been added to the tank, the remainder of the required water shall be added.

4.4.3 Empty chemical containers shall be rinsed with water to remove all traces of pickle chemicals. Rinse water shall be trapped in the sump. Every effort shall be made to avoid storing partially full containers of pickle chemicals. If partially full containers must be stored, they shall be tightly closed and placed in the special acid storage area. The Bench Foreman shall monitor this storage area to assure that the containers remain in good condition.

5.0 FACILITIES OPERATION AND MAINTENANCE

5.1 Operation of the pickle house shall be the responsibility of the Bench Foreman. Maintenance of the pickle house shall be the responsibility of the Maintenance Foreman. The Bench Foreman shall immediately report any malfunction of pickle house equipment to the Maintenance Foreman.

5.0 FACILITIES OPERATION AND MAINTENANCE (CONTINUED)

5.2 The Bench Foreman shall supervise and monitor all operations in the pickle house to assure conformance to this procedure and sound safety practices. Tank temperatures shall be monitored regularly to assure that maximum temperatures are not exceeded.

5.3 The pickle tank vapor outgassing fans shall be operated any time the pickle solutions are being heated to above ambient temperatures. The permanganate tank vapor outgassing fan shall be operated any time the potassium permanganate solution is heated above ambient temperatures and the tank lid is open.

5.4 The Maintenance Foreman shall assure that the filter on the rinse water tank is cleaned daily and that the filter medium is changed semiannually.

BATCH START

STAPLE
OR
DIVIDER

BAKE-OUT TECHNIQUES

INTRODUCTION

The following calculations and costs reflected in the bake-out process are based on heated tracing cable spirally wrapped around the vacuum pipe. Installation costs for the complete baking system are shown including insulation and jacketing but excluding power distribution.

(13)

LIGO

MI Tracing Cable Requirements

Rev 11-10-87
10-26-87
AH-1

PER LIGO PRESENTATION OF 5-27-87 REV 11-10-
THE HEATING REQUIREMENTS FOR
BAKEOUT OF THE 48"ϕ SS TUBE
WERE AS FOLLOWS:

FOR 2" INSUL. COVER

173 w/ft + 10% = 190 w/ft

FOR 3" INSUL COVER

121 w/ft + 10% = 133 w/ft

FOR 4" INSUL COVER

87 w/ft + 10% = 96 w/ft

① THE TOTAL HTG. REQUIREMENTS
FOR THE 5 Mile LENGTH IS:

For 2" INS → 190 w/ft × 26400 ft ≅ 5000 KW
For 3" INS → 133 w/ft × 26400 ft ≅ 3500 KW
For 4" INS → 96 w/ft × 26400 ft = 2500 KW

REV 11-10
10-76
AH

② HEATING TRACE CABLE

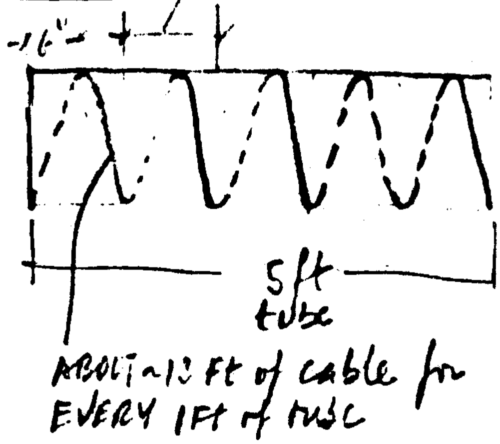
SELECT CHROMALOX M.I. HTG CABLE

2a FOR 2" INSUL. / 190 W/ft tube

USC Stainless Steel Model # R125

14W/ft cable

13 ft x 15 W/ft = 195 W/ft of tube



Total length of cable

13 ft/ft$_t$ x 26400 ft$_t$ = 343200 ft

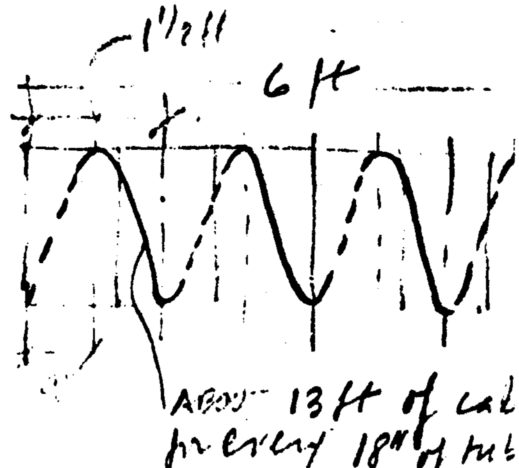
MAX UNJOINTED LENGTH = 600 ft

N° of UNJ. LENGTHS = $\frac{343200}{600}$ = 572 lengths.

2b For 3" INSUL. / 133 W/ft tube

USC S.S Model # R125

15 W/ft x 13 ft = 195 W/1.5 ft of tube



Total length of cable

13 ft/ft$_t$ x 26400 ft$_t$/1.5 ft/ft = 228800 ft

MAX UNJOINTED LENGTH = 520 ft

No of Unjt lengths = $\frac{228800}{520}$ = 440 lengths

REV 11-10-8
10-26-8
AH-3

2.c

For 4" INSUL / 96 W/ft tube
Use S.S. Model # R125

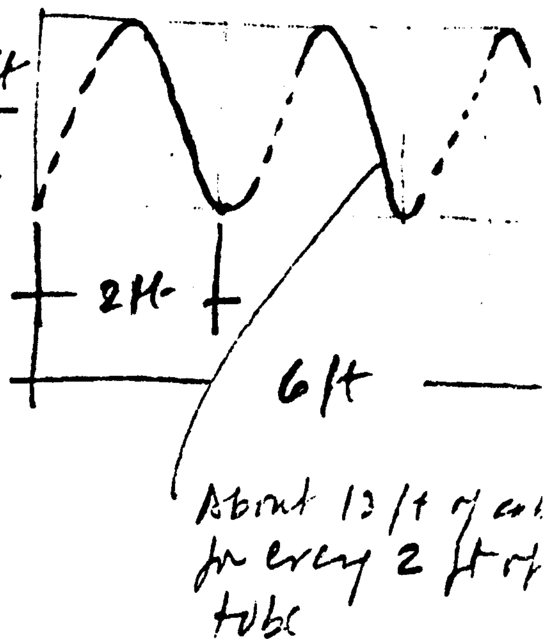
15 W/ft x 13 ft = 19 W/2 ft of tube

Total length of cable

13 ft/ft x 26400 ft / 2 ft/ft = 171600 ft

MAX UNJOINTED LENGTH = 520 ft

No of UNJ. LENGTHS = 171600 / 520 = 330



Rev 11-10-8...
10-11-...

SUMMARY

INSULATION THICKNESS INCHES	HEATING REQUIREMENT PER Ft of TUBE	TOTAL KW	CABLE LENGTH Ft	REMARKS
2"	190 W/ft	5000	343,200	SEE NOTE ××××
3"	133 W/ft	3500	228,800	do
4"	96 W/ft	2500	171,600	do

COSTS

INSUL. THICKN. INCH.	INSUL COST PER Ft	L_i Ft	TOTAL COST OF INSULAT.	COST OF TRACER CABLE PER Ft	L_{TC} Ft	TOTAL COST OF TRACER CABLE	TOTAL COST OF INSUL + TRACER CABLE
(1)	(2) *	(3)	(4) = (2) × (3)	(5) **	(6)	(7) = (6) × (5)	(8) = (4) + (7) ***
2"	25	26,400	660,000	5.00	343,200	1,716,000	2,376,000
3"	29	26,400	765,600	5.00	228,800	1,144,000	1,909,600
4"	32	26,400	844,800	5.00	171,600	858,000	1,702,800

* INCLUDES INSULATION + 0.016" ALUM. JACKET + INSTALLATION

** INCLUDES TRACER CABLE + INSTALLATION

*** DOES NOT INCLUDE POWER DISTRIBUTION SYSTEM

×××× INSULATION: MANVILE PIPE & TANK INSULATION TEMP 450°F FIBREGLASS, 3 lb/cu ft. K FACTOR .44 AT 302°F

REV 11-10-82
10-26-81
AH-5

Manville

Pipe and Tank Insulation

Type: Flexible Board Type Insulation
Temp: 450°F (232°C)

OP/Overall Product in Place

Description
Pipe and Tank Insulation is made from a high temperature fiber glass bonded to a flexible jacketing. The semi-rigid fiber glass board, shipped in a roll form, has a unique fiber orientation, perpendicular to the board surface. Due to this fiber orientation, the net effect is a product with the compressive strength of high density insulation. This permits the insulation to closely conform to rounded surfaces without reducing the thickness of insulation which would cause a loss in insulating efficiency.

Available Types
Pipe and Tank Insulation is available faced with AP (All Purpose) jacketing. Special facing orders are available through your local J-M District Sales Office. AP jacketing is intended for indoor use and is a laminate of white kraft and aluminum foil, reinforced with fiber glass, chemically treated for fire and smoke safety.

Applications
For use on bare pipe or add-on insulation when additional insulation is required. Because of its highly flexible characteristics, Pipe and Tank Insulation can be easily applied to rounded shapes, such as pipes, tanks, ducts, vessels, and similar rounded and/or irregular surfaces. This ease of fit is particularly helpful on retro-fit installations where existing insulation results in non-standard outside diameters.

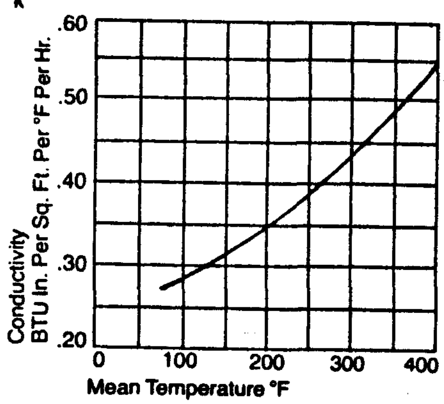
Advantages
Easy to Apply. For most applications only a ruler, knife, 3" wide AP pressure-sensitive tape, and a stapler are needed. When applying simply determine the circumference of the piece being insulated (remember to add twice the thickness of insulation being used to the diameter). Add 2" to 4" for lap seam, and cut to length. Remove two segments to provide for the lap. Lap seams should be stapled with outward clinching staples placed on maximum 4" centers. For vapor barrier applications the staples must be coated with a vapor barrier mastic for a complete vapor barrier seal. All longitudinal and circumferential joints should be sealed with a 3" wide pressure sensitive tape. For some applications banding may be required.

Easy to stock and install. A few rolls, offering a selection of insulation thicknesses, meet both pipe and tank insulation needs, thus eliminating the need to stock an assortment of individual pipe sizes.

Fiber Glass Properties

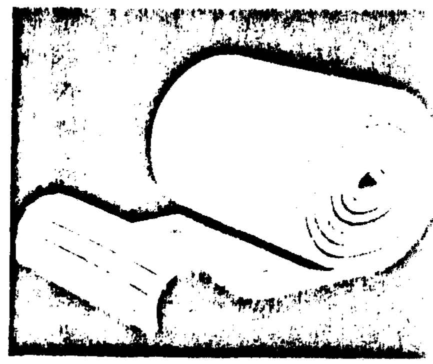
Temperature Limit	450°F (232°C)
Density	3 pcf
Compressive Strength	325 psf at 25% deformation 275 psf at 10% deformation

Thermal Conductivity



**A sufficient thickness of properly installed insulation must be used to prevent insulation surface temperature from exceeding 150°F.*

Example Of Fabrication
To replace 18" x 2" pipe covering
1. Cut piece 72⅛" long (69⅛" plus 3" for lap).
2. Strip off 3" of fiber glass leaving the jacket intact.
3. Physically apply to the pipe the first section cut of any size to verify exact dimension required.



J-M Pipe and Tank Insulation Sizing Chart
Approximate Length in Inches** To Cut Rolls to Fit Large Pipes and Ducts

Pipe Size Inches	Thickness Inches 1	1½	2	3
10	40	43¼	46⅜	52⅝
12	46⅜	49½	52⅝	59
14	50¼	53⅜	56½	62⅞
16	56½	59¼	62⅞	69⅛
18	62⅞	66	69⅛	75⅜
20	69⅛	72¼	75⅜	81¾
22	75⅜	78½	81¾	88
24	81¾	84⅞	88	94½
26	88	91⅛	94¼	100½
28	94½	97⅜	100½	106⅞
30	100½	103¾	106⅞	113⅛
32	106⅞	110	113⅛	119⅜
34	113⅛	116¼	119⅜	125¾
36	119⅜	122½	125¾	132
38	125¾	128¾	132	138¼
40	132	135⅛	138¼	144½
42	138½	141⅜	144½	151

***The above dimensions do not include a lap. ADD 2" through 4" for a lap.*

Sizes and Thicknesses
1"—125 sq. ft./roll (35" x 43 lin. ft.)
1½"—102 sq. ft./roll (35" x 35 lin. ft.)
2"—75 sq. ft./roll (35" x 26 lin. ft.)
3"—51 sq. ft./roll (35" x 17½ lin. ft.)

BATCH START

STAPLE
OR
DIVIDER

LEAK DETECTION

JPL

HIGH VACUUM LEAK DETECTION

SYSTEMS & PARAMETERS

J. J. CUCCHISSI
F. L. LANSING ←

14 NOVEMBER 1984

ENCLOSURE "C"
Sheet 1 of 18

JJC 1–18

JPL

GENERAL LEAK HUNTING REMARKS

- Leak hunting and repair is an exasperating process. Be reasonably certain a leak exists before starting.
- Some leaks may be due to malfunctioning pumps. Check pumps first.
- Leakage usually occurs through flange seals, welded or soldered joints, flaws (cracks) or porous sections of metal.
- As long as the system reaches the operating pressure, there is no need to be concerned with leaks, only when the time to reach operating pressure is unduly long.
- It is not necessary to use the most sensitive leak detection method to ensure that the system is "tight".

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SIZE OF LEAKS

- Physical size is not very important.

- Size of leak is measured in the following leak units:
  - → millitorr-litre/sec (European system)
  - → std-cc/sec (U.S. system)

- Tolerable leak rate depends on the product of operating pressure, p, and pumping speed, S.

For example: GWO $p = 10^{-8}$ torr $= 10^{-5}$ millitorr
total $S \approx 1{,}000{,}000$ l/sec

Tolerable leak rate = 10 millitorr-litre/sec
= 0.01 torr-litre/sec
= 0.013 std-cc/sec*

(TOLERABLE LEAK RATE ≡ DESIGN OUTGASSING RATE)

- Most leak detection devices have sensitivities from 10^{-4} to 10^{-10} std-cc/sec.

*1 std-cc/sec = 0.760 torr-litre/sec

ENCLOSURE "C"
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JPL FUNCTIONAL REQUIREMENTS OF AN "IDEAL" LEAK DETECTOR

- Capability for measurement of total leak and isolation of individual leaks.
- Rapid response.
- Temporary sealing of leak.
- High sensitivity.
- Applicability to any vacuum system without loss of vacuum.
- Simplicity of design.
- Low cost.
- Ease of maintenance and operation.

ENCLOSURE "C"
Sheet 4 of 18

JPL

FUNCTIONAL REQUIREMENTS
DEFINITIONS

*Manufacturers specify SENSITIVITY in the following ways:

(1) Smallest detectable helium concentration in air, at a specified source pressure, in ppm;

(2) Minimum partial pressure of air which, if changed to the same pressure as the probe gas, would produce the minimum detectable indication. For helium leak detectors this is called the SMALLEST LEAK DETECTABLE (SLD) and is defined as the smallest pure helium leak which can be detected at a specified source pressure.

(3) MINIMUM DETECTABLE LEAK (MDL) is the smallest leak that can be unambiguously detected in the presence of noise or background.

(4) Product of the minimum detectable pressure change and the pumping speed at the detector

(5) MINIMUM DETECTABLE SIGNAL is a combination of noise and scale drift errors. Background noise must be subtracted out.

*To normalize readings: sensitivity to He = 2.7 x sensitivity to air.

ENCLOSURE "C"
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JPL

FUNCTIONAL REQUIREMENTS

DEFINITIONS

- RESPONSE TIME is the time it takes for a leak detector to yield a signal output equal to 63% of the maximum signal attained when tracer gas is applied indefinitely to the system under test. It should be < 3sec.

  - The delay in response is due to the time necessary for the helium concentration to build up at the throttle valve.

- CLEAN-UP TIME is the time required for a leak detector to reduce its signal output to 37% of the signal indicated at the time tracer gas ceases to be applied to the test system.

  - The delay in clean-up is due to the time necessary for the pump to remove helium from within the volume of the part. A high speed pump will reduce delays.

- RESPONSE & CLEAN-UP times are characteristic of the <u>system</u>.

ENCLOSURE "C"
Sheet 6 of 18

JPL

METHODS OF LEAK DETECTION

- Apply partial vacuum inside system, soap solution applied inside.
- Use overvacuum or evacuated hood.
- Apply sealing substance on outside of system, change of pressure inside.
- Monitor rate of pressure rise.
- Apply high pressure inside vacuum system, indicator on outside.
- Use spark coil outside system.
- Attach discharge tube to system.
- Use probe gas on outside, examine change of apparent pressure or of nature of gas inside system. (MOST SENSITIVE)

JPL METHODS OF LEAK DETECTION

• METHOD 1: Apply partial vacuum inside, soap solution applied inside.

• PROCEDURE: A person equipped with an oxygen tank gets inside vacuum system, which is then partially evacuated. Person applies detergent solution, looks for "bubbles".

• Used to find large inside leaks, not accessible from outside.

• Only used as a final resort, when all other techniques fail.

• DISADVANTAGE: Strict precautions must be taken—

(1) the person in the system must be under observation at all times.

(2) a continuous and uninterrupted source of oxygen must always be available.

(3) avoid opening wide the valve between the vacuum system and the pumps while the person is inside.

ENCLOSURE "C"
Sheet 8 of 18

JPL METHODS OF LEAK DETECTION

• **METHOD 2**: Use overvacuum or evacuated hood.

• **PROCEDURE**: The pressure is reduced over a portion of the surface outside the vacuum system by using shaped hoods which seal to the surface and are pumped out with a roughing pump. When the pressure is reduced over a leak, a vacuum gauge will show a pressure drop inside the volume of the object being tested.

• **DISADVANTAGE**: Difficult to make hoods that seal to irregular or curved surfaces.

• The hood method is modified to use probe gases and combined with method 8.

ENCLOSURE "C"
Sheet 9 of 18

JPL METHODS OF LEAK DETECTION

• **METHOD 3:** Apply sealing substance outside, measure pressure change inside.

• **PROCEDURE:** Cover outside surface with a material that temporarily or permanently seals the leak. Once the leak is covered, the pressure inside the vessel will continue to drop during pump down.

- Permanent sealants — lacquers, shellacs.
- Temporary sealants — water, acetone, alcohol.

• With temporary sealants, initially there will be a pressure drop. As volatile liquids enter the leak and then evaporate, ionization gauges will indicate a pressure rise.

• Sensitivity $\approx 10^{-6}$ std-cc/sec.

ENCLOSURE "C"
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JPL METHODS OF LEAK DETECTION

• **METHOD 4:** Monitor rate of pressure rise.

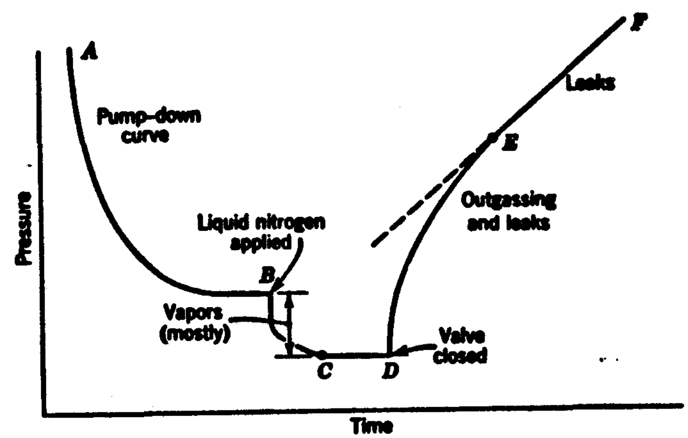
• **PROCEDURE:** First isolate the suspected portion of the vacuum system by isolation valves. Using a pressure gauge suitable for the range, measure dP/dt. The value for dP/dt should agree with the rate for a tight system with metal outgassing only.

• **DISADVANTAGES:**

(1) Very slow process.

(2) Not satisfactory for routine leak hunting.

(3) May require many isolation valves & different valving schemes to locate leaking section.



ENCLOSURE "C"
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JPL

METHODS OF LEAK DETECTION

- **METHOD 5:** Apply high pressure inside, indicator outside.

- Valuable in checking out components prior to installation.
- PROCEDURES:
  - Pressurize vessel with N_2 or air, use soap solution outside, check for bubbles. For large leaks, listen for escaping gas.
  - Pass a flame over outer surface, check for wavering of flame.
  - Pressurize vessel with halogen gas, use halide torch outside. Leaking gas will turn flame green in color.
  - Pressurize with ammonia gas inside and immerse vessel in a tank of hydrochloric acid. "White fog" forms when the two mix.
  - Inject diluted, radioactive Krypton-85 gas under 7 atm pressure. Detect leaks with a radiation counter after a specified "soaking" period.

- Sensitivity is $\approx 10^{-4}$ std-cc/sec.

ENCLOSURE "C"
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METHODS OF LEAK DETECTION

• **METHOD 6:** Use spark coil outside of system.

• **PROCEDURE:** Tesla coil produces high frequency high voltage at the tip.

(1) Observe a change in color of the glow discharge produced by gases entering the leak.

(2) Observe the spark jumping to the leak when the probe tip is one cm or so from it.

• **DISADVANTAGES:**

(1) Could puncture the spot if kept on too long.

(2) Cannot be used on all metal parts (grounding problem).

(3) Useful on glass parts only.

(4) Reliance on visual observation introduces error. → QUALITATIVE ONLY.

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METHODS OF LEAK DETECTION

- **METHOD 7:** Attach discharge tube to system
  - **PROCEDURE:** Similar to method 6.
    Observe a change in color of glow discharge produced by gases entering the leak.
    - Geissler discharge tube
  - **DISADVANTAGE:** Reliance on visual observation introduces error.
    → QUALITATIVE ONLY.

ENCLOSURE "C"
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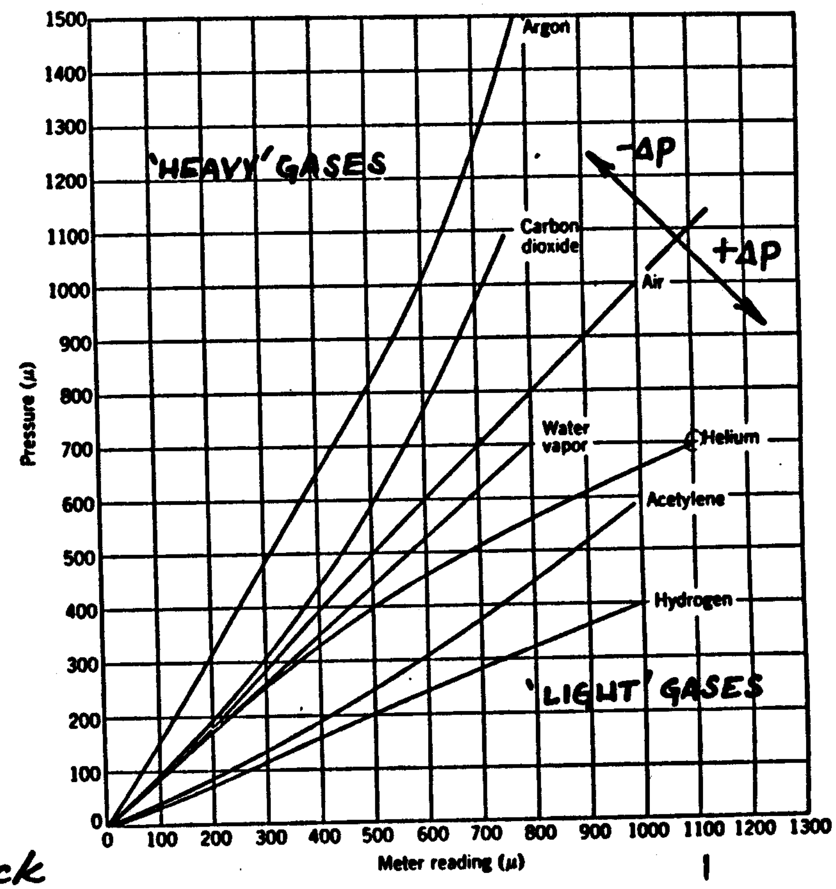
JPL

METHODS OF LEAK DETECTION

• **METHOD 8:** Use probe gas outside, detect behavior of gauge with respect to the probe gas employed.



• Use of gas/gauge combination depends on pressure range of vessel.

• **PROCEDURE:** For a gauge calibrated to read air pressure, a light probe gas will indicate a leak by registering an increase in pressure. A heavy probe gas would show a leak by a decrease in pressure.

• A gain in sensitivity results when only probe gas reaches the gauge. Some gauges will block air in the gas + air mixture.

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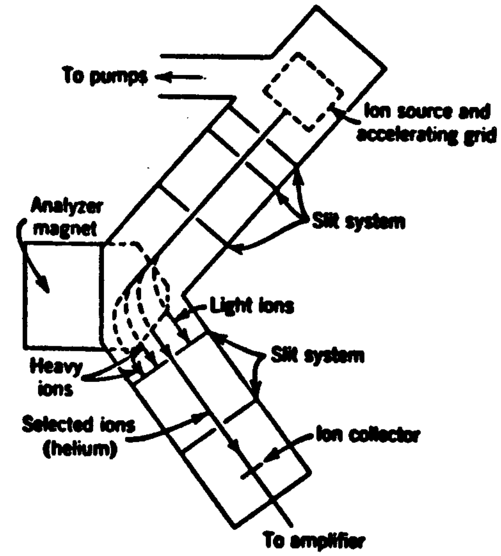
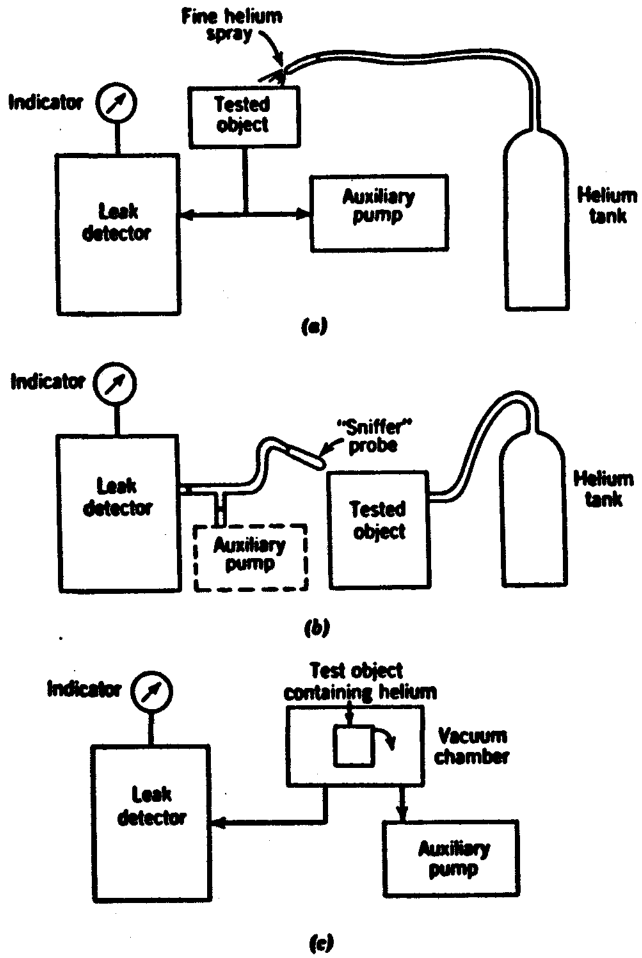
JPL HELIUM MASS SPECTROMETER LEAK DETECTOR



- Originated in the 1940's "Manhattan Project"
- Most sensitive detector commercially available.
- A form of mass spectrometer leak detector (MSLD) which uses a magnetic field to separate gas ions.
- Typical analyzer system consists of:
  - vacuum pump unit (diffusion & mechanical).
  - cold trap for condensable vapors.
  - coupling for connection to test sample.
  - valves and "hoods".
  - Leak indicator and vacuum gauge.
- Locates and measures size of leaks — sensitivity up to 10^{-11} std-cc/sec
- Available in stationary or portable units.
- Costs ≈ $25K, power requirement < 3 kW.
- Size 50" x 30" x 22".

JPL HELIUM LEAK HUNTING CONFIGURATIONS



(a) Vacuum testing. (b) Pressure testing. (c) Pressure-vacuum testing.

ENCLOSURE "C"
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JPL SENSITIVITIES OF LEAK DETECTION METHODS

Leak Detector	Operating Range (μ)	Leak Size (std cc/sec)	Probe	Remarks
1. Spark coil (Tesla, etc.)	50–1000	—	Acetone, methanol, hydrogen, carbon dioxide	For glass.
2. Discharge tube	50–1000	—	Acetone, methanol, hydrogen, carbon dioxide	Residual gases confusing.
3. Pirani and thermocouple gauges	<100	10^{-4}–10^{-6}	Acetone, methanol, hydrogen	Pressure changes. Residual vapors.
4. Thermionic ionization gauge	<0.5	10^{-5}–10^{-7}	Gaseous hydrocarbons, hydrogen, oxygen, helium	Pressure changes. Residual vapors.
5. Halogen leak detector	<200	10^{-6}	Freon 12 or 22	Avoid halogen contamination.
6. Palladium barrier ionization gauge	$<10^{-4}$	10^{-6}–10^{-7}	Hydrogen	Avoid hydrogen contamination.
7. Tungsten diode or triode gauge	<0.5	10^{-6}–10^{-7}	Oxygen	Avoid oxygen contamination.
8. Helium leak detector	<0.1	10^{-10}	Helium	Most sensitive "standard" leak detector.
9. Pirani or thermocouple gauge with backing space	<100	10^{-5}–10^{-6}	Acetone, methanol, hydrogen	Time-consuming.
10. Thermionic gauge with backing space	<0.5	10^{-4}–10^{-7}	Gaseous hydrocarbons, hydrogen, oxygen, helium	Time-consuming.
11. Soap bubbles	Pressure—about 60 psig	5×10^{-5}	Air, helium	Observe for 5–15 min.

ENCLOSURE "C"
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$1 \mu = 10^{-3}$ torr

1 std-cc/sec = 760 μ-litre/sec = 0.760 torr-litre/sec

BATCH START

STAPLE
OR
DIVIDER

LASER COOLING

LIGO PROJECT

LASER COOLING ASSESMENT

AMOR HALPERIN

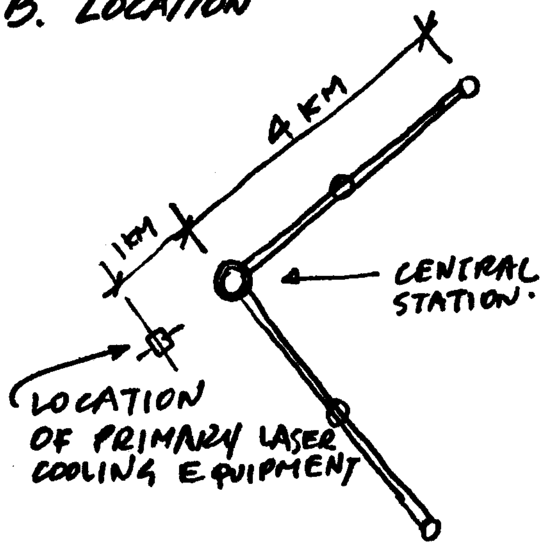
April 29, 1987
MAY 13, 1987 (corrected)

AH-1
4-29-87
5-13-87

A. DATA

1. LOAD: 300 KW
2. FLOW: 30 GPM TO 100 GPM
3. ENT. TEMP: 75°F ± 3°F
4. PRESSURE: 20 PSI TO 80 PSI
5. WATER QUALITY: MICRO-FILTERED & DE-IONIZED

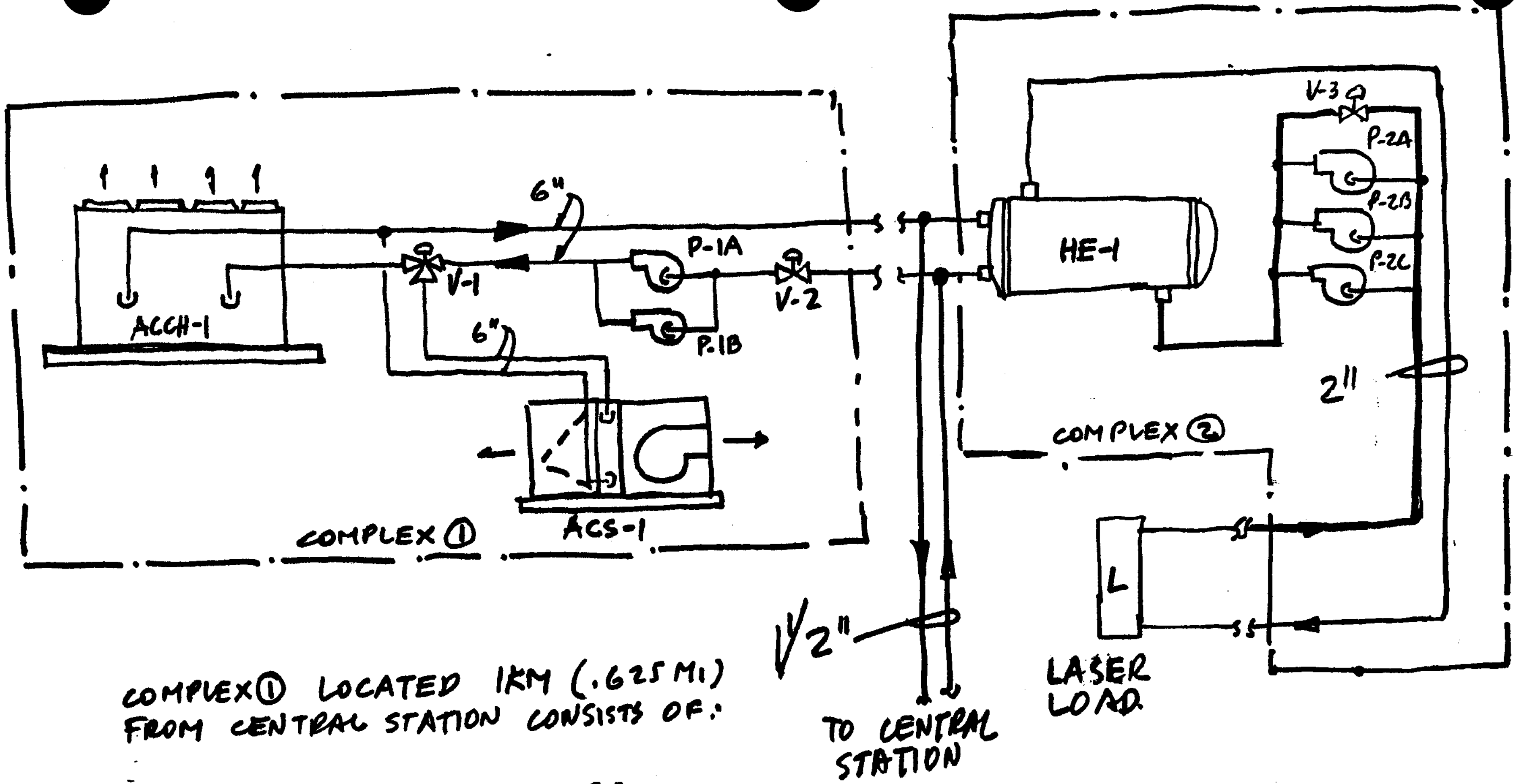
B. LOCATION



C. LOAD (A/C) OF CENTRAL STATION.

FOR 5600 ⌀ OF AREA FOR THE CENTRAL STATION THE APPROX TONNAGE FOR A BLDG OF REGULAR HEIGHT IS ABOUT 400 ⌀/TON or 14 TONS. SINCE THE CENTRAL STATION IS ABOUT 30 Ft High the tonnage will increase by about 25% and the total will be approx. 18 Tons. USE <u>20 TONS</u>

AH-2
4-29-87



COMPLEX① LOCATED 1KM (.625 Mi) FROM CENTRAL STATION CONSISTS OF:

1. ACCH-1 : AIR COOLED CHILLER
2. ACS-1 : ALTERNATE COOLING SYSTEM
3. P-1A, P-1B : CHILLED WATER PUMPS.
4. V-1, V-2 : CONTROL VALVES

COMPLEX② LOCATED 800 Ft FROM CENTRAL STATION CONSISTS OF:

1. HE-1 : HEAT EXCHANGER
2. P-2A, P-2B, P-2C : LASER PUMPS
3. V-3 : BACK PRESSURE VALVE

SCHEMATIC PIPING DIAGRAM

5-13-87

AH-3

4-20-87

D. Total load AT CHILLER. (Primary circuit)

LASER COOLING: 300 KW x 3412 = 1,023,600 BTU/HR
Central Station: 20 TONS x 12000 = 240,000
TOTAL 1,263 600 BTU/HR.
≈ 105 Tons

E. Flow

WITH 10°F CHILLED WATER THE FLOW WILL BE:

$$Flow = \frac{1,263,600}{10 \times 500} = 252 \text{ GPM}$$

F. CHILLER SELECTION. (ACCH-1)

SELECT AIR COOLED CHILLER CARRIER
MODEL # 30GB110 @ 95°F ENT. CONDENS. TEMP. /45°F LWT
CAPACITY OF UNIT IS AS FOLLOWS.

$$C_{CH} = 113.2 \times .983 = 111.3 \text{ TONS}$$

Being .983 the factor for 40% ethylene glycol.
The capacity of the chiller is about 6% higher than the max required load

$$Flow = \frac{111.3 \times 24}{10°F} \times 1.097 = 293 \text{ GPM}$$

Being 1.097 the factor for 40% ethylene glycol.

AH-4
4-29-87/5/13/87

P.D = 14.5 ft (from curve for [illegible] GPM) x 1.185 = 17.2 Ft.
Being 1.185 the factor for 40% ethylene glycol
Power Input = 129.9 kw

COST: $50,000

G. SECONDARY CIRCUIT (LASER COOLING)

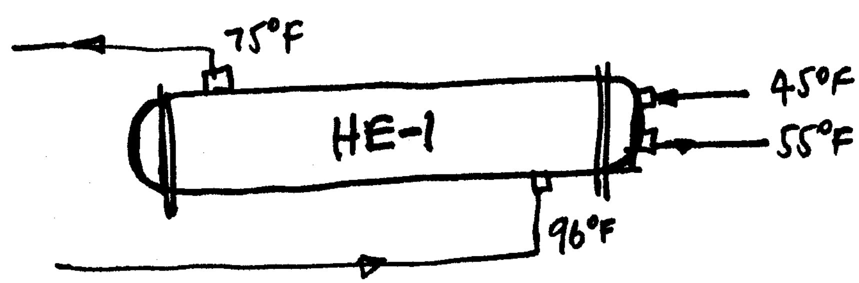
1. LOAD = 1,023,600 BTU/HR.
2. ΔT @ MAX GPM

$$\Delta T = \frac{1,023,600}{100\ GPM \times 500} = 21°F$$

3. LVG TEMP.

LWT = 75°F + 21°F = 96°F

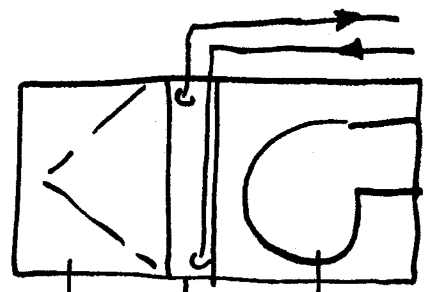
H. SECONDARY CIRCUIT HEAT EXCHANGER.



100 GPM FROM 96°F TO 75°F in shell
205 GPM FROM 45°F TO 55°F in Tubes

COST = $10000

I. ALTERNATE WATER COOLING SYSTEM FOR WINTER (ACS-1)



70 # COIL
10500 ¢ Fan.
30/30 Filter.

COST $12,000

SAVINGS
($5000 for HG ByPass & controls.)
+5000 for energy

J: CHILLED WATER PUMPS. (P-1A, P-1B)

FLOW: 293 GPM

Head:	
chiller	17.2 Ft
HE	10.0 Ft.
3 way valve	6.00 Ft.
2 way valve	5.00 Ft.
6"ϕ Piping 1/2 6x66 =	60.00 Ft
	98.00 Ft

SELECT CHW PUMP — 300 GPM @ 110 Ft head

WEINMAN 2 1/2 KH — 1750 RPM

w.r.t. $3000/pump

AH-5
4-29-87

K. SECONDARY CIRCUIT CH.W. PUMPS
(LASER PUMPS P-2A, P-2B, P-2C)

FLOW = 50 GPM each pump
Head = 80 PSI + 10 PSI (valve + pipe + HE-1)

SELECT BURKS ED 14M OR EQUIVALENT
60 GPM @ 220 Ft Hd / 10 HP

COST $ 2500 EA PUMP

L. CH.W. PIPING (PRIMARY CIRCUIT)

6"φ / SCH. 40 / buried
$60.00/ft including fittings
$10.00/ft trench, below frost line } $65.00 per running ft.

M. CH.W PIPING (SECONDARY CIRCUIT)

2"φ / SS / BURIED / SCHED 80 / 304
$30.00/ft including fittings
$8.00/ft trench, below frost line } $34.00 per running ft

AH-7
4-29-87 / 5-12-87

[illegible]. TOTAL COST OF INSTALLATION OF LASER COOLING EQUIPMENT

LOCATION	1KM	500 ft	160 ft
1. AIR COOLED WATER CHILLER. (ACCH-1)	50,000	50,000	50,000
2. HEAT EXCHANGER (HE-1)	10,000	10,000	10,000
3. ALT. WATER COOLING SYS (ACS-1)	12,000	12,000	12,000
4. CH.W. PUMPS (PRIMARY) (P1-A, P1-B)	6,000	6,000	6,000
5. CH.W. PUMPS (LASER PUMPS (P-2A, P2B, P-2C)	7,500	7,500	7,500
6. PIPING (PRIMARY CIRCUIT)	429,000	65,000	20,800
7. PIPING (SECONDARY CIRCUIT)	6,800	6,800	10,880
8. GLYCOL	10,000	2,500	1,500
9. CONTROLS (LS)	30,000	30,000	30,000
10 ELECTRICAL	30,000	25,000	20,000
11. HOUSING	60,000	60,000	60,000
12 LASER/LASER COOLING INTEGR.	26,000	26,000	26,000
13. WALL BARRIER FOR ACCH-1	—	—	15,000
SUBTOTAL	677,300	300800	254,680
10% CONTINGENCY	67700	30000	25470
TOTAL	745,000	330800	280,150

AH-8
5/13/87

AIR COOLED WATER CHILLER NOISE LEVELS @ 1KM

STEPS	ITEMS	63	125	250	500	1000	2000	4000	8000
		CENTER FREQUENCY — Hz (1KM)							
cooling tower noise criterion	1. Determine Appropriate "NC" Criterion for Neighbor Activity from ASHRAE Guide or Table 2 of B.A.C. Noise Engineering Manual.				NC=	30			
	2. Insert Sound Pressure Levels for Selected "NC" Criterion. (Obtain values from Fig. 1 or Table 1.)	57	48	41	35	31	29	28	27
	3. Tabulate Noise Reduction Provided by Wall Construction. (Obtain values from Table 3.) (B)	9	10	11	12	13	14	15	16
	4. Establish Tentative Outdoor Noise Criterion for the Unit. (Item 2 plus Item 3.) (2)	66	58	52	47	44	43	43	43
	5. List Average Minimum Outdoor Background Noise Levels. (Measured, or Estimated from Figure 2 and Tables 4 and 5.)	45	42	37	32	27	23	19	17
	6. Set final Outdoor Noise Criterion. (High value, by octave band, of items 4 and 5.)	66	58	52	47	44	43	43	43
cooling tower noise levels	7. Enter Cooling Tower Sound Pressure Level Rating at 50 ft.	72	71	67	66	65	62	57	56
	8. Insert Distance Correction to adjust unit ratings to distance of 3300 ft. in direction toward critical neighbor. (For distances greater than 50 ft. use Table 6; for distances less than 50 ft. use Table 7.)	37	37	37	40	42	47	61	80
	9. Establish Outdoor Cooling Tower SPL at neighbor location. (Item 7 minus Item 8 for distances greater than 50 ft. Item 7 plus item 8 for distances less than 50 ft.)	35	34	30	26	17	15	0	0
	10. Apply reflection adjustment to meet condition existing at cooling tower site. Refer to Figures 3 and 4 for effect of reflecting walls; or add 5 dB for close-in build up of noise; 0 dB if no reflection effects.	0	0	0	0	0	0	0	0
	11. Tabulate Resultant Unit SPL at Critical Neighbor Location. (Item 9 plus Item 10.)	35	34	30	26	17	15	0	0
comparison, criteria vs levels	12. Copy Item 6 levels from above. This is the outdoor noise criterion for the critical neighbor.	66	58	52	47	44	43	43	43
	13. Ascertain Tentative Noise Reduction Required for Tower. (Item 11 minus Item 12. Insert "0" for negative values.)	0	0	0	0	0	0	0	0
	14. Apply Judgment Factor. (For conservative approach, use "0" in all bands. To permit tower noise to exceed background levels slightly, insert "5".)								
	15. Tabulate Final Noise Reduction Requirement for the Job. (Item 13 minus Item 14.)	AT 1KM (.625 MILES) NO NOISE REDUCTION							
	16. Indicate Estimated or Rated Attenuation of all Noise Reduction Treatment, if used. (Should at least equal Item 15.)	REQUIRED BECAUSE SPL (ITEM 11) IS LOWER THAN FINAL NC ESTABLISHED (ITEM 12)							

AH-9
5-13-87

AIR COOLED WATER CHILLER NOISE LEVELS @ 500 Ft

STEPS	ITEMS	63	125	250	500	1000	2000	4000	8000
		CENTER FREQUENCY — Hz 500 Ft							
cooling tower noise criterion	1. Determine Appropriate "NC" Criterion for Neighbor Activity from ASHRAE Guide or Table 2 of B.A.C. Noise Engineering Manual.				NC=	30			
	2. Insert Sound Pressure Levels for Selected "NC" Criterion. (Obtain values from Fig. 1 or Table 1.)	57	48	41	35	31	29	28	27
	3. Tabulate Noise Reduction Provided by Wall Construction. (Obtain values from Table 3.)	9	10	11	12	13	14	15	16
	4. Establish Tentative Outdoor Noise Criterion for the Unit. (Item 2 plus Item 3.)	66	58	52	47	44	43	43	43
	5. List Average Minimum Outdoor Background Noise Levels. (Measured, or Estimated from Figure 2 and Tables 4 and 5.)	45	42	37	32	27	23	19	17
	6. Set final Outdoor Noise Criterion. (High value, by octave band, of items 4 and 5.)	66	58	52	47	44	43	43	43
cooling tower noise levels	7. Enter Cooling Tower Sound Pressure Level Rating at 50 ft.	72	71	67	66	65	62	57	56
	8. Insert Distance Correction to adjust unit ratings to distance of 500 ft. in direction toward critical neighbor. (For distances greater than 50 ft. use Table 6; for distances less than 50 ft. use Table 7.)	20	20	20	20	21	22	24	27
	9. Establish Outdoor Cooling Tower SPL at neighbor location. (Item 7 minus Item 8 for distances greater than 50 ft. Item 7 plus item 8 for distances less than 50 ft.)	52	51	47	46	44	40	33	29
	10. Apply reflection adjustment to meet condition existing at cooling tower site. Refer to Figures 3 and 4 for effect of reflecting walls; or add 5 dB for close-in build up of noise; 0 dB if no reflection effects.	0	0	0	0	0	0	0	0
	11. Tabulate Resultant Unit SPL at Critical Neighbor Location. (Item 9 plus Item 10.)	52	51	47	46	44	40	33	29
comparison, criteria vs levels	12. Copy Item 6 levels from above. This is the outdoor noise criterion for the critical neighbor.	66	58	52	47	44	43	43	43
	13. Ascertain Tentative Noise Reduction Required for Tower. (Item 11 minus Item 12. Insert "0" for negative values.)	0	0	0	0	0	0	0	0
	14. Apply Judgment Factor. (For conservative approach, use "0" in all bands. To permit tower noise to exceed background levels slightly, insert "5".)								
	15. Tabulate Final Noise Reduction Requirement for the Job. (Item 13 minus Item 14.)	AT 500 FT NO NOISE REDUCTION REQUIRED BECAUSE SPL ITEM (11) IS							
	16. Indicate Estimated or Rated Attenuation of all Noise Reduction Treatment, if used. (Should at least equal Item 15.)	LOWER OR EQUAL THAN FINAL NC ESTABLISHED (ITEM 12)							

AH-10
5-17-87

AIR COOLED WATER CHILLER
NOISE LEVELS @ 160 ft

STEPS	ITEMS	CENTER FREQUENCY — Hz 160 Ft 63	125	250	500	1000	2000	4000	8000
cooling tower noise criterion	1. Determine Appropriate "NC" Criterion for Neighbor Activity from ASHRAE Guide or Table 2 of B.A.C. Noise Engineering Manual.				NC=30				
	2. Insert Sound Pressure Levels for Selected "NC" Criterion. (Obtain values from Fig. 1 or Table 1.)	57	48	41	35	31	29	28	27
	3. Tabulate Noise Reduction Provided by Wall Construction. (Obtain values from Table 3.)	9	10	11	12	13	14	15	16
	4. Establish Tentative Outdoor Noise Criterion for the Unit. (Item 2 plus Item 3.)	66	58	52	47	44	43	43	43
	5. List Average Minimum Outdoor Background Noise Levels. (Measured, or Estimated from Figure 2 and Tables 4 and 5.)	45	42	37	32	27	23	19	17
	6. Set final Outdoor Noise Criterion. (High value, by octave band, of items 4 and 5.)	66	58	52	47	44	43	43	43
cooling tower noise levels	7. Enter Cooling Tower Sound Pressure Level Rating at 50 ft.	72	71	67	66	65	62	57	56
	8. Insert Distance Correction to adjust unit ratings to distance of 160 ft. in direction toward critical neighbor. (For distances greater than 50 ft. use Table 6; for distances less than 50 ft. use Table 7.)	10	10	10	10	10	10	11	12
	9. Establish Outdoor Cooling Tower SPL at neighbor location. (Item 7 minus Item 8 for distances greater than 50 ft. Item 7 plus item 8 for distances less than 50 ft.)	62	61	57	56	55	52	46	44
	10. Apply reflection adjustment to meet condition existing at cooling tower site. Refer to Figures 3 and 4 for effect of reflecting walls; or add 5 dB for close-in build up of noise; 0 dB if no reflection effects.	0	0	0	0	0	0	0	0
	11. Tabulate Resultant Unit SPL at Critical Neighbor Location. (Item 9 plus Item 10.)	62	61	57	56	55	52	46	44
comparison, criteria vs levels	12. Copy Item 6 levels from above. This is the outdoor noise criterion for the critical neighbor.	66	58	52	47	44	43	43	43
	13. Ascertain Tentative Noise Reduction Required for Tower. (Item 11 minus Item 12. Insert "0" for negative values.)	0	3	5	9	11	9	3	1
	14. Apply Judgment Factor. (For conservative approach, use "0" in all bands. To permit tower noise to exceed background levels slightly, insert "5".)	0	0	0	0	0	0	0	0
	15. Tabulate Final Noise Reduction Requirement for the Job. (Item 13 minus Item 14.)	0	3	5	9	11	9	3	1
WALL BARRIER	16. Indicate Estimated or Rated Attenuation of all Noise Reduction Treatment, if used. (Should at least equal Item 15.)	5	5	6	8	10	12	14	16

AH-11
5-12-82

BATCH START

STAPLE

OR

DIVIDER

POWER REQUIREMENTS

POWER REQUIREMENTS - EDWARDS AFB
ROUGH ESTIMATE

1.	Laser Equipment		300 KW
2.	Laser Cooling (which includes Apex Building chilled water air-conditioner)		250 KW
3.	Apex Building (1 at 5000 sq ft)		60 KW
	Air Handlers	10	
	Lighting	30	
	Crane	10	
	Utility Receptacles	5	
	Area Lighting	5	
4.	Mid & End Buildings (4 at 1000 sq ft each)		106 KW
	Air conditioning	15 x 4 = 60	
	Lighting	6 x 4 = 24	
	Crane (1 operating)	10 x 1 = 10	
	Area Lighting	3 x 4 = 12	
5.	Tunnel		134 KW
	Ventilation	30	
	Lighting 26000 Ft x 4w/ft =	104	
	(Assumes all lights on)		
6.	Support Area - 2 trailers at 5 KW		10 KW
7.	Fire Pump		25 KW
8.	Vacuum Pumps (See breakdown attached)		151 KW
	TOTAL		1036 KW

POWER REQUIREMENTS - MAINE
ROUGH ESTIMATE

1.	Laser Equipment		300 KW
2.	Laser Cooling (which includes Apex Building chilled water air-conditioner)		250 KW
3.	Apex Building (1 at 5000 sq ft)		60 KW
	Air Handlers	10	
	Lighting	30	
	Crane	10	
	Utility Receptacles	5	
	Area Lighting	5	
4.	Mid & End Buildings (4 at 1000 sq ft each)		106 KW
	Air conditioning	15 x 4 = 60	
	Lighting	6 x 4 = 24	
	Crane (1 operating)	10 x 1 = 10	
	Area Lighting	3 x 4 = 12	
5.	Tunnel		134 KW
	Ventilation	30	
	Lighting 26000 Ft x 4w/ft = 104 (Assumes all lights on)		
6.	Support Building		35 KW
7.	Fire Pump		25 KW
8.	Vacuum Pumps (See breakdown attached)		151 KW
	TOTAL		1061 KW

LIGO POWER REQUIREMENTS FOR VACUUM PUMPS

ASSUMPTION: PUMPING SCHEME DESCRIBED IN LIGO COST MATRIX 4/3/87

<u>ION PUMPS (2000 L/S)</u>

Tube Requirements	32
Central Station Reqirements	2
Mid-Station Requirements	2
End-Station Requirements	2
Total ION Pumps	38

<u>TURBO PUMPS (5000 L/S)</u>

Central Station Requirements	1
Mid-Station Requirements	2
End Station Requirements	2
Total Turbo Pumps	5

<u>ROUGH PUMPS (300 CFM)</u>

Central Station Requirements	1
Mid-Station Requirements	2
End-Station Requirements	2
Total Rough Pumps	5

For ION Pumps assume 2 ea. Perkin Elmer Digitel 500's per 2000 L/S pump. Each Digitel 500 requires 1 KW, therefore:

ION Pump Power = 38 X 2 X 1 KW

= 76 KW

For Turbo Pump assume a Leybold Heraeus TMP 3500 (3500 L/S) pumps and extrapolate to 5000 L/S.

$$\text{Turbo Pump Power} = 5 \times 2\ \text{KW} \times \frac{5000}{3500}$$

= 15 KW

For Rough Pumps assume a Kinney Vacuum Model No. T00300 with a 15 HP Motor.

Rough Pump Power = 5 X 12 KW

= 60 KW

TOTALS:

ION Pumps	76 KW
Turbo Pumps	15 KW
Rough Pumps	60 KW
	151 KW

SPECIFICATIONS

PHYSICAL:
19" rack mount. 19"W. x 5¼"H x 18¾"D (including connectors). An additional 1½" is required for cable clearance.
Shipping weight 49 lbs. Unit weight 43 lbs.

ENVIRONMENTAL:
Operating temperature 0° to 40° C. Free air flow is required around the unit.
Altitude: Sea level to 10,000 feet
Humidity: 0 to 80% RH (non-condensing)
Storage temperature: −20° to 70° C

ELECTRICAL:
Input voltage: 117 VAC or 220 VAC ±10%. Selectable from the rear panel.
Line frequency: 48-62 Hz. No adjustment necessary.
Power consumption: Idle, 50 watts. Operating, 250 watts typical. Maximum 900 watts
Detachable power cord.
Fuse 8 amps normal blow (117 volt operation) or 4 amps normal blow (220 volt operation). Accessible from the rear panel.
HV output:
- 5500V ±10% at nominal line and 2 ma current
- Short circuit current 220 ma (60 Hz) 350 ma (50 Hz) ±10% at nominal line.
- Polarity: Positive. May be converted to negative by changing internal jumpers.

AUXILIARY OUTPUTS:
Chart recorder (standard):
- 0-5 volt correponding to 0 to 500 ma.
- 0-5 volts corresponding to 0 to 10,000 volts.
- Fully buffered outputs referenced to chassis ground.

Setpoint (optional):
- Two 1A SPDT relays with NC – C – NO contacts. user adjustable.
- One 1A SPDT relay with NC – C – NO contacts. Fixed. C switches to NO when voltage exceeds 2000 volts.

Computer interface (optional):
- RS-232C serial ASCII interface. Available baud rates are 150, 300, 600, 1200, 2400, 4800, 9600. 7-bit, one stop bit, even parity. No parity required on input.

Bakeout (optional):
220 VAC at 30 amps (resistive load) for main heater control. Three outputs at 120/220 volts 5 amps for auxiliary control.

DISPLAY:
Type: 7-segment red L.E.D. 0.43" character height.
Voltage display: 0000-9900 volts in increments of 100 volts.
Current display: 0.1 × 10 −6 to 5.1 × 10 −1 amps. Autoranging.
Pressure display: 1 × 10 −9 to 1 × 10 −4 torr or 1 × 10 −7 to 1 × 10 −2 pascal. Autoranging. Units selected from the rear panel.
Rate of rise: 7 element bargraph indicates the rate of change of current. Can be used for leak detection.
Status display: Lamps indicate display mode (volts, current or pressure), setpoint 1, 2 and bakeout status, power on and high voltage enable/operating.

PUMP SIZE:
25, 60, 120 or 220 liters/sec. Selectable from the rear panel. Pump size is used to calculate pressure and to control maximum pump power.

SETPOINTS (optional):
Two user adjustable setpoints with variable hysteresis and control parameter. May be protected from change with a 4 digit code.
One fixed setpoint. Activates at 2000 volts.
EEPROM provides permanent setpoint storage for up to 10 years without power.

REMOTE, OPERATE and STANDBY INPUTS:
Optically isolated, requires 12 to 30 VDC at 3 ma max.

BAKEOUT (optional):
Includes all of the features of the setpoint option.
Bakeout setpoint includes variable hysteresis, control parameter and duration timer.

COMPUTER INTERFACE (optional):
COMMANDS:
- High voltage on/off
- Display voltage, current or pressure on LED's
- Keyboard on/off
- Timed logging on/off
- Set timer interval to 1 to 99 minutes
- Exception reporting on/off
- Examine and set all setpoints and bakeout (optional)
- Read date, time, voltage, current, power supply and setpoint status.
- Set the date and time.
- Read the Autorun™ parameters

PERKIN-ELMER **Vacuum Products**

6509 Flying Cloud Drive, Eden Prairie, MN 55344 • Phone: (612) 828-6190 • TLX: 29-0407

VP 1041 11/82 Specifications Subject to Change Without Notice Printed in U.S.A.

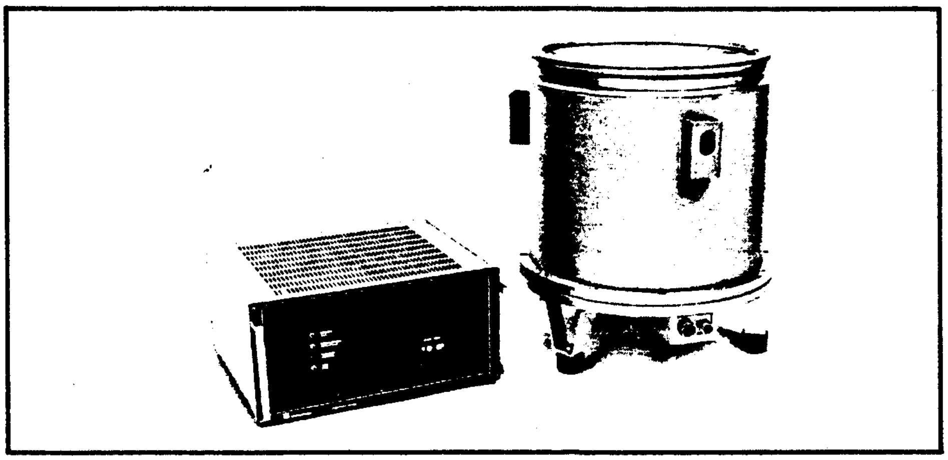
Tri Star Specifications

		Single	
Model Number		**T00150**	**T00300**
Free Air Displacement at Rated RPM, Theoretical	cfm M³/hr	144 244	296 503
Pump Speed (Full Load RPM)		1055	870
Standard Motor	HP-PH HZ/V	7½-3 60/230-460	15-3 60/230-460
Motor Speed (Full Load RPM)		1750	1750
Inlet Connection (Flanged) (1)	Inches	3	4
Inlet Connection (Threaded) (2)	Inches	–	–
Discharge Connection (Flanged) (1)	Inches	–	–
Discharge Connection (Threaded) (2)	Inches	2	3
Cooling Water Inlet Connection (Threaded) (2)	Inches	⅜	⅜
Cooling Water Outlet Connection (Threaded) (2)	Inches	¼	½
Cooling Water Required @ 80°F (26.6°C) (3)	GPM Litres/Min	1 (4) 3.8	1.5 5.7
Overall Height	Inches mm	42⅝ 1083	46 1168
Overall Width (Facing Drive)	Inches mm	18½ 470	24¾ 629
Overall Depth	Inches mm	25⅞ 657	32⅛ 816
Oil Capacity	Gallons Litres	4½ 17	8 30
Weight (Complete Pump Assy Less Oil)	Lbs Kg	725 329	1470 667
Maximum Gas Ballast Flow		10%	5%
Typical Blank Off Pressure with Full Gas Ballast (5)	Torr	2.0	2.0
Ultimate Pressure (with Kinney Hydrocarbon Vacuum Oil and McLeod Gauge) (5)	Microns	10	10

(1) Flanged connections conform to ANSI standards except Model KTC-21 (see note 6)
(2) Threaded connections are NPTF.
(3) Maximum allowable outlet water temperature 110°F (43.3°C)
(4) Can be furnished for use without water on special request
(5) Torr = 1 mm Hg Abs.; 1000 microns = 1 Torr
(6) Model TC0021 has both threaded and flanged connections. Flange is 1¼" with four 5/16-18 tapped holes on a 3½" bolt circle.

TURBOVAC® Turbomolecular Pumps

Model TMP3500



Technical Data

Performance Characteristics		LF400/16-inch ASA
Pumping Speed (volume flow rate)		
for N_2	l/sec	3600
for He	l/sec	3600
for H_2	l/sec	3300
Compression Ratio		
for N_2		$>10^{10}$
for He		6×10^{6}
for H_2		10^{4}
Ultimate Pressure	mbar	$<10^{-10}$
Rotational Speed	RPM	15,000
Start-Up Time	min	20
Oil Filling	cm^3	220
High Vacuum Port	LF	400
Fore Vacuum Port	LF	100
Cooling Water Consumption	l/hr (gal/hr)	50 (14)
Cooling Water Pressure	bar	4 to 7
Cooling Water Connection, Hose Nozzle	inches (mm)	$^{7}/_{16}$ (11)
Bake-Out Temperature	°C	80
Mounting Position		Vertical ± 5°
Weight	lb (kg)	352 (160)
Recommended Backing Pump		DK200 or WAU250/D60A
Solid State Frequency Converter NT3500		
Mains Supply	V	220/115
Maximum Power Input	kVa	1.8
Maximum Output Voltage	V	3x42
Start-Up Current	A	19
Overload Current Limitation	A	13
Rated Frequency	Hz	250
Admissible Ambient Temperature	°C	0 to 40
Dimensions (WxHxD)	inches (mm)	$17^{1}/_{2} \times 9^{1}/_{4} \times 18^{21}/_{32}$ (445x235x480)
Weight	lb (kg)	77 (35)

June 2, 1987

CALTECH/MIT

Laser Interferometer Gravitational-wave Observatory Project

To: Kip, Rai, Robbie, and Ron

From: Frank

File: IE060237.DOC

Subject: Edwards Utility Costs

The attachment reflects the cost of utilities at Edwards.

The electrical costs are in line with those charged by Southern California Edison. If we have an average power consumption of 500 K watts during operation of the facility, the cost will be approximately $400 K per year. We had estimated a cost of roughly $500 K.

We have no plans to use any natural gas. All heating and air conditioning will be provided by electrically powered heat pumps.

Water consumption will be minimal since our needs are mostly for sanitary purposes at the Stations. Most of our personnel will be using facilities provided by JPL. The major requirement is for sufficient water to fill our planned 50 K gallon fire protection storage tank located at the Central Station.

JET PROPULSION LABORATORY
EDWARDS FACILITY

INTEROFFICE MEMORANDUM
26 May 1987

TO: Frank Schutz

FROM: Vi Kitts *Vi Kitts* Section: 351 Ext: 165-7010

Per your request of Thursday, May 21, 1987. The following rates are currently being charged.

Electricity	.08031 per KWH
Water	44.787 per 1000 gallons
Gas	.5656 $ per therm.

If you have any further questions please call.

/vk

DEMAND CHARGES FOR ELECTRICAL POWER

NOTE: At Edwards, Edison have established "Time of Use" rate schedule. At Cherryfield the Bangor Hydro are establishing new rates which will be applicable after June 1985. Edison Time-of-Use rate schedule considered typical and is basis of the following:

Definition

Maximum Demand: Highest average KW demand in a 15 minute period of operation over a one month period.

Time of Use of Demand: Separate maximum demands are measured for each Time of Use period.

Time of Use Periods: Summer time.

1. On-Peak - 1:00 PM to 7:00 PM = 6 hours
2. Mid-Peak - 9:00 AM to 1:00 PM and 7:00 PM to 11:00 PM = 8 hours
3. Off-Peak - All other hours = 10 hours

Total Billing (1983 Rates)

a) Customer Charge $ 560.00

b) Demand Charge (added to Customer Charge)
   1) \$5.05 per KW of on peak Maximum Demand
   2) \$0.65 per KW of mid-peak Maximum Demand
   3) No charge for off-peak Maximum Demand

c) Energy Charge
   1) 7.821c per Kwh during on-peak periods
   2) 6.517c per Kwh during mid-peak periods
   3) 5.431c per Kwh during off peak periods

Example 1

Average load over 30 day period ....1000 KW
Maximum Demand during On-Peak period (125% x Average) = 1250 KW
Maximum Demand during Mid Peak period (125% x Average) = 1250 KW

Bill for 30 day period

a)	Customer Charge	$ 560.00
b)	Demand Charge (On-peak) = $5.05 x 1250	6312.50
	Demand Charge (Mid-Peak) = $0.65 x 1250	812.50
c)	Energy Charge (On-Peak) = 6 hours x 1000 KW x 30 days x 7.821c = ...	14077.80
	Energy Charge (Mid Peak) = 8 hours x 1000 KW x 30 days x 6.517c = ...	15640.80

Energy Charge (Off Peak) = 10 hours x 1000 KW x
30 days x 5.431c = ... 16293.00

Total Bill for 30 day period =
sum of a) + b) + c) = ... $53696.60

Example 2

Average load over 30 day period ....1500 KW
Maximum Demand during On-Peak period (125% x Average) = 1875 KW
Maximum Demand during Mid Peak period (125% x Average) = 1875 KW

Bill for 30 day period

a) Customer Charge .... $ 560.00
b) Demand Charge (On-peak) = $5.05 x 1875 .... 9468.75
Demand Charge (Mid-Peak) = $0.65 x 1875 .... 1218.75
c) Energy Charge (On-Peak) = 6 hours x 1500 KW x
30 days x 7.821c = ... 21116.70
Energy Charge (Mid Peak) = 8 hours x 1500 KW x
30 days x 6.517c = ... 23461.20
Energy Charge (Off Peak) = 10 hours x 1500 KW x
30 days x 5.431c = ... 24439.50

Total Bill for 30 day period =
sum of a) + b) + c) = ... $80264.90

Example 3

Average load over 30 day period ....3000 KW
Maximum Demand during On-Peak period (125% x Average) = 3750 KW
Maximum Demand during Mid Peak period (125% x Average) = 3750 KW

Bill for 30 day period

a) Customer Charge .... $ 560.00
b) Demand Charge (On-peak) = $5.05 x 3750 .... 18937.50
Demand Charge (Mid-Peak) = $0.65 x 3750 .... 2437.50
c) Energy Charge (On-Peak) = 6 hours x 3000 KW x
30 days x 7.821c = ... 42233.40
Energy Charge (Mid Peak) = 8 hours x 3000 KW x
30 days x 6.517c = ... 46922.40
Energy Charge (Off Peak) = 10 hours x 3000 KW x
30 days x 5.431c = ... 48879.00

Total Bill for 30 day period =
sum of a) + b) + c) = ...$ 159,969.80

JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM
3322-85-024
February 20, 1985

TO: Verl Lobb

FROM: J. Dorman

SUBJECT: Rental Costs for Mobile Engine-Generator Equipment

Dr. Drever asked me if I could check the cost for temporary power for the gravity wave observatory.

The following may be useful:

750 KW Unit
Rental Cost $2400 per week (40 hours operation)
$7200 per month (160 hours operation)

Usage above 40 hours/week or 160 hours per month increases rental cost by 50%

Note: 750 KW unit consumes 60 gallons of fuel per hour at $1.00 per gallon.

1000 KW Unit
Rental Cost $3000 per week (40 hours operation)
$9000 per month (160 hours operation)

Increased operation hours increases rental cost by 50%

Note: 1000 KW unit will consume 80 gallons of fuel per hour at $1.00 per gallon.

Nationally there is little variation in rental costs.

Note: These costs are current 1985 costs.

JD:lc

ENCLOSURE "C"

Sheet 3 of 3

BATCH START

STAPLE

OR

DIVIDER

LIGO FACILITY OPERATIONAL SAFETY

SAFETY APPROACH

Providing a safe operating environment for LIGO facility personnel is essential. In addition to sound safety management including adequate training, use of the "buddy system", etc, the facility design itself requires the incorporation of safety measures to provide as fail safe a method as possible of insuring safe operation of the LIGO facility.

Specific safety measures should comply with all OSHA and EPA regulations and should be implemented during the detail design phase.

PRELIMINARY OUTLINE OF HAZARD AREAS TO BE ADDRESSED

BAKE-OUT SYSTEM

- Insulation
- Warning indicators

HAZARDOUS MATERIALS

- Cleaning agents
- Nitrogen

LIGHTING LEVELS

- Adherence to OSHA standards
- Adherence to National Electrical Codes

COMMUNICATIONS

- Links to remote locations
- Status of operations

SITE AND FACILITY ACCESS

- Adherence to OSHA standards

VACUUM SUBSYSTEM SAFETY TECHNIQUES/APPROACHES

VACUUM SYSTEM SAFETY

Potential safety hazards during LIGO operation include:

- Lack of oxygen due to the vacuum
- Displacement of oxygen due to nitrogen
- Burns due to the heat from bakeout
- Shock hazard from pumps, controls and laser power supplies
- Fire
- Pinch points on valves
- Falls from ladders, steps and hatches
- Exposure to the laser
- Exposure to hazardous solvents.

Many of these potential hazards can be minimized by strictly enforcing the buddy system at all times.

The following are some design considerations that can improve personnel safety:

- All exits should be clearly labled
- Illuminated exit signs with backup power
- Arrows indicating nearest exit location
- Emergency lighting units
- Call buttons
- Intercom stations
- Manual fire alarm stations
- Gate valve interlocking for differential pressure
- Oxygen monitors throughout facility
- Nitrogen lines located outside of the tube enclosure
- Nitrogen lines empty when not in use
- Warning lights for bakeout and backfill operations
- Adequate ventilation and air exchange
- The location of personnel must be known at all times
    - Badge readers located at all potential work areas could be used to perform this function

VACUUM SUBSYSTEM SAFETY TECHNIQUES/APPROACHES

FIRE PROTECTION

All lab areas in the central, end and mid-stations should be protected by automatic halon fire suppression systems backed up with automatic sprinklers. The halon will protect those areas most likely to have a fire with a system that will not permanently damage the experimental equipment. The backup sprinklers are used if the fire spreads and threatens the structure itself. There should also be portable halon fire extinguishers for LIGO personnel to use on incipient fires.

All support buildings should have automatic fire sprinklers.

It is probably not cost effective to install fire sprinklers along the length of the tube. An acceptable method for fire suppression along the tube would be to have a mini foam truck stationed at the central station. This truck could respond to the area located by the detection system. All LIGO personnel must be trained in fire fighting.

Due to the size of the LIGO installation be a fire detection system that uses addresable detectors is desireable. From a central point the exact location of the alarm is displayed, and time will not be lost trying to determine its location. The wiring required for an addressable system is the least complex of all types of detection systems.

The fire detection system should be tied into the housekeeping system control unit. This will allow air handler control for smoke evacuation or shutdown.

The most likely sources for fire ignition along the tubes are cables and electrical equipment. Linear beam fire detectors should be used along cable trays with ionization detectors at the pump stations. The linear beam detectors can cover an area up to 100M long, this keeps the number of devices to a mimimum. The ionization detectors cover an area of up to 900 sq. ft.

The end and central stations should have a combination of ionization and photoelectric detectors that are cross-zoned for halon control.

BATCH START

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HOUSEKEEPING SYSTEM

HOUSEKEEPING DATA SYSTEM PROPOSED CONFIGURATION

Written 23 July 1987

Updated 8 January 1988

The Housekeeping Data System (HDS) is the interface between the technical facilities (vacuum pumps, valves, instruments, HVAC, lighting, cooling, fire protection, etc.) and the LIGO operators. Additionally the HDS monitors seismic instruments at the end, mid and central stations. The HDS connects to the Scientific Data System (SDS) so that there is a record of events on the SDS log. The end product of the HDS is a log of all events on a mass storage system. The HDS has operator stations at each end and mid station and two at the central station. These operator stations allow the operators to monitor alarms and control the technical facilities.

The HDS uses standard commercial programmable controller (PLC) hardware. This approach was chosen for cost effectiveness, ease of programming and reliability. The system as proposed can handle up to 64 pump stations.

The HDS is based on its own fiber optic LAN running at 500K baud. Each of the processors in the system is connected to the LAN. All of the operator and communication functions are through serial or parallel ports on these processors. The LAN is not accessible directly by other systems. The HDS uses a distributed control and processing scheme with seventeen processors. Seven of the processors are mini-cell controllers (MCC) that are IBM PC-AT compatible and ten are PLC processors.

One MCC is located in each end and mid station and will have a color display and keyboard for operator interface, a large data buffer and will interface with a Time Code Generator (TCG) that is assumed to be part of the Receiver Timing System. The TCG will be used by the housekeeping system to time-code all data. The seismic activity is assumed to be very time-critical, therefore the TCG information is mated with the seismic data at the point where the data is collected. The MCC will buffer the information and send it down the LAN when the LAN is clear.

All of the seismic data packets need to be accurately time-coded so that the data can be correctly correlated with the receiver data in non-real time. This time coding requires accurate timing information at each of the stations to avoid any delays involved with passing the token on the LAN. It is assumed that the receiver system requires a Frequency and Timing System (FTS) to keep all of its data organized. It is proposed to add more TCGs onto the FTS system to support the HDS.

Due to the number of axes being monitored, the resolution of the information and the frequency of the data gathering, the seismic data represents most of the data on the HDS system and becomes the driver for the entire system design. The system design is based on the following assumptions: three axes per end and mid station, six axes at the central station for a total of 18 axes, data gathered from each axis every 100mSec., data word length of 12 bits and data in the form of one analog output for frequency and one analog output for amplitude per axis.

Three of the MCC are located in the central station. Two of these processors will handle operator interfaces and will also connect to tape drives for mass storage. As originally specified, the HDS requires a gigabyte storage device separate from the SDS. The third processor will connect to the Scientific Data System and to a TCG.

There will be one PLC processor at each mid and end station that primarily handles the seismic data. At each of these locations there will be a rack with 32 analog input points, 48 digital input points and 32 digital output points. The digital I/O and 16 of the analog points are involved with monitoring and controlling the various vacuum and facilities systems. Examples of some of these points are: vacuum level, bellows extension, pump speed/oil pressure/temperature, ambient temperature, valves open/closed, hatches open/closed, pump alarms, fire system, HVAC system and lighting. The system is designed for 50% to 75% loading so that additional points can be easily added in the future. 16 analog points are reserved for seismic monitoring. Each of these processors is mounted in the same rack as the MCC processor.

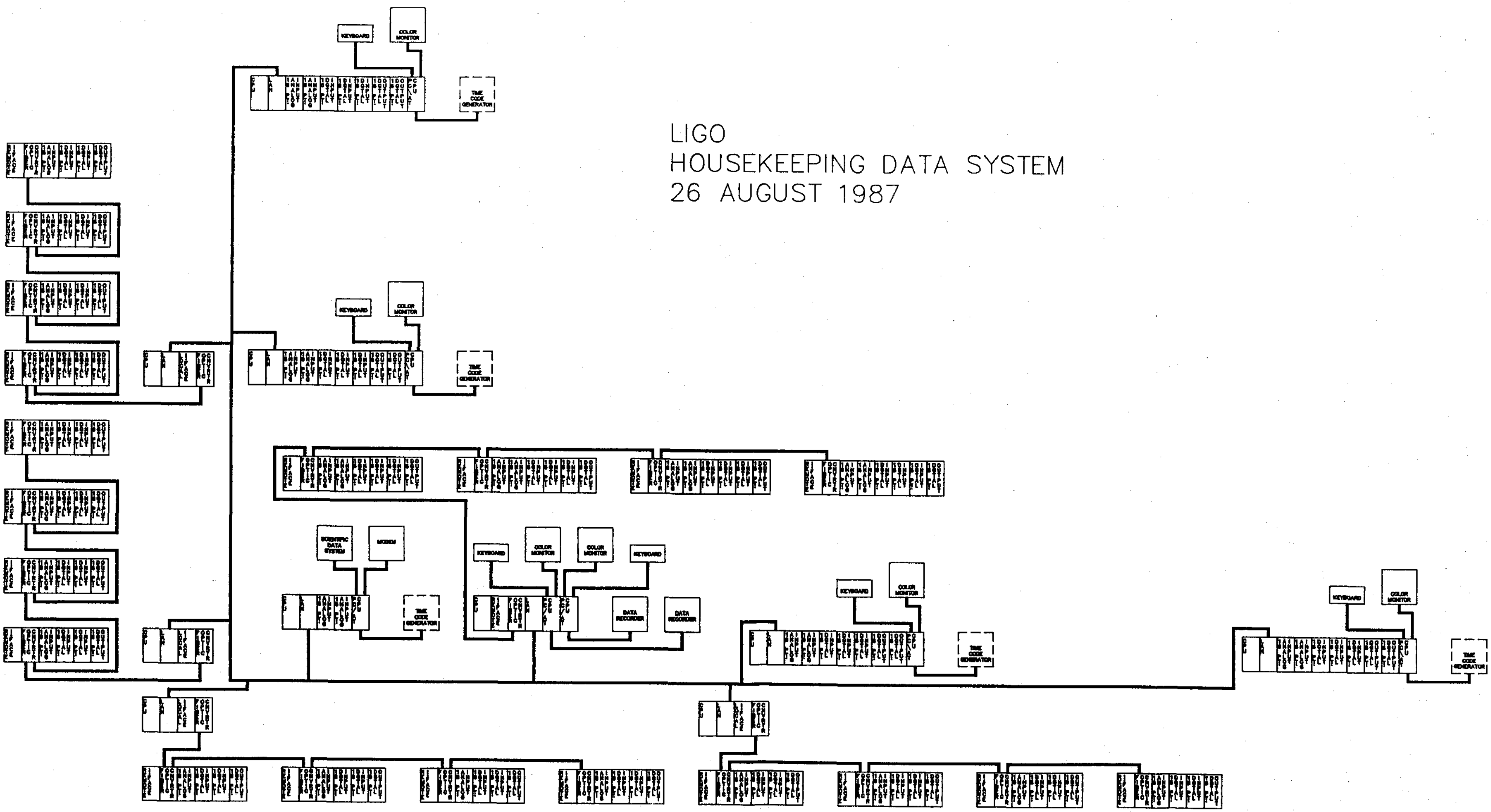
At the central and each mid station there is a PLC processor that communicates with up to 16 remote I/O drops. These remote I/O drops are located at each pump station. Each of these drops will have 16 analog inputs, 32 digital inputs and 16 digital outputs for monitoring and controlling the vacuum and facilities systems at and around each pump station. The four PLC processors will communicate with the remote drops over a fiber optic remote I/O bus. Each of the four processors are on the LAN.

At the central station there are two PLC processors. One of the processors will have 32 analog inputs to be used for monitoring seismic activity at the central station. This processor will be mounted in the rack with the MCC processor that communicates with the SDS and TCG. Both processors are on the LAN. The other processor is in the rack with the two MCC processors that are communicating with the tape drives and communicates with analog and digital I/O over a fiber optic remote I/O bus. This analog and digital I/O will be installed in four racks located in the central station and will be used to monitor and control the vacuum, facilities and laser cooling systems. There will be 16 analog inputs, 48 digital inputs and 32 digital outputs in each of the four racks.

The costing of the HDS does not include any sensors, output devices or spares, but does include installation, all interconnecting cabling, enclosures and power supplies. The pricing is based on 32 pump station drops. The hardware and labor for each system, in 1987 dollars, is approximately $500,000. The system will require 2 man-years of programming effort for a cost of approximately $200,000. The programming is a non-recurring cost. The cost of the FTS and of the TCGs is not included in the cost estimates.

One consideration that needs to be addressed is whether or not the seismic information should be on the SDS or the HDS. If the seismic information were not on the HDS, there would be no requirement for the TCGs, the amount of processors would be cut in half and a data tape would last three days instead of two hours. The SDS requires the speed and number handling ability for the seismic data anyway and the cost addition to that system should be minor.

LIGO
HOUSEKEEPING DATA SYSTEM
26 AUGUST 1987



BATCH START

STAPLE

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LIGO FACILITY COSTING

Facility costing is reflected in the CIT/MIT LIGO Work Breakdown Structure dated August 25, 1987.

COVERED SYSTEM AT EDWARDS
*****(SCHEDULE IS 4.5 YEARS)*****
FILE W1017846, PREPARED 08-26-87, AS NOTED BELOW
COST RELATED WORK BREAKDOWN STRUCTURE

REVISION OF 01 AUGUST 85

REVISED 3060, SLIDING AND FIXED SUPPORTS REDUCED
REVISED 5050, VENTS INCREASED FROM 42 TO 52
REVISED 3010, ADDED 1 BLIND FLANGE/SEAL PER CHAMBER
ADDED 3090, BAKEOUT COVERS FOR 14' AND 10' CHAMBERS

REVISION OF 09 AUGUST 85

REVISED 5060, REDUCED COST OF ELECTRICAL POWER SYSTEM, TO 2000 KW SYSTEM

REVISIONS OF OCTOBER 86

MODIFIED COST ESTIMATES BASED ON PAST YEARS REDESIGN
CHANGED ESTIMATES BASED ON KLEN'S IOM ON VACUUM COMPONENT COST
MODIFIED COST TO REFLECT BOTH 1984 AND 1986 YEAR DOLLARS
ADDED CONTINGENCY ESTIMATES TO TOTAL COSTS
ADDED WATER TANK FOR FIRE FIGHTING SYSTEM
ADDED INCREASED COST OF CULVERT FILL/BACKFILL
ADDED QUOTE FROM VAT ON 40" GATE VALVES-INCREASED COST

REVISIONS OF NOVEMBER 86

ADDED MULTIPLING FACTORS FOR QUANITY DISCOUNTS
ADDED SPREAD OF COSTS BY FISCAL YEARS QUARTERS
ADDED SCIENCE SUPPORT

REVISIONS OF DECEMBER 86/JANUARY 87

ADDED FUNDING FOR MISSING INSTALLATION LABOR
BROKE OUT SOME ELEMENTS TO EASE SCHEDULING/PLANNING
SET UP PROJECT MANAGEMENT AND SYSTEM ENGINEERING FOR SINGLE INSTALLATION
ADDED FUNDS FOR MISSING ELEMENTS
ADDED FUNDS TO COVER SCHEDULE STRETCH OUT

REVISION OF FEBRUARY 06, 1987

ADDED 16" PUMP PORTS TO ALL CHAMBERS (3011G,3012G,3013F,3021F,3032F)
ADDED 16" ROUGHING VALVES (3022C,3014C,3032C)
DELETED 16" ROUGHING VALVES FROM VACUUM PIPE (3071C)
CHANGED AIR COMPRESSORS TO NON-RECIPROCATING TYPES AND INCREASED COST (3043C,G,Q)
DELETED 10" PORTS AND ADDED 16" PORTS (3051D)
INCREASED PRICE OF VACUUM PIPE INSULATION/COVERING BY X 3.5 (3081)
INCREASED QUANITY OF COPPER BUS BAR (3085)
REDUCED QUANTIY OF BUS/VACUUM PIPE CONNECTORS (3086)
INCREASED QUANITY OF SHUNT/FLEX CONNECTORS (3087)
DECREASED QUANITY OF ISOLATION FITTINGS AT VACUUM PIPE SUPPORTS (3088)
ADDED FUNDS FOR CENTRAL STATION SPRINKLER SYSTEM (50156-NEW TASK)
CHANGED COST FOR MID/END/SUPPORT BUILDING FIRE PROTECTION SPRINKLER SYSTEMS (3015E,15F)
INCREASED ESTIMATED COST OF LANDSCAPING/RESEEDING (5016)
ELIMINATED AIR SUPPLIES FROM CENT/MID/END STATIONS (5732,5832,5932)

REVISION OF WBS TO [illegible]SH A BASELINE COST ESTIMATE FOR THE EDWARDS SITE

INCREASED NUMBER OF PUMPS IN LASER COOLING ASSEMBLY (COLUMBIA ONLY) (5073,4,5)
INCREASED COST OF HOUSING LASER COOLING ASSEMBLY (COLUMBIA ONLY) (C5081)
DECREASED COST OF HOUSING LASER COOLING ASSEMBLY (EDWARDS ONLY) E5081)
INCREASED COST OF HOUSEKEEPING ASSEMBLY HARDWARE (5090A)
DECREASED COST OF HOUSEKEEPING ASSEMBLY INSTALLATION LABOR (5090B)
INCREASED NUMBER OF VENTILATION/ACCESS ASSEMBLIES (5053,5054C,5059)
ADDED FUNDS FOR WATER TABLE/EROSION CONTROL (5017)
ADDED BACKUP POWER ASSEMBLY TO PROVIDE COOLING WATER TO LASERS DURING POWER FAILURE (5153)
ADDED BACKUP/EMERGENCY LIGHTING DURING POWER FAILURE (5154)
ADDED ANALOG OUTPUTS TO PENNING/PERANI GAUGES (3014E,22E/F,32E/F,71E/F)

REVISION OF 05 MARCH 1987

CHANGED NOMENCLATURE OF WBS 2000
REDUCED COST OF COPPER BUS BAR (3085)
CHANGED NOMENCLATURE OF WBS 3089
INCREASED WATER SUPPLY FROM QTY 1 TO 2 (SUPPORT AND CENTRAL STATION) (5012)
ADDED HALON SUPPLIES TO MID/END STATIONS (5015D)
CHANGED NOMENCLATURE (5731,5831,5931)
ADDED COST OF FIRE DETECTION ASSEMBLY BACK INTO CENTRAL STATION (5731)
CHANGED QUANITY OF FIRE DETECTION ASSEMBLIES IN MID/END STATIONS (5831,5931)
ADDED WBS TASK FOR SUPPORT BUILDING FIRE PROTECTION (5711)
INCREASED COST OF PLACING CULVERT SECTIONS TO SARGENT CO ESTIMATE (5054A)
CHANGED NOMENCLATURE AND DECREASED MILES OF RUN (5062A)
DECREASED CABLING RACEWAY LENGTH (5062E)
CORRECTED PROGRAMMING ERROR IN SUMMING (5090)

REVISION OF 16 MARCH 1987

DECREASED COST OF SUPPORT BUILDING FIRE DETECTION SYSTEM (5711) 1986$
DECREASED COST OF MID/END STATION FIRE DETECTION ASSEMBLIES (5831,5931) 1986$
DECREASED COST OF CENTRAL STATION FIRE DETECTION ASSEMBLY (5731)
INCREASED COST OF CENTRAL STATION FIRE SUSPRESSION (H20/HALON) (5015G)
DECREASED COST OF MID/END STATION FIRE SUSPRESSION (HALON) (5015E)
DECREASED COST OF SUPPORT BUILDING FIRE SUSPRESSION (H20) (5015F)
ADDED INTERNAL RAIL FOR CART SUPPORT TO CULVER COST (5052B)

REVISION OF 16 MARCH 1987

MODIFIED LABOR COSTS TO REFLECT 4.5 VS 5.5 YEAR SCHEDULE

REVISION OF 03 APRIL 1987

CHANGES REFLECT UPDATE OF COSTS TO 1986 $
INCREASED COST OF AIR MOUNTS (3043)
REDUCED NUMBER OF GENERATORS REQUIRED TO REFLECT ACTUAL APPROACH (3089)
CORRECTED NUMBER OF PUMPS/HOUSINGS AND WATER STORAGE TANKS REQ'D (5015A,D)
CHANGED NOMENCLATURE/PRICE (5732,5832,5932)
INCREASED SUPPORT BUILDING COST ESTIMATE (5700)
ADDED MOBILIZATION/GENERAL CONSTRUCTION COSTS (5051G)
INCREASED COST OF CART RAIL (5052C)
CORRECTED (INCREASED) NUMBER OF EQUIP/ACCESS ENCLOSURES (5053)
INCREASED VENTILATION COSTS (5059A,B)
LASER COOLING COSTS ARE BEING RE-ANALYZED AND WILL BE PROVIDED ON 29 APRIL 87

REVISION OF 15 APRIL 1987 (REFLECTS INITIAL RESULTS OF 4/13 REVIEW)

CHANGED ALL TURBO PUMPS TO DUAL 3500 L/S AND REDUCED PRICE (3014H,3022H,3032H,3800A)
CHANGED ION PUMPS TO PERKIN-ELMER AND REDUCED PRICE (3014A,3022A,3032A,3071A)
CORRECTED NUMBER OF 16 INCH PUMP PORTS REQUIRED (3051D.3051E)
INCREASED NUMBER OF SINGLE/FLANGED LOCK EXPANSION JOINTS (3052C)
ELIMINATED PORTABLE LEAK DETECTORS (3077A)
ELIMINATED DIAGNOSTIC EQUIPMENT INSTALLATION LABOR (3077D)
ELIMINATED PIPE SUPPORT INSULATION (3088)
INCREASED LENGTH OF TIME PORTABLE GENERATORS ARE REQUIRED (3089)
CORRECTED SUBCOST ELEMENTS OF MID/END STATIONS (5031A-F039J, 5041A-5049J)
CONSOLIDATED FIRE PROTECTION/DETECTION ELEMENTS (5731,5831,5931,5711)
CORRECTED COST OF COLUMBIA SUPPORT BUILDING TO REFLECT MAINE LABOR RATES (5700)
CHANGED NOMENCLATURE OF HOUSEKEEPING FROM ASSEMBLY TO SUBSYSTEM (5090)
MODIFIED END STATION MANIFOLD COST ESTIMATE (30321)
REDUCED THE NUMBER OF FIRE HYDRANTS FROM 10 TO 4 PER SITE (5015C)
CORRECTED CONTINGENCY FOR CHANGES IN COST (8000)

REVISION OF 09 JUNE 1987

REVISED COST OF TURBO PUMPS IN ACCORDANCE WITH QUOTES RECEIVED (3014H,3022H.3032H,3800A) 9% QTY DISCOUNT
REVISED COST OF ION PUMPS IN ACCORDANCE WITH QUOTES (3014A,3022A,3032A,3071A) 37% QTY DISCOUNT
REVISED COST OF ION PUMP POWER SUPPLIES IN ACCORDANCE WITH QUOTES (2014B,3022B,3032B,3071B) WITH 37% QTY DISCOUNTS
REMOVED COST OF SOILS/GEOLOGY WORK (5011)
REVISED LASER COOLING COSTS TO REFLECT REDESIGN FOR LOCATION AT 150 FT FROM CENTRAL STATION (5071-82)
REVISED COST OF BAKEOUT INSULATION, COVERING, LABOR (3081A,B,C)
REVISED CONTINGENCY TO BE CONSISTENT WITH COST ANNUAL INCURRED COST
ADDED COLUMNS FOR LENGTH INDEPENDENT AND DEPENDENT COSTS

REVISION OF 25 AUGUST 1987

REVISED TO REFLECT COSTS CONSISTENT WITH EDWARDS SITE ACTIVITY
REVISED COST OF SUPPORT FOUNDATIONS (3062A-3062D)
ELIMINATED SUPPORT BUILDING FIRE SUPPRESSION SYSTEM (5015F)
REDUCED COST OF SITE CLEANUP AND LANDSCAPING (5016)
ELIMINATED SUPPORT BUILDING FIRE DETECTION SYSTEM (5711)
ELIMINATED WATER TABLE EROSION CONTROL (5017)
ELIMINATED SUPPORT BUILDING (5700)
MODIFIED COST OF EXCAVATION WORK (5051A)
ELIMINATED CULVERT BASE FORMATION (5051B)
CHANGED FILL/BACKFILL TO BERM (5051C)
REMOVED CULVERT COSTS AND ADDED PREFORMED COVER COSTS (5052)
MODIFIED COST OF EQUIPMENT ACCESS ENCLOSURES (5053)
ELIMINATED CULVERT INSTALLATION COSTS (5054A,B,C, AND E)
MODIFIED COST OF PROVIDING BORROW (5054D)
ELIMINATED COST OF SUPPORT BUILDING FURNISHINGS (5111C AND 5112C)
ELIMINATED SNOW MOBILES (5140B)
ELIMINATED SUPPORT BUILDING FENCING (5014D)

COST PER SYSTEM-COVERED ABOVE GROUND 1986 $ (JULY '86)	$41,823,373	OR	1984$	$38,669,891
SYSTEM COST WITHOUT INCLUDING CONTINGENCY	$36,683,373			$33,915,840

WBS #	TITLE	UNIT QUANITY	UNIT COST	EXTENSION	SUBASSEMBLY COST	ASSEMBLY COST	LENGTH INDEPENDENT	LENGTH DEPENDENT

1000 PROJECT MANAGEMENT	SUBSYSTEM COST		MODIFIED FROM 5.50 TO 4.50 YR SCHEDULE			*** $806,719	$645,375	$161,344
1010 PROJECT MANAGER	EA	1				*** $370,446		
1020 PROJECT TRAVEL	LOT	1				*** $60,000		
1030 PROJECT DOCUMENTATION	LOT	1				*** $66,200		
1040 PROJECT REVIEWS	LOT	1				*** $23,000		
1050 PROJECT SAFETY	LOT	1				*** $15,000		
1060 PROJECT SECURITY	LOT	1				*** $25,000		
1070 FINANCIAL MANAGER	EA	1				*** $152,176		
1080 PROJECT SUPPORT	EA	1				*** $50,000		
					SUBTOTALS			
2000 SYSTEM ENGINEERING/CONTRACTOR SUPERVISION	SUBSYSTEM COST		MODIFIED FROM 5.50 TO 4.50 YR SCHEDULE			*** $3,271,789	$2,290,252	$981,537
2010 SYSTEM MANAGER	EA	1				*** $282,618		
2020 MECHANICAL/STRUCTURAL MANAGER	EA	1				*** $239,138		
2030 VACUUM/OPTICS MANAGER	EA	1				*** $282,618		
2040 JPL SUPPORT						*** $2,160,650		
2041 TASK MANAGEMENT	EA	1						
2042 CIVIL ENGINEERING	EA	1						
2043 MECHANICAL/STRUCTURAL ENGINEERING	EA	1						
2044 SAFETY	EA	1						
2045 QUALITY ASSURANCE	EA	1						
2050 SYSTEM VALIDATION	SYSTEM	1				*** $50,000		
2055 SYSTEM VALIDATION TEST PLAN	EA	1				*** $25,000		
2500 CONFIGURATION CONTROL	LOT	1				*** $50,000		
					SUBTOTALS			
3000 VACUUM SUBSYSTEM	SUBSYSTEM COST *X		$13,079,831			*** $13,079,831	$2,858,242	$10,221,589
3010 CENTRAL STATION, FOUR VACUUM CHAMBER ASSY						*** $871,621	$871,621	
3011 VACUUM CHAMBER 14'DIA	EA	1	>	*	$196,880			
3011A VESSEL 14'DIA, 4-4'DIA PORTS	EA	1	$180,000	$180,000				
3011B VIEWPORT, OPTICAL	EA	1	$3,200	$3,200				
3011C VIEWPORT, SIGHT	EA	2	$500	$1,000				
3011D LIGHTING, INTERIOR	EA	2	$700	$1,400				
3101E CABLE FEED THRU	EA	4	$1,000	$4,000				
3011F BLIND FLG/SEAL 4'DIA	EA	1	$6,000	$6,000				
3011G PORT, PUMP, 16" DIAMETER	EA	1	$1,280	$1,280				
3012 VACUUM CHAMBER 10'DIA	EA	1	>	*	$151,780 *			
3012A VESSEL 10'DIA, 4-4'DIA PORTS	EA	1	$137,600	$137,600				
3012B VIEWPORT, OPTICAL	EA	1	$3,200	$3,200				
3012C VIEWPORT, SIGHT	EA	2	$500	$1,000				
3012D LIGHTING, INTERIOR	EA	1	$700	$700				
3012E CABLE FEED THRU	EA	2	$1,000	$2,000				
3012F BLIND FLG/SEAL 4'DIA	EA	1	$6,000	$6,000				
3012G PORT, PUMP, 16" DIAMETER	EA	1	$1,280	$1,280				
3013 VACUUM CHAMBER 10'DIA	EA	2	>	*	$295,160 *			
3013A VESSEL 10'DIA, 4-4'DIA PORTS	EA	1	$137,600	$137,600				
3013B VIEWPORT, SIGHT	EA	2	$500	$1,000				
3013C LIGHTING, INTERIOR	EA	1	$700	$700				
3013D CABLE FEED THRU	EA	1	$1,000	$1,000				
3013E BLIND FLG/SEAL 4'DIA	EA	1	$6,000	$6,000				
3013F PORT, PUMP, 16" DIAMETER	EA	1	$1,280	$1,280				
3014 VACUUM SUPPORT PUMP STATION	EA	1		*	$147,801 *			

3014A	ION PUMP, 2000 L/S, PE MODEL 207-2000	EA	2		$11,555	$23,109				:	:
3014B	ION PUMP POWER SUPPLY	EA	2		$1,814	$3,629				:	:
3014C	ROUGHING VALVES, 16 INCH	EA	6		$10,000	$60,000				:	:
3014D	LEAK TEST VALVES, 1 INCH	EA	2		$500	$1,000				:	:
3014E	PENNING GAUGE	EA	2		$1,500	$3,000				:	:
3014F	PIRANI GAUGE	EA	2		$1,000	$2,000				:	:
3014G	MECHANICAL PUMP, 300 CFM	EA	1		$8,000	$8,000				:	:
3014H	TURBO PUMP, 5000 L/S, BALZER TPH 5000	EA	1		$37,062	$37,062				:	:
3014I	MANIFOLD, 16 INCH SS TUBING	EA	1		$8,000	$8,000				:	:
3014J	VALVE, BY-PASS, 6 INCH	EA	1		$2,000	$2,000				:	:
3015	VACUUM CHAMBER INSTALLATION COST	SYS	1					$80,000 *			:
3015A	CENTRAL STATION	EA	4		$10,000	$40,000					:
3015B	MID STATIONS	EA	2		$10,000	$20,000					:
3015C	.END STATIONS	EA	2		$10,000	$20,000					:
3020	CHAMBER ASSEMBLY, MID STATION	EA	2						***	$504,023 :	$504,023 :
3021	VACUUM CHAMBER 10'DIA	EA	2	>				$147,500 *		:	:
3021A	VESSEL 10'DIA, 4-4'DIA PORTS	EA	1		$137,600	$137,600				:	:
3021B	VIEWPORT, SIGHT	EA	2		$500	$1,000				:	:
3021C	LIGHTING, INTERIOR	EA	1		$700	$700				:	:
3021D	CABLE FEED THRU	EA	1		$1,000	$1,000				:	:
3021E	BLIND FLG/SEAL 4'DIA	EA	1		$6,000	$6,000				:	:
3021F	PORT, PUMP, 16" DIAMETER	EA	1		$1,200	$1,200					:
3022	VACUUM SUPPORT PUMP STATION	EA	2					$104,432 *		:	:
3022A	ION PUMP, 2000 L/S, PE MODEL 207-2000	EA	1		$11,555	$11,555				:	:
3022B	ION PUMP POWER SUPPLY	EA	1		$1,814	$1,814				:	:
3022C	ROUGHING VALVES, 16 INCH	EA	3		$10,000	$30,000				:	:
3022D	LEAK TEST VALVES, 1 INCH	EA	2		$500	$1,000				:	:
3022E	PENNING GAUGE	EA	2		$1,500	$3,000				:	:
3022F	PIRANI GAUGE	EA	2		$1,000	$2,000				:	:
3022G	MECHANICAL PUMP, 300 CFM	EA	1		$8,000	$8,000				:	:
3022H	TURBO PUMP, 5000 L/S, BALZER TPH 5000	EA	1		$37,062	$37,062				:	:
3022I	MANIFOLD, 16 INCH SS TUBING	EA	1		$8,000	$8,000				:	:
3022J	VALVE, BY-PASS, 6 INCH	EA	1		$2,000	$2,000				:	:
3030	CHAMBER ASSEMBLY, END STATION	EA	2	>					***	$480,023 :	$480,023 :
3031	VACUUM CHAMBER 10'DIA	EA					*	$147,500 *		:	:
3031A	VESSEL 10'DIA, 4-4'DIA PORTS	EA	1		$137,600	$137,600				:	:
3031B	VIEWPORT, SIGHT	EA	2		$500	$1,000				:	:
3031C	LIGHTING, INTERIOR	EA	1		$700	$700				:	:
3031D	CABLE FEED THRU	EA	1		$1,000	$1,000				:	:
3031E	BLIND FLG/SEAL 4'DIA	EA	1		$6,000	$6,000				:	:
3031F	PORT, PUMP, 16" DIAMETER	EA	1		$1,200	$1,200					:
3032	VACUUM SUPPORT PUMP STATION	EA	2				*	$92,432		:	:
3032A	ION PUMP, 2000 L/S, PE MODEL 207-2000	EA	1		$11,555	$11,555				:	:
3032B	ION PUMP POWER SUPPLY	EA	1		$1,814	$1,814				:	:
3032C	ROUGHING VALVES, 16 INCH	EA	2		$10,000	$20,000				:	:
3032D	LEAK TEST VALVES, 1 INCH	EA	2		$500	$1,000				:	:
3032E	PENNING GAUGE	EA	2		$1,500	$3,000				:	:
3032F	PIRANI GAUGE	EA	2		$1,000	$2,000				:	:
3032G	MECHANICAL PUMP, 300 CFM	EA	1		$8,000	$8,000				:	:
3032H	TURBO PUMP, 5000 L/S, BALZER TPH 5000	EA	1		$37,062	$37,062				:	:
3032I	MANIFOLD, 16 INCH SS TUBING	EA	1		$6,000	$6,000				:	:
3032J	VALVE, BY-PASS, 6 INCH	EA	1		$2,000	$2,000				:	:
3040	CHAMBER SUPPORT ASSEMBLY	EA	1	>					***	$441,120 :	$441,120 :
3041A	CHAMBER FOUNDATION/PIERS-CENTRAL STATION	EA	4		$6,150	$24,600		$24,600 *		:	:
3041B	CHAMBER FOUNDATION/PIERS-MID STATIONS	EA	2		$6,150	$12,300		$12,300 *			:
3041C	CHAMBER FOUNDATION/PIERS-END STATIONS	EA	2		$6,150	$12,300		$12,300 *			:

207 E
23 S

3042A	SUPPORT FRAME-CENTRAL STATION	EA	4		$7,600	$30,400	$30,400 *	:	:
3042B	SUPPORT FRAME-MID STATIONS	EA	2		$7,600	$15,200	$15,200 *		:
3042C	SUPPORT FRAME-END STATIONS	EA	2		$7,600	$15,200	$15,200 *		:
3043	AIR MOUNT-CENTRAL STATION	EA	4				$160,360 *	:	:
3043A	VIBRATION ISOLATOR	EA	3		$7,200	$21,600		:	:
3043B	HEIGHT/LEVEL SERVO MNTR/CNTRL	EA	1		$10,000	$10,000		:	:
3043C	AIR COMPRESSOR & TANK	EA	1		$6,000	$6,000		:	:
3043D	HOUSING, COMPRESSOR	EA	1		$180	$180		:	:
3043E	TUBING/VALVES/FITTINGS	EA	1		$360	$360		:	:
3043F	INSTALLATION LABOR	EA	4		$1,150	$4,600			:
3043G	AIR MOUNT-MID STATIONS	EA	2				$80,180 *		:
3043H	VIBRATION ISOLATOR	EA	3		$7,200	$21,600			:
3043I	HEIGHT/LEVEL SERVO MNTR/CNTRL	EA	1		$10,000	$10,000			:
3043J	AIR COMPRESSOR & TANK	EA	1		$6,000	$6,000			:
3043K	HOUSING, COMPRESSOR	EA	1		$180	$180			:
3043L	TUBING/VALVES/FITTINGS	EA	1		$360	$360			:
3043M	INSTALLATION LABOR	EA	2		$1,150	$2,300			:
3043N	AIR MOUNT-END STATIONS	EA	2				$80,180 *		:
3043O	VIBRATION ISOLATOR	EA	3		$7,200	$21,600			:
3043P	HEIGHT/LEVEL SERVO MNTR/CNTRL	EA	1		$10,000	$10,000			:
3043Q	AIR COMPRESSOR & TANK	EA	1		$6,000	$6,000			:
3043R	HOUSING, COMPRESSOR	EA	1		$180	$180			:
3043S	TUBING/VALVES/FITTINGS	EA	1		$360	$360		:	:
3043T	INSTALLATION LABOR	EA	2		$1,150	$2,300			:
3044	TRAVEL STOPS-MATERIAL AND LABOR	EA	1				$4,000 *		:
3044A	CENTRAL STATION	EA	4		$500	$2,000			:
3044B	MID STATIONS	EA	2		$500	$1,000			:
3044C	END STATIONS	EA	2		$500	$1,000			:
3045	AUXILLIARY JACK-MATERIAL AND LABOR	SET	1				$6,400 *	:	:
3045A	CENTRAL STATION	EA	4		$800	$3,200			:
3045B	MID STATIONS	EA	2		$800	$1,600			:
3045C	END STATIONS	EA	2		$800	$1,600			:
3050	VACUUM PIPE ASSEMBLY							*** $6,834,130 :	: $6,834,130
3051	PIPE						$5,723,676 *	:	:
3051A	PIPE, CRES 304L/4' DIA	FT	25524		$207	$5,283,468		:	:
3051B	FLANGE SET/SEAL/HWDR, 4' DIA	EA	20	1	$3,560	$64,080		:	:
3051D	PORT, 16" DIA/SEAL/BLIND FLG/HWDR	EA	32	1	$1,280	$32,768		:	:
3051E	PORT, 6"/SEAL/BLIND FLG/HWDR	EA	32	1	$600	$15,360		:	:
3051F	FIELD WELD, 48" DIA	EA	656		$500	$328,000		:	:
3015G	PIPE SUPPORT RINGS, MILD STEEL/WELDED	EA	3200						
3052	EXPANSION JOINTS						$417,454 *	:	:
3052A	SINGLE/FLANGED	EA	16	1	$4,917	$70,805		:	:
3052B	DOUBLE/WELDED END	EA	64	1	$4,583	$234,650		:	:
3052C	SINGLE/FLANGED/LOCK	EA	16		$7,000	$112,000		:	:
3053	ISOLATION VALVES						$693,000 *	:	:
3053A	GATE VALVE, CHAMBER 4' DIA	EA	2		$69,300	$138,600		:	:
3053B	GATE VALVE, PIPE 4' DIA	EA	8		$69,300	$554,400		:	:
3060	SUPPORT ASSEMBLY, VACUUM PIPE							*** $611,884 :	: $611,884
3061	SUPPORTS/ANCHORS						$546,784 *	:	:
3061A	SUPPORT, SLIDING	EA	360		$1,150	$414,000		:	:
3061B	SUPPORT, FIXED	EA	64		$1,400	$89,600		:	:
3061C	ANCHOR, FIXED	EA	14		$1,656	$23,184		:	:
3061D	ALIGNMENT	EA	1		$20,000	$20,000		:	:
3062	SUPPORT FOUNDATIONS						$65,100 *	:	:
3062A	FOUNDATION, SLIDING SUPPORT	EA	360		$100	$36,000		:	:
3062B	FOUNDATION, FIXED SUPPORT	EA	64		$150	$9,600		:	:

3062C	FOUNDATION, FIXED ANCHOR	EA	14		$250	$3,500					
3062D	FOUNDATION, DBL EXP JOINT	EA	60		$100	$6,000					
3062E	ALIGNMENT	EA	1		$10,000	$10,000					
3070	VACUUM PIPE PUMP ASSEMBLY							###	$808,611		$808,611
3071	VACUUM PIPE PUMPS	EA	1				$575,811	*			
3071A	ION PUMPS, 2000 L/S	EA	32		$11,555	$369,751					
3071B	ION PUMP POWER SUPPLY	EA	32		$1,814	$58,061					
3071C	ROUGHING VALVES, 16 INCH	EA	0		$10,000	$0					
3071D	LEAK TEST VALVES, 1 INCH	EA	32		$500	$16,000					
3071E	PENNING GAUGE	EA	8		$1,500	$12,000					
3071F	PIRANI GAUGE	EA	8		$1,000	$8,000					
3071G	PIPE PUMP INSTALLATION	SYS	1		$80,000	$80,000					
3071H	CENTRAL STATION PUMP INSTALLATION				$16,000	$16,000					
3071I	MID/END STATION PUMP INSTALLATION				$16,000	$16,000					
3072	VACUUM PIPE TESTING/CLEANING	EA	1		$100,000	$100,000	$100,000	*			
3076	NITROGEN SUPPLY SUBASSEMBLY	SYS	1				$100,000	*			
3076A	CENTRAL STATION	EA	1		$20,000	$20,000					
3076B	END STATIONS	EA	2		$20,000	$40,000					
3076C	MID STATIONS	EA	2		$20,000	$40,000					
3077	DIAGNOSTIC EQUIPMENT	EA	1				$32,000	*			
3077A	LEAK DETECTOR, PORTABLE	EA	0		$20,000	$0					
3077B	RESIDUAL GAS ANALYZER, PORTABLE	EA	2		$12,000	$24,000					
3077C	RESIDUAL GAS ANALYZER HEADS	EA	8		$1,100	$8,000					
3077D	INSTALLATION LABOR	EA	0		$20,000	$0	$0	*			
3080	VACUUM BAKEOUT POWER DISTRIBUTION ASSEMBLY	SYSTEM	1	1				###	$1,738,100		$1,738,100
3081	TWO INCH HIGH DENSITY INSULATION	FT					$679,900	*			
3081A	INSULATION, 2", K=0.33	FT	26150		$9	$235,350					
3081B	INSTALLATION LABOR	FT	26150		$8	$209,200					
3081C	PROTECTIVE COVER, ,016 AL, BANDED 12"	FT	26150		$9	$235,350					
3082	SERVICE DROP, 4160 V 200' LG	EA	64		$2,000	$128,000	$128,000	*			
3083	TRANSFORMER, 4160/125 V 132 KVA	EA	64		$8,000	$512,000	$512,000	*			
3084	SWITCHES, OIL FUSED CUT-OUT 5 KV	EA	128		$1,000	$128,000	$128,000	*			
3085	BUS, COPPER 2" x 1/4"	FT	26150		$4	$104,600	$104,600	*			
3086	CONNECTION, BUS TO VAC PIPE	EA	192	1	$150	$28,800	$28,800	*			
3087	SHUNT, FLEX (20 AT EACH EXP JOINT)	EA	2560	1	$25	$64,000	$64,000	*			
3089	GEN'TOR, MOBILE/750 KW RENTAL	EA	2		$19,200	$38,400	$38,400	*			
3089A	VACUUM PIPE BAKEOUT FUEL COSTS	GAL	14400		$1	$14,400	$14,400	*			
3089B	CENTRAL STATION BAKEOUT FUEL COSTS	GAL	2400		$1	$20,000	$20,000	*			
3089C	MID/END STATION BAKEOUT FUEL COSTS	GAL	3600		$1	$20,000	$20,000	*			
3090	CHAMBER BAKEOUT COVERS							###	$60,000	$60,000	
3091	14' CHAMBER	EA	1			$10,000	$10,000	*			
3092	10' CHAMBERS	EA	5			$10,000	$50,000	*			
3300	FUNCTIONAL SPECIFICATIONS	EA	1					###			
3400	OPERATION/MAINTANCE MANUAL	EA	1					###	$145,455	$116,364	$29,091
3500	SPARES	SET	1					###	$436,364	$349,091	$87,273
3700	PARTS STOCKING/MATERIALS/HANDLING	SYS	1					###	$36,000	$36,000	
3700A	INITIAL PROCUREMENTS	EA	1				$18,000				
3700B	SECOND PROCUREMENTS	EA	1				$18,000				
3800	PORTABLE PUMP ASSEMBLY	EA	1				$112,500	###	$112,500		$112,500
3800A	PROCUREMENT OF PUMP ASSEMBLY MATERIALS				$92,500	$92,500					
3800B	ASSEMBLY OF PORTABLE PUMP EQUIPMENT				$20,000	$20,000					
							SUBTOTALS				
4000	RECEIVER SUBSYSTEM	SUBSYSTEM COST			$1,505,000				$1,505,000	$1,505,000	
4010	MASS SUSPENSION ASSEMBLIES	SET	1					###			
4020	LASER ASSEMBLIES	SET	1					###	$200,000		

4020A LASER ASSEMBLY TEST AND EVALUATION	SET	1				###	$40,000		
4030 FILTER/MODULATOR ASSEMBLIES	SET	1				###			
4040 OPTICS ASSEMBLIES	SET	1				###	$400,000		
[illegible] POCKELS CELLS	SET	1				###			
[illegible] [illegible]ISPLAY ASSEMBLIES	SET	1				###			
[illegible] [illegible]WER SUPPLY ASSEMBLIES	SET	1				###			
[illegible] ELECTRONIC CONTROL ASSEMBLIES	SET	1				###			
4090 ANTICOINCIDENCE ASSEMBLIES	SET	1				###			
4100 RECEIVER CONSTRUCTION/FABRICATION	SET	1				###			
4110 RECEIVER DESIGN LABOR	SYS	1				###	$400,000		
4120 RECEIVER INTEGRATION/TESTING	SYS	1				###	$200,000		
4300 FUNCTIONAL SPECIFICATIONS	EA	1				###	$10,000		
4400 OPERATION/MAINTANCE MANUALS	EA	1				###	$5,000		
4600 SPARES	EA	1				###	$80,000		
4700 RECEIVER PROCUREMENTS (4110-4090)						###	$170,000		
5000 FACILITIES SUBSYSTEM	SUBSYSTEM COST		$15,166,337				$15,166,337	$4,171,979	$10,994,357
5010 SITE DEVELOPMENT	LOT	1				###	$989,091		
5011 SOILS/GEOLOGY	TASK	0	$103,400	$0	$416,091 *				
5012 WATER SUPPLY (CENT. STA AND SUPPORT BLDG)	EA	2	$30,000	$60,000				$60,000	
5012A WELLS									
5012B WATER PUMP									
5012C WATER TREATMENT									
5012D WATER STORAGE									
5012E PIPING/FITTINGS/HDWE									
5013 ACCESS ROADS	MILE	5.6	$52,873	$296,091				$59,218	$236,873
5013A EARTHWORK/GRADING									
5013B BASE COURSE-CRUSHED ROCK/GRAVEL									
5013D DRAINAGE STRUCTURES									
5014 SECURITY	SYS	3750	$16	$60,000				$60,000	
5014A FENCING/GATES-CENTRAL STATION	EA	1	$20,000						
5014B FENCING/GATES-MID STATIONS	EA	1	$10,000						
5014C FENCING/GATES-END STATIONS	EA	1	$10,000						
5014D FENCING/GATES-SUPPORT STATION	EA	0	$20,000						
5015 FIRE PROTECTION GENERAL					$423,000 *				
5015A PUMPS/HOUSINGS	EA	2	$50,000	$100,000				$423,000	
5015B MAINS	FT	1000	$30	$30,000					
5015C HYDRANTS	EA	4	$750	$3,000					
5015D WATER STORAGE TANK	EA	2	$50,000	$50,000					
5015E MID/END STATION FIRE SUPPRESSION-HALON	EA	4	$28,800	$115,200					
5015F SUPPORT BUILDING FIRE SUPPRESSION-H2O	EA	0	$38,400	$38,400					
5015G CENT STATION FIRE SUPPRESSION-H2O/HALON	EA	1	$52,800	$52,800					
5731 CENTRAL STATION FIRE DETECTION	EA	1	$14,400	$14,400					
5831 MID STATION FIRE DETECTION	EA	2	$4,800	$9,600					
5931 END STATION FIRE DETECTION	EA	2	$4,800	$9,600					
5711 SUPPORT BUILDING FIRE DETECTION	EA	0	$14,400	$0					
5016 SITE CLEANUP/LANDSCAPING	EA	1	$50,000	$50,000	$50,000 *			$15,000	$35,000
5017 WATER TABLE/EROSION CONTROL	EA	0	$100,000		$100,000 *				$100,000
5[illegible]20 CENTRAL STATION BUILDING ASSEMBLY	EA	1				###	$978,160	$978,160	
5021 GENERAL CONSTRUCTION	SQ FT	5576	$160	$892,160	$892,160 *				
5021A EXCAVATION/GRADING			$20,000						
5021B FLOOR SLAB/RETAINING WALLS			$187,000						
5022 STRUCTRUAL/FRAMING			$300,000						
5022A EXTERIOR SIDING			^						
5022B INTERIOR SURFACE			^						

5022C	INSULATION			^					
5022D	ROOF & DECKING			^					
5023	PARTITIONS			$195,160					
5024	RAISED FLOORING			^					
5025	ACOUSTIC ISOLATION			^					
5026	DRAINS			^					
5027	SANITARY FACILITIES			^					
5027A	TOILET/LAVATORY			^					
5027B	SEPTIC TANK/HOLDING TANK			^					
5027C	DRINKING FOUNTAIN			^					
5027D	EYE WASH			^					
5027E	SHOWER			^					
5028	LIGHTING & UTILITY RECEPTACLES			$40,000					
5029	HVAC			$150,000					
5029A	AIR HANDLING UNIT			^					
5029B	VENTILATION UNIT			^					
5029C	DUCTING/INSULATION			^					
5029D	CHILLERS, AIR COOLED			^					
5029E	PUMP, CHILLED WATER			^					
5029F	WATER TREATMENT			^					
5029G	PIPING/FITTINGS/HDWE			^					
5029H	DUCT HEATER, ELECTRIC			^					
5029I	AUTOMATIC CONTROLS			^					
5029J	VIBRATION ISOLATION			^					
5730	BRIDGE CRANE, 20 TON x 68'	EA	1	$85,000	$85,000	$85,000 *			
5732	COMPRESSED AIR DISTRIBUTION	EA	1	$1,000	$1,000	$1,000 *			
5030	MID STATION BUILDING ASSEMBLY	EA	2	>			***	$389,760	$389,760
5031	GENERAL CONSTRUCTION	SQ FT	918	$160	$146,880	$146,880 *			
5031A	EXCAVATION/GRADING			$20,000					
5031B	FLOOR SLAB/RETAINING WALLS			$10,000					
5032	STRUCTRUAL FRAMING			$20,000					
5032A	EXTERIOR SIDING			^					
5032B	INTERIOR SURFACE			^					
5032C	INSULATION			^					
5032D	ROOF & DECKING			^					
5033	PARTITIONS			$63,880					
5034	RAISED FLOORING			^					
5035	ACOUSTIC ISOLATION			^					
5036	DRAINS			^					
5037	SANITARY FACILITIES			^					
5037A	TOILET/LAVATORY			^					
5037B	SEPTIC TANK/HOLDING TANK			^					
5037C	DRINKING FOUNTAIN			^					
5037D	EYE WASH			^					
5037E	SHOWER			^					
5038	LIGHTING & UTILITY RECEPTACLES			$10,000					
5039	HVAC			$20,000					
5039A	AIR HANDLING UNIT			^					
5039B	VENTILATION UNIT			^					
5039C	DUCTING/INSULATION			^					
5039D	CHILLERS, AIR COOLED			^					
5039E	PUMP, CHILLED WATER			^					
5039F	WATER TREATMENT			^					
5039G	PIPING/FITTINGS/HDWE			^					
5039H	DUCT HEATER, ELECTRIC			^					
5039I	AUTOMATIC CONTROLS			^					

5039J	VIBRATION ISOLATION				^						
5030	BRIDGE CRANE, 15 TON x 27'	EA	1		$40,000	$40,000	$40,000	*			
5032	COMPRESSED AIR DISTRIBUTION	EA	1		$1,000	$0	$0	*			
5040	END STATION BUILDING ASSEMBLY	EA	2	>				***	$391,760		$391,760
5041	GENERAL CONSTRUCTION	LOT	918		$160	$146,880	$146,880	*			
5041A	EXCAVATION/GRADING				$20,000						
5041B	FLOOR SLAB/RETAINING WALLS				$10,000						
5042	STRUCTRUAL FRAMING				$20,000						
5042A	EXTERIOR SIDING				^						
5042B	INTERIOR SURFACE				^						
5042C	INSULATION				^						
5042D	ROOF & DECKING				^						
5043	PARTITIONS				$63,000						
5044	RAISED FLOORING				^						
5045	ACOUSTIC ISOLATION				^						
5046	DRAINS				^						
5047	SANITARY FACILITIES				^						
5047A	TOILET/LAVATORY				^						
5047B	SEPTIC TANK/HOLDING TANK				^						
5047C	DRINKING FOUNTAIN				^						
5047D	EYE WASH				^						
5047E	SHOWER				^						
5048	LIGHTING & UTILITY RECEPTACLES				$10,000						
5049	HVAC				$20,000						
5049A	AIR HANDLING UNIT				^						
5049B	VENTILATION UNIT				^						
5049C	DUCTING/INSULATION				^						
5049D	CHILLERS, AIR COOLED				^						
5049E	PUMP, CHILLED WATER				^						
5049F	WATER TREATMENT				^						
5049G	PIPING/FITTINGS/HDWE				^						
5049H	DUCT HEATER, ELECTRIC				^						
5049I	AUTOMATIC CONTROLS				^						
5049J	VIBRATION ISOLATION				^						
5930	BRIDGE CRANE, 15 TON x 27'	EA	1		$40,000	$40,000	$40,000	*			
5932	COMPRESSED AIR DISTRIBUTION	EA	1		$1,000	$1,000	$1,000	*			
5700	SUPPORT BUILDING ASSEMBLY	EA	0	>				***	$0		$0
5701	GENERAL CONSTRUCTION	SQ FT	6000		$80	$480,000	$480,000	*			
5701A	EXCAVATION/GRADING				$32,000						
5702	FLOOR SLAB/RETAINING WALLS				$27,200						
5703	STRUCTRUAL FRAMING				$80,000						
5703A	EXTERIOR SIDING				^						
5703B	INTERIOR SURFACE				^						
5703C	INSULATION				^						
5703D	ROOF & DECKING				^						
5704	PARTITIONS				$100,000						
5705	RAISED FLOORING				^						
5706	ACOUSTIC ISOLATION				^						
5707	DRAINS				^						
5708	SANITARY FACILITIES				^						
5708A	TOILET/LAVATORY				^						
5708B	SEPTIC TANK/HOLDING TANK				^						
5708C	DRINKING FOUNTAIN				^						
5708D	EYE WASH				^						

5708E	SHOWER			^					
5709	LIGHTING & UTILITY RECEPTACLES			$52,000					
5710	HVAC			$84,000					
5710A	AIR HANDLING UNIT			^					
5710B	VENTILATION UNIT			^					
5710C	DUCTING/INSULATION			^					
5710D	CHILLERS, AIR COOLED			^					
5710E	PUMP, CHILLED WATER			^					
5710F	WATER TREATMENT			^					
5710G	PIPING/FITTINGS/HDWE			^					
5710H	DUCT HEATER, ELECTRIC			^					
5710I	AUTOMATIC CONTROLS			^					
5710J	VIBRATION ISOLATION			^					
5050	PROTECTIVE HOUSING ASSEMBLY, VACUUM PIPE						### $9,782,416		$9,782,416
5051	EARTHWORK	LOT				$2,146,016 *			
5051A	EXCAVATION, CUT/TRENCH	FT			$450,000				
5051B	FORM CULVERT BASE	FT	0	$5	$0				
5051C	CONSTRUCT BERM OVER CONCRETE HOUSING	FT	26,150	$40	$1,046,016				
5051D	DRAINAGE STRUCTURES	EA	1	$50,000	$50,000				
5051E	EROSION CONTROL	EA	1	$225,000	$225,000				
5051F	CONSTRUCTION ACCESS ROADS	LOT	5	$25,000	$125,000				
5051G	MOBILIZATION/GENERAL CONSTRUCTION	LOT	1	$250,000	$250,000				
5052	CONSTRUCTION OF PREFORMED COVER					$6,500,000 *			
5052A	COVER ASSEMBLY	EA	26000	$250	$6,500,000				
5052B	CONNECTING BANDS & HDWE	EA	0	$180	$0				
5052C	CART SUPPORT INTERNAL RAIL	FT	0	$12	$0				
5053	EQUIPMENT/ACCESS ENCLOSURE	EA	64	$4,000	$256,000	$256,000 *			
5053A	CORR STL CULV 12 GA/8'Dx9'	EA	1						
5053B	STUB, CORR STL 12 GA/8'D	EA	1						
5053C	CONNECTING BANDS & HDWE	EA	1						
5053D	ROOF	EA	1						
5053E	DOOR, MAN ACCESS	EA	1						
5053F	LANDING/LADDER	EA	1						
5053G	DECK/LADDER/ACOUST ISOL	EA	1						
5053H	POWER/LIGHTING	EA	1						
5053I	WINCH	EA	1						
5054	INSTALLATION, CULVERT/COVER SECTIONS					$699,000 *			
5054A	PLACE SECTIONS	EA	0	$600	$0				
5054B	CONNECT/ALIGN SECTIONS	EA	0						
5054C	CONNECT EQUIP/ACCESS ENCL	EA	0						
5054D	PROVIDE BORROW	CYD	233,000	$3	$699,000				
5054E	INSTALL SECTION SEALS	EA	0						
5056	LIGHTING & UTILITY RECEPTACLES	FT	26,150	$4	$104,600	$104,600 *			
5059	VENTILATION SYSTEM	EA	64	$1,200	$76,800	$76,800 *			
5059A	VENTILATION UNIT	EA	1	$850					
5059B	ELECTRICAL/CONTROLS	EA	1	$350					
5060	POWER DISTRIBUTION ASSEMBLY	SYSTEM	1 0.48				### $1,204,164		
5061	UTILITY SUBSTATION		1	$360,000	$360,000	$360,000 *		$172,800	
5061A	TRANSFORMER, 34.5KV/4160 V	EA							
5061B	METERING EQUIPMENT								
5061C	SWITCHGEAR								
5062	TUNNEL/PIPE					$971,008 *			$466,084
5062A	OVERHEAD LINE, 4160 V	MILES	5	$50,000	$250,000				
5062B	TRANSFORMER, 4160/480 V, 250 KVA	EA	16	$15,000	$240,000				
5062C	PANEL, 480 V, HVAC/CRYOPUMPS/CONTROLS	EA	16	$6,563	$105,008				
5062D	TRANSFORMER, 480/120-208 V, 50 KVA	EA	16	$4,000	$64,000				

062E	CABLING/RACEWAYS,480-120/208V	FT	26000	$12	$312,000				
0631	CENTRAL STATION ELECTRICAL					$309,000 *		$148,320	
063A	SWITCHGEAR, 4160 V	EA	30	$4,600	$138,000				
063B	TRANSFORMER, 4160/480 V 500 KVA	EA	2	$25,000	$50,000				
063C	TRANSFORMER, 4160/480 V 250 KVA	EA	1	$15,000	$15,000				
063D	CABLING, 480 V (11 x 500'	FT	5500	$6	$33,000				
063E	TRANSFORMER, 480/120-208 V 150 KVA	EA	5	$8,000	$40,000				
063F	CABLING, 120-208 V (11 x 500')	FT	5500	$6	$33,000				
50632	MID STATION ELECTRICAL					$101,000 *		$48,480	
5063G	SWITCHGEAR, 4160 V	EA	5	$4,600	$23,000				
5063H	TRANSFORMER, 4160/480 V 500 KVA	EA	2	$25,000	$50,000				
5063I	TRANSFORMER, 4160/480 V 250 KVA	EA	0	$15,000	$0				
5063J	CABLING, 480 V	FT	1000	$6	$6,000				
5063K	TRANSFORMER, 480/120-208 V 150 KVA	EA	2	$8,000	$16,000				
5063L	CABLING, 120-208 V (11 x 500')	FT	1000	$6	$6,000				
50633	END STATION ELECTRICAL					$101,000 *		$48,480	
5063M	SWITCHGEAR, 4160 V	EA	5	$4,600	$23,000				
5063N	TRANSFORMER, 4160/480 V 500 KVA	EA	2	$25,000	$50,000				
[illegible]30	TRANSFORMER, 4160/480 V 250 KVA	EA	0	$15,000	$0				
[illegible]63P	CABLING, 480 V	FT	1000	$6	$6,000				
5063Q	TRANSFORMER, 480/120-208 V 150 KVA	EA	2	$8,000	$16,000				
5063R	CABLING, 120-208 V (11 x 500')	FT	1000	$6	$6,000				
5064	SUPPORT BUILDING ELECTRICAL								
5064A	RECEPTACLES	SYS	0	$20,000	$20,000	$20,000 *		$20,000	
5065	POWER SOURCE/LINE TO SUBSTATION	EA	1	$300,000	$300,000	$300,000 *		$300,000	
						***	$280,016	$280,016	
5070	LASER COOLING ASSEMBLY (300 KILOWATTS)	EA							
5071	CHILLER UNIT	EA	1	$48,000	$48,000	$48,000 *			
5072	HEAT EXCHANGER	EA	1	$9,600	$9,600	$9,600 *			
5073	ALT WATER COOLING SYSTEM	EA	1	$11,520	$11,520	$11,520 *			
5074	PUMP, CHILLED WATER, PRIMARY	EA	2	$5,760	$11,520	$11,520 *			
5075	PUMP, CHILLED WATER FOR LASERS	EA	3	$7,200	$21,600	$21,600 *			
5076	PIPING, PRIMARY CIRCUIT	EA	1	$19,968	$19,968	$19,968 *			
5077	PIPING, SECONDARY CIRCUIT	EA	1	$10,368	$10,368	$10,368 *			
5078	GLYCOD	LOT	1	$1,440	$1,440	$1,440 *			
5079	AUTOMATIC CONTROLS	SET	1	$28,800	$28,800	$28,800 *			
5080	ELECTRICAL	SET	1	$19,200	$19,200	$19,200 *			
5081	HOUSING/SUPPORT STRUCTURES	SET	1	$57,600	$57,600	$57,600 *			
5082	WALL BARRIER FOR WATER CHILLER	EA	1	$14,400	$14,400	$14,400 *			
5782	LASER/LASER COOLING INTEGRATION	SYS	1	$26,000	$26,000	$26,000 *			
						***	$586,364	$293,182	$293,182
5090	HOUSEKEEPING SUBSYSTEM	EA	1						
5090A	PROCUREMENT	EA	1	$436,364	$436,364	$436,364			
5090B	INSTALLATION	EA	1	$150,000	$150,000	$150,000			
						***	$25,000	$5,000	$20,000
5100	INTERCOMMUNCIATION ASSEMBLY	EA	1						
5100A	TEMPORARY PHONE INSTALLATION	EA	4			$1,000			
[illegible]100B	PROCUREMENT	EA	1			$12,000			
100C	ASSEMBLY INSTALLATION	EA	1			$12,000			
5105	CABLE TROUGHS-FACILITY TO JPL BUILDINGS	MILE	3	$30,000		$90,000 EST			
						***	$123,000	$123,000	
5110	FURNISHINGS	LOT	1						
5111	SHOP EQUIMENT	LOT	1			$88,000 *			
5111A	CENTRAL STATION	LOT	1		$38,000				
5111B	MID/END STATIONS	LOT	1		$10,000				
5111C	SUPPORT BUILDING	LOT	0		$40,000				
5112	FURNISHING (DESKS, CABINETS,ETC.)	LOT	1			$35,000 *			
5112A	CENTRAL STATION	LOT	1		$10,000				
5112B	MID/END STATIONS	LOT	1		$5,000				
5112C	SUPPORT BUILDING	LOT	0		$20,000				

5120 SECURITY ASSEMBLY	EA	1				***	$109,091	$65,455	$43,636
5120A PROCUREMENT	EA	1			$60,000				
5120B INSTALLATION					$49,091				
5130 SEISMIC MONITOR ASSEMBLIES	EA	1				***	$38,182	$38,182	
5130A PROCUREMENT					$18,182				
5130B INSTALLATION					$20,000				
5140 TRANSPORTATION VEHICLES	EA	1				***	$33,333	$16,667	$16,667
5140A FOUR WHEEL DRIVE	EA	2	$16,667	$33,333	$33,333	*			
5140B SNOW MOBILES	EA	0	$5,000	$0					
5150 EMERGENCY/BACKUP EQUIPMENT	SYSTEM	1				***	$48,000	$38,400	$9,600
5151 EMERGENCY POWER ASSEMBLY	EA	1	$8,600	$8,600	$8,600				
5152 OTHER EMERGENCY EQUIPMENT	EA	1	$30,000	$30,000	$30,000				
5154 EMERGENCY BUILDING/ACCESS LIGHTING	EA	94	$100	$9,400	$9,400				
5300 FUNCTIONAL SPECIFICATIONS	SET	1				***			
5400 OPERATION/MAINTANCE MANUAL	SET	1				***	$120,000	$108,000	$12,000
5600 SPARES	SET	1				***	$320,000	$256,000	$64,000
5620 SPARES STOCKING LABOR/MATERIALS	MISC	1			$20,000	***	$20,000	$16,000	$4,000
5630 FUNCTIONAL REQUIREMENT REDUCTION						***	($297,000)	($207,900)	($89,100)
5810D TEMPORARY HEADQUARTERS TRAILER INSTALLATION							$25,000	$25,000	
6000 DATA ANALYSIS SUBSYSTEM	SUBSYSTEM COST		$305,000				$305,000	$305,000	
6010 PRIMARY PROCESSOR						***			
FUNCTIONAL SPECIFICATIONS									
MAINFRAME									
DISK DRIVES									
DISPLAYS									
BULK STORAGE MEDIA									
SOFTWARE									
LIBRARY SUPPORT									
TAPE DRIVES									
SPARES									
6020 STATION PROCESSORS						***			
FUNCTIONAL SPECIFICATIONS									
MAINFRAME									
DISK DRIVES									
DISPLAYS									
SOFTWARE									
TAPE DRIVES									
LIBRARY SUPPORT									
SPARES									
6030 REALTIME DATA LINKS						***			
EASTERN SITE STATION									
WESTERN SITE STATION									
MIT TO STATIONS									
CALTECH TO STATIONS									
CALTECH/MIT									
6300 FUNCTIONAL SPECIFICATIONS						***	$5,000		
6400 OPERATION/MAINTANCE MANUAL						***	$5,000		
6500 CONFIGURATION CONTROL						***	$5,000		
6600 EQUIPMENT PROCUREMENT						***	$150,000		
6700 INTEGRATION/TESTING						***	$130,000		
6800 SPARE/OPERATING SUPPLIES						***	$10,000		
					SUBTOTALS				
7000 SCIENTIFIC SUPPORT-INCLUDED IN GROUPS GRANTS			MODIFIED FROM 5.50 TO 4.50 YR SCHEDULE				$450,000	$450,000	

7010 CALTECH SUPPORT			***	$212,500		
7020 MIT SUPPORT			***	$212,500		
			SUBTOTALS			
8000 CONTINGENCY AS INDICATED PERCENTAGE OF FISCAL YEAR COST				$5,140,000	$2,570,000	$2,570,000
8010 FY-89 ESTIMATE BASED ON A INCURRED COST OF	$10,000,000	X	12.50%	$1,250,000		
8020 FY-90 " "	$9,500,000	X	12.50%	$1,187,500		
8030 FY-91 " "	$9,200,000	X	15.00%	$1,380,000		
8040 FY-92 " "	$4,500,000	X	15.00%	$675,000		
8050 FY-93 " "	$2,300,000	X	20.00%	$460,000		
	$750,000	X	25.00%	$187,500		
SUBTOTALS	$36,250,000			$5,140,000		
CONTINGENCY TO BE BASED ON ----------->	$36,683,373					
9000 PRELIMINARY OPERATIONS DURING CONSTRUCTION (BREAKDOWN IN W011370P)			(BASED ON 4.5 YR SCHEDULE)	$2,098,697	$839,479	$1,259,218
9010 ENGINEERING PERSONNEL						
9011 LIGO SYSTEM MANAGER						
9012 COLUMBIA SITE MANAGER						
9013 ELECTRONICS ENGINEER/TECHNICIAN						
9014 VACUUM ENGINEER/TECHNICIAN						
9015 MECHANICAL ENGINEER/TECHNICIAN						
9016 COMPUTER PROGRAMMER						
9017 CARETAKER/GUARD						
9018 OTHER PERSONNEL SUPPORT						
9020 SCIENTIFIC PERSONNEL						
9021 FACULTY						
9022 RESEARCH PHYSICISTS						
9023 GRADUATE STUDENTS						
9024 OTHER SCIENTIFIC SUPPORT						
9030 MAINTENANCE EXPENSE						
9031 BUILDINGS						
9031A CENTRAL STATION						
9031B MID STATIONS						
9031C END STATIONS						
9031D SUPPORT BUILDING						
9031E CULVERT/CULVERT ACCESS BUILDINGS						
9032 ROADS/DRAINAGE,ETC						
9033 FENCES						
9034 VACUUM SUBSYSTEM						
9035 POWER SUBSTATION, EQUIPMENT						
9036 ELECTRONICS						
9037 DOCUMENTATION						
9038 VEHICLES						
9038A AUTOMOTIVE						
9038B SNOW MOBILES						
9039 OTHER						
9040 OPERATING EXPENSES						

9041 UTILITIES
9041A TRASH/GARBAGE REMOVAL
9041B TELEPHONE
9041C ELECTRICTY
9041D SNOW PLOWING
9042 TRAVEL
9042A AIR
9042B AUTOMOBILE RENTAL
9042C LOCAL EMPLOYEE
9042D SUBSISTENCE
9042E OTHER
9043 VEHICLES
9043A GASOLINE
9043B OTHER
9044 EQUIPMENT REPLACEMENT
9044A LIBRARY
9044B KITCHEN
9044C RECREATION ROOM
9044D OTHER

$15,635,328	$26,188,046
$41,823,373	

BATCH START

STAPLE
OR
DIVIDER

BATCH START

STAPLE

OR

DIVIDER

QUALITY ASSURANCE FOR FIELD WELDS

WELD INSPECTION

THE TEST METHODS USED TO DETERMINE THE QUALITY OF WELDS ARE BROKEN DOWN INTO TWO GENERAL CLASSIFICATIONS.

- NON DESTRUCTIVE
- DESTRUCTIVE

PIPE SECTIONS LEND THEMSELVES TO THE NONDESTRUCTIVE TYPE OF TESTING, i.e.,

- VISUAL INSP
- LIQUID PENETRANT
- LEAK TESTING
- RADIOGRAPHY (X-RAY GAMMA)

J.K 2/19/85

ENCLOSURE "D"
Sheet 1 of 7

WELD INSPECTION

VISUAL INSPECTION

- WELDS HAVING SURFACE DEFECTS
- ECONOMICAL, EXPEDIENT, AND REQUIRES LITTLE TRAINING. WE HAVE AWS CERTIFIED WELD INSPECTORS.
- MAGNIFIER - LT. SOURCE
- LIMITED TO EXTERNAL OR SURFACE CONDITION ONLY AND THE VISUAL ACUITY OF THE INSPECTOR.

WELD INSECTION

LIQUID PENETRANT

- WELDS THAT HAVE DEFECTS OPEN TO THE SURFACE, i.e., CRACKS, POROSITY AND SEAMS

- PORTABLE, INXPENSIVE, EXPEDIENT + RESULTS ARE EASILY INTERPRETED.

- DYE PENETRANTS, DEVELOPERS, CLEANERS + IF FLUORESCENT DYE IS USED A ULTRAVIOLET LIGHT SOURCE.

- SURFACE FILMS SUCH AS COATINGS, SCALE AND SMEARED METAL MASK HIDE DEFECTS. PENETRANT BLEED OUT CAN ALSO MASK DEFECTS. PART MUST BE CLEANED THOROUGHLY BEFORE + AFTER INSPECTION WHICH IS VERY TIME CONSUMING.

WELD INSPECTION

LEAK TESTING

- WELDS THAT HAVE DEFECTS EXTENDING THRU THE WELD VOLUME.
- TEST RESULTS ARE USUALLY EXPEDIENT AND SOME APPLICATIONS REQUIRE MINIMAL INSPECTOR TRAINING.
- EQUIPMENT CAPABLE OF INDUCING A PRESSURE DIFFERENTIAL + A FORM OF DETECTION DEVICE.
- REQUIRES THE FABRICATION OF SPECIAL TOOLING CAPABLE OF HOLDING PRESSURE ABOUT THE WELD.

ENCLOSURE "D"
Sheet 4 of 7

WELD INSPECTION

X-RAY

- MOST WELD DEFECTS INCLUDING SUB-SURFACE CRACKS, POROSITY, LACK OF FUSION, INCOMPLETE PENETRATION, SLAG, CORROSION + FIT-UP DEFECTS.
- PERMANENT FILM RECORD OF DEFECTS + GAMMA RAY SOURCE CAN BE POSITIONED INSIDE PIPES WITH RELATIVE EASE.
- GAMMA RAY SOURCE + FILM.
- RADIATION SAFETY HAZARD. REQUIRES HIGHLY SKILLED PERSONNEL FOR OPERATION AND INTERPRETATION.

WELD INSPECTION

OBSERVATION:

- VISUAL INSPECTION SHOULD BE EMPLOYED FOR ACCEPTANCE OF ALL WELDS. HOWEVER, SURFACE APPERANCE ALONG DOES NOT PROVE QUALITY WORKMANSHP + WELD SOUNDESS. FINAL JUDGMENT OF WELD QUALITY MUST BE BASED ON EVIDENCE THAT SUPPORTS WELD SOUNDESS.

- IF WE EMPLOY VISUAL INSPECTION, THE INSPECTOR MUST MAKE THE FOLLOWING OBSERVATIONS PRIOR TO AND DURING THE WELDING PROCESS.
  - THE PLATE IS FREE OF LAMINATIONS
  - THE EDGE PREPARATION IS CORRECT
  - THE ROOT OPENINGS ARE AS SPECIFIED
  - THE ROOT PASS IS SOUND
  - THE QUALIFIED WELD PROCEDURE, IS FOLLOWED
- HE MAY THAN BE REASONABLY SAFE IN HIS ASSESSMENT OF THE COMPLETED WELD.

WELD INSPECTION

X-RAYS ARE NEEDED TO CONFIRM WELD SOUNDESS.

X-RAYS WILL UNCOVER SUBSURFACE DEFECTS, SUCH AS CRACKS, POROSITY, LACK OF FUSION, INCOMPLETE PENETRATION, SLAG, CORROSION + FIT-UP DEFECTS.

CONCLUSION:

- VISUAL AND X-RAY INSPECTION SHOULD BE EMPLOYED DURING THE FIELD + FABRICATION WELDING PROCESS.
- X-RAY CAN BE IMPLEMENTED ON A PERCENTAGE BASIS.
- LEAK TESTING DURING FIELD WELDING MUST ALSO BE CONDUCTED.