MASTER

UCRL-15321-V-2

**REVIEW OF CURRENT STATUS
OF
HIGH FLUX HEAT TRANSFER TECHNIQUES**

**Volume II
(Appendices B, C & D)**

**Prepared for:
FUSION ENERGY DIVISION
LAWRENCE LIVERMORE NATIONAL LABORATORY
LIVERMORE, CALIFORNIA**

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September 1980

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IOB

BY

CHK

PAGE

DATE _____

APPENDIX B

REPORT OF TELEPHONE

CONTACTS

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DISCLAIMER

To this, I have presented what are some of the ways accounted for by an agency of the United States, over time, to have been a "top-down Government" and not a "people's Government" that only in the end and after a long time, is currently, expected to implement its decisions and legal liability in responsibility. The idea is to complement the judgments of a number of other independent scholars, who have been able to point out requirements that are the result of various strategies against global justice. I believe that a thorough knowledge of global justice, or how to make more "democratic" management of factors on the globe, is necessary to make it more of an instrument, transnational, of factors on the globe.

So far, I have not said anything about the United States Government and its agency-related.

4.7.

AN EXPERIMENTAL EVALUATION OF MATERIALS
FOR USE AS LIMITERS, WALL ARMOR OR BEAM DUMPS

M. Ulrickson

The materials which have in the past been chosen for limiters, wall armor, and beam dumps (IABD) do not have well-defined thermal and mechanical properties under the type of operating conditions present in these applications. In particular, the combination of heat flux, pulse length, and repetition rate found in a Tokamak is a virtually unexplored regime in materials testing. Many material properties such as crack growth rates, recrystallization, and thermal fatigue depend very strongly on temperature and strain rate. Since these properties are very important for selecting a material which is suitable for IABD application, it is essential that material testing duplicate the actual operating conditions as closely as possible.

There are two separate and easily identifiable operating conditions that IABD materials will experience. Limiters and wall armor will both be subject to "fault conditions" such as run-away electrons or neutral beams firing when there is no plasma. These conditions are characterized by short duration, very high heat flux pulses to the material. The result of this type of bombardment is single cycle failure of the material (thermal shock). Under "normal operating conditions," the heat flux is relatively modest and the pulse length is about one second and thermal fatigue effects determine the lifetime of the materials. Tests representing both types of operating conditions are being carried out for all candidate materials. Thermal shock testing is very useful

for screening materials because only a small amount of time is needed for a given material.

Thermal shock testing was carried out using an electron beam gun capable of delivering up to 1.8 A of 10 kV electrons for a maximum pulse length of 1.0 second. The area of the deposition is about 1 cm^2 . The samples were $1" \times 1" \times 1/2"$ in most cases. The surface temperature of the sample was measured using an infra-red optical pyrometer. In addition, the sample temperature was monitored using thermocouples on the back surface. The agreement between the two techniques was excellent. Examples of the surface temperature versus time for tungsten, molybdenum, and OFHC copper are shown in Figures 1-3. The solid curves were calculated from the heat flux and material thermal properties as a function of temperature. The small spot size requires a two-dimensional thermal analysis be done. The results of these tests are shown in Table I. Those materials which cracked before melting or showed very low melting flux limits were not fatigue tested. It must be emphasized that the results are for a case of two-dimensional heat flow, whereas in actual applications the limits are determined by one-dimensional heat flow. Limits for one-dimensional heat flow are shown in Table II.

Thermal fatigue tests on those materials which looked good in the thermal shock tests were carried out using the same apparatus. The samples were exposed to multiple pulses at 80% or less of the thermal shock flux limit for 0.5 sec pulses. The repetition rate was chosen to keep the equilibrium

temperature less than 300° C. The results indicate that the lifetime of materials under normal operating conditions is determined by thermal fatigue effects. In many cases, the material was very severely damaged after only a few hundred pulses.

The results of testing thus far indicate that from a purely materials standpoint, carbon (graphite), tungsten, copper, and molybdenum are the most suitable materials for LABD applications. Additional testing of large samples (12" x 12" x 1/2") is needed to get a better evaluation of thermal fatigue effects since the stress distribution in the small samples is very different from that in a realistic size piece. This testing will be done using the PBT Neutral Beam test stand. In addition, information about surface effects (such as spattering or chemical erosion) must be considered before selection of a suitable material can be made for a given application.

Table I

THERMAL SHOCK TEST RESULTS

Material	Flux* (kW/cm ²)	Duration Of Pulse (sec)	Damage Observed**
1. OFHC Copper	8.00	0.25	Surface melted.
2. Tungsten (Cross-Rolled)	9.40	1.00	Surface melted.
3. Tungsten (Pressed & Sintered)	9.40	1.00	Surface melted.
4. Tungsten (HIT Miter)	9.40	0.50	Surface melted.
5. Tungsten (Cross Rolled)	9.00	1.00	Surface melted.
6. Tungsten (pressed & Sintered)	7.70	0.50	Sample cracked.
7. Zr B ₂ Si C	3.50	0.12	Sample broke into many pieces.
8. Molybdenum	9.60	0.50	Surface melted.
9. TiW (Mo + 0.5% Ti + 0.1% Zr)	7.80	1.00	Surface melted.
10. 70% Mo + 30% W	8.40	0.75	Surface melted.
11. Tungsten-Rhenium (W + 10% Rh)	8.40	0.75	Surface melted.
12. Thoriated Tungsten (W + 2% ThO ₂)	9.40	1.00	Surface melted.
13. Boron Carbide	3.50	0.20	Sample broke into many pieces.
14. ATJ Graphite	9.00	1.00	Sublimated. Vacuum window was coated with large amounts of carbon.
15. Pyrolytic Graphite	17.30	0.75	
16. CMB Graphite	6.25	0.50	
17. Silicon Carbide (Hot Pressed)	3.75	0.50	Sample broke into many pieces.

Table I (Continued)

Material	Flux* (kW/cm ²)	Duration Of Pulse (sec)	Damage Observed**
18. Silicon Carbide (Recrystallized)	3.00	0.50	Sample fractured.
19. Niobium Carbide	2.00	0.10	Sample fractured.
20. Tantalum Carbide- Carbon Composite	9.50	0.40	Sublimated.
21. Copper Infiltrated Tungsten	7.50	0.20	Copper drawn to surface and then evaporated.
22. Copper Impregnated Graphite	6.00	0.25	Window plated with copper.
23. GIC-17 Graphite (Fractor Grade)	7.50	0.50	Sublimated.
24. DS-13 Graphite (Fractor Grade)	7.00	0.40	Sublimated.

* Flux values were calculated from temperature versus time traces (see Figures 1-3 using a two-dimensional heat flow program.

** These results cannot be compared quantitatively to Table I because of the two-dimensional nature of the heat flow.

Table II.

THERMAL SHOCK LIMITS*

Material	Heat Flux Required to Melt Surface For Pulse Length of 0.5 Sec (kw/cm ²)
OFHC Copper	5.25
Tungsten	9.40
Molybdenum	7.00
Pyrolytic Graphite	13.00
ATJ Graphite	5.30
Boron Carbide	1.90
Silicon Carbide	2.80
Aluminum	2.25

* These numbers are based on one-dimensional heat flow.

Table III

Material	Flux (kW/cm ²)	Duration (Sec)	Number of Pulses	Damage Observed
OFHC Cu	5.5	0.5	1,000	Slight cracking of the surface in checkerboard pattern (depth ~ 0.1 mm). Also some distortion of surface.
	5.5	0.5	5,000	Crack growth rate appears very slow.
W	7.0	0.5	300	Large deep crack about 0.25" deep. Crack appeared to be growing rapidly.
	5.0	0.5	1,400	Small surface deformation. No cracks.
W + 10% Ph	7.0	0.5	700	Severe surface cracking.
W + 2% ThO ₂	7.0	0.5	500	Severe surface cracking
Mo	5.0	0.5	1,700	Sample started to melt on surface. Perhaps caused by laminations in the sample. No cracks were observed.
TCM	6.0	0.5	200	Sample badly cracked and cracks growing rapidly. Cracks ~ 1/8" deep.
ATJ Graphite (Moulded)	5.0	0.5	1,000	Slight pit in the surface. Did not find any material on window, so suspect that material was lost through chemical reactions with residual gas in system because of high temperature (~ 2800° C). There was no evidence of cracking.
Graphite (Reactor)	5.0	0.5	1,200	No cracks. Slight pit in surface.

THERMAL SHOCK TESTING

- TEMPERATURE RAISED FROM ROOM TEMP. TO MELTING OR FRACTURE POINT IN A SINGLE PULSE
- USEFUL FOR SEPARATING MATERIALS
- BRITTLE MATERIALS CRACK BEFORE MELTING
- DETERMINES FLUX LIMIT FOR DUCTILE MATERIALS (SURFACE MELTS)

THERMAL FATIGUE TESTING

- MULTIPLE CYCLES AT FIXED FLUX AND PULSE DURATION UNTIL SAMPLE FAILS
- DETERMINES TRUE OPERATING LIMIT FOR DUCTILE MATERIALS
- LIMITS DEPEND ON CONFIGURATION

MECHANICAL SYSTEMS & TECHNOLOGY LABORATORY

THERMAL BRANCH

Units in the Branch:

Heat Transfer Unit

Thermal Systems Unit

Broadly stated, the R&D projects undertaken in the Thermal Branch seek to provide leadership in the thermal sciences through:

- o development of fundamental understanding
- o advanced/innovative applications of high potential impact to General Electric businesses
- o critical technical support to General Electric product operations and within Corporate Research and Development

Under this very broad mission, the R&D projects undertaken in the Branch encompass a wide variety of subjects which involve thermodynamics, heat transfer, fluid mechanics, combustion science, electric field effects, and physics. The technology levels of these activities range from exploratory, or basic research efforts, to projects directed at solving critical problems in current Company products. The Branch is organized into two unit-level operations, the Thermal Systems Unit and the Heat Transfer Unit.

The role of the Thermal Systems Unit is to develop technology of relevance to the broad category of thermal systems. Much of the focus of this Unit is towards the development of concepts for cost-effective, energy-efficient space heating and cooling systems and for the utilization of low-grade (e.g. solar) or low-temperature (e.g. industrial waste streams) heat sources. The exploratory research projects undertaken include those concerned with development and demonstration of entirely new concepts in low temperature engines, thermodynamic cycles for industrial process heat generation from waste streams, solar collectors and thermal energy storage. Such innovative concepts may provide entirely new product opportunities for the Company. Other activities in the Thermal Systems Unit have for several years been focused on the development of technology for significant increases in the efficiency of the Company's heat pump product line for residential and commercial applications. Currently such activities also involve the development of advanced heat pump-based systems. Research projects involved in obtaining a fundamental understanding include the development of "first principles" models for two-phase flow heat exchangers.

Programs undertaken in the Heat Transfer Unit are broadly concerned with the development of phenomenological understanding and the innovative application of heat transfer and electrohydrodynamics technologies. Personnel in this group are among the leaders in the development of a fundamental understanding of the flow and heat transfer phenomena in fluidized beds. Experimental support for fluidized beds ranges from small cold-flow facilities to a 2' x 2' combustion facility capable of achieving the very wide range of operating conditions needed for basic studies in this technology. Other major expertise has developed in the areas of two-phase thermohydraulics and coupled electrical, thermal and flow phenomena. The focus of activities in these areas have ranged from basic research to the development of improved cooling concepts for current and next generation products. Such products have ranged from electric motors and transformers to large nuclear steam reheaters for utilities. Recent studies in the area of electrostatic effects in gas/solid flows have led to new ideas for particulate cleanup from gas flows and for process control. We see many promising future efforts in this particular technology area.

WILLIAM M. BROBECK & ASSOCIATES

BASELINE BEAM DUMP

JOB 95-27.20

PAGE 1

BY JMR CHK HL

DATE 8/20/80

A BASELINE BEAM DUMP
FOR COST COMPARISON
PURPOSES

WILLIAM M BROBECK & ASSOCIATES

BASELINE BEAM DUMP

JOB 95-27.20

PAGE 2

BY JRM CHK HL

DATE 9/15/80

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WILLIAM M. BROBECK & ASSOCIATES

BASELINE BEAM DUMP

JOB 95-27.20 PAGE 3
BY JRM CHK HL DATE 8/20/80

ABSTRACT

On the basis of the 10 Kw/cm^2 beam distribution and the RCA designed cooling element a system was designed and the cost estimated. Total initial cost came to \$160,563 per beam dump. Each system can be independently operated if 120 PSI treated water is supplied. However some savings might be realized by integrating components of the thirteen beam dumps.

Page four shows our conception of the beam dump surface configuration.

BASELINE BEAM DUMP

JOB 95-27.7 PAGE 1
BY JPP/CHK/HL DATE 2/21/80

SUMMARY

THE PURPOSE OF THIS WORK WAS TO
OBTAIN A BASELINE FOR THE BEAM
DUMP DESIGN AND ESTIMATE ITS
COST. THIS IS THE FIRST STEP IN
THE DETAILED EXAMINATION OF THE
AVAILABLE ALTERNATIVES FOR THE DESIGN
OF THE BEAM DUMP.

THE FOLLOWING ASSUMPTIONS WERE MADE:

1) ABOUT 1000 OPERATING HOURS PER YEAR:

1) 370 GPM OF TREATED WATER

AT 30° F AND 100 PSI

AVAILABLE WITHIN 5'.

2) SPACE IS AVAILABLE FOR THE

SYSTEM WITHIN 70' OF THE BEAM DUMP.

3) 480 VOLT THREE PHASE

SERVICE IS AVAILABLE

WITHIN 5'.

6) ALL FOUR VALVES ARE ELECTRICALLY OPERATED AND INTERLOCKED.

7) TANKS SERVE AS STORAGE BEFORE AND AFTER PUMPING.

THE FIGURES ON PAGE 4

ILLUSTRATE THESE ASSUMPTIONS.

THE SECOND FIGURE IS A SUMMARY TO PAGE 4 AND IS A VISUAL CHECK OF THE COMPONENT SIZES.

SOME RELUCTANCE SURFACE OPTIONS WERE EXAMINED AND THE ONE PREFERRED WAS CHOSEN BECAUSE OF ITS SIMPLICITY AND THE ACCURACY OF THE DATA. THE WATER HANDLING IN THE PLANT WAS ESTIMATED AND THE WEIGHTS ESTIMATED.

THE WATER PIPES, PUMPS AND TANKS WERE ALSO ESTIMATED AND THE WEIGHTS ESTIMATED.

JOB 15-27.25 PAGE 6

BY D. A. CHK

DATE 11-15-70

THE NEWS SHOWED THAT THE NEW YORK
 STATE POLICE HAD BEEN CALLED TO
 INVEST THE MATTER. THE POLICE
 HAD BEEN ADVISED THAT THE
 SUBJECT HAD BEEN SEEN IN THE
 AREA OF THE NEW YORK STATE
 POLICE HEADQUARTERS.

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BEAM DUMP COST COMPARISON
(FOR A THIRTEEN DUMP SYSTEM)

SYSTEM	CAPITAL COST ⁽¹⁾ K\$	OPERATING COST K\$	TOTAL COST K\$
DIRECT PUMPING	2,814.5	1	2,315.5
LN ₂ BLOWDOWN	2,423.2	293.3	2,716.5
N ₂ GAS BLOWDOWN	2,362.1	781.5	3,143.6

- (1) Includes Computer Control System
Includes Installation @ 15% of Equipment Cost
Includes E.D.I.A. @ 35% of Equipment Cost
Includes Contingency @ 35% of Equipment Cost
Includes Escalation @ 10% of Sum

(E.D.I.A. - Engineering, Design, Inspection and Administration)

JOB 95-27.20 PAGE 1
BY JRM CHK AL DATE 7/29/80

TITLE: BEAM DUMP SURFACE
DESIGN

ABSTRACT:

A BEAM DUMP SURFACE AND THE
NECESSARY MANIFOLDING WERE DESIGNED.
THE SURFACE ELEMENTS ARE THOSE
PROPOSED BY RLCA BUT WITH THE
ANGLE OF INCIDENCE ADJUSTED TO GIVE
A PELL POWER OF 2 kW/cm^2 OR LESS.

THE WEIGHTS AND COSTS OF THE VARIOUS
COMPONENTS ARE ESTIMATED AND A TOTAL
COST IS ESTIMATED IN ATTACHED II.

JOB 95-27.20 PAGE 3
BY JRM CHK HL DATE 7/29/80

INDEX

PAGE	TOPIC
4	THE BEAM POWER DISTRIBUTION
11	BEAM DUMP SURFACE CONFIGURATION
20	BEAM DUMP SURFACE WEIGHT AND COST
24	MANIFOLDING DESIGN AND ESTIMATE
29	STRUCTURAL COMPONENTS

BASELINE BEAM DUMP

JOB 95-27
BY JRM CHKPAGE 4 OF
DATE 7/29/80

FOR A BASELINE I WILL CONSIDER
FLAT COOLING ELEMENTS SET AT AN ANGLE TO
REDUCE THE INCIDENT FLUX. THE ELEMENT
CROSS SECTION IS THAT PROPOSED BY RLA
AND IS SHOWN ON PAGE 22.

THE POWER DENSITY ($\bar{P}$) FOR THE BEAM
IS SHOWN ON PAGE 5. IF WE ASSUME
A GAUSSIAN DISTRIBUTION IN BOTH DIMENSIONS
 $\bar{P}$ CAN BE EXPRESSED AS:

$$(1) \bar{P}(x, y) = \bar{P}_0 e^{-\frac{1}{2} \left(\frac{x}{\sigma_x} \right)^2} e^{-\frac{1}{2} \left(\frac{y}{\sigma_y} \right)^2}$$

FROM FIGURE 1 THE FOLLOWING
TABLE CAN BE MADE

$$P(13.3, 0) = .38 \text{ KW/cm}^2$$

$$P(0, 50) = .3 \text{ KW/cm}^2$$

$$P(0, 0) = 10 \text{ KW/cm}^2$$

FROM THESE VALUES WE CAN CALCULATE
THE CONSTANTS IN EQN 1.

PAGE 5

SEE FIGURES

1 AND 2

OF INTRODUCTION

BASELINE BEAM DUMP

JOB 95-27
BY JRM/CHKPAGE 6 OF
DATE 7/29/80

$$P(0,0) = \bar{P}_0 = 10 \text{ Kw/cm}^2$$

$$P(13.3, 0) = \bar{P}_0 e^{-\frac{1}{2} \left(\frac{13.3}{\sigma_z} \right)^2} = 10 \exp \left[-\frac{1}{2} \left(\frac{13.3}{\sigma_z} \right)^2 \right] = .38$$

SOLVING FOR σ_z

$$\sigma_z = \frac{13.3}{\sqrt{-2 \ln(.038)}} = 5.2$$

$$P(0, 50) = .3 \text{ Kw/cm}^2 = 10 \exp \left(-\frac{1}{2} \left(\frac{50}{\sigma_y} \right)^2 \right)$$

SOLVING FOR σ_y

$$\sigma_y = \frac{50}{\sqrt{-2 \ln(.03)}} = 18.88$$

SUBSTITUTING σ_z & σ_y INTO EQN (1)

$$(2) \quad P(z, y) = 10 \exp \left(-\frac{1}{2} \left[\left(\frac{z}{5.2} \right)^2 + \left(\frac{y}{18.88} \right)^2 \right] \right)$$

JOB 95-27

PAGE 7

BY JRM CHK

DATE 8/5/80

THE TOTAL BEAM POWER CAN BE
FOUND BY INTEGRATING $P(z, y)$ OVER
AN INFINITE x, y PLANE:

$$P = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \bar{P}_0 \exp\left[-\frac{1}{2}\left(\frac{x}{\sigma_x}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] dx dy = \bar{P}_0 2\pi \sigma_x \sigma_y$$

$$P = 10 \cdot 2.57 \cdot 18.8 \cdot 5.2 = 6.14 \text{ KW}$$

THIS IS HIGH BECAUSE A WORST CASE
WAS ASSUMED.

JOB 95-2720 PAGE 4
BY JRM CHK HLL DATE 7/29/80

THE FOLLOWING FIGURES SHOW THE BEAM DISTRIBUTION USED IN THIS WORK AS IT COMPARES TO THAT RECEIVED FROM LLL. THE LLL DATA IS BASED ON A PEAK POWER OF 9.5 LW/cm^2 WHILE THE DISTRIBUTION USED HAS A PEAK OF 10 LW/cm^2

PAGES 9 AND 10

SEE FIGURES 1 AND 2

OF INTRODUCTION

BASE-LINE BEAM DUMP

JOB 95-27.

PAGE 11 OF

BY SRM CHK #1

DATE 7/29/80

BASE LINE BEAM Dump

JOB 95-27

PAGE 12 OF

BY JRM CHK JH DATE 7/31/80

CALCULATION OF 3 PLATE CONFIGURATION

ASSUME EACH PLATE HAS A PEAK POWER DENSITY OF 2 Kw/cm^2 . THIS IS ACCOMPLISHED BY TILTING EACH PLATE UNTIL THE POWER DENSITY IS 2 Kw/cm^2 .

UNDER THESE CONDITIONS THE PRODUCT

$$\text{POWER DENSITY} \times \text{LENGTH} = K$$

Diagram showing a tilted plate with a length l_c and a width of 14 cm . The power density is labeled as $\bar{P} = 2 \text{ Kw/cm}^2$. To the right, the total power density is labeled as $\bar{P} = 10 \text{ Kw/cm}^2$.

$$l_c \bar{P} = 10 \times 14$$

$l_c = 70 \text{ cm}$ THIS IS FOR THE CENTER PLATE

BASELINE BEAM DUMP

JOB 95-27. PAGE 13 OF
BY JLM CHK JAL DATE 7/31/80

OUTER PLATES WILL HAVE A LENGTH
GIVEN BY:

$$(3) \quad 2L_i = \bar{P}(0, \sum_{n=1}^{i-1} y_n) / 4 \quad \text{OR} \quad L_i = 7\bar{P}(0, \sum_{n=1}^{i-1} y_n)$$

WHERE

$$\sum_{n=1}^{i-1} y_n$$

IS THE SUM OF THE WIDTHS OF ALL THE
INNER PLATES.

USING EQN'S (3) AND (2) WE CAN
OPTIMIZE THE AMOUNT OF MATERIAL
IN THE BEAM DUMP

THIS WILL BE DONE FOR THE
3, 5 AND 7 PLATE CONFIGURATIONS.

BASELINE BEAM DUMP

JOB 95-27.20 PAGE 14
BY JRM/CHK/HL DATE 8/5/90

ASSUME A 1.075" WIDE ELEMENT
AND CALCULATE THE LENGTH REQUIRED
FOR A 2 kW/cm² FLUX.

FROM EQN (3)

$$Q_i = 7 \bar{P}(0, \sum_{n=1}^{i-1} y_n)$$

NOW SINCE WE HAVE EQUAL SEGMENTS

OF 1.075".

$$\sum_{n=1}^{i-1} y_n = 1.075 \sum_{n=1}^{i-1} 1 = 1.075(i-1)$$

$$Q_i = 7 \bar{P}(0, 1.075(i-1))$$

i	y (cm)	Q _i (cm)	i	y	Q _i
1	0	70	14	35.5	14
2	2.73	69.27	15	39.23	14
3	5.46	67.13	16	40.96	14
4	8.19	63.71	17	43.69	14
5	10.92	59.21	18	46.42	14
6	13.65	53.90	19	49.15	14
7	16.38	48.04	20	51.88	
8	19.11	41.93			
9	21.84	35.84			
10	24.57	30.01			
11	27.31	24.60			
12	30.04	19.75			
13	32.77	15.53			

BASELINE

BEAM DUMP

JOB 95-27.20 PAGE 15

BY JPM CHK HL

DATE 8/5/80

CALCULATE THE TOTAL AREA

$$A = \frac{1.075 \times 4 \sum_{i=1}^{19} Q_i}{.3937} = \frac{1.075 \times 4 \times 682.92}{.3937} = 7458.86$$

RCA SUGGESTS 7.8 GPM FOR 50 CM OF LENGTH AND A TOTAL FLOW OF 1800 GPM. THIS IS A FLOW OF $7.8 \times 3 = 23.4$ GPM FOR EACH 1.075" X 50 CM SECTION: OR

$$\frac{23.4 \text{ GPM}}{50 \text{ CM}} \times 4 \times 682.92 \text{ CM} = 1280 \text{ GPM}$$

FOR OUR TOTAL LENGTH OF 2732 CM.

BASELINE BEAM DUMP

JOB 95-27 20 PAGE 16
BY JPM CHK J/L DATE 8/20/80

PAGES C-25 AND C-26 SHOW ONE QUARTER OF VARIOUS BEAM DUMP CONFIGURATIONS. THE PLATE WIDTHS HAVE BEEN OPTIMIZED SO THAT FOR EACH BEAM DUMP DESIGN HAS THE MINIMUM SURFACE AREA. THE COMPUTER CODE USED FOR THE OPTIMIZATION IS IN APPENDIX A.

ALSO SHOWN IS A CASE WHICH USES ONE 112 IN ELEMENT WIDTHS THROUGHOUT. THE FOLLOWING TABLE COMPARES THE NUMBER OF PLATES TO THE ELEMENT AREA REQUIRED:

PLATES	AREA CM ²	AREA INCH ²
1	14000	2170
2	9876	1531
3	8710	1350
4	8182	1268
5	7906	1225
19	7459	1156

BASELINE FEAR DUMP

JOB 95-27.20 PAGE 17

BY JRMCHK/HL DATE 8/20/80

THE OPTIMUM NUMBER OF PLATES IS NOT OBVIOUS BUT THE ONE INCH ELEMENT IS PROBABLY A LITTLE SMALL. IF FABRICATION TIME COULD BE SAVED A LARGER ELEMENT WOULD BE MORE DESIABLE.

THE ONE INCH ELEMENTS WILL BE USED IN THIS WORK SO THAT THE ROA DATA CAN BE UTILIZED.

C-25

08/11/92

1/1

6/4/40 19-

BASELINE BEAM DUMP

JOB 25-7110 PAGE 30
BY ERN CHK ML DATE 9/20/90

BEAM DUMP SURFACE WEIGHT

CALCULATE THE WEIGHT/UNIT LENGTH

FROM THE DIAGRAM TAKE THE CORRECT

AREA AS

$$A_2 = 1.075 \times .1 + \frac{\overbrace{.05 \times 1.075}^{\text{FIN AREA}}}{2} = .134 \text{ INCH}^2$$

AND THE STAINLESS AREA

$$A_3 = (.31 - .15 - .018) \times 1.075 = .153 \text{ INCH}^2$$

THE SPECIFIC GRAVITY FOR COPPER AND STAINLESS

ARE 8.91 AND 8.06 RESPECTIVELY AND

THE DENSITY OF WATER IS $3.61 \times 10^{-2} \text{ LB/LIN}^3$.

THUS THE WEIGHT OF COPPER IS

$$W_{\text{CP}} = .134 \times 8.91 \times 3.61 \times 10^{-2} = 4.31 \times 10^{-2} \text{ LB/LIN}^3$$

FOR STAINLESS

$$W_{\text{SS}} = .153 \times 8.06 \times 3.61 \times 10^{-2} = 4.46 \times 10^{-2} \text{ LB/LIN}^3$$

JOB

PAGE 1

BY

CHK YLC

DATE 11/1/77

FROM PAGE 15 THE TOTAL LENGTH IS

$$L = 4 \times 683 = 2732 \text{ cm} \times 0.037 \text{ m/cm} = 1076''$$

THE TOTAL WEIGHT IS

151

$$W_{\text{L}} = W_{\text{CL}} = 1076 \times 4.31 \times 10^{-5} = 46 \text{ g}$$

FROM THE TABLES

$$W_{\text{S}} = W_{\text{CL}} L = 1076 \times 4.31 \times 10^{-5} = 46 \text{ g}$$

TOTAL WEIGHT IS

$$53142 = 94 \text{ g}$$

JOB 95-27.20

PAGE 12

BY: L. H. CHK HL

DATE 9/11/80

BELOW IS THE CORRECTION

3-11 1/2" x 1-1/2" x 1-1/2" x 1-1/2"

1-1/2" x 1-1/2" x 1-1/2" x 1-1/2"

1-1/2" x 1-1/2" x 1-1/2" x 1-1/2"

1-1/2" x 1-1/2" x 1-1/2" x 1-1/2"

1-1/2" x 1-1/2" x 1-1/2" x 1-1/2"

$$4 \text{ in} / 25 = 19.1 \text{ in} / 25$$

$$19.1 \text{ in} / 25 \times 15,000 \times 11 = 16,800$$

$$15,000 \times 11 = 16,800$$

Buttons

1/29

PROBATE MATRICES THREE

AS 1

$$\frac{17,000}{94} \times 94.5 = 63,000$$

A.

B.

Same as A except with fins removed

CALORIMETER HEAT SINK ELEMENT

Figure 48.

BASELINE DESIGN

JOB 45-0700 PAGE 24
BY CHK HL DATE 1/14/90

BEAM DUMP MANIFOLDS

EACH OF 76 ELEMENTS WILL HAVE THREE INLET PORTS. ASSUME TWO INLET MANIFOLDS AND TWO OUTLET MANIFOLDS. THEREFORE EACH MANIFOLD NEEDS $(76/2) \times 3 = 114$ PORTS. THIS SEEMS EXCESSIVE SO LETS MOUNT A SMALL MANIFOLD ON EACH ELEMENT AS SHOWN BELOW.

SMALL MANIFOLD

THIS DRAWING IS APPROXIMATELY ACTUAL SIZE. IT WOULD BE MOUNTED ON EACH ELEMENT. THIS REDUCES THE TOTAL NUMBER OF PORTS ON EACH MANIFOLD TO 114 OR TWO FOLDS OF 57.

LARGE MANIFOLD

JOB

PAGE 25

BY

CHK MC

DATE

ASSUME THE PIPE REQUIRED BETWEEN THE
SMALL AND LARGE MAINS TO BE AN
AVERAGE SIZE OF 14" OR HALF OF
THE SUM OF THE BEAM DUMPS. IN ADDITION
ASSUME THAT IT IS 14" IN DIA. OF 14" AND
IS ALL PIPE IN A ROW. (E.G. $152 \times 14 = 2128" \frac{1}{2} DIA.$)

THE SIX INCH EXTERIOR PIPE MUST BE TOO
EMPTY THE TWO MAINS. ASSUME 1
IN OF THREE FEET FOR EACH OF THE
 $4\frac{1}{2}$ FEET DIAMETER MAINS. (E.G. $4\frac{1}{2} \times 3 = 13.5$
FEET) THE SIX INCH EXTERIOR PIPE
MUST BE THE SIX INCH EXTERIOR PIPE WITH THE
THREE FEET DIAMETER MAINS.

MANIFOLD & PIPE WEIGHTS

MAIN SPLIT MATERIAL

4" x 12' LWT. PIPE - REQUIRED

$$V = 324 \text{ in}^3$$

$$W = 324 \times 8.06 \times 2.41 \times 10^{-3} \text{ lb/in}^3 = 112 \text{ lb}$$

DETAILS NOT SHOWN, ASSUME WEIGHT IS
HALVED OR 56 lb

MAIN MANIFOLD

$$2 \times 4 \times 14$$

$$V = 152 \text{ in}^3$$

$$W = 152 \times 8.06 \times 2.41 \times 10^{-3} = 44 \text{ lb}$$

ASSUME 2/3 OF WEIGHT IF IN R
MANIFOLDING OR 29 lb

SMALL MANIFOLD

$$.75 \times .5 \times 10 \times 10 \times 10$$

$$V = .40 \text{ in}^3$$

$$W = .403 \times 8.06 \times 2.41 \times 10^{-3} = .12 \text{ lb}$$

$$\text{FINISH WGT. T} = .06 \text{ lb}$$

JOB 95-2720 PAGE 296
 BY JRM CHK HL DATE 9/15/80

11.40" BORE INCH	2.2	596	116
4" BUTTER FIDE (TYPE K)	6.75	1.51	113
1/4" COPPER TUBE (TYPE K)	177 FT	.145	25.7
6" COPPER TUBE (TYPE K)	3.3 FT	13.1	46
TOTAL			240

JOB 45-27,20 PAGE 29
 BY DJMCHK HC DATE 8/15/80

RCA ESTIMATES 1400LB FOR THE TOTAL
 BEAM DURING THIS FROM 10.2 PAGES THE WEIGHT
 OF THE STRUCTURE ONLY IS:

$$1400 - 439 = 961 \quad \# \text{ FOR STRUCTURE}$$

IF WE ASSUME STEEL, AT ^{INCLUDING LABOR} $\$4/1\#$
 THEN

$$4 \times 961 = \$3844$$

JOB 95-27.20 PAGE 1
BY JRM CHK P/L DATE 7/24/93

1. 2" DIA. PIPE 1/2" WALL THICKNESS
12' LONG, 1/2" DIA. HOLES

JOB 95-27-20 PAGE 2
 BY JRM CHK HIL DATE 7/29/80

ABSTRACT

FOR 1200 A.M. TO 1200 A.M. 1200 A.M.
 ONE OF THE WICKS WERE USED FOR
 THE SURVEY.

WICKS WERE USED TO SURVEY THE
 WICKS WERE 6" THICK AND WERE
 USED TO SURVEY THE WICKS
 WERE USED.

WICKS WERE USED TO SURVEY THE
 WICKS WERE USED TO SURVEY THE
 WICKS WERE USED TO SURVEY THE
 WICKS WERE USED TO SURVEY THE

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INDEX

1. INTRODUCTION
2. TECHNICAL DATA
3. TEST DATA
4. DISCUSSION
5. CONCLUSIONS
6. REFERENCES
7. APPENDICES
8. SUMMARY

BASELINE KEAM DUMP

JOB 95-27.20 PAGE 4
BY JRM CHK DATE 8/6/90

FROM THE TOTAL POWER CALCULATE THE
TEMPERATURE RISE OF THE WATER.

WE KNOW THE POWER TO BE:

$$P = 6.14 \text{ KW}$$

FROM PAGE 7

ASSUME 1200 GPM FLOW.

WE CALCULATE THE ENERGY/GAL AS
FOLLOWS:

$$\bar{E} = \frac{6.14 \text{ MW}}{1200 \text{ GAL}} \frac{\text{MINUTE}}{60 \text{ MIN/HR}} = \underline{85.3 \text{ WHR/GAL}}$$

WATER WEIGHS 8.34 lb/GAL THUS
THE ENERGY/POUND IS

$$\frac{85.3 \text{ WHR/GAL}}{8.34 \text{ lb/GAL}} = 10.2 \frac{\text{WHR}}{\text{lb}}$$

CONVERTING TO MORE APPROPRIATE UNITS

$$\frac{10.2 \text{ WHR}}{\text{lb}} \times \frac{859,184 \text{ cal}}{453.59 \frac{\text{gm}}{\text{lb}} \text{ WHR}} = 19.4 \frac{\text{cal}}{\text{gm}}$$

PASTLIDE PETAIDUMP

JOB 95-2720 PAGE 5

BY JLM CHK HL DATE 8/6/80

THE HEAT CAPACITY OF WATER IS $\frac{1 \text{ cal}}{\text{gm } ^\circ\text{C}}$

THE TEMPERATURE RISE (ΔT) IS

$$\Delta T = \frac{19.4 \text{ cal/gm}}{1 \text{ cal/gm } ^\circ\text{C}} = \underline{\underline{19.4 ^\circ\text{C}}}$$

BASELINE BEAM DUMP

JOB 95-27.20 PAGE 6

BY JRM CHK AL DATE 8/13/80

CALCULATE THE PIPE DIAMETER *
REQ'D FOR 1800 GPM, IN 70 FT OF
PIPE FOR 10 FT HEAD LOSS.

THE 70 FT PUMPING DISTANCE ASSUMES
THAT THE AVERAGE BEAM DUMP HEIGHT
IS 15' AND THAT BOTH INLET AND OUTPUT
TANKS ARE 20' FROM THE BEAM DUMP
 $L = 70'$, $h_f = 10'$

THE FLOW (Q) IN CUBIC FT./SEC IS:

$$Q = 1800 \times \frac{\text{GAL}}{\text{MIN}} \times \frac{2.31 \text{ INCH}^3/\text{GAL}}{60 \text{ SEC}/\text{MIN}} \times \frac{1}{(12 \text{ INCH}/\text{FT})^3}$$

$$Q = 4.01 \text{ f}^3/\text{SEC}$$

THE KINEMATIC VISCOSITY FOR WATER:

$$\nu = 1.4 \times 10^{-5}$$

THE REYNOLDS NUMBER CAN BE
EXPRESSED AS:

$$Re = \frac{2.5}{7f} 10^{\frac{1}{27f}} \quad \text{AND} \quad Re = \frac{4Q}{\pi \nu d}$$

$$\text{AND} \quad d^5 = \frac{8fLQ^2}{g\pi^2 h_f}$$

*SEE APPENDIX C FOR REFERENCE

BASELINE BEAM DUMP JOB 95-27.20 PAGE 7
 BY JLM CHK HL DATE 8/20/80

THE VARIABLES ARE DEFINED AS:

f = friction factor

d = pipe diameter

g = Acceleration of gravity

L = Length of pipe run

Re = Reynolds

Q = FLOW RATE

ν = kinematic viscosity

WE ASSUME COPPER PIPE (ie.
 THE SMOOTH PIPE CASE)

APPENDIX D IS A COPY OF
 THE PROGRAM USED TO CALCULATE
 THE TUBING SIZE.

THE FOLLOWING TABLE GIVES
 THE CALCULATED DIAMETERS
 FOR VARIOUS HEAD LOSS'S.

HEAD LOSS (FT)	1	10	100	1000
DIAMETER (IN)	8.88	5.50	3.42	2.12

JOB 95-27.20 PAGE 8
BASE LINE BEAM DUMP BY JEM CHK HL DATE 8/20/80

FROM THE QUOTE FOR 6" TUBING

ESTIMATE 1/4, 3, 4 INCH TUBE			
NOMINAL SIZE	WEIGHT FT	\$/FT	\$/LB
1/4	.145	.56	3.85
3	4	15.40	3.85
4	6.51	25.06	3.85
6	13.9	53.51	3.85

BASELINE LFAH

JOB 45-1000 PAGE 9
BY T. CHK HL DATE 8/15/70MINIMIZE THE AREA OF A CYLINDRICAL TANK OF
CONSTANT VOLUME

$$V = \pi R^2 h \Rightarrow h = \frac{V}{\pi R^2}$$

$$A = 2\pi R^2 + 2\pi R h = 2\pi R (R + h)$$

$$A = 2\pi R \left(R + \frac{V}{\pi R^2} \right) = 2\pi R^2 + \frac{2V}{R}$$

$$\frac{\partial A}{\partial R} = 2\pi 2R + 2V(-1)\frac{1}{R^2} = 0$$

$$R^3 = \frac{V}{2\pi}$$

$$2\pi R^2 = V = \pi R^2 h$$

$$h = 2R \text{ OR THE DIAMETER } D = h$$

$$V = 2\pi R^3$$

$$A = 6\pi R^2$$

E-1 BEAM DUMP

JOB 95-2770 PAGE 10
BY JT, CHK HL DATE 7/5/00

TANK WEIGHTS FOR STANDARDS

DIMENSION OF 1350 GAL
HOLDING TANK (CYLINDRICAL)

SURFACE AREA

$$A = 2\pi R^2 + 2\pi R h$$

$$A = 2\pi R [R + h]$$

$$\text{VOLUME} = \pi R^2 h = V$$

$$h = V / \pi R^2$$

MINIMIZE A

$$\frac{\partial A}{\partial R} = \frac{\partial}{\partial R} \left[2\pi R \left(R + \frac{V}{\pi R^2} \right) \right]$$

$$= 2\pi \left(R + \frac{V}{\pi R^2} \right) + 2\pi R \left(1 - \frac{2V}{\pi R^3} \right) = 0$$

$$\frac{R + V}{\pi R^2} + R - \frac{2V}{\pi R^2} = 0$$

$$2R = \frac{V}{\pi R^2}$$

$$R^3 = \frac{V}{2\pi}$$

$$R = \left(\frac{V}{2\pi} \right)^{1/3}$$

$$36.75'' = R$$

$$h = 73.5$$

C-45

BASELINE RENTAL DUMP

JOB NO. 181120 PAGE 11
BY [] CHK HL DATE 8/17/90WATER TANK WEIGHT $\frac{1}{2}$ LOST

TANK SURFACE AREA

$$A = 2\left[\frac{\pi D^2}{4}\right] + \pi D h = 25458 \text{ in}^2$$

ASSUME 16 GA STAINLESS THEN THE THICKNESS IS .0598.

TOTAL VOLUME OF STAINLESS

$$V = 25458 \times .0598 \text{ in}^3 = 1522 \text{ lb}$$

ASSUME A UNIT OF $1 \frac{1}{2} \text{¢/lb}$ FOR MATERIAL

AND 2 MAN DAYS FOR CONSTRUCTION

AT $\$35/\text{hr}$ THE TOTAL COST IS

$$C = 1522 \times 1.75 + 2 \times 8 \times 35 = \$3223$$

$$\text{FREIGHT AT } .16 \frac{\$}{\text{lb}} = \frac{244}{3467}$$

BASELINE BEAM DUMP

JOB 95-27,20 PAGE 12
BY JRM,CHK HL DATE 6/5/80

HOT WATER PUMP COST

CALCULATE THE HORSEPOWER REQ'D

$$HP = 270 \frac{\text{GAL}}{\text{MIN}} \times 20 \text{ PSI} \times .000583 = 3.15 \text{ HP}$$

ASSUME THAT THE COST IS PROPORTIONAL
TO POWER THEN FOR THE LARGE PUMP
WE HAVE:

$$HP = 1400 \times 220 \times .000583 = 231 \text{ HP}$$

AND THE COST IS \$18900 AND

$$\frac{\$18900}{231} \times 3.15 = \$258$$

GIVES THE SMALL PUMP HOT WATER COST

WILLIAM M. BROBECK & ASSOCIATES

JOB 95-27.20 PAGE 1
BY JRM CHK HL DATE 9/15/80

TITLE:

BEAM DUMP COST

ESTIMATE

DIRECT DUMPING SYSTEM

Beam Dump Control & Cooling System Block Diagram
Direct Pumping System

Beam Dump Control Logic and Computer System

ABSTRACT

THIS ESTIMATE IS A SUMMARY
OF THE COST ALLOCATED IN THE
PREVIOUS SECTIONS AND OF THE
QUANTITIES REQUIRED (APPENDIX B).

RATES PER UNIT FOR THE ITEM COST
ARE SHOWN FOR EACH ITEM IF N/A
APPEARS IN THE 1 COLUMN THE COLUMN
THE COST IS ZERO. N/A MEANS.

A TOTAL COST OF \$160,000 HAS
BEEN ESTIMATED FOR THE
WORKED, ETC. ETC.

JOB 95-27.20 PAGE 3
BY JRM CHK *fl* DATE 9/15/20

BY JAM CHK *JA* DATE 9/15/80

1158 v

1. 1. 1.

4.

1-9

— 2 —

19. - - - - -

For the purpose of this study, the following hypotheses were formulated:

U. S. DEPARTMENT OF AGRICULTURE

MFTF - B

BEAM DUMP
COST ESTIMATE

ITEM NO.	DESCRIPTION	REF.	EQUIPMENT (Delivered @ Site)					TOTAL
			Unit	Base Quantity	Spares	Total Quantity	Unit Cost \$/Unit	
1	BEAM DUMP		EA	1			5475.1	5
2	325 HP PUMP MOTOR STAND		EA	1			18900	18
3	SMALL PUMP-MOTOR STAND		EA	1			258	2
4	WATER TANK		EA	2			3467	6
5	6" COPPER PIPE		FT	70			53.61	3
6	3" COPPER PIPE		FT	10			15.40	15
7	INTER LOCK SWITCH		EA	4			50	5
8	FLOAT SWITCH		EA	2			50	2
9	REMOTE VALVES		EA	4			2000	20
10	HEAT EXCHANGER		EA	1			10000	10
11	WATER SOFTENER		EA	1			1029	10
12	CONTROL LOGIC AND PROCESSOR		EA	1			2700	2
	TOTAL							10
	ENGINEERING 35%							3
	INSTALLATION 15%							1.5
	CONTINGENCY 35%							3
	TOTAL							16.5
	ESCALATION 10%							1.65
	PAGE TOTAL							18.15

Ref: HL (Incl): Job: 95-27 20
Date: 9-19-80 Date: Page 4 of

Date: 9-19-80 Date: Page 4 of

covered (at Site)

[illegible]

C-53

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT

LOCATION

MFTF BEAM DUMP COST ESTIMATION

JOB NO. 95-27.20 BY

CHECKED

DATE 9-19-50

SHEET 5 OF 5

[illegible]

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT _____ LOCATION _____

JOB NO. _____ BY _____ CHECKED _____ DATE _____ SHEET _____ OF _____

ITEM	DESCRIPTION	QTY.	UNIT	MATERIAL		LABOR			TOTAL ITEM COST	
				UNIT COST	TOTAL \$	UNIT HRS.	TOTAL HRS.	\$		
	BEAM DUMP SURFACE COST									
	MATERIAL									
	CORRUG. B.D. 1/4" x 1"									
	2 1/2" x 1/4" .969 10/E	7457	100H	.203 1/4	1500				1500	
	STANDARD 1/4" x 1"	7457	100H	.06 1/4	450				450	
	1 1/2" x 1/4" .969 10/E	7457	100H	.06 1/4	450				450	
	BEAM DUMP SURFACE	1157	100H	5.19 1/4	6000				6000	
	AND STAIN 1/4" x 1"									
	FIXTURES	1	SEA	1500	1500					
				1500	1500					
	OVER (UNITS)								245	
										21042

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT

LOCATION

BEAM DUMP

JOB NO. 95-27.20 BY

CHECKED

DATE _____

SHEET 6 OF 6

[illegible]

W. M. BROBECK & ASSOCIATES
ESTIMATE**PROJECT**

LOCATION

MFTF BEAM DUMP COST ESTIMATE

JOB NO. 95-27.20 BY _____

CHECKED

DATE _____

9-19-80

SHEET 7

OF

[illegible]

6-57

ESTIMATE

PROJECT_

LOCATION

MFTF BEAM DUMP COST ESTIMATE

JOB NO. 95-27.20 BY

CHECKED

DATE _____

9-19-80

SHEET

OF

[illegible]

C-58

6-45

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT _____ LOCATION MP17 BEACH DUMP COST ESTIMATE
JOB NO. 95-27.20 BY _____ CHECKED _____ DATE 9-19-80 SHEET 9 OF _____

[illegible]

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT	LOCATION

LOCATION MFTF BEAM DUMP COST ESTIMATE

JOB NO. 95-27.20 BY _____ CHECKED _____ DATE 9-19-80 SHEET 10 OF _____

[illegible]

ESTIMATE

LOCATION

MFTF BEAM DUMP COST ESTIMATION

DATE _____

9-19-50

SHEET //

OF

[illegible]

19-3

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT _____ LOCATION MFT + BEAM DUMP COST ESTIMATE

JOB NO. 95-27.20 BY _____ CHECKED _____ DATE 9-19-80 SHEET 12 OF _____

[illegible]

C-62

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT	LOCATION	MFIF	BEAM	DUMP	COST	ESTIMATE

JOB NO. 95-27.20 BY _____ CHECKED _____ DATE 9-19-80 SHEET 17 OF _____

[illegible]

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT	LOCATION	COST ESTIMATE
	MFTT BEACH DUMP	

JOB NO. 95-27.20 BY _____ CHECKED _____ DATE 9-19-80 SHEET 14 OF _____

[illegible]

49-3

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT

LOCATION

MFTF BEAM DUMP COST ESTIMATE

JOB NO. 95-27.20 BY _____

CHECKED

DATE _____

9-19-80

SHEET

OF

[illegible]

59-3

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT _____ LOCATION MFTF BEAM DUMP COST ESTIMATE

JOB NO. 95-27.20 BY _____ CHECKED _____ DATE _____ SHEET 16 OF _____

[illegible]

99-7

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT	LOCATION	M FIF- B	BEAM DUMP COST ESTIMATE
---------	----------	----------	-------------------------

JOB NO. 95-27.20 BY HL CHECKED DATE SHEET 17 OF

ITEM	DESCRIPTION	QTY.	UNIT	MATERIAL		LABOR			TOTAL ITEM COST	
				UNIT COST	TOTAL \$	UNIT HRS.	TOTAL HRS.	\$		
12	CONTROL LOGIC AND MICRO COMPUTER									
	MICRO COMPUTER	2	EA						2000	4000
	SOFTWARE (PROGRAMMING IN ASSY. AND HIGH-LEVEL LANGUAGE)								16000	16000
	I/O INTERFACE BOARD ENGINEERING	1	EA		200	35	5.7	200	400	7700
	I/O INTERFACE BOARD	13	EA						400	5200
	TOTAL UNITS									
	TOTAL									35100
	TOTAL PER BOARD				(35100 / 13)					2700

C-67

BEAM DUMP COST ESTIMATE

BLOWDOWN SYSTEMS

BLOW DOWN TANK

JOB 95-27.20

PAGE 4

BY HL CHK:1

DATE 9-22-80

DESCRIPTION OF BEAM DUMP COOLING SYSTEM
USING A HIGH PRESSURE BLOW DOWN TANK
PRESSURIZED BY COMPRESSED NITROGEN.

THE MAIN COMPONENTS OF THE COOLING SYSTEM
ARE:

- BEAM DUMP MAINFOLDS AND PIPING
- HIGH PRESSURE VESSEL (250 PSI) HOLDING
980 GAL OF H_2O
- HOLDING TANK OF ALSO 980 GAL. CAPACITY.
- A 270 GPM PUMP/MOTOR SYSTEM USED TO
TRANSFER THE WATER FROM THE HOLDING
TANK TO THE PRESSURE VESSEL.
- A WATER COOLING UNIT
- A REGULATED PRESSURE RELEASE VALVE (V_1)
- A HIGH PRESSURE SHUTOFF VALVE (V_2)
- WATER INLET AND OUTLET VALVES (V_3 & V_4)
- HEAT EXCHANGER
- ANALOG TO DIGITAL INTERFACE AND MICROCOMPUTER

THE SYSTEM SHOWN IN FIG. () OPERATES AS
FOLLOWS:

- WATER ENTERS THE SYSTEM THROUGH INLET
VALVE V_3 , THE WATER COOLING UNIT AND
ENTERS THE HOLDING TANK
- FROM THE HOLDING TANK THE WATER IS TRANS-
FERRED TO THE PRESSURE VESSEL BY THE 270 GPM
PUMP/MOTOR UNIT.
- DURING THE OPERATION OF THE BEAM DUMP THE
PRESSURE VESSEL IS PRESSURIZED BY COMPRESSED
NITROGEN THROUGH THE PRESSURE REGULATOR
VALVE V_1

Beam Dump Blow Down Version
With Compressed Nitrogen

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT MPTF - B LOCATION BLOW DOWN PRESSURE SYSTEM
JOB NO. 95-27.20 BY HL CHECKED _____ DATE 9-26-80 SHEET _____ OF _____

ITEM	DESCRIPTION	QTY.	UNIT	MATERIAL		LABOR			TOTAL ITEM COST	
				UNIT COST	TOTAL \$	UNIT HRS.	TOTAL HRS.	\$		
1	PRESSURE VESSEL									
	MAT. SS 304 CRCS									
	HEADS 54" OD 3/8 WTHK	400	LG	1.53	613				613	
	ASME TYPE									
	SPIN AND FACING OF					35	3	105	105	
	TOTAL	2	EA						718	1436
	STRAIGHT CYL. PORTION OF	2058	LG	1.53	3150				3150	
	TANK									
	FORM AND WELD					35	4	140	140	
	TOTAL	1	EA						3290	3290
	WELD HEADS TO CYL. AND					35	16	560	560	560
	ADD FLANGES									
	TOTAL / TANK	1								5286
	COST OF HEADS AND									
	STRAIGHT PORTION QUOTED									
	BY "R. VERNSON" 10,000 DOLLARS									

Blow Down Tank

JOB 95-27.10

PAGE

4

BY WJB CHK/H

DATE 9/22/80

RELEASE VOLUME: ASSUME 45 SECS OF FLOW

$$1280 \text{ GAL/MIN} \times \frac{3 \text{ MIN}}{4} = 960 \text{ GAL}$$

$$960 \text{ GAL} \times 23.1 \text{ IN}^3/\text{GAL} = 221760 \text{ IN}^3$$

ASSUME A CYLINDER 54 IN DIAMETER
CYLINDER LENGTH:

$$V = \pi r^2 l$$

$$l = V/\pi r^2 = \frac{221760}{\pi (27)^2} = 96.8 \text{ IN OR } 8 \text{ FT}$$

FROM ASME PRESSURE VESSEL CODE SEC. VIII
SECTION AD 201

$$t = \frac{PR}{S - 0.5P}$$

$$t = \frac{(50)(27)}{(20000) - (0.5)(250)}$$

$$t = .340 \text{ IN. USE } 3/8 \text{ IN. THICK}$$

Beam Dump Blow Down Version
With Liquid Nitrogen

W. M. BROBECK & ASSOCIATES
ESTIMATE

PROJECT MTTF - B

LOCATION BLOW DOWN PRESSURE SYSTEM

JOB NO. 95-27.20 BY HL

CHECKED

DATE

SHEET

OF

ITEM	DESCRIPTION	QTY.	UNIT	MATERIAL		LABOR			TOTAL ITEM COST	
				UNIT COST	TOTAL \$	UNIT HRS.	TOTAL HRS.	\$		
	OPERATING COST WITH HIGH PRESSURE NITROGEN BOTTLES									
	AMOUNT OF NITROGEN FOR FOR 13 BEAM DUMPS AND 1000 SHOTS = 239720 #3									
	COST OF N2 BOTTLES	114200	EA	4.5	515000				515000	515000
	HANDLING OF N2 (CONNECT DISCONNECT)	114200	EA			35	.067	2.33	266470	266470
	TOTAL OPERATING COST									781470
	OPERATING COST / BEAM DUMP									60113
	INSTALLATION COST									
	13 HIGH PRESSURE TANK								5286	68718
	13 LOW " " " "								3467	45071
	TOTAL									113790

NITROGEN BOTTLES

JOB 95-27.20

PAGE 6

BY HL CHK

DATE 9-26-80

(JEFF WONG LIQUID AIR 483 2560)

VOLUME OF WATER TANK

$$221760 \text{ in}^3 = 128.33 \text{ ft}^3$$

$$\text{Pressure} = 250 \text{ PSI}$$

$$\begin{aligned} \text{NITROGEN BOTTLE} &= 250 \text{ ft}^3 @ 14.6 \text{ PSI} \\ &= 14.6 \text{ ft}^3 @ 250 \text{ PSI} \end{aligned}$$

(ONLY ~80% OF PRESSURE IS AVAILABLE)

- TOTAL VOLUME OF DISPLACEMENT
PER SHOT FOR 13 BERM DUMPS

$$128.33 \cdot 13 = \underline{1668.3 \text{ ft}^3 @ 250 \text{ PSI}}$$

- NUMBER OF NITROGEN BOTTLES REQUIRED
FOR ONE SHOT TO DISPLACE 1668.3 ft^3

$$1668.3 / 14.6 = 114.2$$

- COST / SHOT @ \$ 4-5 / BOTTLE

$$114.2 \times (4.5) = \underline{\underline{\$ 515}}$$

- LIFE CYCLE COST FOR 1000 CYCLES

$$(N_2) \$ 515 \cdot 1000 = \$ 515 000$$

LABOR 2 min CONNECT DISCONNECT/BITPLE
2835/HR

$$114200 \cdot \frac{2 \times 2}{60} \cdot 835 = \$ 266470$$

$$\text{TOTAL } 515000 + 266470 = \$ 781470$$

W. M. DROBECK & ASSOCIATES
ESTIMATE

PROJECT MFTF-2

LOCATION BLOW DOWN PRESSURE SYSTEM

JOB NO. 95-27-20 BY HL

CHECKED

DATE

SHEET

OF

ITEM	DESCRIPTION	QTY.	UNIT	MATERIAL		LABOR			TOTAL ITEM COST	
				UNIT COST	TOTAL \$	UNIT HRS.	TOTAL HRS.	\$		
	OPERATING COST USING LIQUID NITROGEN									
	CRYO CONTAINERS FILLUPS	1175	EA	125	147060					147060
	RENTAL FEE 36 CONTAINERS @ \$300 / MONTH FOR 3 YEARS									140400
	HANDLING	1000	EA			35	.166	5.83	583	5833
	TOTAL									293290
	INFO. SUPPLIED BY JEFF WONG APPLICATIONS ENG. LIQUID AIR 495 0333									
	INSTALLATION COST VAPORIZER AND COMPRESSOR									30000
	13 HIGH PRESSURE TANKS	13	EA						5286	68718
	13 LOW " " " "	13	EA						3467	45071
	TOTAL									143790

(20)

LIQUID NITROGEN

JOB 95-77.20 PAGE 9
B-HL CHK DATE 9-76-PD

(JER WONG LIQUID AIR 403 8560)

USING LIQUID NITROGEN

CRYOGENIC CONTAINER (ONE)

MONTHLY RENTAL FEE \$ 300

ANNUAL - 300 x 12 = \$ 3900

COST OF LIQUID NITROGEN

\$ 125 EQ. TO 27000 ft³ @ 14EQ. TO 1577 ft³ @ 250 PSI

ASSUMING 90% OF LIQUID NITROGEN VOLUME
IS USABLE THE AMOUNT OF N₂ PER
CRYO CONT. EQ.

$$1577 \times (.9) = 1419.3 \text{ ft}^3 @ 250 \text{ PSI}$$

NUMBER OF CONTAINERS REQUIRED FOR
13 BEAM DUMPS AND ONE SHOT
EQUALS :

$$1668.3 / 1419.3 = 1.1754$$

ASSUME 3 CONTAINERS / BEAM DUMP FOR
A TOTAL OF

$$3 \times 13 = 39 \text{ CONTAINERS}$$

WILLIAM M. BROBECK & ASSOCIATES

JOB 95-27-20 PAGE 10
BY HL CHK DATE 9-26-80

- NUMBER OF SHOTS POSSIBLE WITH
36 CONTAINERS :

$$36 / 1.1754 \approx 30.6 \text{ SHOTS}$$

- COST FOR 1000 SHOTS .

(N₂)

$$1176.47 \text{ CONTAINERS @ } \$125 = \underline{\$147060}$$

RENTAL FEE FOR 3 YEARS

$$36 @ 3900 = \underline{\$140400}$$

$$\text{VAPORIZER AND COMPRESSOR} = \underline{\$15000}$$

$$\text{HANDLING} = \underline{\$5833}$$

$$\text{TOTAL} = \underline{\$308290}$$

SUB-APPENDIX A

COMPUTER PROGRAMS


```

10 REM THIS ROUTINE IS SAVED UNDER "DROP"
20 REM THIS IS AN ITERATIVE CALCULATION FOR PIPE DIAMETER
30 REM FLOW IN FT^3/SEC
40          G= 1250*231/12^3*60
50          REM
60          REM
70 REM RUN IN FEET
80          L=70
90          REM
100         REM
110 REM P IS THE HEAD LOSS IN FEET
120         P =10
130         REM
140         REM.
150 REM ENTER CALCULATIONAL LOOP AND CALCULATE THE INCREMENT
160         FOR I=1 TO 5
170             N =10^(-I+1)
180             REM
190             REM
200 REM INCREMENT THE PIPE DIAMETER
210             D=D+N
220             REM
230             REM
240 REM CALCULATE THE FRICTION FACTOR
250             F=D^5*32.2*3.1416^2*P*8/L*G^2
260             REM
270             REM
280 REM INTERIM CALCULATION FOR CONVENIENCE IN CALCULATING THE REYNOLDS NO.
290 REM AND TO PREVENT OVERFLOW
300             Q= 1/(2*SQRT(F))
310             IF Q>50 THEN GOTO 210
320             R=2.51/SQRT(F)*10^Q
330             REM
340             REM
350 REM CALCULATE NEW VALUE OF PIPE DIAMETER AND TEST IF EQUAL
360             D2=4*G/3.1416/1.48-5*R
370             IF (D-D2)>0 THEN GOTO 210
380             REM
390             REM
400 REM SET DIAMETER TO PREVIOUS VALUE AND INCREMENT
410             D=D-N
420             NEXT I
430             REM
440             REM
450 REM IF OUTPUT THE PIPE DIAMETER IN INCHES
460             PRINT 12*D
470             REM
480             REM
490 REM END THE PROGRAM
500             END
510             END
READY

```

```

1000M
1001M
1002M THIS PROGRAM IS STORED IN DATA
1003M=1
1004M=1000000000
1005M=10.00
1006M=X1=X1+1
1007M FOR X2= 0 TO 45
1008M IF X2-X1=0 THEN EXIT 310
1009M=0
1010M FOR X3= 0 TO 45
1011M X4= 50 -X1 -X2 -X3
1012M IF X4=0 THEN GOTO 200
1013M R1=0
1014M R2= 70*EXP(-1/2*(X1-X2)^2)
1015M R3= 70*EXP(-1/2*((X1+X2)/2)^2)
1016M R4= 70*EXP(-1/2*((X1+X2+X3)/2)^2)
1017M IF R3>R4 THEN R3=R4
1018M RETURN TO CONTINUE
1019M IF R2>R3 THEN R2=R3
1020M IF R1>R4 THEN R1=R4
1021M R=R1+R2+R3+R4+R4
1022M PRINT 1550, X1,X2,X3,X4,1550,R,1550,R1,R2,R3,R4
1023M IF R > R1 THEN GOTO 200
1024M R1=R
1025M D1=R1
1026M D2=R2
1027M D3=R3
1028M D4=R4
1029M V1=R1
1030M V2=R2
1031M V3=R3
1032M V4=R4
1033M NEXT X3
1034M PRINT 1, 550, V1,V2,V3,V4,1550,R1,1550,D1,D2,D3,D4
1035M NEXT X2
1036M GOTO 50
1037M END
1038M
1039M

```

L1	L2	L3	L4	AREA	W 1	W 2	W 3	W 4
13.	0.	10.	11.	7315.6	70.0	55.2	55.2	33.3
13.	1.	10.	10.	7235.0	70.0	55.2	53.2	31.2
13.	2.	9.	10.	7157.9	70.0	55.2	51.1	31.2
13.	3.	9.	9.	7111.2	70.0	55.2	48.9	29.1
13.	4.	8.	8.	7055.9	70.0	55.2	46.7	29.1
13.	5.	9.	8.	7034.3	70.0	55.2	44.4	27.1
13.	6.	7.	8.	7014.5	70.0	55.2	42.2	27.1
13.	7.	7.	7.	7009.6	70.0	55.2	39.9	25.2
13.	7.	7.	7.	7009.6	70.0	55.2	39.9	25.2

L1	L2	L3	L4	AREA	W 1	W 2	W 3	W 4
14.	0.	10.	10.	7295.1	70.0	53.2	53.2	31.2
14.	1.	9.	10.	7218.8	70.0	53.2	51.1	31.2
14.	2.	9.	9.	7153.9	70.0	53.2	48.9	29.1
14.	3.	8.	9.	7100.3	70.0	53.2	46.7	29.1
14.	4.	8.	8.	7050.5	70.0	53.2	44.4	27.1
14.	5.	7.	8.	7032.6	70.0	53.2	42.2	27.1
14.	6.	7.	7.	7019.5	70.0	53.2	39.9	25.2
14.	7.	6.	7.	7018.8	70.0	53.2	37.7	25.2
14.	7.	6.	7.	7018.8	70.0	53.2	37.7	25.2

SUB-APPENDIX B

REVIEW OF SPUTTERING INFORMATION

REVIEW OF SPUTTERING INF.

JOB 95-27.7

PAGE 1

BY JEM CHK JAL

DATE 9/17/90

N.Y. PLESHIVTSEV* IN 1959

EXTRACTED A SPUTTERING RATIO FROM

1701.7₁₀₀ FOR AN 90° Cu TARGETRADIATED BY H⁺ AT AN INCIDENT

ANGLE OF 60° AND AN ENERGY OF

20 KEV. EXTRAPOLATED FROM 2 TO 90 KEV

WE ESTIMATE SPUTTERING, $\bar{P}$ OF H⁺ IONS, USING THESE VALUES AND LOOKING

AT THE BELLY AREA FOR WHICH THE

SPUTTERING RATIO IS GREATER THAN 500/μm²WE WILL CALCULATE THE ^{PRODUCT OF} SPUTTERED IONS

WE PREVIOUSLY ASSUMED THAT THE

GAUSSIAN DISTRIBUTION OF THE

ION BEAM POWER DENSITY

$$(1) \quad \bar{P} = 10 \exp \left[-\frac{1}{2} \left(\frac{\bar{P}}{1.855} - \sqrt{\frac{\bar{P}}{5.2}} \right)^2 \right]$$

AND WE ARE ASSUMING $\bar{P} = 9$ THUS

SPUTTERING RATIO IS 1701.7, AND

* N.Y. PLESHIVTSEV

EXTRACTED FROM A 90° Cu TARGET IONS

-27.

REVIEW OF SPUTTERING INFORMATION

JOB 45-27.7 PAGE 2

BY JLMCHK HL DATE 9/17/80

$$(2) -2 \ln(.9) = \frac{y^2}{10.79^2} + \frac{z^2}{5.2^2}$$

NOW THERE IS THE FORMULA FOR THE

ELLIPTIC INDICES OF WHICH THE

BEAM POWER IS 9 KW/cm².

TO FIND THE SPOT SIZE WE

NEED TO KNOW THE SPOT SIZE

THE OVERALL SPOT SIZE

THE SPOT SIZE IS 4.5 CM

THE SPOT SIZE IS 4.5 CM

LET Z TO BE 4.5 CM

THE SPOT SIZE IS 4.5 CM

THE AXES

$$Z_0 = 4.5 \sqrt{10.79^2} = 23.9 \text{ CM}$$

$$Y_0 = 4.5 \sqrt{5.2^2} = 9.5 \text{ CM}$$

NOW SINCE THE SURFACE WILL BE TILTED

AT 11.5° THE Z AXIS WILL ACTUALLY

HAVE THE FOLLOWING LENGTH

$$Z_0 = 23.9 / \sin 11.5 = 11.95 \text{ CM}$$

THIS GIVES A TOTAL AREA SURFACE AREA
OF:

$$A = (11.95 \times 2)(9.67 \times 2) = 414. \text{ in}^2$$

Now we want to find the percentage of
the total area which is on the
area of the wall. This is the same
as the area of the wall divided by the
total area.

$$P = \int_{-9.67}^{9.67} \int_{-11.95}^{11.95} 10.44 \left(\frac{1}{2} \left[\frac{y^2}{16.98^2} + \frac{z^2}{5.2^2} \right] \right) dz dy$$

It is not possible to tabulate this integral.
A standard statistical table to solve
the integral is not possible. We will
estimate the integral.

$$x = \frac{y}{16.98} \quad 1 = \frac{z}{5.2}$$

AND THE INTEGRALS CAN BE REWRITTEN AS

$$(3) D = 10(25\pi) \left[\int_{-14.59}^{14.59} \frac{\exp(-\frac{1}{2}x^2)}{\sqrt{25\pi}} dx \right] \left[\int_{-11.95}^{11.95} \frac{\exp(-\frac{1}{2}b^2)}{\sqrt{25\pi}} db \right]$$

THE FACTORS OF TEST NORMALIZE TO
 1.0 UNTIL TO 1 WHEN TAKEN OVER ALL
 PLACES. NOW FROM EQUATION 10.11

$$\left(\frac{100}{100} \right) \left(\frac{1}{1.0} \right) \left(\frac{1}{1.0} \right) = 2(1.0) - 1 = 2(1.0) - 1 = 3544$$

10.11, 11-0 EQUATION 10.11

$$P = 10(27)(19.5)(1.0) = 775 \text{ kW}$$

$$P = 10(27)(19.5)(1.0) = 775 \text{ kW}$$

10.11, 11-0 EQUATION 10.11

10.11, 11-0 EQUATION 10.11

$$P = 10(27)(19.5)(1.0) = 6169 \text{ kW}$$

AND THE PERCENTAGE OF THE BEAM

10.11, 11-0 EQUATION 10.11

$$P = 100 \frac{775}{6169} = 12.6\%$$

NOW THE TOTAL FIELD CURRENT BEFORE
 OF SPUTTERING IS 10 AMPS, AND 12.5%
 OF THIS IS USED FOR SPUTTERING.

TO CALCULATE THE PARTICLE FLOW

$$1.6 \times 10^{-12} \text{ coulombs}$$

1.6E-12

$$10 \text{ AMPS} / 1.6 \times 10^{-12} \text{ coulombs} = 6.25 \times 10^{19} \text{ particles/sec}$$

USING A SPUTTERING YIELD OF 1

THE NUMBER OF ATOMS/SEC IS 6.25E19

TO GET:

$$6.25 \times 10^{19} \text{ atoms/sec} = 2.5 \times 10^{19} \text{ atoms/sec}$$

THE WEIGHT OF 1 ATOM OF TITANIUM IS:

$$1.66 \times 10^{-24} \text{ g/atom} \times 47.88 \text{ amu} = 1.05 \times 10^{-22} \text{ gm/atom}$$

AND THE SPUTTERING RATE IS 1.0E19

SEC IS:

$$2.5 \times 10^{19} \times 1.05 \times 10^{-22} = 2.62 \times 10^{-3} \text{ gm/sec}$$

JOB 95-0717 PAGE 6
 REVIEW OF SPUTTERING INFORMATION BY CCK CHK WL DATE 9/17/90

NOW THE REQUIRED TOTAL LIFE IS
 1.00E+05 AT 30 SEL EACH OF
 3×10^4 SEL TOTAL OPERATING LIFE.

THUS TOTAL WEIGHT OF LUTTER SPUTTERED
 IS:

$$2.64 \times 10^{-3} \text{ gm/sec} \times 3.0 \times 10^4 \text{ sec} = 79 \text{ gm}$$

TO CALCULATE THE LOSS IN THICKNESS
 WE FIRST MUST CALCULATE THE
 TOTAL VOLUME OF MATERIAL SPUTTERED:

$$79 \text{ gm} / 8.9 \text{ gm/cm}^3 = 8.88 \text{ cm}^3$$

NOW THE THICKNESS IS CALCULATED
 BY DIVIDING THE TOTAL VOLUME SPUTTERED
 BY THE TOTAL AREA.

$$8.88 \text{ cm}^3 / 9.4 \text{ cm}^2 = .001 \text{ cm}$$

CONVERTING TO INCHES

$$.001 \text{ cm} \times .3937 = .0004 \text{ in.}$$

SUB-APPENDIX C

EXCERPTS FROM REFERENCE

PUBLICATIONS

*Pages
C-92 - C-94 Removed
Reprint*

FINAL REPORT

WATER COOLED D.C. HEAT SINK DEVELOPMENT

Purchase Order No. 2660502 from:

UNIVERSITY OF CALIFORNIA
LAWRENCE BERKELEY LABORATORY
BERKELEY, CALIFORNIA

Work Performed for:

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
LIVERMORE, CALIFORNIA

Work Performed by:

RCA CORPORATION
SSD-ELECTRO-OPTICS AND DEVICES
POWER PRODUCTS ENGINEERING
LANCASTER, PENNSYLVANIA 17604

SEPTEMBER 30, 1977

Authors: Willis E. Harbaugh
Richard C. Bauder
William A. Novajovsky

the beam axis. The higher density part of the beam will hit elements which are at $\approx 5.5^\circ$. Based on a 18 kW/Cm^2 maximum beam density, these elements will be 1.72 kW/Cm^2 . At its widest point the 5.5° portion of the trough will be 12.4 centimeters. With a possible beam misalignment of 2.54 Cm the maximum power density at the edge of this section based

on $P_{xyz} = P \text{ total} = P \max e^{-\left(\frac{x}{\phi Z}\right)^2} e^{-\left(\frac{y}{\phi Z}\right)^2}$ (where $Z=700 \text{ Cm}$, $\theta=6.108 \times 10^{-3} \text{ Rad.}$, $\phi=1.221 \times 10^{-2} \text{ Rad.}$ and $P \max=18 \text{ kW/Cm}^2$) will be $P_{xyz}=8.65 \text{ kW/Cm}^2$ or $.83 \text{ kW/Cm}^2$ normal to the surface when $y=0$ and $x=\frac{12.4}{2}-2.54=3.66$. At the start of the 8.5° section this power density will be 1.28 kW/Cm^2 .

The lower power density (1.28 kW/Cm^2 compared to 1.72 kW/Cm^2) in the 8.5° section is advantageous because the space available for piping between adjacent collector sections is limited on the leading end. Three-eighths inch tubing would be used between the collector elements and the four inch headers in the 8.5° section and one-half inch tubing would be used in the 5.5° section.

These small diameter tubes would provide strain relief for the collector elements. The collector elements would be positioned at $8\frac{1}{2}^\circ$ and $5\frac{1}{2}^\circ$ from the beam axis. However, the sections lie in planes which are at 8° and 5° . This provides a .25 mm offset which hides the leading edge of each collector element from the beam. The elements would be kept in the offset position by strap plates as shown in Figure 49.

The entire structure would be attached to a supporting framework. The complete assembly would weigh approximately 1400 lbs. dry. Inlet pressure would be approximately 280 psig, back pressure 60 psig and flow 1800 gpm.

A.

32.0' 1

70.27"

5.5"

B.

Same as A except with fins removed
CALORIMETER HEAT SINK ELEMENT

Figure 48.

WILLIAM M. BROBECK & ASSOCIATES

JOB
BY

CHK

PAGE
DATE

APPENDIX D

Beam Dump Manufacturing Schedule

MFTF-B

JOB 95-27.20 PAGE 0
BY HL CHK JRM DATE 9/22/80

MFTF BEAM DUMP SCHEDULE

The main activities of the beam dump schedule are as follows:

- Prototype Development
- Prototype Selection and Verification
- Engineering
- Fabrication
- Installation and Testing
- Control System Installation and Testing

MFTF-B

JOB 95-27.20 PAGE 1
BY HL CHK *plm* DATE 9-22-90

ESTIMATED MONEY AMOUNTS FOR

ENGINEERING $\$ 28723 \times 13 = \$ \underline{373400}$ INSTALLATION $\$ 12310 \times 13 = \$ \underline{160003}$

USING AN HOURLY RATE OF \$35.- for
INSTALLATION AND \$ 55 for ENGINEERING
THE MONEY ALLOTTED REPRESENTS

$$373400 : 55 = \underline{6789 \text{ MHRS}}$$

$$160003 : 35 = \underline{4572 \text{ MHRS}}$$

FOR ENGINEERING AND INSTALLATION
IN ESTIMATING.

ASSUMING A FIVE PERSON ENGINEERING
TEAM THE TIME FOR
ENGINEERING AMOUNTS TO

$$6789 \text{ MHRS} \frac{12}{(5 \cdot 40 \cdot 52)} \approx \underline{8 \text{ MONTH}}$$

AND FOR ASSEMBLY USING A 6 MAN INSTALLATION
TEAM

$$4572 \text{ MHRS} \frac{12}{(6 \cdot 40 \cdot 52)} \approx \underline{4.4 \text{ MONTH}}$$

4 MAN TEAM $\sim 6.5 \text{ MONTH}$

THE BEAM DUMP FABRICATION LABOR IS
APPROX. $\frac{2}{3}$ OF THE TOTAL BEAM DUMP COST OF
\$ 30037 OR $\sim \$20000$. ASSUMING AGAIN A

MTTF - B

JOB 95-27-20 PAGE 2
BY HL CHK HL DATE 9-22-80

THREE MAN TEAM THE NUMBER OF WEEKS
REQUIRED TO FINISH THE JOB FOR 13 UNITS
IS:

$$\begin{aligned} & \$ 20000 \times 13 \text{ UNITS} / (\$35/\text{HR} \times 3(\text{MAN}) \times 40 \text{ HRS}/\text{WEEK}) \\ & = \underline{62 \text{ WEEKS}} \end{aligned}$$

FABRICATION AND INSTALLATION CAN
OVERLAP BY AT LEAST 50 TO 75 PERCENT
TO SHORTEN THE LENGTH OF THE SCHEDULE.

FURTHER ASSUMPTIONS:

BIDS TO BUILT PROTOTYPES ARE
BEING RELEASED RIGHT NOW (SEPT. 80).
EVALUATION OF PROTOTYPES AND START OF
ENGINEERING IS EXPECTED TO BEGIN IN
12 MONTH.

THE WHOLE DEAN DUMP SYSTEM HAS TO BE
INSTALLED AND OPERABLE BY JAN. 1984.
CONSIDERING A THREE MONTH CONTINGENCY AND
A THREE MONTH TESTING PERIOD THE INSTALLATION
INCLUDING PRELIMINARY TESTING HAS TO BE
COMPLETE BY JULY 1983.