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FROM: H. S. Davis
Reactor Design & Development
ENGINEERING DEPARTMENT

Subject: AN EVALUATION OF COSTS FOR CONSTRUCTING HIGH DENSITY
CONCRETE SHIELDS AT 105-K

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COMMENTS ON ISSUE B

The data presented in the original issue of this document were based upon cost information as reported by Kaiser Engineers for September 30, 1954. To increase the usefulness of this issue of Document HW-33951, final cost data as reported by Kaiser Engineers on April 30, 1954 have been included on Page 10(a). Revised values for Hanford cost indices and estimated savings in project costs are given on Page 19 and Page 21, respectively.

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AN EVALUATION OF COSTS FOR CONSTRUCTING HIGH DENSITY
CONCRETE SHIELDS AT 105-K

Introduction

High density concrete was used extensively for the second time at Hanford during the construction of the biological shields at 105-K. This shield construction maximizes development work aimed at providing adequate shielding at a more reasonable cost. An estimated savings of \$11,300,000 in the total project cost of the 105-K reactors were realized by using high density concrete instead of steel and masonite in the biological shields. In addition, these concrete shields provide greater resistance to deterioration, earthquake, and blast forces than do the shields constructed prior to 1953. Besides demonstrating that the biological shields at 105-K cost about one-third as much as steel and masonite shields, the cost data compiled in this report are useful for indicating ways whereby additional savings may be obtained in designing and constructing future shields.

Summary

The primary purpose of this report is to present cost data associated with the recent construction of biological shields at Hanford. These data are useful for analysing shields which have been built during the past four years and for ascertaining ways to improve future designs. Specifically, the objectives of this study are to:

1. Compile and analyse cost data associated with the construction of the high density concrete shields at 105-K and the steel-masonite shields at 105-C, and
2. Determine unit costs for erecting steel forms at Hanford and for filling them with high density concrete.

Direct costs for constructing concrete shields at 105-K are summarized in Tables 1 and 2. Shown in Tables 3 to 5 are unit costs for heavy aggregates and high density concrete. Unit costs for erecting steel forms and filling them with concrete are presented in Tables 6 and 7. Costs for steel-masonite shields are based upon data from 105-C, and are summarized in Tables 8 and 9. Savings in construction and project costs, realized by using concrete instead of steel and masonite, are presented in Table 10. Conclusions based upon a study of these cost data are presented below. A list of tabular data is presented on page 8. A description of the aggregates and concrete used in constructing these shields is presented in document HW-32968, "Analysis of Control Data for High Density Concrete Placed at 105-K", written by the author September 7, 1954.

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General Comments and Conclusions

1. Original cost data used in this study are from Cost Reports issued monthly by Kaiser Engineers. Summarized in Tables 1 and 2 are recorded costs to October 1, 1954 for major shielding components such as inlet-outlet crates, side crates, top shields, and high density concrete. Individual costs are presented separately for each reactor in Table 1. It is noted that costs for KE average about 5.4 percent greater than costs for KW, even though KW was built first. The sums of recorded costs for both reactors are presented in Table 2 and used later in evaluating total and unit costs figures for the various shielding items.
2. Included in Tables 1 and 2 are costs for several minor shielding items as well as costs for the biological shields. For example, included in the cost of the "steel forms" are allowances for such items as s/s seals, neoprene seals, and aluminum reflectors. Included in Item 473 for high density concrete are also costs for (a) concrete and forms used in placing 168 cubic yards of Type 2 concrete, (b) 23 cubic yards of grout fill, and (c) an unrecorded amount of grout and mortar used in step plugs and ball hoppers. Costs for the thermal shields are not included.
3. Listed separately in Table 2 are distributed costs associated with the construction of temporary items in the 105-K building. The \$378,450 allowed for temporary construction represents about 9.1 percent of the \$4,162,196 charged for the direct construction of reactor shields. As of September 30, 1954, distributed costs assigned to the major shield components by Kaiser accountants vary from 6 to 13 percent of the direct costs for these items. At the present time these costs for temporary construction in the 105-K building are being re-distributed uniformly at a rate of about 7.1 percent of the direct construction cost.
4. Summarized in Table 3 are costs for purchasing, transporting, and processing heavy aggregates. Processed aggregates valued at \$903,984 were used in the construction of the high density concrete shields at 105-K. This figure includes processing costs incurred in the sub-contract with the Lake City Gravel and Materials Company. The cost for labor supplied by Kaiser Engineers for handpicking limonite and bagging sand are recorded in Table 4. The steel punchings and heavy aggregates transferred from 105-K to other projects at Hanford may be considered to be worth from \$29,094 to \$79,154 depending upon book value assigned to them. Using the first figure, the net value of these excess aggregates becomes \$50,060.
5. Total and unit costs for labor, material, and equipment associated with the placing of high density concrete in shielding structures at 105-K are presented in Table 4. Shown in Table 5 are unit cost and percentage values for Type 1, 2, and 3 concrete and two types of grout fill. The main contributor to the high material cost of Type 1 and 2 concrete is the cost of steel aggregate.

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6. Except for steel aggregate, unit costs for processed aggregates shown in Table 3 are about twice as much as corresponding values presented in document HW-27752, "Design and Material Cost Data for High Density Concretes Placed by the Prepacked Method", April 16, 1953, by H. S. Davis. This increase in the cost of heavy aggregates is due primarily to the expense of processing raw materials at 105-K. These processing costs are much higher than those assumed in HW-27752 based upon more favorable circumstances than were experienced at 105-K. However, had processed limonite been obtained at one-half the 105-K costs, the total cost for a cubic yard of Type 1 concrete would have been \$638 instead of \$678. Under prevailing job conditions, this \$40 difference certainly justifies the additional effort required to obtain high quality aggregate and grout sand for 105-K.
7. As shown in Table 5, limonite and magnetite for Type 3 concrete cost from 92 to 95 dollars per cubic yard; whereas, limonite and steel aggregate for Type 1 concrete cost about four times as much. In the design of the 105-K shields, material costs were reduced approximately \$500,000 by using 1800 cubic yards of Type 3 concrete in the less critical sections of the biological shields. About \$60,000 of this cost reduction can be credited directly to the use of the "Prepakt" method since it is unlikely that two types of conventional concrete could have been placed economically in the left side shields.
8. Shown in Table 6 are the results of a study designed to evaluate the total cost of each major component of the biological shields at 105-K. It is noted that costs for the biological shields represents 97.1 percent of the total cost recorded in account 350-47 for reactor shielding. This 97.1 value also includes costs for wood forms used with Type 2 concrete in the 105-K building, and high density mortar used in step plugs and ball hoppers. Also presented in Table 6 and 7 are unit costs for the various shield components. Not including distributed costs, the average construction cost of the biological shields is \$942 per cubic yard. Depending upon location and type of concrete used, the cost of steel forms represents about 50 percent of the total cost of the biological shields. The most expensive type of steel form construction is that used in the inlet and outlet crates, which is about 1.75 times as expensive as that used in the side or top shields. The unit cost of the steel forms used in the top shields is slightly less than for the side shields. One reason for this difference is that approximately 500 tons of steel plate, excessed from 105-C, were fabricated at P.S.N.S.Y. into girders and thermal plates, and used in erecting the top shields at 105-K. Steel forms used in the inlet, outlet and side shields consist of "crates" which were (a) fabricated at the Puget Sound Navy Shipyard and then (b) assembled and welded into place at Hanford. These elaborate forms are an integral part of the biological shield, and have important functions to perform in addition to containing concrete.

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9. The total and unit construction costs shown in Tables 6 and 7 indicate the relative costs for the various items associated with major components of the 105-K biological shields. Summarized below are percentage figures for labor, material, and equipment based upon these data.

PERCENTAGE OF BIOLOGICAL SHIELD COST

<u>Shield Component</u>	<u>Labor</u>	<u>Material</u>	<u>Equipment</u>	<u>Total</u>
<u>Inlet-Outlet</u>				
Steel Forms	5.8	14.1	1.0	20.9
Concrete	3.2	11.0	2.2	16.4
Total	9.0	25.1	3.2	37.3
<u>Left-Right</u>				
Steel Forms	6.4	10.5	1.1	18.0
Concrete	5.6	11.7	4.0	21.3
Total	12.0	22.2	5.1	39.3
<u>Top & Bottom</u>				
Steel Forms	6.4	4.4	0.9	11.7
Concrete	3.3	6.0	2.4	11.7
Total	9.7	10.4	3.3	23.4
<u>B-Shield</u>				
Steel Forms	18.6	29.0	3.0	50.6
Concrete	12.1	28.7	8.6	49.4
Total	30.7	57.7	11.6	100.0

The above data, as well as the unit figures given in Table 7, are useful for determining possible savings during the design and construction of future reactors, for making economic studies, and for evaluating optimum shield thicknesses. However, good judgment is required in applying these data to problems wherein conditions differ from those at 105-K. For example, had the respective shields at 105-K been twelve inches thinner or thicker, the total cost for steel forms would not have been much different from their actual cost; yet, the cost for high density concrete would have decreased or increased almost proportionately to the change in net volume of concrete used.

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10. Of general interest are the costs summarized below for major purchase of material, freight, and services. These data are based upon construction costs presented in Tables 1 to 7 for all shielding items in account 350-47 of the 105-K reactors.

COSTS OF PURCHASED MATERIAL AND SERVICES

	<u>Recorded Cost</u>	<u>Percent Based On</u>	
		<u>Material Only</u>	<u>Total Cost</u>
<u>Fabrication at P.S.N.S.Y.</u>	\$ 635,383	26.9 26.9	15.4 15.4
<u>Heavy Aggregates</u>			
Steel Aggregate	603,918	25.4	14.7
Limonite	169,750	7.2	4.1
Magnetite	65,664	2.8	1.6
Lake City Processing	143,806	6.1	3.5
Not used in 105-K Shields	(-79,154)	(-3.3)	(-1.9)
Total	903,984	38.2	22.0
<u>Prepakt Concrete Co.</u>	148,230	6.3	3.6
<u>Material on M & E List</u>	268,227	11.3	6.5
<u>Additional Purchased Items</u>			
Reinforcing Steel	44,593	1.9	1.1
Portland cement	29,611	1.2	0.7
Others	335,414	14.2	8.2
Total	409,618	17.3	20.1
<u>Material and Purchased Services Given Above</u>	2,365,442	100.0 %	57.5 %
<u>Labor</u>	1,260,881		30.6
<u>Equipment</u>	488,080		11.9
<u>All Shielding at 105-K</u>	4,114,403		100.0
<u>Distributed Costs*</u>	292,123		7.1
<u>Direct Construction Cost:</u>	4,406,526		107.1
378,450 -292,123 *	86,327		2.1
50,060 -2,267	47,793		1.2
Total Cost given in Table 1	4,540,646		110.4

- * Distributed costs have been figured as 7.1 percent of construction costs. (See paragraphs 3 and 4, and Table 2 for an explanation of these values.)

11. Construction costs for the biological shields of the 105-C reactor are shown in Table 8. The inlet and outlet sides of the 105-C shield consist of "B-blocks" held together by "tie-straps". These "B-blocks" as well as the two side shields, are made of laminated layers of steel and masonite. The top at 105-C is a high density concrete shield

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similar to those at 105-K. It is noted that the smaller biological shield at 105-C cost nearly as much as did both shields at 105-K. This is due primarily to the high cost of material, machining, and fabrication associated with steel-masonite construction. Unit costs for this type of shield construction are compared in Table 9 with unit costs for the 105-K shields. In comparing total costs for similar components, such as the inlet shield at 105-C with the inlet shield at 105-K, allowance should be made for the fact that about nine inches of steel and masonite is as effective as ten inches of Type 1 concrete.

12. It is noted that steel-masonite shields cost about \$3549 per cubic yard of gross shield volume as compared to an average cost of \$1326 for the inlet and outlet shields made with Type 1 concrete. Biological side shields made with Type 3 concrete cost about \$827 per cubic yard. The unit cost for the 105-K top shield is less than the unit cost of the 105-C top shield since (a) a greater quantity of concrete was placed at 105-K, and (b) excess steel plate was used in fabricating girders and thermal plates for 105-K.
13. Considerable savings in construction and project costs for 105-K were realized when high density concrete was used in the biological shields instead of steel and masonite. Estimated values of savings, based upon the cost data discussed above, are presented in Table 10. In this study, in order to allow for small differences in the attenuation effectiveness of high density concrete and steel-masonite shields, new values of shield volumes were computed. Thus, the protection provided by the steel-masonite shields of Examples 1 and 2 is comparable to that provided by the present 105-K shields made with high density concrete. As shown in Table 10, the biological shields at 105-K would have cost about \$12,700,000, instead of \$4,280,000, had they been made with steel and masonite instead of high density concrete. This represents a total savings of about \$11,300,000 in the project cost of the 105-K reactors.
14. Considered in this cost study are all known costs associated with the construction of shielding structures at 105-K. Whereas, construction work has been completed for several months, minor charges and changes in the various shielding accounts are still being made. It is expected that some minor costs will continue to trickle in as long as these accounts are open. However, it is estimated that the 105-K costs for reactor shielding given in this report represent over 99.5 percent of the final recorded costs. The integrity of these cost data is related directly to the care used in reporting individual costs for items such as man-hours of labor and material, and in assigning them to the various shielding accounts; that is, cost control procedures over which the author has no control. However, the author is indebted to Kaiser's Cost Reports, and the care used by foreman, accountants and other personnel in reporting and recording cost data. The author also acknowledges the generous assistance given by accountants and engineers associated with Kaiser Engineers, the Atomic Energy Commission, and the General Electric Company during the preparation of this report.

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TABLE 1
HIGH DENSITY CONCRETE SHIELDING*
CONSTRUCTION COSTS TO OCTOBER 1, 1954
(Individual Costs for 105-KE and 105-KW)

Cost Code	Labor S/T	Labor P/T & P/R (Taxes)	Material & (Misc. Charges)	Permanent Material	Shop Costs	Equipment Usage	Sub-Contractors	Total to End of Month Sept. 30, 1954
471	105,894 86,145	21,785 17,320	66,065 60,854	220,091 219,924	7,935 11,428	25,655 13,586		447,425 409,257
472	108,700 100,403	26,017 21,460	55,843 55,581	180,469 171,662	26,949 38,650	27,927 16,447		425,905 404,203
473	213,492 197,991	49,079 46,987	167,991 160,023	405,472 404,766	6,312 2,771	190,221 171,943	174,399 ^a 159,553 ^a	1,206,966 1,144,444
474	5,204 3,673	1,090 778	2,384 1,344	1,832 1,898	0,000 0,000	3,007 2,221		13,517 9,914
476				2,267 2,629				2,267 2,629
477	107,388 95,799	24,496 27,180	28,564 34,965	56,526 58,704	1,661 1,763	15,484 21,589		234,119 240,000
Total for KE	540,678	122,467	320,847	866,657	42,857	262,294	174,399	2,330,199 ^b
Total for KW	484,011	113,725	312,767	859,583	54,612	225,786	159,963	2,210,447 ^b
Total KE & KW	1,024,689	236,192	633,614	1,726,240	97,469	488,080	334,362	4,540,646

* These values are accumulative totals of monthly costs figures issued by Kaiser Engineers.
Top figures for each Item are costs for 105-KE (Account 5107-350-47).
Lower figures for each Item are costs for 105-KW (Account 5109-350-47).

- (a) Based upon Kaiser's Cost Report for 10/31/54 these values are \$163,984 and \$173,382, respectively.
(b) Based upon Kaiser's Cost Report for 10/31/54 these values are \$2,314,946 and \$2,212,937, respectively.
(c) Since shield construction at 105-K has been completed for several months, and all major costs recorded, the above data are indicative of the total construction costs for the 105-K reactor shield.

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TABLE 2
CONSTRUCTION COSTS TO OCTOBER 31, 1954
(Total Costs For 105-KW and 105-KE)
High Density Concrete Shielding

Cost Code	Description of Shielding	Labor S/T, P/T & P/R Taxes	Material & (Misc. Charges)	Permanent Material	Shop Costs	Equipment Usage	Sub-Contractors	Total Construction Costs
471	Front and Rear Crates	231,144	78,012 (48,907)	440,015	19,363	39,241		807,775
472	Side Crates	256,580	50,149 (61,275)	352,131	65,599	44,374		768,833
473	H1 Density Concrete	507,549	88,812 (239,202)	810,238 ^a	9,083	362,164	334,362	2,112,208
474	Regular Concrete	10,745	1,069 (2,659)	3,730		5,228		20,772
476	Test Facil.			4,896				4,896
477	Top & Bottom Biol. Shield	254,863	37,122 (26,407)	115,230	3,424	37,073		447,712
	Sub-total	1,260,881	255,164	1,726,240	97,469	488,080	334,362 ^c	4,162,196
	Adjustments Total		(378,450) ^b 633,614					(378,450) ^b \$4,540,646 ^d

- (a) This figure represents total cost of aggregates plus freight, and handling charges.
- (b) This figure represents total of costs from clearing account 397 charged to above accounts for 105-K temporary construction, cranes, scaffolding, layout, etc.
- (c) This figure is \$2,267 less than the sum of the following sub-contract costs used in this report: \$44,593 for reinforcing steel, \$143,806 for crushing aggregates by Lake City Gravel and Materials, and \$148,230 for services of the Prepack Concrete Company. A total of \$337,366 is reported for this item in Kaiser's Cost Report of October 31, 1954.
- (d) This total is \$4,527,464 in Kaiser's Cost Report for October 31, 1954; the reduction being caused by adjustments in distributing the clearing accounts for 105-K. The total for November 30, 1954 is \$4,523,754.

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TABLE 2(e)

 DIRECT CONSTRUCTION COSTS TO APRIL 30, 1955 (FINAL)^c
 (Total Costs for 105-KW & 105-KE)

Cost Code	Description of Shielding	Labor S/T, P/T & P/T Taxes	Material & (Misc. Charges)	Permanent Material	Shop Costs	Equipment Users	Sub-Contractors	Total Construction Costs
107-350	Front and Rear Crates	231,643	77,602 (60,389)	438,150	19,362	33,609	---	800,366
172	Side Crates	257,123	49,358 (58,404)	349,286	65,620	38,414	---	759,801
173	H1 Density Concrete	507,376	90,786 (166,055)	808,383 ^a	9,106	340,648	314,596	2,070,855
174	Regular Concrete	10,745	1,070 (1,655)	3,730	---	4,598	---	20,143
176	Test Facil.		362	4,534				4,896
177	Top and Bottom Biol. Shield	254,692	37,025 (33,455)	114,808	3,424	32,655	---	442,604
	Sub-Total	\$1,261,579	\$256,203	\$1,718,891	\$97,512	\$449,924	\$314,596	\$4,098,705 ^d
397	Adjustments		(319,958) ^b					(319,958) ^b
	Total		\$576,161					\$4,418,663

(a) This figure represents total cost of aggregate plus freight, and handling charges.

(b) This figure represents total of costs from clearing account 397 charged to above accounts for 105-K temporary construction, cranes, scaffolding, layout, etc. (Clearing account charges as of Feb. 28, 1955.)

(c) The major differences in the cost data presented in Table 2 for September 30, 1954 and those presented in the above table for April 30, 1955 are due to:

-1 - Adjustments in the 397 clearing account, and -2 - Adjustments in the account for Equipment Usage due primarily to sale of surplus equipment.

(d) This figure is 98.5 percent of the corresponding value given in Table 2 for September 30, 1954.

(e) The data presented in Table 2 on the preceding page were used in preparing the unit cost figures for this report. See Note on Page 1.

TABLE 3
SUMMARY OF COSTS FOR HEAVY AGGREGATES PURCHASED FOR 105-K

Type of Heavy Aggregate	Cost of Raw Material			Cost of Processed Material			
	Tons Purchased	Purchase Price	Freight	Total Cost \$ Per Ton	Processing Cost	Tons ^a Used	Tons ^b Excess Value \$ Per Ton
Montello Limonite Mine Run (10"-16") Coarse Aggregate Grout Sand Reserve	5,700	\$ 64,110	48,172	19.75	\$ 46,800 67,300	1,418 1,428	244 102 716 71.83 70.13 19.75
James Limonite Mine Run (13/4"-8") Coarse Aggregate Fine Aggregate Reserve	2,000	(4,400 ^c (12,906	39,862	28.58	14,000	1,274 104	175 51.63 51.63 28.58
Dodge Magnetite Coarse Aggregate Grout Sand Reserve	2,945 104	27,299	21,996	16.18	----- 7,706	2,467 149	19.30 44 54 48.50 16.18
Woolsey Magnetite Stockpiled Coarse Aggregate Fine Aggregate Reserve	1,163	9,885	6,484	14.03	4,000 4,000	151 157	392 130 34.81 34.81 14.08
Steel Aggregate Steel Shot Commercial C. Aggr. 105-C Excess Material Total	82 4,150 752 16,896	8,150 508,334 18,096 \$653,480	3,764 65,574 \$185,852	145.30 138.29	\$143,806 ^d	62 4,020 52 11,302 ^a	145.30 142.76 24.06 2557 ^b (43.00)

(a) Total cost of raw material and processing: \$983,138. Value of aggregates used in 105-K construction: \$903,984.

(b) Value of excess aggregates: \$79,154. (540 tons of 105-C punchings have been transferred to Blaw-Knox, and 116 tons of magnetite-limonite aggregates have been transferred to Minor Construction to-date.) See paragraph 4.

(c) Cost for screening near James Mine by Champion, Inc.

(d) Cost of equipment and services supplied by Lake City Gravel and Materials Company.

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TABLE 4
CONSTRUCTION COSTS FOR HIGH DENSITY CONCRETE*
 (Item 473 for Shielding at 105-KE and 105-KW)

	<u>Total Cost</u> <u>(Dollars)</u>	<u>Unit Cost^c</u> <u>(\$/cu.yd.)</u>	<u>Percent</u> <u>of Cost</u>
<u>Kaiser Labor</u>			
1 Inside 105-K Bldg.	406,039	104.06	19.7
2a Outside 105-K Bldg.	93,510	23.95	4.5
2b Handpicking Limonite	8,000	2.05	0.4
	<u>507,549</u>	<u>130.07</u>	<u>24.6</u>
<u>Materials & Services</u>			
3a Misc. Material	37,599	9.64	1.8
3b Portland Cement	29,611	7.59	1.4
4 Labor-Bagging Sand	20,616	5.28	1.0
5 Equipment Purchases	986	0.25	0.1
7,9 Processed Aggregates	903,984	231.67 ^f	43.9
8 Shop Costs	9,083	2.33	0.4
10 Prepakt Concrete Co.	148,230	37.99	7.1
11 Reinforcing Steel	44,593	11.43	2.2
	<u>1,194,702</u>	<u>306.18</u>	<u>57.9</u>
<u>Equipment Usage</u>			
12 Cranes and Shovels	183,518	47.03	8.9
13 Trucks and Tractors	60,290	15.45	2.9
14 Other Equipment	118,356	30.33	5.7
	<u>362,164</u>	<u>92.81</u>	<u>17.5</u>
<u>Sub-Total</u>	<u>2,064,415</u>	<u>529.06</u>	<u>100.0</u>
15 Distributed Costs ^d	146,573	37.56	7.1
16 Net Excess Material ^e	50,060	12.83	2.4
<u>Total</u>	<u>2,261,048</u>	<u>579.45</u>	<u>109.5</u>

* For a description of cost items see the notes for Table 7 given on page 17.

- (c) These unit costs are based upon a net volume of 3902 cubic yards of high density concrete placed at 105-K, and therefore, they are greater than values of unit costs presented in Table 7 based upon gross shield volumes. If the amount of concrete and grout fill placed in step plugs were known the net volume would be greater than 3902 cubic yards and unit costs would be slightly less than given above.
- (d) These are distributed costs to allow for temporary construction in the 105-K building.
- (e) This value is the difference between (810,238 plus 143,806) and (903,984). It represents the net value of excess aggregate plus warehousing charges.
- (f) This is an average value for aggregate used in high-density concrete at 105-K. See Table 5.

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TABLE 5
UNIT CONSTRUCTION COSTS FOR DIFFERENT
TYPES OF HIGH DENSITY CONCRETE USED AT 105-K
(Dollars per Cubic Yard of Concrete)

Processed Aggregates					Average Cost ^a per Cubic Yard of Concrete
Type ^b	Mix	Type	Cost/cu.yd.	Percent	
1	d	Montello Limonite	54	8.0	678
		Steel Aggregate	300	44.2	
		Grout Sand	27	4.0	
			<u>381</u>	<u>56.2</u>	
1	e	James Limonite	45	6.9	657
		Steel Aggregate	288	43.8	
		Grout Sand	27	4.1	
			<u>360</u>	<u>54.8</u>	
2	f	Dodge Magnetite	32	6.4	500
		Steel Aggregate	145	29.0	
		Grout Sand	26	5.2	
			<u>203</u>	<u>40.6</u>	
3	j	Montello Limonite	33	8.5	389
		Dodge Magnetite	32	8.2	
		Grout Sand	27	6.9	
			<u>92</u>	<u>23.6</u>	
3	k	James Limonite	45	11.5	392
		Dodge Magnetite	23	5.8	
		Grout Sand	27	6.9	
			<u>95</u>	<u>24.2</u>	
Average Cost for High Density Concrete:			232	43.9	529
Grout Fill	Cubic Yards				
S-250	7.01 ^c	S-110 Steel Shot	404		590
M-168	16.29	Magnetite Sand	70		256
Average Cost for Grout Fill:			170		356

(a) Average cost for items associated with high density concrete other than aggregate is \$297.39 per cubic yard, or 529.06 minus 231.67. See Table 4. These figures do not include distributed costs shown on lines 15 and 16 of Table 4. Costs for processed aggregates are presented in Table 3.

(b) See Page 9 of HW-32968 for aggregate proportions.

(c) Does not include grout fill used in step plugs, or ball-hoppers.

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TABLE 6
BREAKDOWN OF CONSTRUCTION COSTS FOR SHIELDING *
STRUCTURES MADE WITH HIGH DENSITY CONCRETE AT 105-K
(Accounts 5107-350-47 and 5109-350-47)^a

Item	Shield Component	Gross Volume (cubic yards)	Net Volume of concrete (cubic yards)	Construction Cost (Dollars)			Unit Costs (Dollars/cubic yard)	
				Kaiser Labor	Material & Purchase Services	Equipment Usage	Forms and Concrete Total	Gross Shield Net Concrete
471	Inlet & Outlet Steel Forms Concrete Total	1,203	965	231,144 125,365 356,509	565,434 439,248 1,004,682	39,241 89,455 128,696	835,819 654,068 1,489,887	694.78 543.69 1,238.47
472	Left & Right Steel Forms Concrete Total	1,822	1722	256,580 224,336 480,916	419,425 466,815 886,240	44,374 160,076 204,450	720,379 851,227 1,571,606	395.38 467.19 862.57
477	Top & Bottom Steel Forms Concrete Total	1,217	1024	254,863 132,978 387,841	176,186 238,954 415,140	37,073 94,887 131,960	468,122 466,819 934,941	384.65 383.58 768.23
474	Ordinary Concrete	(438)		10,745	4,799	5,228	20,772	47.42
476	105-K Bldg. ^b Concrete & grout	191	191	24,870	49,685	17,746	92,301	483.25 ^g
471-477	Test Facilities				4,896		4,896	
471-477	B-Shields & Bldg.	4,410	3902	1,260,881	2,365,442	488,080	4,114,403	932.97
471,472) & 477)	B-Shields Only	4,242	3734	1,225,266	2,306,062	465,106	3,996,434	942.11

*See following page for descriptive notes.

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Descriptive Notes For Table 6

- (a) Distributed costs from clearing account (Code 397) are not included in this table.
- (b) Included in this item are costs for high density concrete placed in walls of the tool dolly room and around openings in the rear barrier walls of the 105-K buildings. Also included is the cost (\$1,744) of some of the material used in placing 23 cubic yards of grout. These values do not include costs for grout or concrete placed in step plugs or in ball-hoppers.
- (c) Permanent material costs of \$468,059, \$303,677, and \$135,640 were used for Items 471, 472, and 477, respectively, instead of \$440,015, \$352,131, and \$115,230 given in Table 2. The adjusted figures are in agreement with cost values for permanent materials listed on the M. and E. list for these items.
- (d) In distributing the costs for high density concrete presented in Item 473 to the respective shield components (Items 471, 472, 477, and the 105-K building) the following conditions exist:

- (1) Material costs for heavy aggregate are based upon the unit costs presented in Table 3 and the actual tonnages of each type of aggregate used in each shield. (See document HW-32968 for aggregate tonnages.)
- (2) Other costs are distributed proportionately on the basis of net volume of concrete placed in each shield as follows:

<u>Item</u>	<u>Shield Component</u>	<u>Percent</u>
471	Inlet and Outlet	24.7
472	Left and Right Sides	44.2
477	Top Shield	26.2
---	105-K Buildings	4.9

- (e) Total costs for the work done at the Puget Sound Navy Shipyard under purchase order D.P. 64282 are as follows:

P.S.N.S.Y. Labor	\$321,813	Motor Freight	\$23,326
P.S.N.S.Y. Overhead	249,691	Rail Freight	5,434
Material*	45,276		\$28,760
	<u>\$616,780</u>		

Security	1,900
Cages, etc.	1,350
Total	<u>\$620,030</u>

* Material furnished by P.S.N.S.Y. This figure does not reflect a credit of \$13,407 from sale of excess material.

The \$620,030 total is distributed as follows: \$312,390 to account 471, \$208,034 to account 472 and \$99,606 to account 477.

- (f) See description of cost items presented on pages 5, and 17.
- (g) Unit costs per cubic yard: \$500 for Type 2 concrete, \$361 average for grout fill. See Table 5.

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TABLE 7
UNIT COSTS FOR COMPONENTS OF BIOLOGICAL SHIELDS
Based upon total costs for 105-KE and 105-KW
to October 1, 1954. Costs are expressed in
dollars per cubic yard of gross shield volume.

B-Shield Component	Code	Inlet and Outlet		Left and Right Sides		Top	
		1203		1822		1217	
Gross Volume (Cubic Yards)		Steel Forms	Concrete	Steel Forms	Concrete	Steel Forms	Concrete
Kaiser Labor At Site	100-200						
(1) At 105-K Bldg.		192.15	83.81	140.82	99.02	209.41	87.88
(2) Outside 105-K Bldg.			20.40		24.10		21.39
Material, Freight and Purchased Services							
(3) Misc. Material	300-385	29.44	14.00	24.54	16.54	26.04	14.68
(4) Purchased Services	387	35.40	4.23	2.98	5.00	4.47	4.44
(5) Equipment Purchases	410	15.97	0.20	6.92	0.24	4.59	0.21
(6) P.S.M.S.Y. Fabrication	410	230.70		114.04		79.40	
(7) Major Mat'l Purchases	420-430	142.41	278.07	45.82	153.36	27.47	105.07
(8) Shop Costs	500-561	16.69	1.87	36.93	2.23	2.81	1.96
(9) Crushing (Lake City)	780		27.16		32.09		28.48
(10) Prepack Concrete Co.	780		30.43		35.96		31.91
(11) Re-Steel	780		9.16		10.82		9.60
Equipment Usage							
(12) Cranes & Shovels	601	17.94	37.68	10.93	44.52	9.58	39.51
(13) Trucks & Tractors	602-604	2.77	12.38	2.43	14.63	4.79	12.98
(14) Other Equipment	605	11.91	24.30	11.00	28.71	16.09	25.47
Unit Cost (\$/cu. yd.) ^a		694.76	543.69	395.38	467.19	384.65	383.58
Total Cost (Dollars)		835,819	654,068	720,379	851,227	468,122	466,819

(a) Increase these values approximately 7.1 percent to include distributed costs from clearing account 397.
These distributed costs are for temporary construction in the 105-K building.

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Descriptive Notes for Table 7

The unit cost data presented in Table 7 are based upon the construction cost figures presented in Tables 1 to 6 and cost reports issued by Kaiser Engineers. To aid in analyzing these data, additional descriptive information is presented below:

- (a) To obtain total construction costs, multiply these unit cost figures by the corresponding values of gross volume.
- (b) Approximately 20.0 percent of Kaiser labor charged to high-density concrete account 473 was done outside of the 105-K buildings. Thus, amounts listed under line 2 are for such things as construction, maintenance, and removal of the aggregate plants; and for the processing, blending and handling of heavy aggregates outside of the 105-K buildings.
- (c) Miscellaneous materials (Line 3) include supplies from Kaiser's warehouse stock such as cement, lumber, pipe, steel plate, electrical supplies, paint, welding material, expendable tools, and safety shoes. Charged to account 473 are \$14,112 at 105-KE and \$15,499 at 105-KW for portland cement. Distributed costs from clearing account 397 are not included in this table.
- (d) Purchased services (Line 4) associated with the fabrication of the Steel Forms cover extra costs incurred at the Puget Sound Navy Shipyard (Supplements 7 and 9 of DP-64283) for extra gages and for checking, straightening, and honing tubes.
- (e) Purchased services (Line 4) associated with "concrete" are primarily for Kaiser labor used to operate the sand and aggregate plant and to bag sand. Purchased services also include a small amount of aggregate testing performed at the North Pacific Division Laboratory, Troutdale, Oregon.
- (f) Values listed under line 6 include all fabrication and freight costs for work done at the Puget Sound Navy Shipyard except for the extras listed under line 4.
- (g) Major material purchases (Line 7) include the cost of all items listed on the M. and E. list plus freight.
- (h) Values listed under equipment purchases (Line 5) represent excess amounts in Kaiser's accounts (Code 410 to 430) which are not included in lines 6 and 7. These values in line 5 may be considered as warehousing and handling charges, or miscellaneous charges for material not included on the M. and E. list.
- (i) Fabrication and shop costs are given in line 8. These costs were in the following Hanford shops operated by Kaiser Engineers: structural steel, sheetmetal, machine, boilermaker or pipe shop.
- (j) Total cost values for crushing and processing heavy aggregates, supervising "Prepakt" operations and for supplying reinforcing steel were obtained by dividing the actual costs for these contracted services by the net volume of concrete placed in the respective shields. (See pages 12 to 14). The unit costs given in lines 9, 10, and 11 are not the same for each shield component since ratios of gross to net volume are not constant.

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TABLE 8

CONSTRUCTION COSTS FOR IRON-MASONITE AND CONCRETE SHIELDS
INSTALLED AT 105-C DURING 1951-1952

Shield Description	Gross-Volume (cubic yards)	A. & J. Labor	Material	Equipment Usage	Total
<u>Side Shields</u> ^b	1066				
Total Cost (Dollars) ^d		768,197	2,492,776	117,512	3,378,485
Unit Cost (\$/cu. yd.) ^d		720.64	2,338.43	110.24	3,169.31
<u>Top and Bottom Shields</u> ^c	472				
Total Cost (Dollars)		194,428	207,430	37,881	439,739
Unit Cost (\$/cu. yd.)		411.92	439.47	80.26	931.65
<u>Side, Top & Bottom Shields</u>	1538				
Total Cost (Dollars)		962,625	2,700,207	155,393	3,818,225
Unit Cost (\$/cu. yd.)		625.90	1,755.65	101.04	2,482.59

(a) Total cost figures are taken from the Cumulative Report, July 26, 1954, for Project CG-431-B.

(b) These "side shields" consist of Inlet, Outlet, Left and Right sides of the biological shield at 105-C. They are composed of laminated layers of steel plate and masonite.

(c) The construction and composition of these shields are similar to the top and bottom shields of 105-K, in that they are composed of high density concrete of similar composition encased by structural steel forms.

(d) To estimate costs for constructing iron-masonite shields during 1953-1954, these unit costs should be increased approximately 12.0 percent to allow for increases in Hanford building and construction costs occurring after 105-C was completed. See Page 19.

(e) Direct construction costs for the inlet and outlet shields at 105-C may be estimated from the following cost figures prepared by E. W. Jenks, Engineering and Construction Services Unit. These figures are for the fabrication and installation of 220 B-blocks and 162 sub-B-blocks, and do not include costs for tie straps.

	Material	Labor	Freight	Installation	Total
Total Cost (Dollars)	578,438	989,068	77,172	299,136	1,943,814
Unit Cost (\$/cu.yd.)	936	1,600	125	484	3,145

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TABLE 9
COMPARISON OF UNIT CONSTRUCTION COSTS*
FOR BIOLOGICAL SHIELDING AT 105-C AND 105-K

(In dollars per cubic yard of shielding if constructed during 1953-1954)

	<u>Volume</u> (Cubic yards)	<u>Labor</u>	<u>Material</u>	<u>Equipment</u> <u>Usage</u>	<u>Total</u> <u>Unit Cost</u>
<u>Side Shields</u>					
<u>105-K (Steel Forms and Concrete)</u>					
Inlet - Outlet	1203	317	895	114	1326
Left - Right	1822	283	521 ^a	120	924
Average	3025	297	669	118	1084
<u>105-C (Steel and Masonite)</u>					
Inlet & Outlet B-Blocks	618	420	2980	122	3522
L-R Sides & Tie Straps	448	1342	2120	124	3586
Average	1066	807	2619	123	3549
<u>Top Shields (Steel Forms and Concrete)</u>					
<u>105-K</u>	1217	341	365	116	823
<u>105-C</u>	472	461	492	90	1043

*These figures include distributed costs associated with the construction of temporary items in the 105 building such as cranes, badge houses, barricades, clean-up, scaffolding, inspection, layout and boilers. They do not include distributed costs from the 600, 700 and 800 accounts associated with general project construction. Costs presented in Table 7 have been increased 7.1 percent to allow for temporary construction costs at the 105-K buildings.

Costs presented in Table 8 for 105-C have been increased 12.0 percent to allow for general increases in construction costs since 1952. Presented below are values of Hanford cost indices which indicate recent rises in building and construction costs.

<u>Hanford Cost</u> <u>Index</u>	<u>1951</u> <u>January</u>	<u>1952</u> <u>January</u>	<u>1953</u> <u>January</u>	<u>1954</u> <u>January</u>	<u>1955</u> <u>January</u>
Building	194.1	206.3	211.6	218.6	228.3
Construction	258.9	265.0	282.4	292.3	312.8

Procurement for 105-C was initiated in the spring of 1951; the top shield was completed about July 1, 1952. Procurement for 105-K was initiated during the fall of 1952, the top shield at 105-K was completed two years later.

(a) This figure is \$618 or \$424 per cubic yard for the left or right sides at 105-K, respectively. The right side contains magnetite-limonite (Type 3) concrete. The inlet and outlet shields contain iron-limonite (Type 1) concrete. The right side and top shields contain both Type 1 and Type 3 concrete. See drawing H-1-21629.

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TABLE 10
SAVINGS IN CONSTRUCTION AND PROJECT COSTS*
OBTAINED BY USING HIGH DENSITY CONCRETE
INSTEAD OF STEEL AND MASONITE FOR THE
BIOLOGICAL SHIELDS AT 105-K.

	Direct Construction Costs			Total Direct Cost of Construction	Total Cost ^c of Project
	Inlet-Outlet	L. & R. Sides	Top		
EXAMPLE 1 (105-C Type Shield)					
Material	Steel-Masonite	Steel-Masonite	Steel Forms & H. D. Concrete		
Shield Volume (cu. yd.) ^b	1453	1329	1169		
Unit Cost (\$/cu. yd.)	3522	3586	1043		
Shield Cost	5,117,466	4,765,794	1,219,267	11,102,527	14,877,386
EXAMPLE 2 (105-IR Type Shield)					
Material	Steel-Masonite	Steel-Masonite	Steel-Masonite		
Shield Volume (cu. yd.) ^b	1453	1329	799a		
Unit Cost (\$/cu. yd.)	3522	3586	3549		
Shield Cost	5,117,466	4,765,794	2,835,651	12,718,911	17,043,341
EXAMPLE 3 (105-K Biol. Shield)					
Material	Steel Forms and High Density Concrete				
Shield Volume (cu. yd.)	1203	1822	1217		
Unit Cost (\$/cu. yd.)	1326	924	823		
Shield Cost	1,595,669	1,683,190	1,001,322	4,280,181	5,735,443
ESTIMATED SAVINGS IN DOLLARS					
Example 3 over Example 1	3,521,797	3,082,604	217,945	6,822,346	9,141,943
Example 3 over Example 2	3,521,797	3,082,604	1,834,329	8,438,730	\$11,307,898

*See following page for a description of items in Table 10.

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Descriptive Notes For Table 10

- (a) Volumes of steel, masonite and concrete used in Examples 1 and 2 are computed values which would be required to adequately shield the 105-K reactors and provide protection comparable to the present 105-K shields made entirely with steel and high density concrete.
- (b) Values of unit costs are from Table 9.
- (c) To evaluate total project costs for components of the biological shields, distributed costs have been computed as 34 percent of the direct construction costs reported in this report. This additive allows for:
 - (1) The following costs incurred by the General Electric Company: engineering design, construction supervision, and indirect construction costs;
 - (2) Costs associated with the operation and maintenance of the construction camp at North Richland; and
 - (3) Distribution of construction costs from the 600, 700, and 800 accounts and other project costs not included above.

The average amount of distributed costs associated with the cost of constructing items at 105-C is 34.5 percent based upon data given in the Cumulative Report for Project CG-431-B, July 26, 1954. Additives applied to irradiation equipment may be larger than those applied to components of the 105 building. In his "Unitization Report" for Project CA-431, July 14, 1953, E. S. Bell used percentages of 34.8 and 60.3 in evaluating the total project cost for the side shields and top shield, respectively. (See below.)

- (d) Use of steel and masonite in the top shield probably would increase the cost of the 105 Building and Ball Safety System. This factor has not been considered in this study.

Note: (Issue B Only)

The revised Hanford cost indices given on Page 19 indicate that construction costs for 105-K were about 9.0 percent higher than those for 105-C, instead of 12.0 percent. Data given in the Unitization Report of the 100-K Area Facilities (KEC-33) indicate that indirect and distributed costs ran 29.6 percent of direct construction costs for 105-K. Using these revised figures, the savings in total project costs given in Table 10 are now estimated to be:

Example 3 over Example 1 - - - - - \$ 8,443,188

Example 3 over Example 2 - - - - - \$10,479,995

Instead of \$ 9,141,943 and \$11,307,898, respectively.

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