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Category
Hanford Code **C-65**

Date **6-16-66**

RICHLAND FIVE-YEAR

02 R&D PROGRAM

CO-60 PROGRAM

**RICHLAND OPERATIONS OFFICE
DOUGLAS UNITED NUCLEAR, INC.
GENERAL ELECTRIC COMPANY - HAPD
ISOCHEM INC.
BATTELLE - NORTHWEST**

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By Gerri Moley, 11-22-94

Verified By SB Roberts, 12-20-94

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R I C H L A N D F I V E - Y E A R

O 2 R & D P R O G R A M

C O B A L T - 6 0 P R O G R A M

June 16, 1966

RICHLAND OPERATIONS OFFICE

DOUGLAS UNITED NUCLEAR, INC.

GENERAL ELECTRIC COMPANY - HAPD

ISOCHEM, INC.

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RICHLAND FIVE-YEAR

02 R&D PROGRAM

Co-60 PROGRAM

Principal Contributors

C. E. Bowers, Chairman--DUN

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1. STATISTICAL SUMMARY SCHEDULE

Dollars (in thousands)

General Electric (N-Reactor)
Douglas United Nuclear
Isochem
Pacific Northwest Lab

TOTAL

Man Years

General Electric (N-Reactor)
Douglas United Nuclear
Isochem
Pacific Northwest Lab

TOTAL

Equipment (dollars in thousands)

General Electric (N-Reactor)
Douglas United Nuclear
Isochem
Pacific Northwest Lab

TOTAL

1966	1967	1968	1969	1970	1971	5 Year Total
	40	40	75	100	75	330
	40	40	40	40	40	200
						530
	0.8	0.8				
	1.0	1.0				
	1.8	1.8				
		10				

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COBALT-60 PROGRAM

2. INTRODUCTION

Although the market for Co-60 is obviously expanding, the sources of supply are not clearly defined.

The role of the Hanford production-oriented reactors remains uncertain, even though they currently constitute the only available source of massive quantities of intermediate activity Co-60; recent indications of increased participation by commercial power reactors have served to further obscure Hanford's role. Utilization of the Hanford complex in any national cobalt program will be largely dependent upon the level of effort devoted to "incidental" production by commercial test and power reactors during the next few years. The Cobalt-60 Program Mission has, as its main objectives, the clarification of the Hanford position by virtue of demonstrating cobalt production at low unit cost.

The capability exists for the production of 1-2 megacuries of Cobalt-60 per year in reactor test facilities, without attendant displacement of plutonium production; the technology for this production capacity has been fairly well achieved. Further experimental irradiation is necessary to develop the technology for optimum larger scale production utilizing reactor process tubes or requiring extensive loading modifications.

It is estimated that the Richland reactors can produce more than 200 megacuries per year of Co-60 in the 20-60 curies per gram range, or (alternatively) more than 100 megacuries in the 80-100 curies per gram range (including approximately 30 megacuries in N-Reactor graphite cross-cooling channels). In order to achieve maximum production rates, it is necessary to optimize target geometry and density, and to integrate cobalt production with the production of other isotopes.

Efforts during FY66 have been largely concentrated in an Exploratory Cobalt Program administered by the Testing Subsection in Douglas United Nuclear, and in a simultaneous investigation of cobalt production potential in the graphite coolant channels at the N-Reactor. In addition, arrangements have been made for the development of a cobalt coated process tube for investigation of this promising source of Co-60.

3. INCENTIVES

The current and potential market for Co-60 encompasses a broad range of uses, including radiography, medical therapy, nuclear gauging, radiation processing and remote heat sources. It is particularly in the areas of radiation processing and remote heat sources that the low-to-intermediate level activities feasible at Hanford would be utilized. Competition in this range (15-100 curies/gram) is apt to be keen among commercial power reactors; plans have already been disclosed for

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aggressive megacurie production rates of 15-50 curies/gram cobalt-60. However, encouragement can be gotten from the expanding market implications of such industrial activity--it is entirely possible that the unique operating environment of Hanford reactors may produce incidental or production-scale cobalt at minimum attainable cost. Thus a persistent program, incorporating minimal (at least) development and market exploration efforts, appears warranted.

Cobalt production of an "incidental" nature (i.e., with little or no direct sacrifice in plutonium production) may be achieved in several manners, including the following possibilities:

- a. Production in cobalt-coated process tubes
 - b. Production in N-Reactor graphite coolant channels
 - c. Production in peripheral targets charged for reactor shield protection
 - d. Production in reactor test facilities
- (Some items will require supporting enrichment.)

Alternatively, it is conceivable that future market conditions might dictate large- or full-scale production schemes, in which cobalt is produced at the cost of a high level of enrichment. The type of dual operation that would be utilized in such production schemes provides the potential for a large, high intensity gamma irradiator (i.e., after fuel cycle is complete and fuel discharged, use the reactor as a gamma facility); lignin irradiation (to produce desirable polymers) and certain oxo-chemical processes could be exploited in this approach.

At any rate, the possibility of producing and marketing a non-defense product at a level of \$10-\$20 million/year continues to provide a significant incentive for at least demonstrating cobalt production capability. And it is academically obvious that the market potential must be continuously evaluated--thus persisting, even if low level, technical activity is indicated. Accordingly investigative effort will proceed through FY68; if a major market for Cobalt-60 develops prior to July, 1968, large scale production could be initiated within 6-8 months after authorization.

4. SCOPE AND OBJECTIVES

The Cobalt-60 Program was designed to achieve the following objectives:

- a. Define the capability of the Richland reactors to produce massive quantities of Co-60 at minimum unit cost.
- b. Demonstrate the capability of the Richland reactors to produce massive quantities of Co-60 by irradiation of test quantities of cobalt in prototypic reactor loading schemes.

The program, in achieving these two major objectives, will, of necessity, explore various associated areas, including: 1) applications in terms of specific activity, geometry, and potential uses of irradiated cobalt as determined in the cobalt MFC study^{8/}; 2) cobalt heat generation characteristics; 3) encapsulation requirements; and 4) control and measurement of target activity.

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5. PROGRESS DURING REPORT PERIOD

Experimental and small-scale production irradiations were completed in representative Hanford production reactor test facilities, and two C-Reactor overbore tubes were charged with cobalt, with target activities of approximately 40 and 100 curies/gram. Arrangements were made to acquire a cobalt coated process tube for irradiation and analysis. Plans were completed for the near-future irradiation of two single-strip loadings in the N-Reactor graphite coolant system tubes. Encapsulation and post-irradiation handling problems were examined and, for the most part, resolved; no significant complications are expected in this area. A calorimeter was designed and fabricated for routine assay of irradiated cobalt targets of any shape. A total of 92,500 curies of low activity cobalt was produced for the Isotope Sales Department, ORNL. Cobalt physics and operating parameters were established.

6. BUDGET PERIOD PLANS AND EXPECTED RESULTS

Work will proceed to firmly establish cobalt production capability and cost. The following specific objectives will be pursued, with estimated achievement schedules as indicated:

1. Secure technology for producing megacurie quantities of cobalt-60 with activities of up to 100 curies/gram --July, 1967.
2. Define encapsulation problems and recommend solutions --January, 1967.
3. Produce test quantities of Co-60 with varying activities of up to 40 curies/gram using prototypic reactor loading schemes--June, 1966.
4. Demonstrate theoretically the capability for large scale production of cobalt-60 with specific activity of 40 curies/gram--January, 1967.
5. Investigate feasibility and costs of cobalt production in coated process tubes and recommend program--July, 1967.
6. Demonstrate formally the feasibility of cobalt production at a cost of \$0.10 per curie--1970.

7. EVALUATION OF PROGRESS AGAINST PLANS AND OBJECTIVES

Progress during this initial report period has reasonably paralleled expected results. Original scheduling called for achieving the milestones "Secure technology for megacurie quantities of Co-60 with activities of

- (a) 20-60 curies per gram - January, 1966
- (b) 100 curies per gram - July, 1967, and

"Produce test quantities of Co-60 with an activity of 40 curies per gram using prototypical reactor loading schemes - July, 1966."

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PROGRAM SUMMARY CHART

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1966

January February March April May June July August September

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PROGRAM SUMMARY CHART (CON'T)

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1968

June July August September October November December January

DUN analyze ex-
perimental and
production results
of Cobalt Program

DUN issue report
and evaluate pro-
duction alterna-
tives

DUN secure
technology
for produc-
tion at 100
curies/gram

Evaluate co-
balt produc-
tion in coated
tubes; issue
report

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These objectives have essentially been attained. Cobalt has been irradiated up to 40 curies/gram in Testing facilities; in addition, two irradiations which are now in progress will produce activities up to 100 curies/gram with no procedural changes.

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MISSION 8
DUN COBALT-60 PROGRAM SUMMARY

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2. DUN SCOPE AND OBJECTIVES

The DUN scope and objectives are identical with overall Program objectives, namely:

Define and demonstrate the capability of the Richland reactors to produce massive quantities of Co-60.

3. PROGRESS DURING REPORT PERIOD

Specific progress has been made toward Cobalt-60 Mission goals in FY66; accomplishments include:

1. "Exploratory" irradiations/^{1/} were completed in the Hanford Test Reactor and in Testing facilities 3674KW and 2-B Snout KW; a long-term irradiation was initiated in Test Facility 4268KE. The irradiations covered linear densities of 135 grams/foot to 540 grams/foot, with various thicknesses of BNL type strips; in addition, several cobalt foils and cobalt wires were incorporated in the loadings to evaluate flux and rise factor details.
2. Pilot production irradiations were completed in two KER Loop facilities operated in a single pass cooling mode. Final activities for the two charges were 6 and 30 curies per gram, respectively.
3. Two charges were placed in C-Reactor overbore facilities with target activities of 40 and 100 curies per gram for discharge next fiscal year.
4. A Testing Radioisotope Calorimeter (TRIC)/^{2/} was designed and fabricated for accurate, non-geometry-dependent determination of cobalt activity by correlation to heat generation rates (± 3 per cent).
5. A cobalt-60 Source Comparator was designed and operated; this comparator was specifically designed for cobalt irradiation capsules and is accurate to ± 3 percent.
6. A charge distribution was designed/^{3/} to "flatten" the specific activity along the charge length by varying target density along the charge length.
7. Heat transfer limitations were studied and defined./^{4/}

/1/ RL-REA-2394, Exploratory Cobalt Irradiations, T. L. Deobald, 7/25/65.

/2/ DUN-664, TRIC, The Testing Radioisotope Calorimeter, C. B. Organ & V. P. Nichols, to be issued.

/3/ DUN-660, The Optimization of Co-60 Production in the Hanford Testing Facilities, M. H. Montgomery, 2/1/66.

/4/ DUN-177, Cobalt Irradiation Heat Transfer, T. L. Deobald, 11/1/65.

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OPERATIONS OFFICE

U. S. ATOMIC ENERGY COMMISSION
RESEARCH AND DEVELOPMENT STATISTICAL SUMMARY
02 PROGRAM

HAN- _____

1. MISSION NO. AND TITLE <u>Mission 8-DUN: Cobalt-60 Program</u> MISSION SUB-PROGRAM TITLE _____		2. BUDGET ACTIVITY NO. _____
3. CONTRACTOR AND CONTRACTOR NUMBER	A. <u>Douglas United Nuclear, Inc.</u> B. _____ C. _____	4. PERSON IN CHARGE: <u>T. W. Ambrose</u> INVESTIGATOR: <u>C. E. Bowers</u> INVESTIGATOR: _____

FIVE YEAR FORECAST

	CURRENT BUDGET YEARS *		FY 19	FY 19	FY 19	5 YEAR TOTAL
	FY 1967	FY 1968				
5. MAN-YEARS						
A) SCIENTIFIC AND TECHNICAL	1.0	1.0				
B) OTHER	0	0				
TOTAL	1.0	1.0				
6. COSTS (\$000'S)	\$	\$	\$	\$	\$	\$
A) DIRECT LABOR (INCL. COST OF SERV.)	20	20				
B) MATERIALS, TECH. SERV., SUB CONTRACTS	12	13				
C) SPONSORED WITH BNW	0	0				
TOTAL DIRECT	32	33				
D) INDIRECT EXPENSES	8	7				
TOTAL OPERATING COSTS	40	40				
E) EQUIPMENT (NEW)	10					
F) IRRADIATION UNIT COSTS						

7. COMMENTS:

* AGREES WITH SCHEDULE 189

PREPARED BY C. E. Bowers

DATE 5-10-66

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8. Vendors were compared and funding arrangements completed for development of a cobalt-coated process tube for irradiation and evaluation.
9. The use of cobalt as reactor shield protection was proposed; evaluation will not be complete until FY67.

4. BUDGET PERIOD PLANS

The DUN Co-60 budget period plans are:

Complete the Exploratory Cobalt Program and secure technology for producing megacurie quantities of intermediate-activity cobalt in the reactor test facilities

Establish technology for large-scale production of cobalt in the 0-100 curies/gram range, utilizing production facilities

Evaluate feasibility of Co-60 production in coated process tubes

Define and resolve encapsulation and handling problems

Assess use of cobalt as protection for reactor shields and evaluate attendant production potential

Periodically adjust program level as indicated by market status (per cobalt MFC).

5. REFERENCE REPORTS ISSUED

1. R1-REA-2394, Exploratory Cobalt Irradiations, T. L. Deobald, 7/25/66.
2. DUN-177, Cobalt Irradiation Heat Transfer, T. L. Deobald, 11/1/65.
3. DUN-660, Optimization of Cobalt-60 Production in the Hanford Testing Facilities, M. H. Montgomery, 2/2/66.
4. DUN-609, Cobalt-60 Source Comparator, C. B. Organ, 1/26/66.
5. DUN-664, TRIC, The Testing Radioisotope Calorimeter, C. B. Organ and V. P. Nichols (to be issued).
6. DUN-992, Interim Report - Exploratory Cobalt Irradiations, M. H. Montgomery, to be issued.
7. DUN-961, Alternate Co-60 Production Methods, L. E. Kusler, 4/13/66.
8. DUN-849, Study of Applications for Hanford Produced Cobalt-60, L. E. Kusler, 4/26/66.

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COBALT-60 PROGRAM - MISSION 8-GE

SUMMARY

Capabilities of 30 megacuries per year with specific activities up to 85 curies per gram per year in N-Reactor graphite cross coolant channels estimated.

Basic technology of irradiating cobalt targets well established.

Techniques for encapsulation established.

Test quantities of BNW standard cobalt strips exist.

Target designed and compatibility with graphite cross coolant environs established.

Commence irradiation to establish specific activities of 40 curies per gram and 150 curies per gram during May, 1966.

Should a major market for Co-60 materialize prior to July, 1968, an accelerated program could initiate production as early as 6 to 8 months after authorization.

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RESEARCH AND DEVELOPMENT STATISTICAL SUMMARY

02 PROGRAM

HAN- _____

1. MISSION NO. AND TITLE <u>Mission 8-GE: Cobalt-60 Program</u>		2. BUDGET ACTIVITY NO. <u>2000 R&D</u>	
MISSION SUB-PROGRAM TITLE _____		_____	
3. CONTRACTOR AND <u>A. General Electric Company</u>		4. PERSON IN CHARGE: <u>M. C. Leverett</u>	
CONTRACTOR <u>B.</u>		INVESTIGATOR: <u>J. W. Riches</u>	
NUMBER <u>C.</u>		INVESTIGATOR: <u>E. G. Pierick</u>	

FIVE YEAR FORECAST

	CURRENT BUDGET YEARS *		FY 19	FY 19	FY 19	5 YEAR TOTAL
	FY 19 67	FY 19 68				
5. MAN-YEARS						
A) SCIENTIFIC AND TECHNICAL	0.8	0.8				
B) OTHER						
TOTAL	0.8	0.8				
6. COSTS (\$000'S)	\$	\$	\$	\$	\$	\$
A) DIRECT LABOR (INCL. COST OF SERV.)	10	11				
B) MATERIALS, TECH. SERV., SUB CONTRACTS	7	5				
C) SPONSORED WITH BNW	8	8				
TOTAL DIRECT	25	24				
D) INDIRECT EXPENSES	15	16				
TOTAL OPERATING COSTS	40	40				
E) EQUIPMENT (NEW)						
F) IRRADIATION UNIT COSTS						
7. COMMENTS:						

* AGREES WITH SCHEDULE 189

PREPARED BY E. G. Pierick

DATE _____

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2. GE SCOPE AND OBJECTIVES

The objective of the cobalt-60 program is to develop the capability of N-Reactor to satisfy markets for Co-60 in the 10-20 megacurie per year range at low unit cost by July, 1968.

The scope of work will include: (a) the determination of future modes of reactor loading and operation for the production of Co-60, (b) the optimization of these loadings to produce low-cost Co-60, (c) the development and implementation of these tests to verify calculated production rates, (d) the evaluation of these tests and extrapolation to full capacity loadings, (e) the determination of encapsulation problems and recommended solutions, (f) the evaluation of a modified Szilard-Chalmer technique to produce high activity cobalt, and (g) the determination of suitability and advisability of N-Reactor to participate as a Co-60 source supplier.

3. PROGRESS DURING REPORT PERIOD

The basic technology of irradiating cobalt targets to produce Co-60 is well established. Despite the fact that reactor-grade cobalt is difficult to shape because it is brittle, cobalt is readily available in forms suitable for encapsulation into targets for irradiation and no chemical separation process is required after irradiation. Cobalt is dimensionally stable during irradiation, provided the target temperature is less than 430 C. At about 430 C, cobalt undergoes a phase change. This change may be of some consequence to dimensional stability if, during irradiation, the cobalt internal temperatures reaches the transformation temperature. Pure cobalt's corrosion behavior is similar to pure iron. In hot, pure water it forms an oxide scale that tends to flake off. Encapsulation of the cobalt in stainless steel isolates the cobalt from the water, makes targets compatible with cooling water and constitutes the primary barrier for the end-use after irradiation.

Techniques for encapsulating cobalt in stainless steel have already been developed at Brookhaven National Laboratories (BNL).

As a gamma heat source, cobalt-60 is predicted to be the primary competitor with other gamma emitters with price the probable deciding factor. Studies conducted to date provide the groundwork for selecting the best-suited locations in the N-Reactor to produce low-cost Co-60. Of prime interest is the use of the graphite cross coolant system. The in-reactor portion of the graphite cooling system consists of 640 Zircaloy tubes penetrating the moderator from side to side. These tubes are 3/4-inch in diameter. In this location, valuable plutonium-producing fuel is not displaced from the reactor. Also, through prudent placement of the cobalt in the graphite cooling system, additional radial flattening of the reactor could be obtained, permitting easier achievement of maximum reactor power and increased neutron economy. Standard BNL cobalt strips have been selected as the target shape for the initial studies.

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Cobalt targets that have been designed for use in the graphite cross coolant tubes are capable of being charged and discharged from the reactor. Also, tests in the experimental cross coolant mockup indicate that the target is free from vibration under normal flow as well as coolant flow up to 40 percent above normal flow. Preliminary investigation indicates that the target design will comply with chemistry and metallurgy, thermal hydraulics and physics parameters. A sufficient inventory of BNL standard cobalt strips for testing purposes exists at N-Reactor.

4. BUDGET PERIOD PLANS AND EXPECTED RESULTS

An engineering study has shown that to produce Co-60 in the range of 10 to 20 megacuries per year in N-Reactor at a cost of \$0.10 per curie requires an experimental program to optimize the reactor loading scheme for particular activity levels to verify production rates. Program plans are geared to perform tests with small quantities of cobalt to develop the capability of N-Reactor as an efficient supplier of large quantities of Co-60 by July, 1968. Should a major market for Co-60 materialize prior to July, 1968, an accelerated program could initiate production as early as 6 to 8 months after authorization, however, at a less advantageous position on the learning curve.

During FY67, test quantities of cobalt will be charged into the graphite coolant system tubes for irradiation to measure the effective thermal and epithermal flux levels and the production rates for this reactor loading scheme. Engineering aspects of the large-scale utilization of the graphite cooling system tubes for target irradiations will be evaluated.

Results of these tests will be incorporated into a parametric study of reactor loading schemes to establish production rates for Co-60 of specific activity levels ranging from 30 to 150 curies per gram.

Other activities in support of cobalt in graphite cross coolant are:

- Determine the post-irradiation handling system requirements for large-scale high specific activity cobalt.

- Confirm that target design is compatible with the chemistry and metallurgy, thermal hydraulics and physics of N-Reactor.

- Determine potential benefits from flattening of reactor by cobalt.

- Determine the suitability and advisability of N-Reactor to participate as a Co-60 source supplier.

Longer range plans include making studies and in-reactor testing to determine if advantage can be taken of the recoil neutron energy to excite Co-60 atoms to a state where it is susceptible to a metatheses reaction (modified Szilard-Chalmer technique) and thus provide a means

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for obtaining essentially pure Co-60 (specific activity of 1130 curies per gram). Also, determine method of producing Co-60 with uniform specific activity by controlled movement of the targets through the reactor.

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