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ORNL-3955, Vol. I
Special

HISTORY OF THE AEC SODIUM COMPONENTS
DEVELOPMENT PROGRAM

Volume I

Edited by H. W. Savage

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

OAK RIDGE NATIONAL LABORATORY

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UNION CARBIDE CORPORATION

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Reactor Division

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DECEMBER 1966

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
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FOREWORD

The assembly and preparation of background information for this document was initiated and carried essentially to completion under the direction of the late H. Wesley Savage, a long-time member and active participant in the deliberations of the Sodium Components Development Program Working Group. It is a tribute to his interest in the broad area of liquid-metals technology and to his intimate familiarity with the work in this field in the United States that this History of the Sodium Components Development Program was conceived with the wide scope reflected by the final document. The material he accumulated and organized was edited after his death by W. R. Huntley and R. E. MacPherson of Oak Ridge National Laboratory.

We believe this History will be of great interest to those who have had a part in the development of liquid-metal components technology during the last eight to nine years, and we sincerely hope that it will serve as an accurate reflection of the contribution the Sodium Components Development Program Working Group is making to that developing technology.

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December 1962	1099
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February 1963	1118
March 1963	1127
April 1963	1134
May 1963	1147
June 1963	1158
July 1963	1170
August 1963	1182
September 1963	1191
October 1963	1201
November 1963	1211
December 1963	1219
January 1964	1226
February 1964	1233
March 1964	1241
April 1964	1249
May 1964	1256
June 1964	1264
July 1964	1272
August 1964	1280
September 1964	1290
October 1964	1299
November 1964	1309
December 1964	1319
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INTRODUCTION

The Sodium Components Development Program (SCDP) is an effort sponsored by the United States Atomic Energy Commission to demonstrate, within the industrial complex of the United States, competence for the design and fabrication of safe, reliable, and economical components for advanced sodium-cooled nuclear power plants. Development of the supporting technology required is a further objective.

In 1957 the need for such a program was realized by G. W. Wensch, Civilian Power Reactors Branch, and E. J. Wagner, Naval Reactors Branch. Steps were taken to establish an organization composed of the necessary administrative, technical, and legal representatives from the AEC, industry, and the national laboratories. A technical advisory group was formed called the Sodium Components Development Working Group, whose function it was to review the current status of sodium components technology, recommend those areas in which work was required by industry, formulate requests for proposals in these areas, and monitor the progress of subsequent AEC contracts for this work. Closely following establishment of the Working Group, it was necessary to establish the Sodium Components Development Program Contractor Selection Board, which was charged with the responsibility of evaluating proposals for component development and related work and recommending contractors to be assigned responsibility in these areas.

The Sodium Component Development Working Group has been continuously active since its establishment in 1957 in fulfilling those commitments to the AEC for which it was originally established. A total of 38 meetings had been held up to July 1, 1965. Five of these meetings (three in the last three years) were information meetings with a broad attendance by domestic and foreign workers in the field of liquid-metals technology. The information meetings are one of the many ways in which the SCDP fulfills its commitment to coordinate and to foster the exchange of sodium components technology. Of the 38 meetings, 26 involved the direct review of work in progress by contractors to the SCDP and thus brought to bear

on specific development problems the wide and varied viewpoints of the technical experts attached to the Working Group.

In 1963 the original Working Group was dissolved and a new organization formed with membership restricted to personnel from the AEC and the national laboratories. This newly formed group included several of the previous members who, along with the new members, have continued the successful pursuit of the program's objectives up to the present time. Appendix A contains the charter for the Sodium Components Development Program, which was drawn following reorganization of the Group in 1963. This charter contains the procedures by which the Group is functioning currently.

The Contractor Selection Board was very active in the early phases of the Sodium Components Development Program, as was required to get necessary work under way. Throughout 1958 and the first half of 1959, all areas in which the Working Group had proposed programs received active consideration. Those programs wherein work was approved by the AEC were carried through solicitation, proposal review, and contractor recommendation. Once those major elements of the program were under way, the Contractor Selection Board ceased to function as an active entity; and its role was taken over by ad hoc selection boards appointed as necessary.

The remaining arm of the Sodium Components Working Group has been the subcommittees appointed to monitor specific programs and report to the Working Group. These subcommittees were used extensively from the earliest days of the program and continue to perform a useful and irreplaceable function.

SODIUM COMPONENTS DEVELOPMENT PROGRAM WORKING GROUP

The Working Group had its roots in a meeting called at AEC Headquarters in Washington, D.C., on January 30, 1957. This meeting was sponsored by the Civilian Power Reactors Branch and the Naval Reactors Branch of the AEC. The purpose was to discuss the status of sodium steam-generator technology with industrial representatives and to determine what course should be taken in this respect in view of the developing interest in sodium-cooled power reactors. Attendees at the first meeting were

Members

G. W. Wensch, Chairman	AEC-Washington
R. W. Dickinson	Atomics International
J. J. Morabito	Atomic Power Development Associates
W. R. Simmons	Argonne National Laboratory
F. A. Smith	AEC-Chicago
W. R. Wykoff	Los Alamos Scientific Laboratories

Alternates and Others

A. Amorosi	Atomic Power Development Associates
F. W. Davis	AEC-Washington
W. D. Gilbert	AEC-Washington
W. C. Hayes	Atomics International
T. M. Hotchkiss	Southern California Edison
D. O. Leeser	Atomic Power Development Associates
R. A. Noland	Argonne National Laboratory
J. M. Simmons	AEC-Washington
A. M. Stelle	Atomics International
J. L. Van Ullen	Knolls Atomic Power Laboratory
J. T. Wader	Los Alamos Scientific Laboratories
E. J. Wagner	AEC-Washington
A. C. Werden	Southern California Edison
R. D. Wylie	Babcock & Wilcox

One year later, on February 27, 1958, the first meeting of the newly formed Working Group was held. Appendix B contains minutes of all but one meeting of this group (most formally issued, several reconstructed from notes of attendees) during the period January 30, 1957 to June 18, 1965. Table 1 shows the total membership throughout this period and records attendance at all meetings. Table 2 lists the names of all alternates and others who attended meetings of the group. Table 3 indicates the industrial organizations involved in the program and the component development program on which they worked. Also listed are the meetings at which the industrial contracts were discussed. Table 4 gives the date and location of the Working Group meetings, with an indication of the type of meeting (information, executive, contractor review), and specifies the contractors whose work was reviewed at each meeting.

Table 1. SCDP Working Group Membership and Meeting Attendance

	Jan. 30, 1957	Feb. 27-28, 1958	Mar. 27-28, 1958	May 1-2, 1958	May 26-27, 1958	June 10-11, 1958	Aug. 5-6, 1958	Sept. 10-12, 1958	Oct. 16-17, 1958	Nov. 14, 1958	Dec. 12, 1958	Feb. 18-20, 1959	Mar. 19-20, 1959	Apr. 30-May 1, 1959	Sept. 16-18, 1959	Dec. 10-11, 1959	Jan. 28-29, 1960	Mar. 10-11, 1960	Apr. 27-28, 1960	June 16-17, 1960	Aug. 11-12, 1960	Sept. 15-16, 1960	Nov. 2-4, 1960	Dec. 8-9, 1960	Mar. 15-17, 1961	May 25-26, 1961	Oct. 4-6, 1961	Jan. 10-12, 1962	Mar. 21-22, 1962	June 5-6, 1962	Oct. 10-11, 1962	May 13-14, 1963	Aug. 20-21, 1963	Jan. 16-17, 1964	Apr. 17-18, 1964	June 11-12, 1964	Nov. 16-17, 1964	Mar. 3-4, 1965	June 16-18, 1965			
Meeting No.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38			
Working group chairmen and affiliations																																										
J. F. Kaufmann, AEC-Wash (IDO)		X	X	X	X	X	X																	X	X	X	X	X				X	X							X		
T. A. Nemzek, AEC-CH (San)				X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X			X	X	X	X	X	X	X	X		
G. W. Wensch, AEC-Wash	X																																								X	
Working group members and consultants and affiliations																																										
R. E. Aronstein, AEC-CH (CP)																								X		X			X													
C. A. Barrett, NASA-Cleve																										X			X													
R. W. Dickinson, AI	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								X	X	
J. J. Dissler, AEC-NY																												X	X	X	X	X										
O. E. Dwyer, BNL																																										
K. Goldmann, UNC			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	
R. E. Harris, AEC-Wash (Tenn)													X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									
T. P. Heckman, AEC-CH										X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
J. P. Holliday, AEC-San												X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X			X	X	X			X	
I. E. Jackson, AEC-Wash						X	X	X		X																											X	X	X			
R. H. Jones, AEC-Wash																																										
R. W. Lockhart, GE-APED							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X		
J. J. Morabito, APDA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									
A. E. Mravca, AEC-CH							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X		
J. J. Purcell, AEC-CH																																										
C. A. Pursel, AEC-CH																																										
C. W. Richards, AEC-CP																																										
H. W. Savage, ORNL							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
W. R. Simmons, ANL	X																																									
F. A. Smith, ANL, AEC-CH (ANL)	X	X	X	X		X	X	X	X		X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
T. Trocki, GE-APED		X		X	X	X																																				
J. Wise, AEC-NY																																										
W. R. Wykoff, LASL	X														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		

Table 2. Alternates and Other Participants in
Meetings of the SCDP Working Group

Alternates and Others		Numbers of
Name	Affiliation	Meetings Attended (see Table 1)
R. Anderson	APDA	14, 15
A. Amorosi	APDA	0
C. V. Backlund	AEC-SAN	37
J. A. Bailey	AEC-SAN	34, 37
G. Billuris	GE-APED	15
F. W. Davis	AEC-Wash	0
J. P. DeKany	AEC-CP	28
J. H. DeVan	ORNL	24, 30
J. P. Duffy	AEC-SAN	37
A. G. Fremling	AEC-CH	28, 31
R. J. Gariboldi	AEC-CH	35, 36, 37
W. D. Gilbert	AEC-Wash	0
G. C. Gower	AEC-CH	33, 34, 35, 36, 37, 38
W. T. Hallett	AI	29
W. C. Hayes	AI	0
K. C. Hoffman	BNL	38
T. M. Hotchkiss	So. Cal. Ed.	0
J. R. Humphreys	ANL (LASL)	12, 18, 29
K. D. Kuczen	ANL	20, 23, 38
D. P. Kuntz	AEC-Wash	34
D. O. Leaser	APDA	0
J. V. Levy	AEC-CP	31
R. E. MacPherson	ORNL	30, 34, 36, 38
W. B. McDonald	ORNL	7, 8, 12, 15, 28, 30
J. M. McKee	UNC	26
W. T. Morgan	AI	14
L. R. Nichols	NASA	25
R. A. Noland	ANL	0
G. V. Packer	AEC-Wash	21, 28
D. E. Pollock	AEC-Wash	28
J. B. Radcliffe	AEC-SAN	37
L. Redecke	AEC-CH	33, 36
O. Seim	ANL	13
J. M. Simmons	AEC-Wash	0
A. M. Stelle	AI	0
D. C. Thomas	AEC-Wash	28
J. L. Van Ullen	KAPL	0
J. T. Wader	LASL	0
E. J. Wagner	AEC-Wash	0
A. C. Werden	So. Cal. Ed.	0
L. A. Whinery	LASL	20, 38
J. E. Wimberg,	AEC-CH	36, 38
R. D. Wylie	B&W	0
J. Yevick	APDA (AEC-Wash)	29

Table 3. Contractor Attendance at Working Group Review Meetings

Contractor	Work	Numbers of Meetings Attended (see Table 1)
American Locomotive Company (ALCO)	Heat exchanger, steam generator (first unit)	7, 11, 15, 20, 22, 23, 24, 25, 26, 27, 28, 31
Atomics International (AI)	Sodium components test installations, steam generator, miscellaneous	14, 16, 18, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 37
Atomic Power Development Associates (APDA)	Sodium technology, sodium-water reaction	13, 14, 15, 25, 28, 29, 30, 31, 36, 38
Babcock & Wilcox Company (B&W)	Steam generator (second unit)	31, 36, 38
Baldwin-Lima-Hamilton Corporation (BLH)	Steam generator (first unit)	30, 31
Battelle Memorial Institute (BMI)	Oxide analysis	14, 17, 24, 28
Combustion Engineering, Inc. (CE)	Heat exchanger, steam generator (first unit)	8
Crane Company (CR)	Flow controller	13
General Electric Company (GE-APED)	Mass transfer	14, 15, 16, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 37
Griscom-Russell Company (GR)	Heat exchanger, steam generator (first unit)	7
Mine Safety Appliances Research Corporation (MSAR)	Mechanical properties	16, 24, 26, 28, 31
Ohio Injector Company (OI)	Flow controller	9
United Nuclear Company (NDA-UNC)	Oxide meter, miscellaneous	14, 15, 16, 21, 24, 25, 26, 28, 29, 30, 31
Westinghouse Electric Corporation (WE)	Flow controller, cold traps, sodium pump test facility	31

Table 4. Meetings of SCDP Working Group

Number	Date	Location	Information Meeting	Executive Meeting	Contractor Review	Contractors Reporting
0	January 30, 1957	AEC Headquarters, Washington, D.C.		X		
1	February 27-28, 1958	AEC Headquarters, Washington, D.C.		X		
2	March 27-28, 1958	Atomics International, Canoga Park, California		X		
3	May 1-2, 1958	Argonne National Laboratory, Argonne, Illinois		X		
4	May 26-27, 1958	Atomic Power Development Associates, Detroit, Michigan		X		
5	June 10-11, 1958	AEC Headquarters, Washington, D.C.		X		
6	August 5-6, 1958	AEC Headquarters, Washington, D.C.	X	X		
7	September 10-12, 1958	Griscom-Russell Co., Massillon, Ohio		X	X	GR
		American Locomotive Co., Schenectady, New York		X	X	ALCO
8	October 16-17, 1958	Combustion Engineering Corp., Chattanooga, Tennessee		X	X	CE
		Oak Ridge National Laboratory, Oak Ridge, Tennessee		X		
9	November 14, 1958	AEC Chicago Operations, Argonne, Illinois		X	X	OI
10	December 12, 1958	Nuclear Development Associates, White Plains, New York		X		
11	February 18-20, 1959	AEC Chicago Operations, Argonne, Illinois		X	X	ALCO, CE, GR
12	March 19-20, 1959	Atomics International Canoga Park, California		X		
13	April 30-May 1, 1959	Atomic Power Development Associates, Detroit, Michigan		X	X	CR, APDA
14	September 16-18, 1959	General Electric Company, San Jose, California		X	X	GE, BMI, AI, NDA, APDA, WE
15	December 10-11, 1959	AEC Chicago Operations, Argonne, Illinois		X	X	GE, APDA, NDA, ALCO
16	January 28-29, 1960	Atomics International, Canoga Park, California		X	X	AI, MSAR, GE, NDA
17	March 10-11, 1960	Battelle Memorial Institute, Columbus, Ohio		X	X	BMI
18	April 27-28, 1960	Los Alamos Scientific Laboratory, Los Alamos, N. Mexico		X	X	AI
19	June 16-17, 1960	Atomic Power Development Associates, Detroit, Michigan		X		
20	August 11-12, 1960	American Locomotive Co., Schenectady, New York		X	X	ALCO
21	September 15-16, 1960	Du Pont Co., Niagara Falls, New York		X	X	AI, CE, NDA
22	November 2-4, 1960	AEC Idaho Operations, Idaho Falls, Idaho		X	X	ALCO
23	December 8-9, 1960	AEC Chicago Operations, Argonne, Illinois		X	X	ALCO, GE, AI
24	March 15-17, 1961	Atomics International, Canoga Park, California		X	X	AI, GE, MSAR, NDA, BMI, ALCO
25	May 25-26, 1961	Consumers Public Power District, Lincoln, Nebraska	X	X	X	ALCO, AI, CE, NDA, APDA
26	October 4-6, 1961	General Electric Company, San Jose, California		X	X	GE, ALCO, AI, MSAR, NDA
27	January 10-12, 1962	AEC Chicago Operations, Argonne, Illinois		X	X	AI, ALCO GE
28	March 21-22, 1962	AEC Headquarters, Washington, D.C.		X	X	ALCO, AI, APDA, MSAR, GE, UNC, BMI
29	June 5-6, 1962	NASA Lewis Research Center, Cleveland, Ohio		X	X	AI, UNC, APDA, GE
30	October 10-11, 1962	Oak Ridge National Laboratory, Oak Ridge, Tennessee		X	X	BLH, AI, GE, UNC, APDA
31	May 13-14, 1963	AEC Headquarters, Washington, D.C.		X	X	UNC, APDA, MSAR, B&W, ALCO, AI, WE, GE
32	August 20-21, 1963	Rickey's Studio Inn, Palo Alto, California	X	X		
33	January 16-17, 1964	AEC Headquarters, Washington, D.C.		X		
34	April 17-18, 1964	Hollywood Roosevelt Hotel, Hollywood, California	X	X		
35	June 11-12, 1964	AEC New York Operations, New York		X		
36	November 16-17, 1964	AEC Chicago Operations, Argonne, Illinois		X	X	APDA, B&W
37	March 3-4, 1965	AEC San Francisco Operations, Berkeley, California		X	X	GE, AI
38	June 16-18, 1965	Pick-Congress Hotel, Chicago, Illinois	X	X	X	APDA, B&W

SODIUM COMPONENTS DEVELOPMENT PROGRAM
CONTRACTOR SELECTION BOARD

The Contractor Selection Board (CSB) was formed by authority of the Director of the Division of Reactor Development on April 14, 1958 to solicit proposals and to recommend award of cost-type contracts for the development, design, manufacture, and testing of improved, less expensive, and more reliable components for use in sodium systems. Table 5 itemizes the meetings and the membership of the CSB during its period of formal existence.

The 19 priority items in sodium technology are listed below that were recommended initially to the Board by the Working Group as requiring investigation:

1. Heat exchanger and steam generator
2. Sodium components test facility
3. Flow control valves
4. Low-level oxide analysis
5. Mass transfer studies
6. Physical properties of materials
7. Shell-side heat transfer
8. Continuous oxide-concentration meter
9. Detector for hydrogen in sodium
10. Device for removal of sodium vapor from gas
11. Detector for sodium vapor in gas
12. Improved thermocouples
13. Level gage
14. Flowmeter
15. Sodium isotope exchange
16. Devices for inspection in sodium
17. Examination of used components and storage of equipment
18. Miscellaneous
19. Sodium frosting research

During its tenure, the CSB was instrumental in contract negotiations involving items 1 through 6 and 9, which were the items considered most important and on which clear-cut development programs could be formulated. After the initiation of these programs, contractor selection activity was insufficient to justify continued existence of the Board, and ad hoc procedures were adopted.

Table 5. Meetings of Sodium Components Selection Board and Attendance^a

	May 28, 1958		June 5-6, 1958		June 16-19, 1958		July 8-9, 1958		Aug. 4-8, 1958		Aug. 18, 1958		Nov. 13, 1958		Dec. 1, 1958		Dec. 24, 1958		Jan. 2, 1959		Jan. 16, 1959		Feb. 12, 1959		Mar. 9, 1959		Mar. 13, 1959		Mar. 23, 1959		Mar. 25, 1959		Apr. 7, 1959		May 19, 1959	
Meeting No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																		
Committee established by	← DRD →						← COO →																													
Attendance																																				
W. M. Babb, AEC-Wash	C	C	C	C		C																														
R. F. Berent, AEC-CH								A(NS)	A(NS)						A(NS)	A(NS)	A(NS)	A(NS)																		
J. A. Erlewine, AEC-CH																																				
R. S. Gruhn, AEC-CH	A	A	A	A	A	A	LA	LA																												
R. C. Hageman, AEC-CH																																				
R. E. Harris, AEC-Wash																																				
T. P. Heckman, AEC-CH							S	S	S		S	S	S	S																						
J. R. Humphreys, Jr., ANL																																				
I. E. Jackson, AEC-Wash																																				
J. P. Jewett, AEC-CH							TA																													
J. F. Kaufman, AEC-Wash	T	T	T	T	T(C)	T	T	T	T																											
J. J. King, AEC-Wash	S	S	S	S	S	S																														
E. G. Kunz, AEC-CH																																				
C. C. McSwain, AEC-CH							T	T	T																											
T. A. Nemzek, AEC-CH		T	T	T	T		C	C	C																											
M. B. Powers, AEC-CH	A	A	A	A	A	A	T	T	T																											
F. A. Smith, ANL			TA	TA	TA	TA																														
E. B. Stephenson, AEC-CH																																				
T. F. Thulstrup, AEC-CH							A(NS)		A(NS)																											
J. Yore	O																																			
Meeting followed Sodium Components Committee meeting No. (see Table 4)	4	4	5	5	5	6	8	9	10	10	10	10	11	11	12	12	12	13																		

^aLegend:

A - Alternate	O - Observer
C - Chairman	S - Secretary
LA - Legal advisor	T - Technical member
NS - Not specified	TA - Technical advisor

SUBCOMMITTEES

Throughout the history of the Sodium Components Development Program, the use of subcommittees has been common. Table 6 lists the subcommittees that were formed, and Appendix C contains the available reports of subcommittee meetings.

Table 6. Sodium Components Development Program Subcommittees

Committee	Membership	Formed	Remarks
Shell Side Heat Transfer	H. W. Savage, ORNL R. W. Dickinson, AI K. Goldmann, UNC	March 1960 at SCDP meeting 17	See Appendix C for subcommittee reports
Griscom-Russell Once-Through Steam Generator	F. A. Smith, ANL W. R. Simmons, ANL J. J. Morabito, APDA R. W. Lockhart, GE-APED	April 1960 at SCDP meeting 18	Ad hoc committee; filed one report; see Appendix C
Mechanical Properties of Materials	K. Goldmann, UNC W. F. Anderson, AI J. H. DeVan, ORNL G. Stern, NDA T. P. Heckman, AEC-CH J. J. Purcell, AEC-CH J. M. McKee, UNC C. J. Klamut, BNL	April 1960 at SCDP meeting 18	See Appendix C for subcommittee reports
Effects and Analysis of Carbon in Sodium	R. W. Lockhart, GE-APED Jules Wise, AEC-NY T. P. Heckman, AEC-CH	August 1960 at SCDP meeting 20	Conducted series of round-robin analyses; report on first round-robin carbon analysis in Appendix C
Mass Transfer	H. W. Savage, ORNL J. H. DeVan, ORNL J. M. McKee, UNC D. I. Sinizer, AI J. P. Holliday, AEC-SAN	Approximately December 1960 (first report to SCDP meeting 24)	See Appendix C for subcommittee reports
Sodium Components Test Installation Design Review	C. W. Richards, AEC-CP J. J. Morabito, APDA R. W. Lockhart, GE-APED H. W. Savage, ORNL W. R. Wykoff, LASL R. E. Aronstein, AEC-CH	Approximately March 1961 (first report to SCDP meeting 25)	Ad hoc committee; see Appendix C for available report
Steam Generator Optimization	W. R. Simmons, ANL	Approximately October 1961 (first report to SCDP meeting 27)	Other members unrecorded; ad hoc committee; no subcommittee minutes available
Steam Generator Testing	A. E. Mravka, CH G. C. Gower, CH K. D. Kuczen, ANL K. C. Hoffman, BNL R. E. MacPherson, ORNL L. A. Whinery, IASL	August 1963 at SCDP meeting 32	See Appendix C for subcommittee reports and status reports to Working Group
Long-Range Planning	Jules Wise, AEC-NY O. E. Dwyer, BNL R. E. Harris, AEC-Wash	August 1963 at SCDP meeting 32	USAEC Report NYO-10725 issued

Table 6 (continued)

Committee	Membership	Formed	Remarks
Babcock & Wilcox proposal for Sodium-Water Reaction Studies	F. A. Smith, AEC-CH W. R. Wykoff, LASL W. R. Simmons, ANL O. E. Dwyer, BNL	Approximately May 1963 (first report to SCDP meeting 32)	Ad hoc committee; no subcommittee minutes available
Analytical Procedures for Sodium	Jules Wise, AEC-NY R. W. Lockhart, GE-APED R. W. Bane, ANL C. F. Metz, LASL J. C. White, ORNL D. T. Eggen, AI L. Newman, BNL F. A. Smith, ANL	Approximately October 1963 (first report to SCDP meeting 33)	Outgrowth of analytical subcommittee established in August 1960
Mass Transfer Program Review	C. A. Pursel, AEC-CH O. E. Dwyer, BNL H. W. Savage, ORNL W. R. Simmons, ANL W. R. Wykoff, LASL C. Klamut, BNL	January 1964 at SCDP meeting 33	See Appendix C for reports of task force

SUMMARY OF DEVELOPMENT PROGRAMS

Early in its history the SCDP, as previously indicated, was responsible for generation of a list of priority development programs that were initiated as the objectives could be defined to the satisfaction of the Working Group, the CSB, and the AEC. Because of the size of the initial task and the rapidly changing state of liquid-metals technology, many of these programs were never thoroughly delineated, were modified to cover other related problems, or were replaced with other development problems that assumed greater importance. A general review of all the development programs carried out to date is presented in the following outlines. We have chosen to group the programs according to specific areas of liquid-metals technology rather than according to any arbitrary size or priority arrangement.

Appendix D contains available invitations to bid on these programs, and Appendices E and F contain detailed replies by all participating contractors and individuals to a standard questionnaire regarding their work. Appendix G contains monthly coordination reports for each active contract in the period January 1962–October 1965.

Effects of Sodium on Containment Materials

Title of program:	Mass Transfer in Sodium Systems
Contractor:	General Electric Company Atomic Products Division San Jose, California
Project manager:	R. W. Lockhart
AEC Contract No.:	AT-(04-3)-189, Project Agreement No. 15
Contract authorization date:	June 30, 1959
Contract completion date:	Work in progress as of July 1965

Purpose

The purpose of this program was to investigate mass transfer and corrosion in sodium systems to aid reactor designers in material selection. Reliability and economy in components for 1200°F sodium service was a goal.

History and Present Status

Work was started in late 1959 on the evaluation of candidate materials (e.g., type 316 stainless steel, 2 1/4% Cr-1% Mo iron-base alloy, and 5% Cr-1/2% Mo-1/2% Ti iron-base alloy). Testing was carried out in six forced-convection test loops. The program evaluated the corrosion and mass transfer effects of three major variables: (1) loop maximum temperature, (2) overall loop temperature difference, and (3) oxide content. The tests were operated with maximum temperatures of 1100 or 1200°F; the loop temperature difference was kept at 500 or 250°F; the oxide levels were maintained at about 12 ppm or about 50 ppm, as determined by plugging indicators. Mass transfer data were obtained from one loop over a period of about 20,000 hr to verify that mass transfer rates were linear over long operating periods. Measured mass transfer rates were also shown to vary linearly with oxide content and velocity. An increase of 100°F in the sample temperature produced about a threefold increase in the rate. Varying the temperature difference produced no significant change in measured rates. Based on the loop observations,

an empirical equation was developed to estimate steady-state weight changes.

The mass transfer data analysis showed no statistically significant difference in the rates between type 316, 2 1/4% Cr, or 5% Cr steels. It was concluded that maximum corrosion and mass transfer rates expected for 1200°F operation at the lower oxide content would be in the vicinity of 2 mils per year. This would be prohibitive for thin fuel cladding. Localized corrosion effects were also observed that are not fully understood.

Throughout the program, sodium was analyzed for carbon, metallic impurities, and oxygen. Except for oxygen, no correlation was established between impurity levels and rates of mass transfer.

A new program of sodium impurity separation and analysis was initiated in late 1964 to improve analytical techniques. Evaluation will be made of liquid ammonia dissolution, vacuum distillation, and mercury amalgamation. Capacity for kilogram samples is being provided to help insure high sensitivity.

As of July 1965, two new corrosion loops were under construction for continued testing in scaled-down systems that more adequately mock up large reactor systems.

Topical Reports

1. R. W. Lockhart et al., Sodium Mass Transfer: II. Screening Test Data and Analysis - Mass Transfer Results, USAEC Report GEAP-3726, Vol. 1, April 1962.
2. H. W. Alter and P. A. McManus, Sodium Mass Transfer: III. The Application of Liquid Ammonia as a Leaching Agent, USAEC Report GEAP-4006, April 1962.
3. R. W. Lockhart, Sodium Mass Transfer: II. Screening Test Data and Analysis - 1961 Corrosion Sample Data, USAEC Report GEAP-3726, Vol. 3, May 1962.
4. R. W. Lockhart, G. Billuris, and M. R. Lane, Sodium Mass Transfer: I. Test Loop Design, USAEC Report GEAP-3725, June 1962.
5. F. J. Hetzler and R. S. Young, Sodium Mass Transfer: II. Screening Test Data and Analysis - Metallurgy, USAEC Report GEAP-3726, Vol. 2, June 1962.

6. L. E. Pohl, Sodium Mass Transfer: IV. 1962 Corrosion Sample Data, USAEC Report GEAP-4181, January 1963.
7. R. W. Lockhart, Sodium Mass Transfer: V. 1962 Test Run Reports, USAEC Report GEAP-4182, June 1963.
8. W. W. Sabol and R. W. Lockhart, Sodium Mass Transfer: VII. Methods for Determining Impurities in Sodium Samples, USAEC Report GEAP-4178, September 1963.
9. E. L. Dunn, Sodium Mass Transfer: VI. Statistical Correlation of 1961-1962 Corrosion Data, USAEC Report GEAP-4183, February 1964.
10. J. D. Mottley, Sodium Mass Transfer: VIII. Corrosion of Stainless Steel in Isothermal Regions of a Flowing Sodium System, USAEC Report GEAP-4313, February 1964.
11. L. E. Pohl, Sodium Mass Transfer: X. 1963 Corrosion Sample Data, USAEC Report GEAP-4437, February 1964.
12. R. W. Lockhart, Sodium Mass Transfer: XI. 1963 Test Run Reports (January-June), USAEC Report GEAP-4438, February 1964.
13. R. W. Lockhart et al., Results of the USAEC Round-Robin Analysis for Carbon Impurity in Sodium, USAEC Report GEAP-4602, March 1964.
14. W. W. Sabol et al., Sodium Mass Transfer: XIII. The Determination of Total Carbon in Sodium, USAEC Report GEAP-4540, June 1964.
15. R. W. Lockhart, Sodium Mass Transfer: XII. 1963 Test Run Reports (July-December), USAEC Report GEAP-4439, October 1964.
16. R. W. Lockhart et al., Sodium Mass Transfer: IX. The Effect of Carbon and Carbonate Additions in a Sodium Test Loop, USAEC Report GEAP-4436, December 1964.
17. E. L. Dunn, K. B. Stewart, and J. L. Jaech, Sodium Mass Transfer: XIV. Statistical Analysis of 1961-1964 Sample Weight Change Data, USAEC Report GEAP-4830, February 1965.
18. M. C. Rowland, D. E. Plumlee, and R. S. Young, Sodium Mass Transfer: XV. Behavior of Selected Steels Exposed in Flowing Sodium Test Loops, USAEC Report GEAP-4831, March 1965.
19. E. G. Brush, Sodium Mass Transfer: XVI. The Selective Corrosion Component of Steel Exposed in Flowing Sodium, USAEC Report GEAP-4832, March 1965.
20. M. C. Rowland et al., Sodium Mass Transfer: XIX. Long Term Exposure Effects in a Bimetallic 316 SS-2 1/4 Cr Test Loop, USAEC Report GEAP-4835, April 1965.

21. L. E. Pohl, Sodium Mass Transfer: XX. 1964 Corrosion Sample Data, USAEC Report GEAP-4836, May 1965.
22. D. Dutina and J. L. Simpson, Sodium Mass Transfer: XVII. The Determination of Hydrogen in Loop Sodium and Cover Gases, USAEC Report GEAP-4833, June 1965.
23. D. E. Plumlee, R. W. Lockhart, and L. E. Pohl, Sodium Mass Transfer: XVIII. Studies of Carbon Movement in Pumped Sodium Test Loops, USAEC Report GEAP-4834, June 1965.
24. R. W. Lockhart, M. C. Rowland, and L. E. Pohl, Sodium Mass Transfer: XXI. 1964 Run Reports, USAEC Report GEAP-4837, June 1965.
25. M. C. Rowland and D. E. Plumlee, Sodium Mass Transfer: XXII. Metallurgical Examination of the Test Loops, USAEC Report GEAP-4838, October 1965.

Effects of Sodium on Containment Materials
(continued)

Title of program:	Mechanical Properties of Materials in Sodium
Contractor:	Mine Safety Appliances Research Corporation Callery, Pennsylvania
Project manager:	R. C. Andrews
AEC Contract No.:	AT-(11-1)-765
Contract authorization date:	July 1959
Contract completion date:	Work in progress as of July 1965

Purpose

The purpose of this program is to determine the effect of sodium on the mechanical properties of austenitic and ferritic steels. Tests are being run to determine whether the allowable stresses, as established in air and inert gases, are suitable for the design of long-life sodium equipment.

History and Present Status

The program was established to study the effects of air, helium, and sodium on type 316 stainless steel and on 2 1/4% Cr-1% Mo steel under creep, creep-to-rupture, and fatigue conditions. Two type 316 stainless steel test loops were built at MSAR and have been used for the sodium tests. Each loop has provisions for inserting and removing the various material specimens. The majority of the air and helium tests have been done at the University of Michigan under subcontract. A series of tests was originally scheduled to evaluate the two construction materials in sodium and to evaluate the effects of oxygen, carbon, and nitrogen. The tests of the 2 1/4% Cr-1% Mo steel were made at 1100°F, and the tests of type 316 stainless steel were made at 1200°F. Recently, type 304 stainless steel and Armco iron were added to this program. Room-temperature impact tests on all materials have also been added.

Topical reports are being issued as data analyses are completed. The reports issued thus far are listed below. The effects of low-oxygen (approximately 30 ppm) sodium on type 316 stainless steel did not appear to be significantly detrimental (topical report MSAR 64-18, March 1964). The effects of 1100°F sodium on 2 1/4% Cr-1% Mo steel were reported in detail in topical report MSAR 64-81, issued in July 1964. In summary, it was reported that the 2 1/4% Cr-1% Mo steel in sodium had slightly lower rupture, tensile, and yield strengths and decarburization occurred. The effects on type 316 stainless steel of sodium contaminated with carbon are reported in topical report MSAR 65-194, issued in December 1965. The major effect noted was a large reduction in ductility.

As of July 1965, tests were continuing in the two sodium test loops with type 304 stainless steel specimens. Tests with oxygen contents of approximately 300 ppm and with carbon additions were under way.

Topical Reports

1. Test Facility Design and Operation Procedures, USAEC Report MSAR 63-161, November 1963.
2. Results of Physical Property Tests of 316 SS Specimens in 1200°F Sodium with Low Oxygen, USAEC Report MSAR 64-18, March 1964.
3. Results of Physical Property Tests of 2 1/4 Cr - 1 Mo Steel Specimens in Sodium with High and Low Oxygen, Air, or Helium Environments at 1100°F, USAEC Report MSAR 64-81, July 1964.
4. Results of Mechanical Properties Tests of 316 SS Specimens in 1200°F Sodium Contaminated with Carbon, USAEC Report MSAR 65-194, December 1965.

Progress Reports

1. Effect of High-Temperature Sodium on Austenitic and Ferritic Steels, April, May, and June 1965, USAEC Report MSAR 65-96, August 1965.
2. Effect of High-Temperature Sodium on Austenitic and Ferritic Steels, July, August, and September 1965, USAEC Report MSAR 65-149, October 1965.

Measurement of Impurities in Sodium

Title of program: Electrochemical Meter for Continuous
Measurement of Oxygen in Sodium

Contractor: United Nuclear Corporation
Development Division
5 New Street
White Plains, New York 10601

Project manager: G. Stern

AEC Contract No.: AT-(30-1)-2877

Contract authorization
date: September 1961

Contract completion
date: Work in progress as of July 1965

Key project personnel: H. Steinmetz (deceased)
B. Minuskin
M. Kolodney (Consultant)

Abstract from Contract

Purpose. The Commission is sponsoring a development program with an objective to develop a capability in industry for manufacturing economic reliable components for service in 1200°F sodium. Sodium oxide in liquid sodium represents a major problem in the operation of sodium-cooled reactors. High concentrations of the oxide impurity can lead to plugging in portions of the sodium heat transfer apparatus. To date no instrument has been developed which will give the reactor operator a continuous indication of the oxide concentration in the system.

Scope of Work. The contractor will design, fabricate, and deliver to the Commission an instrument capable of continuous measurement of sodium oxide impurity in high-temperature sodium. The instrument will be subjected to conditions and will meet specifications listed in Functional Requirements. It is expected that the contractor will familiarize himself with technology to date on sodium oxide detection and will conduct necessary development work to design the instrument. The instrument design shall be approved by the contracting officer prior to fabrication by the contractor. A report will be submitted to the Commission at the end of the contract period which will include the following:

1. Analysis of the basic problems involved in measurement.
2. Justification for selection of a particular method.
3. Preliminary design of practical instrument.
4. Fabrication history (if any).
5. Test data (if any).
6. Cost of first unit including complete supporting apparatus.
7. Cost of special tools.
8. Estimated cost of subsequent units.
9. Expected operating cost.
10. Anticipated useful operating life.
11. Predicted performance under operating conditions.

The objective of this program is the development of a continuous, direct-reading instrument capable of operating in the temperature range of 800-1200°F. The instrument is to be capable of measuring oxygen in sodium from 100 ppm down to a few ppm. The meter is to be insensitive to impurities other than oxygen which are commonly found in sodium.

History and Present Status

The major problem was to obtain an electrochemical cell whose voltage was stable over long periods of time when in contact with liquid metal at elevated temperature. Various ceramics were tested to this end, with work being done on Cu-CuO, Ni-NiO, zirconia containing varying amounts of calcium, and thoria cells. Three thermal-convection test loops were operated to serve as test beds for the cells. Oxide levels in the test loops were varied by changes in cold-trap temperature, and the response of the electrochemical cells was observed as a function of cold-trap temperature. Development of a leaktight ceramic-to-metal seal was a necessary part of the program. Zirconia-to-Kovar seals were tested with unfavorable results. The seal problem was solved by employing a frozen sodium seal between the ceramic cell and metal housing with a backup elastomer O-ring seal.

Construction of a forced-circulation loop was completed in April 1963, and preoperational checkout was completed in February 1964. Limited tests of the response to carbon and hydrogen additions were made. Thoria-15 wt % Y_2O_3 ||Cu:CuO cells demonstrated a useful life of about three months

at 600 to 650°F and acceptable voltage drift. This type of cell was the most successful tested and was selected for field use at Atomic Power Development Associates, Argonne National Laboratory, and Los Alamos Scientific Laboratory. The oxygen meters were in various stages of installation and shakedown at these three installations as of July 1965.

Four units installed at APDA appeared to be working satisfactorily in the first two one-half months of testing. Two units installed at Argonne were fractured by thermal shock.

This device can make an important contribution to liquid-metal technology in that it provides a continuously reading oxygen-selective meter suitable for use in sodium or potassium. The meter should prove particularly useful in liquid-metal corrosion studies, because oxygen level is probably the single most important variable in the corrosion process.

Progress Reports

1. H. Steinmetz, Development of a Continuous Meter for Oxygen in Sodium, Quarterly Progress Report for the Period September 1 to December 1, 1961, USAEC Report UNC-5000, Jan. 15, 1962.
2. H. Steinmetz, Development of a Continuous Meter for Oxygen in Sodium, Quarterly Progress Report for the Period December 1961 to February 28, 1962, USAEC Report UNC-5010, Apr. 15, 1962.
3. H. Steinmetz, Development of a Continuous Meter for Oxygen in Sodium, Quarterly Progress Report for the Period March 1962 to May 31, 1962, USAEC Report UNC-5028, July 15, 1962.
4. H. Steinmetz, Development of a Continuous Meter for Oxygen in Sodium, Quarterly Progress Report for the Period September 1, 1961 to July 31, 1962, USAEC Report UNC-5032, Aug. 24, 1962.
5. H. Steinmetz, Development of a Continuous Meter for Oxygen in Sodium, Quarterly Progress Report for the Period September 1, 1962 to December 31, 1962, USAEC Report UNC-5050, Jan. 25, 1963.

Measurement of Impurities in Sodium
(continued)

Title of program:	Determination of Oxygen in Sodium at Concentrations Below 10 ppm
Contractor:	Battelle Memorial Institute 505 King Avenue Columbus, Ohio 43201
Project manager:	Daniel R. Grieser
AEC Contract No.:	(unknown)
Contract authorization date:	July 1, 1959
Contract completion date:	June 30, 1961

Abstract from Contract

Justification. The attainment of economic nuclear power will, to a large extent, be determined by the ability to achieve higher thermal efficiencies and utilization of low-cost low-cross-section structural materials. In the case of sodium-cooled reactors, it is anticipated that operating temperatures will run at 1200°F sodium outlet from the reactor and structural materials may include zirconium alloys for higher neutron economy and ferritic steels for cost reduction. These developments will impose more stringent requirements on sodium purity with respect to oxygen and, consequently, on the analytical methods for its determination.

Analytical techniques developed to date permit the determination of oxygen in liquid sodium to a level of 10 ppm $\pm$ 10 ppm. While this sensitivity is adequate for systems containing ferrous alloys and stainless steels, metals such as zirconium, niobium, and beryllium have oxygen tolerance levels considerably below 10 ppm. The development of improved analytical methods is, therefore, indicated.

Purpose. To initiate an effort directed at the development of a fast and reliable method for the determination of oxygen in sodium at concentrations below 10 ppm. A study of sampling techniques is to be a part of this program.

Nature and Scope of Work. The contractor shall develop a high-sensitivity method to determine oxygen concentration in sodium at oxygen levels

below 10 ppm. The contractor will review existing methods and try to improve and/or combine these methods to achieve the objective. The possibility of a new approach should be investigated.

At the conclusion of the contract, the contractor will submit a topical report describing the method of analysis developed and the investigation leading to the developed method.

History and Present Status

AEC issued a request for proposal for this work in January 1959, and the proposal from Battelle Memorial Institute was accepted. The following methods for the oxygen determination were investigated but were not developed successfully:

1. Mass spectrometry
2. Arc-emission spectroscopy
3. Coulometry
4. Polarography
5. Ellipsometry

Work was discontinued when chemical methods being investigated by United Nuclear Corporation appeared to show more promise. No patents were issued and no hardware was perfected or delivered in this program.

Topical Report

1. D. R. Grieser et al., Determination of Oxygen and Sodium at Concentrations Below 10 ppm, USAEC Report BMI-1538, Aug. 23, 1961.

Measurement of Impurities in Sodium
(continued)

Title of program:	Measurement of Oxygen in Sodium Below 10 ppm
Contractor:	United Nuclear Corporation Development Division 5 New Street White Plains, New York 10601 (Prior to June 1961, Nuclear Development Corporation of America)
Project manager:	G. Stern
AEC Contract No.:	AP-(30-1)-2303, Project XV
Contract authorization date:	March 21, 1960
Contract completion date:	August 30, 1961
Key project personnel:	H. Steinmetz (deceased)

History and Present Status

This work was a follow-up to the work done at Battelle Memorial Institute in which no successful technique was developed for analysis of oxygen at less than 10 ppm. A brief review of the BMI Program is covered in the preceding section.

The objective of this program was the development of a high-sensitivity chemical method for the determination of oxygen in sodium in the 0 to 10 ppm range. The analytical technique developed under this contract was an amalgamation process followed by a reaction of the sodium oxide with alcohol and then a reaction with an organic acid to convert the sodium oxide to an equivalent amount of water. The water was then titrated with Karl Fischer reagent. The method had the advantage of not requiring a complete separation of the sodium from the sodium oxide.

The analysis of a series of samples of zirconium-gettered sodium gave a mean value of 3 ppm of oxygen with a standard deviation of ± 1.5 ppm. The program was not developed further due to the very demanding laboratory technique required. Also, the emphasis at UNC was shifted toward the continuous oxygen meter at this time.

Progress Reports

1. H. Steinmetz, Development of a High Sensitivity Analytical Method for Oxygen in Sodium Metal, June 27, 1960 to September 30, 1960, USAEC Report NDA-2154-2, Oct. 30, 1960.
2. H. Steinmetz, Development of a High Sensitivity Analytical Method for Oxygen in Sodium Metal, October 1, 1960 to December 31, 1960, USAEC Report NDA-2154-3, Mar. 1, 1961.
3. H. Steinmetz, Experimental Determination of Contaminants in Sodium, January 1, 1961 to March 31, 1961, USAEC Report NDA-2154-5, May 1, 1961.
4. H. Steinmetz and B. Minushkin, Experimental Determination of Contaminants in Sodium, USAEC Report NDA-2154-6, Aug. 30, 1961.

Measurement of Impurities in Sodium
(continued)

Title of program:	Techniques for Measurement of Impurities in Sodium
Contractor:	Mine Safety Appliances Research Corporation Callery, Pennsylvania
Project manager:	R. C. Andrews
AEC Contract No.:	AT-(11-1)-765
Contract authorization date:	April 1965
Contract completion date:	Work in progress as of July 1965

Purpose

This project is for investigating new techniques for the analytical determination of carbon, oxygen, and hydrogen contaminants in sodium. The purpose of the work is to develop continuously reading fast-response instrumentation for on-stream applications and laboratory analytical techniques with higher sensitivity than those now in use.

History and Present Status

This program was started in early 1965, and therefore no definitive results are available. As of July 1965, preliminary screening and feasibility studies were in progress in the following areas:

Laboratory Techniques

1. Preparation of sodium standards to be used for laboratory tests.
2. Mass spectrometry of the off-gases during high-temperature refluxing of sodium.
3. Paramagnetic effects — the measurement of variations in magnetic moments due to impurities in sodium.
4. Surface-tension changes of sodium as related to the contaminants in the liquid metal.
5. Separation of sodium and sodium oxide with reactants such as naphthalene and organic solvents such as tetrahydrofuran.

On-Stream Techniques

1. Changes in physical properties of a submerged gage material due to carburization by contact with sodium.
2. Use of an electrical potential to concentrate oxide at the sodium-wetted surface of a reference metal such as niobium. Changes in the electrical resistivity of the electrode would be a measure of oxygen level.
3. Detection of particles in liquid metal by monitoring electrical resistivity changes across an orifice in which the particles are being precipitated by cooling.
4. Continuous monitoring of the cover gas of sodium systems for hydrogen by means of lithium hydride fuel cells, aqueous cells, or similar apparatus.

Progress Reports

1. Development of Techniques for Measurement of Impurities in Sodium, USAEC Report MSAR-65-95, July 30, 1965.
2. Development of Techniques for Measurement of Impurities in Sodium, USAEC Report MSAR-65-150, Oct. 25, 1965.

Measurement of Impurities in Sodium
(continued)

Title of program:	Sodium Technology Loop (Resistivity Meter)
Contractor:	Atomic Power Development Associates, Inc. 1911 First Street Detroit, Michigan 48226
Project manager:	Ralph H. Jones January 1, 1961 to July 6, 1962 Peter S. Lindsey July 7, 1962 to December 31, 1964 Eugene F. Hill January 1, 1965 to date
AEC Contract No.:	AT-(11-1)-865, Project Agreement No. 3, Blake Resistivity Meter AT-(11-1)-865, Project Agreement No. 11, The APDA Sodium Technology Loop
Contract authorization date:	January 1, 1961
Contract completion date:	Work in progress as of July 1965

Initial Objective

The initial objective was to evaluate the efficiency of specified devices for determining impurities in sodium in the range of 1 to 100 ppm. The contractor was to evaluate a sodium-contaminants monitor developed by R. L. Blake of the United Kingdom Atomic Energy Authority. The tests were to compare the results of the Blake meter with results obtained under the existing procedures for determining impurities in sodium, which consisted of the use of plugging indicators and chemical analyses. Tests were conducted that involved the addition of oxygen, various inert gases, and carbon.

Modification to Contract Scope Under Project Agreement No. 3

The contract was originally scheduled to run from January 1, 1961, until December 31, 1961, but the contract completion date was extended on several occasions when the Atomic Energy Commission requested additional

work. On January 1, 1963, the scope of the contract was amended as follows:

- Phase 1.
- A. Addition of a temperature-compensation resistor to the meter bias circuit to improve the temperature stability.
 - B. Addition of a thermostatic control to anticipate rate of change of temperature designed to eliminate the effects of loop temperature transients.
 - C. Modification of meter to accommodate sodium temperature of 900°F and modification of the range of the temperature compensation to compensate for sodium temperature changes up to 900°F.
 - D. Determination of the possibility of self-calibration of the instrument and increasing of the range of the meter to concentration equivalent of 500 ppm oxygen.
 - E. Incorporation of a variable-orifice plugging meter in the present loop to determine if a more accurate calibration of the Blake meter is possible in concentration of oxide below 10 ppm.
- Phase 2.
- A. Determination of the reaction of the meter to reaction products of sodium and CO, CO₂, and CH₄ and a separate calibration of meter response to additions of solid Na₂CO₃.
 - B. Determination of the response of the meter to gaseous additions of hydrogen. The meter was to be calibrated for NaH and NaOH, where the NaH and NaOH were introduced in controlled and measured amounts. If possible the efficiency of the loop cold trap in removing NaH and NaOH was to be obtained.

On June 24, 1963, the scope of the contract was amended to include:

- Item 1. A determination of the reaction of the test Blake meter to the introduction of measured amounts of liquid water into the sodium loop.
- Item 2. A determination of the effects of the water-sodium chemical reaction to the loop system. The effects to be noted shall include pressure rise, temperature rise, oxygen content of

the sodium, hydrogen content of the cover gas, and physical changes to the water injection equipment.

On November 15, 1963, the scope of the contract was again amended to include the following new section:

A second hydrogen gas injection run will be conducted to approach a contamination level of approximately 300 ppm of sodium hydride to establish the response of the upgraded Rhometer and the improved plugging meter to sodium hydride contamination. As a part of this run, preliminary information on the rate of dissociation of sodium hydride versus temperature for a 300 ppm concentration of the hydride will be obtained. The contamination run will be followed by a closely monitored temperature ramp to detect any breakpoint in sodium hydride dissociation in the 570 to 970°F range. The loop will be held at this breakpoint (if one exists) and at one or more higher temperature levels to establish the pattern of sodium hydride dissociation in loop environment. More recent analytical techniques will be used on sodium samples taken during experiments to attempt to validate the determination of hydride levels. Surveillance will be maintained of the cover gas by means of chromatographic inspections to provide a material balance in the event dissociation occurs or the injected hydrogen shall fail to react.

Work Under Project Agreement No. 11

The objective of the work under Project Agreement No. 11 was to continue operation of the sodium technology loop and to obtain development information in the following areas:

A. Instrumentation for Sodium Systems. Development and evaluation of in-line instruments for the protection and determination of impurities in sodium.

B. Sodium System Cleanup Processes. Development and evaluation of sodium purification techniques and devices.

C. Chemical and Physical Behavior of Sodium Impurities.

Investigation of the chemical and physical behavior of impurities in sodium loop environment.

D. Laboratory Analysis. Complementary development work and refinement of analytical techniques for the determination of sodium contaminants.

Another change in scope was made on May 12, 1965, when work was authorized for a supercentrifuge study.

History and Present Status

The sodium technology loop at APDA was originally designed for testing of the Blake meter. The loop was constructed of 4-in.-diam stainless steel pipe. The loop capacity was approximately 1000 lb of sodium, and the sodium flow could be regulated from 10 to 400 gpm. A sodium holdup tank of 30-gal capacity, which was about 25% of system capacity, was available that could be adjusted and sampled readily. The loop could be operated continuously at 1000°F and at 1200°F for short periods of time. The loop construction was completed in February 1962, and initial shakedown runs on the Blake meter were reported in March 1962. A topical report, APDA-149, "Evaluation of the Blake Sodium Resistivity Meter," was issued in October 1962 covering the exploratory operations performed in the APDA test loop.

In May 1963, work had progressed on the Rhometer temperature compensator to the point of successful operation at 900°F. The extension of the instruments temperature compensation from 600°F was accomplished by circuit modification.

Water injection tests were completed in August 1963 that demonstrated the response of the Rhometer, the variable-orifice plugging meter, and the nickel diffusion-tube hydrogen monitor to the introduction or inleakage of water into an operating sodium loop.

In November 1963, methane gas was injected into the loop at 620°F. No reaction was indicated during injection by the Rhometer or by the plugging meter, and 100% of the methane charge was reported in the cover gas. Repair of loop hardware was begun in November 1963. The retention tank was removed from the loop so that it could be cleaned of deposits, and

tank connecting lines were capped off to facilitate replacement in the event this unit would be required for future experiments. The loop cold trap was replaced in order to relieve operating limitations that had become increasingly evident in the fifteenth month of trap service. Plugging of the trap had frequently occurred during fast temperature ramps and could only be avoided by a very deliberate approach to saturation temperatures. This unit was removed and sealed for future inspection of the York Mesh section and filter. A replacement cold trap was installed that was a duplicate of the original unit. The work under Project Agreement No. 3 was completed in January of 1964, and a final report covering evaluation of the resistivity meter was prepared.

In February of 1964, the sodium technology loop was shut down for modifications to accomplish the work outlined under Project Agreement No. 11. The modified loop was to be used to determine the thermal stability of sodium contaminants and to evaluate new processes designed for sodium purification. Supporting chemistry for this project also began at this time. Work on the development of new methods for the improvement of existing methods of chemical analysis of sodium for total carbon, carbonate, oxygen, and hydrogen was initiated. Shakedown operations of the modified loop were initiated in September of 1964. This shakedown marked the first operation of the new flowing-sodium sampling stations and the first application of supporting chemistry to monitor impurities.

Loop shakedown continued through November 1964, with a temperature ramp to 900°F to observe the performance of newly installed heaters and controls and to determine system blank values for in-line meters operating with high-purity sodium. One of the Rhometer temperature-compensator coils failed and was replaced. Spark-plug level probes in the 1200°F thermal decomposition tank frequently failed by shorting out from the vapor deposits and seal failure. Similar probes in the 1000°F surge tank also gave trouble. The new flowing-sodium sampling coils were operated successfully and no difficulty was experienced with the Swagelok couplings during the initial evacuation or in containment while operating at 900°F. Although the type 304 stainless steel coil was thoroughly cleaned, carbon determinations were not uniform along the length of the coil until pre-sampling circulation was extended to a 4-hr cycle. The effect was probably

due to subsurface contamination of the tube that could have been introduced by cold working.

Erratic zero shifts of the Rhometer output were observed in December 1964. These zero shifts were traced to a small movement of the winding assembly on the toroid transformer, which can produce a large upset in the meter reading. It was demonstrated that piping disturbances in the vicinity of the Rhometer, which can occur while hand valves are being turned, could shift the reading by 0.10 to 0.12%. This percentage is roughly equivalent to an error of 50 to 60 ppm Na_2CO_3 impurity, an exceedingly large value.

In January and February 1965, tests of sodium carbonate injection were made. Use of a 7-in. "tea bag" showed that no injection was obtained. Evaluation was initiated on several methods of dissolving sodium carbonate in recirculating sodium. Forced flow of sodium for 28 hr through a specifically designed container loaded with Na_2CO_3 at 850°F was also unsuccessful. A chemical analysis of the material remaining after the container was removed from the loop showed that none of the sodium carbonate had dissolved. Because the results of the loop tests indicated that the solubility behavior of sodium carbonate was substantially different from that indicated in the published literature, it was decided that an attempt to substantiate the solubility data for sodium carbonate in sodium would be necessary. Suitable equipment for these studies was designed, and as of July 1965 work was still in progress on the determination of the solubility of sodium carbonate in sodium.

During May 1965, four oxygen-meter probes from United Nuclear Corporation were installed in the loop and sodium flow was resumed. The oxygen meters have operated satisfactorily; however, no direct correlation with actual oxide concentration can be made until more information is available on the effect of individual impurities on the behavior of the meter.

A conceptual design of a method of installation of a supercentrifuge in the sodium technology loop was completed in June 1965.

In summary, the primary technological contributions of the APDA sodium technology loop have been in the areas of instrumentation development and chemical analysis. In the area of instrumentation, the response of the Blake Rhometer to a variety of sodium impurities has been established.

As a result of this work, a basis has been developed for redesigning the instrument to make it suitable for reactor use. In the area of chemical analysis, the following has been done:

1. development of a new method for analyzing carbon in sodium,
2. development of a new method for analyzing carbonate in sodium,
3. development of a new method for analyzing oxygen in sodium,
4. development of a new method for analyzing hydroxide in sodium,
5. development of a new method for analyzing nonhydroxide hydrogen in sodium,
6. development of a new method for analyzing total hydrogen in sodium,
7. determination of feasibility of a new in-line hydrogen detector for sodium systems,
8. determination of the solubility of sodium carbonate in sodium.

Topical Reports

1. Evaluation of the Blake Sodium Resistivity Meter, USAEC Report APDA-149, October 1962.
2. Operation of the Sodium Technology Loop for Contamination Meter Evaluations, USAEC Report APDA-163, March 1964.
3. H. Bradley and S. A. Meacham, Determination of Carbon in Sodium by a High-Temperature Combustion Method Utilizing Gas Chromatography, USAEC Report APDA-164, Nov. 25, 1964.
4. D. F. Boltz and S. A. Meacham, Determination of Carbonate Carbon in Sodium Metal, USAEC Report APDA-166, Jan. 15, 1965.
5. D. F. Boltz, J. O. Kermoshchuk, and S. A. Meacham, Determination of Oxygen in Sodium, USAEC Report APDA-168, July 1965.

Progress Reports

1. Quarterly Technical Progress Report on AEC Sponsored Activities, January-March 1965, USAEC Report APDA-170.
2. Quarterly Technical Progress Report on AEC Sponsored Activities, April-June 1965, USAEC Report APDA-174.
3. Quarterly Technical Progress Report on AEC Sponsored Activities, July-September 1965, USAEC Report APDA-178.

Measurement of Impurities in Sodium
(continued)

Title of program:	Hydrogen Detector
Contractor:	Atomics International P.O. Box 309 Canoga Park, California 91304
Project manager:	H. Strahl
AEC Contract No.:	AT-(11-1)-GEN-8
Contract authorization date:	July 1, 1960
Contract completion date:	June 30, 1961

Abstract from Contract

Justification. A considerable number of the nuclear power plants under construction include in the primary heat cycle a sodium-H₂O steam generator. A mixture of sodium and water would react violently with the generation of heat, Na₂O, NaOH, NaH, and hydrogen gas. The early detection of a leak from the high-pressure H₂O to the sodium is vital to the life of this component and possibly to the operation of the entire plant.

Purpose. To develop a rugged and sensitive device that can detect hydrogen in minute quantity from an H₂O-sodium reaction in a flowing stream of high-temperature sodium.

Nature and Scope of Work. The various existing devices for measuring the individual products of a nonradioactive Na-H₂O reaction, or allied devices, should be surveyed. A device that appears most promising shall be fabricated and tested in a facility provided by the Commission. The device shall be designed for nuclear power plant use.

Functional Specifications. The instrument for detecting the presence of hydrogen in sodium shall be capable of the following:

1. measuring hydrogen from an H₂O-sodium reaction in the range 0 to 30 ppm,
2. accuracy of $\pm 1\%$ of range,
3. response time of 5 sec,
4. operation at a pressure of -14.7 to 175 psig,
5. operation at a sodium temperature of 1200°F, maximum,

6. operation at a sodium velocity of 30 fps,
7. operation with total sodium volume in loop of 10,000 gal,
8. operation with a sodium system flow rate of 5,000,000 lb/hr,
9. operation with an inert gas blanket of argon, helium, or nitrogen,
10. design life of 10 years,
11. operation without plugging,
12. maintainable or replaceable as a unit,
13. remote reading and recording of generated signal,
14. compliance with Section VIII of ASME Boiler and Pressure Vessel Code, including methods of attachment to or sampling from Code vessels.

History and Present Status

The initial work on a hydrogen detector at Atomics International resulted in a device with a nickel diaphragm through which hydrogen could diffuse from the flowing sodium stream into an evacuated volume. The pressure of the evacuated volume was monitored, and when a pressure rise occurred, the content of the volume was analyzed spectrographically for hydrogen.

The original hydrogen detection device was later improved by addition of a continuously evacuated system maintained at about 10 mm of mercury and a Pirani gage, which is a thermal-conductivity vacuum gage used to monitor the pressure downstream of the nickel diaphragm. This modification provided a device with continuous monitoring capability. The device was further improved by placing the sensor in a heated bypass line, where its temperature could be maintained at about 750°F, independent of the loop temperature.

Tests of the improved hydrogen-detection device were conducted in a loop that had a 60-lb sodium inventory at temperatures from 500 to 900°F. Sodium flow rates were varied from 10 to 40 gpm. Injections of both hydrogen and water were made at a point 14 ft upstream of the detector that were equivalent to 1 to 5 ppm (assuming complete mixing with the sodium inventory). Data were obtained which showed the effects of temperature

and hydrogen level on the elapsed time between injection and sensor response. The response time varied from about 5 to 40 sec over the range of conditions tested.

It was concluded that the nickel diaphragm coupled with the Pirani gage provided a practical instrument for detection of water leakage into an operating sodium system, so no further testing was done after June 30, 1961.

Topical Report

1. H. Strohl, A Device for Continuous Detection of Hydrogen in Sodium, USAEC Report NAA-SR-6986, May 31, 1962.

Sodium Equipment

Title of program: Flow Controllers (Valve Tests)
Contractor: Atomics International
P.O. Box 309
Canoga Park, California 91304
Project manager:
AEC Contract No.: AT-(11-1)-680
Contract authorization
date:
Contract completion
date: Approximately April 1962

Abstract from ContractNature and Scope of the Work

1. The work under this agreement shall be unclassified and shall consist of the design, fabrication, and delivery to the Commission of a flow control device and operator of advanced design with a torque tube seal as set out in Contractor's proposal dated June 20, 1958, as amended by supplemental proposal dated August 15, 1958, meeting the performance specifications set out in Appendix A (which Appendix is attached hereto and made a part hereof) for test in a sodium test loop. Said performance specifications are a program objective and do not represent a warranty on the part of the Contractor.

2. The flow control device and operator to be delivered pursuant to Section 1 hereof shall be tested as follows:

- a. In a static gas atmosphere at 1000°F;
- b. Cold water flow tested to simulate, wherever possible, actual service conditions.

3. The Contractor shall also deliver to the Commission the following information:

- a. Detailed drawings of the flow control device and operator, including all features;
- b. Specifications for all parts;
- c. Methods of inspection and maintenance to be used during service;
- d. Fabrication methods and procedures used;

- e. Report operability at high temperature and cold flow characteristics based on the test performed pursuant to Section 2 hereof;
- f. Predicted performance of a twenty-inch flow control device and operator on extrapolation of the data on the ten-inch flow control device and operator developed under this contract;
- g. Cost estimates for the manufacture of a twenty-inch flow control device and operator.

History and Present Status

The objective of this program was to fabricate and test large (10- to 12-in.-diam) flow controllers for flow characteristics and ability to withstand thermal shock. The AEC initially sponsored valve fabrication studies at Westinghouse Electric Corporation, the Crane Company, and at Ohio Injector Company. The 12-in. controller development at Westinghouse was terminated following failure of ball bearings in the operating mechanism during 1000°F gas tests. The design study by Crane Company was terminated after submittal of the preliminary design to the AEC. A valve was fabricated by Ohio Injector Company, and this unit was tested at Atomics International.

The flow tests of the Ohio Injector Company valve in sodium at Atomics International were conducted at temperatures of 600, 825, and 1000°F and at sodium flows up to 6500 gpm. Vibration was observed at the higher flow rates and the valve was not recommended for flows above 5000 gpm. Data were obtained on the amount of flow reduction obtained as a function of valve opening.

The Ohio Injector Company flow controller was also subjected to thermal shock tests at Atomics International. Some valve bore distortions occurred during the initial thermal shock tests from 1200 to 1025°F. The distortion was believed to be due to stress relieving of welds. A later portion of the thermal shock program consisted of 500 cycles at 35°F/sec for 5 sec from 1200 to 1025°F sodium inlet temperature. The 500 cycles were completed without valve binding. It was concluded that the Ohio

Injector Company flow controller, as slightly modified during testing, was successful.

Topical Report

1. OIC Flow Controller Test, USAEC Report NAA-SR-TDR-6081, Jan. 30, 1961.

Sodium Equipment
(continued)

Title of program:	Ultrasonic Under-Sodium Scanner
Contractor:	Atomic Power Development Associates, Inc. 1911 First Street Detroit, Michigan 48226
Project manager:	C. C. Scott
AEC Contract No.:	AT-(11-1)-865, Project Agreement 4
Contract authorization date:	December 1, 1964
Contract completion date:	Work in progress as of July 1965
Key project personnel:	Shuh-Pan-Yang Benson Carlin (Consultant)

Purpose

The objective of this program is to develop an image-scanning device for operation in liquid sodium for viewing fuel handling and for locating foreign objects. The approach to be used by the contractor in developing such a device shall be dependent upon the results obtained from testing transducers in sodium. The scope of the work under this contract is (1) to establish the feasibility of operation of ultrasonic transducers in sodium, (2) based on the information derived under (1) to develop a conceptual design of a practical method for viewing objects immersed in sodium, and (3) to prepare a time schedule and cost estimate for development of the device.

History and Present Status

The under-sodium scanning system would permit objects in liquid sodium to be discerned by means of sound waves and thereby simplify maintenance and fuel-handling procedures. Although the principle of transmitting an attenuating sound in water is well established, the application of this principle to liquid sodium is not well known. Thus, it is important to define the parameter of the attenuation of sound in sodium before a concept for a general-purpose scanning system can be established.

Attenuating tests are being conducted in a sodium facility specifically designed and fabricated for the task. Two ultrasonic transducers have been installed in the facility in such a way that they can be rotated and then separated by distances ranging from $1/2$ to 10 in. Attenuation measurements will be made over these distances. The electronic system used for previous underwater scanning tests has been modified for use in this project. Because the gain of the electronic receiver is nonlinear with respect to the amplitudes of input pulses, a wide-band attenuator extended to microwave range for precise measurements is required. To improve the 500-v 2-Mc pulse-modulated transmitter and the 90-db wide-band receiving system, a network was inserted between the amplifiers and the receiving system to filter out line-induced noises and to increase the stability of sweep on the oscilloscope. A transistorized wide-band pulse preamplifier was built and tested. Fabrication of the major components of the sodium facility was completed in February 1965, and assembly of the facility was begun. A small test tank with two piezo-electric disks on the top and bottom was designed, fabricated, and tested. The purpose of the tank was to test the sensitivity of the electronics. Two kinds of media, water and mercury, were used in the tests. Both gave sufficiently strong signals that decreased exponentially with distance.

The tests of the sodium system are being done in a dry box. The purification system for the dry box was operated continuously in May 1965 and found to be very satisfactory. The purification system provides a dry-box atmosphere having a moisture content less than 0.1 ppm and an oxygen content less than 1.0 ppm. The facility was filled with sodium, and observation of the molten-sodium surface several days after filling revealed that the surface had retained a shiny appearance similar to that of mercury.

Transducers with lead metaniobate electric disks performed satisfactorily in liquid sodium at temperatures from melting point to 500°F. Ultrasonic attenuation measurements in liquid sodium as a function of temperature of the medium have been made in the temperature range from the melting point of sodium to 500°F. Attenuation increased as the temperature increased, in agreement with theory. The absorbant coefficient measured in liquid sodium at 500°F is low compared with that of pure water measured at room temperature.

In order to determine the temperature limitations for piezo-electric materials, lead metaniobate and quartz crystals were installed in the transducers and operated at temperatures up to 600°F. Of the two types tested at 600°F, the lead metaniobate crystals generated stronger signals than the quartz crystals. Tentative conclusions were that the lead in the metaniobate crystals will operate satisfactorily at 600°F in general purpose scanning systems. The performance of the quartz crystals at this temperature was marginal.

As of July 1965, this work was continuing toward the immediate objective of establishing the feasibility of the ultrasonic-scanning system.

Progress Reports

1. Quarterly Technical Progress Report on AEC Sponsored Activities, April-June 1965, USAEC Report APDA-174.
2. Quarterly Technical Progress Report on AEC Sponsored Activities, July-September 1965, USAEC Report APDA-178.

Sodium Equipment
(continued)

Title of program:	Analysis of the Sodium Cold Trap of the Enrico Fermi Reactor
Contractor:	Westinghouse Electric Corporation Atomic Power Division P.O. Box 355 Pittsburg, Pennsylvania 15230
Project manager:	J. H. Wright
AEC Contract No.:	AT-(30-1)-3186
Contract authorization date:	March 4, 1963
Contract completion date:	Approximately July 1965

Purpose

The initial objective of the program was to examine and analyze the Enrico Fermi primary sodium cold trap in order to:

1. determine the chemical and physical composition of the trap contents,
2. determine the spatial distribution of the chemical species in the trap and determine their physical form,
3. evaluate the operational performance of the trap with particular regard to maldistribution of flow and flow bypassing,
4. develop criteria for sodium cold-trap design.

History and Present Status

Under this contract, Westinghouse sampled, analyzed, and evaluated the performance of a nonradioactive cold trap removed from the Enrico Fermi Atomic Power Plant at Lagoona Beach, Michigan. The trap, a 500-gal vessel containing stainless steel wire mesh, was operated for 3700 hr in the primary sodium system. The trap was prematurely removed from service so that a new one could be installed prior to nuclear operation of the plant.

A method was developed for removing suitable sodium-mesh samples from the cold trap. Fifty-five representative samples were taken from selected areas of the trap. Methods for the determination of the impurities of

interest in the cold trap were adapted from procedures described in the literature. Based on the chemical analyses of the cold trap contents, less than 20% of its designed oxygen-removal capability was realized. The major portion of the contaminants was concentrated in the lower mesh area. The trap contained an estimated 50 lb of oxygen and 0.9 lb of carbon. The carbonate, hydrogen, and nitrogen values were relatively low. Spectrographic analyses for metallic impurities revealed relatively high concentrations of copper (up to 360 ppm) and iron (up to 110 ppm). Independent laboratory analyses were run to corroborate the Westinghouse data.

Even though the innermost cylindrical wall collapsed and the lower mesh area was displaced upward, the cold trap operated satisfactorily. Flow maldistribution was not evident. Radial flow pattern and a pressure-drop monitor are proposed improvements for the Fermi cold-trap design. All work was completed and a final report was being edited as of July 1965.

Topical Report

1. E. E. Garcia and B. D. LaMont, An Annotated Bibliography for Analytical Methods for Alkali Metals, USAEC Report WCAP-2540, March 1964.

Sodium Equipment
(continued)

Title of program:	Conceptual Design of Large Sodium Pump Test Facility
Contractor:	Westinghouse Electric Corporation Atomic Power Division P.O. Box 355 Pittsburg, Pennsylvania 15230
Project manager:	J. H. Wright
AEC Contract No.:	AT-(30-1)-3123
Contract authorization date:	November 1, 1962
Contract completion date:	April 4, 1964
Key project personnel:	C. C. Randall D. Commetti R. L. Whitney

Purpose

The objective of this program was to formulate a development program for large sodium pumps and then to establish a conceptual test facility design and provide a cost estimate. Phase I of this program consisted of the formulation of the development program. This work consisted of identification of the sodium pump requirements for large, 1000- to 1500-Mw(e), sodium-cooled power reactors and definition of the sodium-pump problem areas. Phase II consisted of the conceptual test facility design and cost estimate.

History and Present Status

A pump development program was formulated and an estimated schedule of accomplishments was prepared. Requirements for the pump test facility were also established. A conceptual design of sufficient detail was prepared for the estimation of capital and operating costs. The design considered buildings, utility services, related auxiliaries, test loops and components, and separate test rigs required for the performance of the development test program.

The conceptual design provides for a facility with two identical flow loops, each sized for a maximum flow rate of 60,000 gpm. Pumps with a capacity of 60,000 gpm could be operated in each loop or larger pumps of up to 120,000-gpm capacity could be operated by using the two loops as parallel flow paths. The system would have provisions for high-rate temperature transients of the order of 10°F/sec for short periods of time. It has been estimated that the engineering equipment and construction of this facility would cost approximately \$6,000,000. Such a system would be expected to accommodate pumps with total developed heads of up to 380 ft of sodium and maximum sodium temperatures of 1200°F.

The work on this contract at Westinghouse was completed, and the contract was terminated in April 1964. The results of the study are covered in a series of topical reports, which are listed below.

Topical Reports

1. D. R. Nixon, Survey of Sodium Pump Technology, USAEC Report WCAP-2255, June 1963.
2. C. C. Randall et al., Sodium Pump Development and Pump Test Facility Design, USAEC Report WCAP-2347, August 1963.
3. J. R. Blanchfield, Jr., Conceptual Design and Cost Estimate for Sodium Pump Test Facilities, USAEC Report WCAP-2526, November 1963.

Heat Exchangers for Steam Generation

Title of program:	Sodium-Heated Steam-Generator Summary
Contractor:	Atomic Power Development Associates, Inc. 1911 First Street Detroit, Michigan 48226
Project manager:	J. J. Morabito
AEC Contract No.:	AT-(11-1)-865, Task 1
Contract authorization date:	July 17, 1962
Contract completion date:	September 19, 1962
Key project personnel:	The following Sodium Components Development Program Working Group members and their colleagues contributed to the summary report: J. J. Morabito, Editor, APDA H. Muenchow, Associate Editor (nonmember), APDA F. Smith, AEC-CH T. Heckman, AEC-CH R. Dickinson, AI W. Simmons, ANL K. Goldmann, UNC R. Lockhart, GE H. Bowers, IASL

Purpose

The purpose of this program was to summarize current data and information concerning sodium-heated steam generators. The information was assembled for use by future fabricators of sodium-heated steam generators.

History and Present Status

The work on this contract was completed with the issuance of a topical report, Sodium-Heated Steam-Generator Summary, USAEC Report TID-18072, Sept. 19, 1962.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Study of Optimum Steam Conditions and Cycles for Large Sodium-Cooled Nuclear Power Plants
Contractor:	Atomic Power Development Associates, Inc. 1911 First Street Detroit, Michigan 48226
Project manager:	J. J. Morabito
AEC Contract No.:	AT-(11-1)-865, Project 1
Contract authorization date:	July 16, 1964
Contract completion date:	September 14, 1964
Key project personnel:	V. Lomuller P. P. Ross P. E. Heidman (Detroit Edison Company)

Purpose

This study was made to determine the economically optimum steam conditions and cycles for large sodium-cooled nuclear power plants. The analysis was to encompass the effect of steam pressure, steam temperature, reheat, and fuel cost on plant economics.

History and Present Status

The optimum steam conditions of those considered were steam temperature at 950°F, steam pressure at 3500 psig, and single reheat cycle. These conditions were found to be economically optimum for plants with fuel costs of both 10 and 30 cents per million Btu. Increasing the steam pressure from 1450 to 3500 psig, the range considered, gave a higher capital credit for all corresponding cases. A steam temperature of 950°F was economically more favorable than a temperature of 1050°F for most corresponding cases considered. Single reheat, in contrast to no reheat was also more favorable for most cases, especially at the lower pressures. The study was completed with the issuance of a topical report by J. A. Ford and M. J. Morabito, "Study of Optimum Steam Conditions and Cycles for Large Sodium-Cooled Nuclear Power Plant," USAEC Report TID-21292, Sept. 14, 1964.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Intermediate Heat Exchanger and Steam Generator
Contractor:	ALCO Products, Inc. Schenectady, New York
AEC Contract No.:	AT-(11-1)-666
Contract authorization date:	Approximately 1957
Contract completion date:	June 1963

Abstract from Contract

Nature and Scope of Work. The work under this agreement shall be unclassified and shall consist of the following:

1. Selection and preparation of a preliminary design for a 70 megawatt* steam generator and for a 70 megawatt* heat exchanger meeting the performance specifications set out in parts A and B respectively of Appendix A (which Appendix is attached hereto and made a part hereof) for use as components in a sodium-cooled reactor system and shall include:
 - a. Dimensioned outline and assembly drawings;
 - b. Preliminary drawings showing details of all unusual features;
 - c. Specifications to cover at least all the points in the functional specifications, set out in Part A or Part B, as appropriate, of Appendix A, including water quality control, as applicable;
 - d. Data sheets on the predicted performance of the steam generator and heat exchanger; and
 - e. The methods of inspection to be used after the steam generator and heat exchanger are in operation.
2. Preparation of a report of any other designs considered, and reasons for their elimination.

*Later reduced to 30 Mw.

3. The preparation of an analysis of the preliminary designs prepared in accordance with Section 1 of this Article to justify their selection, including:
 - a. Optimization of the division of heat transfer surface between intermediate heat exchanger and steam generator;
 - b. The basis for sizing of units;
 - c. Preliminary stress analyses of critical points for mechanical and thermal stress under conditions as set out in the appropriate functional specifications of Appendix A;
 - d. The design basis for the selection of applicable stresses; and
 - e. The basis for the selection of materials to be used and the justification for use of any unusual materials.
4. The preparation of an economic evaluation of the preliminary designs prepared in accordance with Section 1 of this Article. For analysis purposes, an equivalent capitalized cost of \$400.00 per fluid horsepower is to be used. Capital costs are to be presented in detail and will specifically identify (i) engineering costs, (ii) fabrication costs, (iii) material costs, (iv) cleaning and inspection costs, and (v) quality control. This evaluation will include estimates for:
 - a. The cost of the first steam generator and heat exchanger, including all necessary ancillary components;
 - b. The cost of any special tools required for maintenance;
 - c. The anticipated price of subsequent production models of the steam generator and heat exchanger; and
 - d. Expected operating costs.
5. Preparation of a detailed outline of the proposed research and development program required to develop and prove the preliminary designs, prepared in accordance with Section 1 of this Article. The program for the steam generator and for the heat exchanger should each be delineated in terms of:
 - a. Objectives;
 - b. Detailed description of the work to be accomplished;
 - c. Time estimate for accomplishment; and
 - d. Estimated costs.

6. In carrying on the work described in Sections 1 through 5 of this Article, the following limitations will apply:
- a. Reimbursement for experimental work in connection with Sections 1 through 5 hereof, will be made only to the extent that such experimental work has been approved by the Contracting Officer. It is the intent of the Commission to limit experimental work to that aiding mathematical analyses of design.
 - b. The work described in Sections 1 through 5 of this Article will be completed at a cost not to exceed the cost limitation set out in Section 1 of Article VI.

APPENDIX A

PART A

FUNCTIONAL SPECIFICATIONS FOR STEAM GENERATORS

I. SCOPE

This specification covers the requirements for a steam generator required to generate superheated steam from a heat source of 70 thermal megawatts by circulation of nonradioactive liquid sodium.

II. DESIGN DATA

Operating conditions (based on 100% load)

1. Steam Side

Temperature at unit outlet	1050°F
Pressure at unit outlet	2200 psig
Feedwater temperature	~600°F
Design temperature (boiler, if superheater is used)	~700°F
Design temperature (superheater, if used)	1200°F
Design pressure	2500 psig
Steam quality leaving unit	99.75% at 125% rated steam flow
Steam purity leaving unit	1 ppm total solids

2. Sodium Side

Rated heat load (approximately)	2.39×10^8 Btu/hr
Rated flow	As calculated
Inlet temperature	1140°F
Outlet temperature	650°-850°F
Operating pressure	100 psig
Design temperature	1250°F
Maximum pressure drop (across steam generator)	15 psi

3. Steam Generator Operation

The steam generator will be operated to give constant pressure at the turbine inlet.

The sodium inlet temperature to the unit will be allowed to float depending upon the reactor outlet temperature which may vary by 60°F maximum below peak temperature. The goal is to have the temperature of the sodium returning to the intermediate heat exchanger maintained as constant as practicable.

The steam temperature at the unit exit will not be controlled, but will float between its full load value and the temperature of the entering sodium. Its exact value will depend on the configuration of the unit.

The sodium flow rate will vary approximately linearly with load.

Normal startup and shutdown procedures will be specified by the proposer. Normal minimum startup rate will be 100°F/hr on sodium side.

After startup, or at any time within the range of 15% to 100% load, load change will be made by changing sodium flow rate and power to match demand. Normal rates of change are:

- a. Full-range ramp: $\pm 5\%$ (of full-load value) per minute from 20-100%.
- b. Short-time ramp: $\pm 20\%$ (of full-load value) in 1 minute.
- c. Step change: $\pm 10\%$ (of full-load value).

III. STEAM GENERATOR TRANSIENTS

This section indicates the transients that shall be used in calculating steam generator stresses.

1. Normal Operation

Number of startup cycles for use in design: 1,000

Number of operating cycles for use in design: 10^6

2. Casualty Conditions

The steam generator units shall be capable of withstanding the following thermal transient conditions:

Condition	Sodium Temp. at Start of Transient	Predicted Max. Rate of Change of Sodium Temperature for 3 seconds	Predicted Duration of Transient	Sodium Temp. at End of Transient
Primary reactor sodium pump stops; secondary sodium flow to generator continues	1140°F (inlet)	-35°F/sec	14 sec	650 to 850°F (inlet)
Sodium flow stops; feedwater flow continues	1140°F (inlet)	-35°F/sec	16 sec	650 to 850°F (inlet)
Feedwater flow stops; sodium flow continues	650 to 850°F (outlet)	+50°F/sec	9 sec	1140°F (outlet)

The above transients are subject to revision depending upon generator design.

The predicted number of cycles of each above condition during the life of the equipment is about 25.

IV. WATER ANALYSIS

To be specified by proposer.

V. MATERIALS

To be specified by proposer. Only materials commercially available should be considered. Material selected must be compatible with conditions.

VI. MAINTENANCE

The unit should be so designed as to be accessible for inspection and repairing or plugging of tubes. A design using sodium on the outside and water or steam on the inside should permit the complete inspection of the interior surfaces of pipes or tubes which contain water.

APPENDIX A

PART B

FUNCTIONAL SPECIFICATIONS FOR SODIUM-SODIUM HEAT EXCHANGERS

I. SCOPE

This general specification is intended to serve as a guide in establishing the requirements for design, development, fabrication, and test operation of sodium heat exchange equipment for sodium-cooled nuclear power plant application.

II. GENERAL REQUIREMENTS

1. The sodium-sodium heat exchanger will be suitable for transferring heat from a radioactive primary sodium reactor coolant to a nonradioactive secondary sodium coolant.
2. The operating conditions are given under "Detail Requirements."
3. In general, the heat exchange equipment shall be designed to utilize conventional configurations which permit maximum use of existing fabrication procedures, skills, and equipment.

III. DETAIL REQUIREMENTS

1. Sodium-sodium heat exchanger — operating conditions
 - a. Primary sodium side
 - (1) Inlet temperature 1200°F
 - (2) Outlet temperature 700°F to 900°F
 - (3) Design pressure 100 psig
 - (4) Maximum pressure drop 15 psi

b. Secondary sodium side

(1) Inlet temperature	To be recommended
by proposer
(2) Outlet temperature	1140°F
(3) Design pressure	100 psig
(4) Maximum pressure drop	15 psi

c. Heat transfer capability ~70 Mw (2.39×10^8
Btu/hr)

2. Transients

a. Normal

- (1) Normal and planned startup and shutdown rates not to exceed temperature changes of 100°F/hr.
- (2) Power changes in the operating range will be accomplished by varying sodium flow.
- (3) Linear increase in load from 10% to 100% in three minutes. (Use 10,000 cycles for design.)
- (4) Step change in steam demand of 10% of rated steam flow in three seconds. (Use 1 million cycles for design.)

b. Reactor Scrams

- (1) The predicted changes based upon operating conditions are:
 - (a) Primary sodium inlet temperature drops 60°F in first 1/2 second.
 - (b) It drops a total of 130°F in 6 seconds.
 - (c) The predicted sodium temperature at the end of the condition is the normal sodium outlet temperature.
- (2) Number of cycles for use in design: 1000

c. Casualty Conditions

- (1) Primary pump stops, but secondary pump continues to run. The predicted changes are to be specified by the proposer. Number of cycles for use in design: 5.
- (2) Secondary pump stops, but primary pump continues to run. The predicted changes are to be specified by the proposer. Number of cycles for use in design: 5.

d. General Conditions

- (1) The sodium nozzles shall be designed for a total moment of 40,000 ft-lb and a 400 lb thrust.
- (2) The exchanger shall permit complete gravity drainage of the shell and tubes through the inlet and/or outlet nozzles, or drain connections.
- (3) Shells and channels shall be vented where gas traps may occur. Helium and/or nitrogen gas may be entrained in the sodium due to leakage of the pump seal and other sources.
- (4) The tube sheets (if used) shall be accessible during shutdown for repair of a defective tube and shall require a minimum of cutting of headers and piping.
- (5) The heat exchanger will be located in a concrete vault and will be inaccessible during operation due to Gamma radiation.
- (6) Experience indicates that a shell-and-tube heat exchanger will rapidly go isothermal during low flow rates and at shutdown conditions. Prior to reaching the isothermal conditions, severe temperature gradients are experienced across the faces of the tube sheets. This is caused by the rapid temperature stratification of the fluids.
- (7) It may be necessary occasionally to simultaneously close the inlet and outlet valves of a circulating loop and isolate the heat exchanger. This isolation will cause an internal convection flow that will result in the exchanger eventually going isothermal.
- (8) It is necessary to minimize the temperature gradients, particularly at the tube sheets, by slowing the rate of approach to the isothermal condition. Extreme care must be exercised in orienting the baffles, locating the inlet and outlet nozzles, and in the general design of the heat exchanger in order that rapid stratification may be overcome.

- (9) In addition to the calculations normally required by applicable codes, stress analyses of combined mechanical hydrostatic and thermal stresses in all critical areas will be performed by the proposer prior to initiation of fabrication. The AEC will furnish an appropriate structural design basis which specifies allowable values for combined stresses, conditions for using creep and stress-rupture properties and similar information required for adequate stress analysis.

IV. STRUCTURAL DESIGN BASIS

The achievement of a well-proportioned design which satisfies safety as well as operational requirements requires particular attention to design, fabrication and welding techniques, and inspection and testing procedures. The following shall be carefully considered:

1. The ASME Code and TEMA Class R standards shall be used as the minimum design requirement for all components. However, conformance to the codes does not necessarily constitute a suitable design.
2. Design drawings shall reflect full appreciation of the stresses associated with gross structural discontinuities.
3. A minimum of local structural discontinuities shall be used.
4. It is essential to evaluate completely the stress and strain values caused by the loadings and transients as indicated.
5. Calculated stresses and deformations shall be restricted to the elastic range with the possible exception of the extreme transient conditions as indicated in this specification.

V. MATERIALS OF CONSTRUCTIONS

Only materials which are known to require no extensive development and which are compatible with specified service conditions shall be used for construction.

VI. CLEANING

The general, commercial cleaning procedures, such as ASTM Standard A380-54T for cleaning stainless steel, shall be considered acceptable. Specific cleaning procedures shall be recommended by the proposer.

VII. TESTING AND INSPECTION

The testing and inspection necessary is to be recommended by the proposer.

History and Present Status

Three independent studies of new heat exchanger concepts were made for the AEC during FY-1958. The study contract with ALCO Products, Inc. was extended to include detailed design and fabrication of one 30-Mw intermediate heat exchanger (IHX) and one 30-Mw steam generator. In February 1961, ALCO was authorized to initiate detailed shop drawings and to issue purchase orders for the IHX. The initial schedule called for delivery of both units during late 1962. ALCO Products, Inc., decided to withdraw from the nuclear heat exchanger field in the spring of 1962. Consequently the fabrication of the 30-Mw steam generator was turned over to Baldwin-Lima-Hamilton in August 1962. The fabrication of the IHX was continued at ALCO because this unit was more nearly complete. The IHX was completed in February 1963 and shipped to the Sodium Components Test Installation at Canoga Park, California, for testing.

Because of ALCO's initial involvement in the 30-Mw steam generator program, some work was accomplished for the steam generator during 1963. ALCO purchased the bimetallic type 316 stainless steel-Inconel tubing from Superior Tube Company for the steam generator and developed welding procedures for the material. Considerable cracking difficulty was encountered in the root pass of welds joining the bimetallic tube to the Inconel-overlaid stainless steel tube sheet. This problem was finally solved by modification of the joint design and a change in the welding procedure to reduce the stress on the weld during its solidification. The procedures for the fillet weld of 1/2-in.-OD, 0.105-in.-wall, Inconel-type 316 stainless

steel composite tubing to Inconel-overlaid type 316 stainless steel tube sheets utilizing a cold wire feed were supplied to Baldwin-Lima-Hamilton. This joint modification was incorporated in the final design.

A final report covering the Inconel overlay procedure for type 316 stainless steel tube sheets for the steam generator, the development of automatic welding procedures for the intermediate heat exchanger and steam generator tube-to-tube sheet joints, and the thermal shock tests of specimens simulating the tube-to-tube sheet joints on the intermediate heat exchanger and steam generator was completed and issued as USAEC Report APAE 123.

Topical Reports

1. Tube to Tubesheet Welding Development Programs for 30-mw Prototype Sodium Intermediate Heat Exchanger and Steam Generator, USAEC Report APAE-123, June 1963.
2. Test Program for 30-mw Prototype Sodium Intermediate Heat Exchanger and Steam Generator, USAEC Report APAE-122, Sept. 14, 1962.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Preliminary Design for Steam Generator and Intermediate Heat Exchanger
Contractor:	Griscom-Russell Company Massilon, Ohio (Now Baldwin-Lima-Hamilton Corporation Philadelphia, Pennsylvania 19142)
AEC Contract No.:	AT-(11-1)-664
Contract authorization date:	June 26, 1958
Contract completion date:	March 1959

Purpose

The objective of this program was to develop a conceptual design for a steam generator and an intermediate heat exchanger of advanced design with high performance and reliability.

History and Present Status

Original design work was done on units of 70-Mw capacity. Later evaluations were made for 30-Mw units. The design work included optimization, sizing, stress analysis, materials selection, and an outline of development required to prove the design. A final design report was issued to the Chicago Operations Office of the AEC on February 25, 1959.

The design concept evolved under this contract was not fabricated or tested. A concurrently developed design by ALCO Products Company was selected by the AEC for fabrication and subsequent testing at the Sodium Components Test Installation at Atomics International. The ALCO heat exchanger and steam generator program is covered in the preceding section.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Fabrication and Testing of Steam Generator
Contractor:	Baldwin-Lima-Hamilton Corporation Philadelphia, Pennsylvania 19142
Project manager:	P. S. Otten
AEC Contract No.:	AT-(11-1)-1213
Contract authorization date:	August 29, 1962
Contract completion date:	Approximately June 1965

Purpose

The primary objective of this program was to complete the manufacture and testing of a 30-Mw steam generator using the ALCO design and material procured by ALCO. Baldwin-Lima-Hamilton took over the remaining portions of the contract when ALCO decided to discontinue manufacture of nuclear systems. A secondary objective was to move and restore a high-pressure high-temperature test loop using equipment located at ALCO. Tests were to be run with sine-wave bimetal tubing to obtain heat transfer and metallurgical information at simulated operating conditions.

History and Present Status

Fabrication of the steam generator shell was started in December 1962, with a scheduled completion date of November 1963. The required bimetal tubes of stainless steel and Inconel were fabricated by Superior Tube Company. Final delivery of the tubing was made in June 1963, and delivery of welding equipment from ALCO was made at the same time. Considerable time was spent repairing tube-to-tube sheet weld defects, which were located by dye penetrant and helium mass spectrometer leak checks. These welding difficulties were one of the major factors in extension of the completion schedule. Upon completion of assembly, both the shell and tube sides were hydrostatically tested with distilled water. A series of strain-gage measurements was made during hydrotesting, and a report on the data

was later issued. Upon completion of the hydrostatic test, the steam generator was dried by heating to 400°F in an annealing furnace, evacuated, and then purged with dry nitrogen until the dew point of the effluent nitrogen was a minus 40°F. The steam generator was shipped to Atomics International for testing in August 1964.

The secondary objective of this contract was the operation of the ALCO high-pressure high-temperature loop. The loop was removed from ALCO and reassembled and modified at Baldwin-Lima-Hamilton. The loop was in shakedown operation at the time of cancellation of this portion of the contract in January 1964. The loop was disassembled in early 1964, and portions of the loop equipment were transferred to Argonne National Laboratory.

Topical Reports

1. The ALCO Steam Generator Fabrication and Inspection Report, USAEC Report COO-1213-26, April 1965.
2. Report on Hydrostatic Test and Strain Gage Measurements on ALCO Steam Generator, USAEC Report COO-1213-27, May 1965.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Analysis and Evaluation of Performance Data on the ALCO Steam Generator and Intermediate Heat Exchanger
Contractor:	Baldwin-Lima-Hamilton Philadelphia, Pennsylvania 19142
Project manager:	John G. Gaydos
AEC Contract No.:	AT-(11-1)-1501
Contract authorization date:	June 15, 1965
Contract completion date:	June 1967

Purpose

The objective of this program is to analyze and evaluate performance data obtained by Atomics International on the ALCO steam generator and intermediate heat exchanger.

History and Present Status

Results are not yet available.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Sodium Components Test Installation Design Study
Contractor:	Atomic Power Development Associates 1911 First Street Detroit, Michigan 48226
Project manager:	R. H. Anderson
AEC Contract No.:	AT-(11-1)-772
Contract authorization date:	June 19, 1959
Contract completion date:	June 30, 1960

Purpose

The purpose of this program was to provide criteria and a conceptual design for a test facility capable of subjecting sodium components to steady-state and transient conditions expected in full-size power plants.

History and Present Status

This contract was active for approximately a one-year period and a design report was issued entitled "Sodium Components Test Facility," APDA-134, November 1959. The report on the test facility covered design criteria, construction time estimate, cost estimate, and a survey of existing facilities. Attempts were made to use existing equipment wherever feasible.

Topical Report

1. Sodium Components Test Facility, USAEC Report APDA-134, November 1959.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Sodium Components Test Installation
Contractor:	Atomics International P. O. Box 309 Canoga Park, California 91304
Project managers:	Roman Cygan Ralph Jones Thomas Withers James Leppart (present manager)
AEC Contract No.:	AT-(11-1)-GEN 8
Contract authorization date:	November 1960
Contract completion date:	Work in progress as of July 1965

Purpose

The primary purpose of the sodium components test facility is to provide a system to proof-test prototypes of heat transfer components for future liquid-metal-cooled reactors. The main objective of building and testing these heat transfer components is to obtain information on (1) fabricability, (2) overall heat transfer and fluid flow performance, (3) structural integrity, and (4) control response characteristics.

A secondary objective will be the testing of sodium equipment, such as throttling devices, flow and pressure indicators, impurity indicators, etc.

History and Present Status

Construction work on the sodium components test installation (SCTI) was started in May 1961. An existing 35-Mw sodium heater and existing pumps were incorporated into the facility. Sodium piping installation was started in October 1962. Ten-inch stainless steel pipe and fittings were used for the major flow paths. The intermediate heat exchanger (sodium to sodium) was fabricated by ALCO and installed in the SCTI in January 1963. The first steam generator to be tested was designed and partially fabricated by ALCO. Fabrication was completed by Baldwin-Lima-Hamilton. This unit was delivered to the test area in September 1964.

and was installed during the subsequent 3 1/2 months. The primary and secondary sodium drain tanks were changed at this time to increase the combined sodium capacity to 12,500 gal.

As of July 1965, preoperational procedures had been completed for the many auxiliary systems, such as compressed air preheaters, inert gas system, and instrument air system; and sodium circulation was about to begin.

It is now planned to test three prototype steam generators. This includes the presently installed ALCO-BLH unit, the AI modular steam generator, and a Babcock & Wilcox steam generator.

Topical Report

1. Technical Description of a Sodium Component Test Installation, USAEC Report NAA-SR-5993, Jan. 4, 1961.

Progress Reports

1. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, January-March 1964, USAEC Report NAA-SR-9700.
2. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, July-September 1964, USAEC Report NAA-SR-10501.
3. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, October-December 1964, USAEC Report NAA-SR-10850.
4. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, January-March 1965, USAEC Report NAA-SR-11200.
5. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, July-September 1965, USAEC Report NAA-SR-11650.
6. Atomics International Annual Technical Progress Report, AEC Unclassified Programs, Fiscal Year 1964, USAEC Report NAA-SR-9999.
7. Atomics International Annual Technical Progress Report, AEC Unclassified Programs, Fiscal Year 1965, USAEC Report NAA-SR-11450.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Modular Steam Generators
Contractor:	Atomics International P.O. Box 309 Canoga Park, California 91304
Project manager:	D. T. Eggen
AEC Contract No.:	AT-(11-1)-GEN 8 Sub Account 7519-4493
Contract authorization date:	May 1962
Contract completion date:	June 1965

Purpose

The purpose of this program was to develop a once-through single-wall sodium-heated supercritical steam generator of modular design. The program was to include module optimization studies and fabrication development.

History and Present Status

General design and development studies for the modular steam generator were started in May 1962. A specific design for a set of modules with about 20-Mw(t) capacity at steam conditions of 2400 psi and 1050°F was started in July 1962. The design consisted of 37-tube units and had two evaporator modules and two superheater modules. The evaporator units were fabricated with Croloy, the iron-base 5% Cr-1/2% Mo alloy. The superheater units were fabricated of type 321 stainless steel. Internal tube-to-tube sheet welding techniques were developed for both the ferritic and austenitic steels. The evaporator and superheater modules were completed in June 1965 and are being stored until testing gets under way. It is planned to test these units in the Sodium Components Test Installation after completion of tests of the presently installed ALCO-BLH steam generator. Topical reports issued on the design, welding development, stress analysis, fatigue testing, and fabrication are listed below.

Topical Reports

1. D. F. Casey et al., Design, Performance and Economics Evaluation of Sodium-Heated, Modular, Supercritical, Steam Generators, USAEC Report NAA-SR-8508, Aug. 19, 1963.
2. M. M. Levin, Photoelastic Determination of Stresses in the AI Steam Generator, USAEC Report NAA-SR-8515, Jan. 30, 1964.
3. M. M. Lemcoe, Experimental Stress Analysis of 37-Tube Modular Steam Generator Head, USAEC Report NAA-SR-8514, Jan. 30, 1964.
4. D. F. Casey et al., Final Design of Sodium-Heated, Modular Steam Generators for the SCTI, USAEC Report NAA-SR-9826, Feb. 1, 1965.
5. D. F. Casey et al., SCTI - Modular Steam Generator Control System Study, USAEC Report NAA-SR-TDR-10994, Feb. 4, 1965.
6. G. Kazlauskas, A Device for Internal T.I.G. Arc Welding of Tube to Tube Sheet Joints, USAEC Report NAA-SR-8541, Mar. 15, 1965.
7. M. M. Lemcoe, Fatigue Testing of 37-Hole Modular Steam Generator Head, USAEC Report NAA-SR-9827, Apr. 20, 1965.

Progress Reports

1. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, January-March 1964, USAEC Report NAA-SR-9700.
2. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, July-September 1964, USAEC Report NAA-SR-10501.
3. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, October-December 1964, USAEC Report NAA-SR-10850.
4. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, January-March 1965, USAEC Report NAA-SR-11200.
5. Atomics International Quarterly Technical Progress Report, AEC Unclassified Programs, July-September 1965, USAEC Report NAA-SR-11650.
6. G. Kazlauskas, A Device for Internal T.I.G. Arc Welding of Tube to Tube Sheet Joints, USAEC Report NAA-SR-8541, Mar. 15, 1965.
7. Atomics International Annual Technical Progress Report, AEC Unclassified Programs, Fiscal Year 1965, USAEC Report NAA-SR-11450.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Shell-Side Heat Transfer Studies
Contractor:	Atomics International P.O. Box 309 Canoga Park, California
Project manager:	J. S. McDonald
AEC Contract No.:	AT-(11-1)-GEN-8-4468
Contract authorization date:	July 1, 1961
Contract completion date:	June 30, 1963

Abstract from Contract

Justification. Methods for predicting liquid metal heat transfer coefficients developed from fundamental heat transfer theory have been satisfactorily substantiated by experimental data for liquid metals flowing through round tubes and annuli. However, these methods have proved entirely inadequate for predicting liquid metal heat transfer performance in heat exchange units. Generalized equations found to be satisfactory for normal fluids in shells frequently predict Nusselt numbers for liquid metals which may differ from experimental results by as much as a factor of 10. This inadequacy is of little consequence in the design of heat exchangers where the heat transfer is between liquid metal and some other fluid which has a low heat transfer coefficient in comparison with the liquid metal. However, in the design of liquid metal-to-liquid metal heat exchangers and liquid-metal-heated steam generators, the liquid metal heat transfer coefficient may be a significant factor in determining heat exchanger dimensions required to meet specified operating conditions. In the case of liquid-metal steam generators, it is usually preferable for structural design reasons to carry the high-pressure steam in the tubes with the liquid metal in the shell. Where liquid-metal shell-side performance is an important factor, it has been necessary to develop an empirical relationship from experimental data obtained for the particular shell-side geometry being considered. At this time, it is impossible to

reliably evaluate by analytical methods liquid-metal heat transfer performance for a wide variety of shell-side geometries. Such an evaluation would strongly aid in the selection of the shell-side geometry best suited for any particular liquid-metal heat exchanger application.

Purpose. A program of research and experimental work is sought, the purpose of which will be to establish reliable shell-side heat transfer correlations for sodium for a wide variety of tube-and-shell heat exchanger geometries.

Nature and Scope of Work. A literature survey should be made of the existing data and the methods used in determining the data. The proposed work should be approached first from a fundamental analytical basis and followed by an experimental program. The experimental program should result in the development of equations that will prove reliable in the design of large-capacity liquid-metal heat exchangers and steam generators.

Functional Specifications

1. Liquid metal - Na or NaK
2. Flow - both laminar and turbulent flow; use Reynolds Number 400,000 as an upper limit
3. Coolant - (1) sodium or NaK, (2) H₂O
4. Temperature range - 500 to 1300°F
5. Heat flow rates - to 200,000 Btu/ft² hr
6. Geometric parameters - (a) tube size 1/4 to 1 in. inside diameter; (b) tube spacing center to center - 1 1/2 to 4 diameters

History and Present Status

The objective of this work was to obtain shell-side heat transfer coefficients of liquid metal-to-liquid metal heat exchangers. The parameters of tube size, tube pitch, and angle of **attack** were to be investigated for use in refining calculations of plant-size heat exchangers.

A 1-Mw regenerative sodium loop was constructed and some preliminary data were obtained on three tube bundles. A failure occurred in a sodium cooler in February 1963, and no further testing was done. The program was

terminated by the AEC in June 1963. The remaining equipment and preliminary data obtained were preserved by Atomics International for use in the event technical interest in the program is revived in the future. No topical reports were issued because the work was not completed.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Second Steam Generator
Contractor:	Babcock & Wilcox Company Barberton, Ohio
Project manager:	P. B. Probert
AEC Contract No.:	AT-(11-1)-1280
Contract authorization date:	March 20, 1963
Contract completion date:	December 1967

Purpose

The purpose of this program is to design a full-size steam generator [1000 Mw(e) in three units] and to design and fabricate a 30-Mw(t) prototype sodium-heated steam generator. These tasks are part of the AEC's program to develop the technology in industry for furnishing sodium-heated steam generators.

History and Present Status

Work was started in March 1963 on the design of a full-size sodium-heated steam generator. In May 1963, the design size was increased so that three steam generators could produce enough steam for a 1000-Mw(e) plant. The overall size of one of these boiler units will be approximately 12 ft 6 in. in inside diameter and 70 ft in height. The steady-state operating steam pressure will be 2400 psig. Each boiler will be a once-through type and will use single-walled tubes.

It was planned to begin design work on the 30-Mw prototype steam generator after most of the design work was completed on the full-size unit so that the prototype could better test problem areas of the full-scale design. The full-scale design was completed in July 1964, and the prototype design was scheduled for completion in July 1965.

Development work was done at Babcock & Wilcox on (1) carbon transfer, (2) model steam generator tests, (3) welding and x-raying procedures,

(4) coiled-tube two-phase heat transfer, and (5) corrosion of the iron-base alloy Croloy (2 1/4% Cr) in products of a sodium-water reaction. Investigation of the sodium-water reaction is being done by APDA under a subcontract from Babcock & Wilcox.

The schedule for this program calls for fabrication of the 30-Mw prototype by November 1966. This steam generator will then be tested in the sodium components test installation by Atomics International.

Topical Reports

1. Preliminary Design Report Full-Size Steam Generator, USAEC Report BW-67-2, July 1, 1964.
2. Materials Selection, USAEC Report BW-67-3, September 1964.

Progress Reports

1. Research Report, Heat Transfer in Coiled Tubes, USAEC Report B&W-4413, Nov. 22, 1963.
2. P. B. Probert, Interim Status Report, USAEC Report BW-67-1, Jan. 22, 1964.
3. D. W. Koch, Research Report, Progress Report, Model Sodium Steam Generator Test, USAEC Report B&W 5452, Mar. 6, 1964.
4. Research Report, Heat Transfer in Coiled Tubes, USAEC Report B&W 4438, July 21, 1964.
5. Second Progress Report on Model Sodium Heated Steam Generator, B&W Research Report 5455, USAEC Report B&W-1280-18, Dec. 31, 1964.

Heat Exchangers for Steam Generation
(continued)

Title of program:	Small-Leak Sodium-Water Reaction Test Program
Contractor:	Atomic Power Development Associates, Inc. 1911 First Street Detroit, Michigan 48226
Project manager:	H. O. Muenchow
AEC Contract No.:	AT-(11-1)-865, Project Agreement No. 10
Contract authorization date:	February 1, 1964
Contract completion date:	Work in progress as of July 1965.

Purpose

The objective of this program is to design and build a loop to evaluate the consequences of a water leak into a sodium heat exchanger system.

History and Present Status

A test loop has been designed that contains a reaction vessel, sodium pump, oxide removal system, sodium water reactor trigger mechanisms, and required instrumentation. It is planned to conduct a series of 12 leak tests covering a range of small water leaks to determine the effect of leak rate on tube wastage. Some parameters to be investigated are water leak rate, exposure time, distance of adjacent tube surface from leak, water leak velocity, materials of construction, and reaction temperatures. As of July 1965, the loop was in the latter stages of construction, with insulation and electrical work in progress.

Progress Reports

1. Quarterly Technical Progress Report on AEC Sponsored Activities, USAEC Report APDA-174, June 1965.
2. Quarterly Technical Progress Report on AEC Sponsored Activities, USAEC Report APDA-178, September 1965.

Operating Experience

Title of program: Compilation of Operating Experience
 for Enrico Fermi Fast Reactor

Contractor: Atomic Power Development
 Associates, Inc.
 1911 First Street
 Detroit, Michigan 48226

Project manager: Evan C. Kovacic

AEC Contract No.: AT-(11-1)-865, Project Agreement No. 15

Contract authorization
 date: January 28, 1965

Contract completion
 date: Work in progress as of July 1965

Purpose

The objective of this program is to compile a report on the noteworthy technical experience gained during the design, construction, and operation of the Enrico Fermi Atomic Power Plant.

History and Present Status

APDA will conduct an internal literature search to provide the technical data for the compilation. Important components and systems will be reviewed in individual reports. Work was in progress as of July 1965 on reports of the following categories of Enrico Fermi experience:

- Primary System Development
- Nuclear Test Program
- Low-Power Nuclear Test Results
- Steam Generators
- Sodium System Flowmeters
- Control and Safety Rod Drives
- Sodium-Sampling Procedures
- Sodium System Level Detectors
- Fuel Handling in the Reactor Vessel

Progress Reports

1. Quarterly Technical Progress Report on AEC Sponsored Activities, USAEC Report APDA-174, June 1965.
2. Quarterly Technical Progress Report on AEC Sponsored Activities, USAEC Report APDA-178, September 1965.

APPENDICES

APPENDIX A
AEC SODIUM COMPONENTS DEVELOPMENT PROGRAM

OBJECTIVES, ORGANIZATION,
AND PROCEDURES

FEBRUARY 1965

AEC SODIUM COMPONENTS DEVELOPMENT PROGRAM
OBJECTIVES, ORGANIZATION, AND PROCEDURES

Table of Contents

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I. Objective

The Sodium Components Development Program (SCDP) is a Commission-wide effort to develop, within the United States' industrial complex, a competence for manufacturing safe, reliable, and economical components for advanced sodium-cooled nuclear power plants and the supporting technology to achieve this objective.

II. Purposes

The purposes of the SCDP are:

- A. To co-ordinate the development and exchange of information and foster the technical effort in the areas related to advanced sodium-cooled reactor components.
- B. To complement the objectives of the Atomic Energy Commission Civilian Power Program.
- C. To insure that safe, reliable, and economical components, capable of utilizing 1200°F bulk sodium outlet temperature, can be manufactured by industry on a time scale that will permit start of construction of a prototype converter reactor power plant in the near future, fast breeder reactor prototype in 1969, and a 1000 MWe plant in 1989 or earlier.

III. Organization

The organization of the SCDP and the responsibilities of each organizational element are listed below: (An organization chart is shown in Figure I.)

A. Division of Reactor Development and Technology (DRD&T)

Programmatic guidance for the over-all program.

B. Liquid Metal Cooled Reactors Branch

Specific program direction, program formulation and redirection, preparation of requests for contractor selection, and through DRD&T the delegation of the execution and administration of contracts to Field Offices.

C. Field Offices

Technical evaluation, direction, and contract administration of the work in progress. In accordance with specific requests from DRD&T, engages in contractor selection and contract negotiation for new work or redirection of existing work.

The Field Offices now participating in the program are:

- 1. Chicago Operations Office, including Canoga Park Area Office.
- 2. New York Operations Office.
- 3. San Francisco Operations Office.

Other operations offices may be called on to participate in the program as appropriate and as program objectives may require.

FIGURE IORGANIZATION OF THE SODIUM COMPONENTS DEVELOPMENT PROGRAM

1. The Chief of the Liquid Metal Cooled Reactors Branch, Division of Reactor Development and Technology, and Chairman of the Working Group serve in a dual capacity.

IV. Functions of the Working Group, Consultants, and Standing Committees

A. Working Group

The Working Group shall define the R&D necessary to meet the technical and time objectives of the program. Through review and evaluation of the work in progress, the Group may recommend the solicitation of new work or the termination of current work.

B. Consultants

The Consultants assist the Working Group in a technical advisory capacity in areas pertinent to achieving the objectives of the SCDP.

C. Standing Committees

Standing Committees assist the Working Group and are established for a specific area of interest. The Committees are authorized through the Chairman of the Working Group who appoints the Committee Chairman and assigns responsibility to review specific programs within the assigned area of technical interest. The Committee reports on the progress of work and recommends program direction to the Working Group. In no event does the Standing Committee direct contractors either to perform or to redirect their efforts.

At present the Working Group has the assistance of four standing committees:

1. Standing Committee for Mechanical Properties.
2. Standing Committee for Sodium Corrosion and Mass Transfer.
3. Standing Committee for Sodium Impurities.
4. Standing Committee for Steam Generator Testing.

V. Membership of the Working Group, Consultants, and Standing Committees

A. Working Group

The membership of the Working Group is limited to employees of the Atomic Energy Commission. The Code of Ethics included in Chapter 4124, "Conduct of Employees," of the AEC Manual will be followed by all members.

B. Working Group Consultants

The Consultants to the Working Group are members of National Laboratories working in the areas of the liquid metal technology or component development. No employees of commercial contractors shall be direct consultants to the Working Group except for limited, very specific assignments.

C. Standing Committees

The Standing Committees are chaired by employees of the AEC. All members are employees of the AEC or National Laboratories except that, upon concurrence of the Chairman of the Working Group, an employee of a commercial contractor may be appointed as a member of a committee where his special technical knowledge is needed until a suitable replacement is found.

VI. Operating Procedures

A. Review of Work in Progress

The Working Group with assistance from the Consultants and Standing Committees reviews and evaluates the results developed from work in progress and its relation to the objectives and purposes of the SCDP. It conducts its business on a formal basis, and records of its proceedings are maintained. At executive sessions of the Working Group, only members, Consultants, and invited guests are admitted.

A general information meeting is held at least once a year. Its purpose is to keep the parties that are participating in related programs informed of progress in sodium components development. At these meetings the contractors present the results and status of their respective work.

Each member of the Working Group, its Consultants, and each member of a Standing Committee are provided with appropriate reports. These reports will include both contractor-prepared progress and topical reports and a monthly SCDP Status Report which is prepared by the Reactor Engineering Division of the Chicago Operations Office.

B. Initiation of New Work - Solicited Proposals

All identified problem areas, which result in proposals and recommendations for the initiation of new work, from whatever source they may originate, shall be channeled to a field office for review and subsequent transmittal to the Chief, Liquid Metal Cooled Reactors Branch, Division of Reactor Development and Technology.

1. Proposals for new work shall include, as a minimum, the following:

- a. The nature of the work,
- b. A reasonably detailed scope of work or technical specification as may be appropriate,
- c. Justification for inclusion in the program,
- d. Estimated costs by fiscal years,
- e. List of others in the AEC that have received the proposal for consideration and possible implementation.

2. The Chief, Liquid Metal Cooled Reactors Branch, DRD&T, with such assistance as may be requested from the field offices, Working Group, and Consultants, will determine if the proposed new work is to be initiated.

Should the proposal be accepted for implementation, the Chief, Liquid Metal Cooled Reactors Branch, will request the Director, Division of Reactor Development and Technology, to initiate the work without a formal contractor selection or to have a selection board recommend a contractor.

3. The Director, Division of Reactor Development and Technology, if appropriate, will cause a contractor selection board to be convened to recommend a contractor. In many cases he will call upon the field office managers to perform this function.

4. The Operations Office Manager convenes the selection board as requested in accordance with AEC Procurement Regulations Part 9-56, "Selection of Contractors by Board Process," or where special situations dictate otherwise and DRD&T determines it to be advisable, the proceedings of the Selection Board will be in accordance with the applicable requirements set forth in AECPR 9-56.

The Selection Board shall utilize information regarding the SCDP requirements. This information shall be communicated to the Selection Board by the Chairman of the Working Group.

Consistent with AECPR 9-56, DRD&T may request that the Selection Board include a member of the Working Group, representative from a field office other than the selection office, or other designated technical personnel as appropriate.

5. Selection Board - The Chairman of the Selection Board makes the recommendation known to the Manager of the Operations Office. Upon approval of the selection by the Manager, the Director of DRD&T and the Chief of the Liquid Metal Cooled Reactors Branch are advised.
6. Contract Authorization - The Director, DRD&T, notifies the appropriate field office manager via Form WRD-1, "Contract Authorization," to negotiate and administer the contract.

C. Initiation of New Work - Unsolicited Proposals

Unsolicited proposals may originate from non-AEC contractors in the form of general statements of a problem relating to the SCDP, which they would propose to investigate under contract, or from present AEC contractors. In this latter case, the contractor may propose to do the work under an existing contract or project, or as a new separate effort. In either case, the proposal shall be channeled to a field office for review and subsequent transmittal to the Chief, Liquid Metal Cooled Reactors Branch, DRD&T.

1. All unsolicited proposals shall include, in so far as it is practicable,
 - a. The nature of the work,
 - b. A reasonably detailed scope of work or technical specification as may be appropriate,
 - c. Justification for inclusion in the program,
 - d. Estimated costs by fiscal years,
 - e. List of others in the AEC that have received the proposal for consideration and possible implementation.
2. The Chief, Liquid Metal Cooled Reactors Branch, and the Director, DRD&T, process unsolicited proposals the same as solicited proposals except that procurement will be in accordance with AECPR Subpart 9-4.52 and AECPI Subpart 9-4.52, "Unsolicited Proposal for R&D Contracts Submitted by Individuals and Commercial and Not-for-Profit Organizations Other than Education Institutions."

D. Negotiation, Execution, and Administration of Contracts

1. Upon receipt of a Contract Authorization, Form WRD-1, the manager of the field office directs his staff to negotiate an agreement with the selected contractor.
2. Upon negotiation of the contract, the manager of the field office delegates authority for both technical and contract administration functions within his office. The names of the field office personnel involved will be communicated to the Chief, Liquid Metal Cooled Reactors Branch. The manager will have copies of progress and topical reports sent to DRD&T, the Working Group members, and interested contractors as specified.

APPENDIX A - MEMBERSHIP OF THE WORKING GROUP, CONSULTANTS, AND STANDING COMMITTEES1. Working Group

G. W. Wensch, Headquarters, Chairman
R. N. Jones, Vice Chairman and Secretary
C. A. Pursel, Chicago Operations Office
C. W. Richards, Canoga Park Area Office
J. P. Holliday, San Francisco Operations Office
J. Wise, New York Operations Office

2. Consultants

W. R. Simmons, Argonne National Laboratory
O. E. Dwyer, Brookhaven National Laboratory
W. R. Wykoff, Los Alamos Scientific Laboratory
H. W. Savage, Oak Ridge National Laboratory

3. Standing CommitteesStanding Committee for Mechanical Properties

J. J. Purcell, Chicago Operations Office, Chairman
J. H. DeVan, Oak Ridge National Laboratory, Member
J. McKee, United Nuclear Corporation, Member
C. Klamut, Brookhaven National Laboratory, Member
L. Kelman, Argonne National Laboratory, Member

Standing Committee for Sodium Corrosion and Mass Transfer

J. P. Holliday, San Francisco Operations Office, Chairman
H. W. Savage, Oak Ridge National Laboratory, Member
J. H. DeVan, Oak Ridge National Laboratory, Member
D. Gardiner, Oak Ridge National Laboratory, Member
C. Klamut, Brookhaven National Laboratory, Member

Standing Committee for Sodium Impurities

J. Wise, New York Operations Office, Chairman
F. A. Smith, Argonne National Laboratory, Member
R. Bane, Argonne National Laboratory, Member
J. White, Oak Ridge National Laboratory, Member
L. Newman, Brookhaven National Laboratory, Member
A. Romano, Brookhaven National Laboratory, Member
G. R. Waterbury, Los Alamos Scientific Laboratory, Member

Standing Committee for Steam Generator Testing

A. E. Mravca, Chicago Operations Office, Chairman
G. C. Gower, Chicago Operations Office, Member
K. Kuczen, Argonne National Laboratory, Member
K. Hoffman, Brookhaven National Laboratory, Member
R. E. MacPherson, Oak Ridge National Laboratory, Member
L. E. Whinery, Los Alamos Scientific Laboratory, Member

APPENDIX B - SCDP - STANDING COMMITTEE CHARTERS1. Standing Committee for Mechanical Properties - Charter

The standing Committee for Mechanical Properties was initiated by the Chairman of the SCDP Working Group to review the R&D work specific to determining the mechanical properties of the materials used in the construction of sodium-cooled reactor systems. This Committee shall visit the contractors engaged in this effort as often as necessary to determine work progress, evaluate their efforts, and formulate recommendations as appropriate. A report shall be prepared by the Committee members and forwarded to the Chairman of the Working Group.

2. Standing Committee for Sodium Corrosion and Mass Transfer - Charter

The Standing Committee for Sodium Corrosion and Mass Transfer was established by the Chairman of the SCDP Working Group to assist in reviewing and evaluating all SCDP sponsored work and investigations involving corrosion and mass transfer behavior of materials in sodium service for the purpose of advising the Working Group of the progress, status, and adequacy of the work.

This Committee shall assist in the evaluation of proposals for new work in the area of corrosion and mass transfer with respect to meeting the objectives of the SCDP.

3. Standing Committee for Sodium Impurities - Charter

February 1965

The charter for this committee is being revised. When completed and approved, it will be issued as an addendum to this document.

4. Standing Committee for Steam Generator Testing - Charter

The Committee for Steam Generator Testing shall function within the framework of the SCDP to assist as required in the development of safe, reliable, economical sodium-heated steam-generating equipment having high performance capabilities. This Committee shall visit the contractors engaged in steam generating equipment development, fabrication, and testing for the purpose of progress reviews and work evaluation. Reports shall be prepared which contain the Committee's findings, evaluations, and recommendations. These reports will be transmitted to the Chairman of the SCDP.

APPENDIX B

MINUTES OF SODIUM COMPONENTS DEVELOPMENT
PROGRAM WORKING GROUP
MEETINGS 1 THROUGH 38

Minutes of the Sodium Heat Exchanger Coordinating Committee

Initial Meeting

January 30, 1957

Washington, D.C.

The meeting was sponsored by the Civilian Power Reactors Branch and Naval Reactors Branch of the AEC on January 30, 1957. The purpose was to discuss first hand with representatives of NRB, KAPL, and Babcock & Wilcox the progress made on sodium steam generators.

The following persons were in attendance:

G. W. Wensch, Chairman, CPRB, AEC
W. D. Gilbert, Vice-Chairman, CPRB, AEC
W. R. Wykoff, Secretary, IASL
J. M. Simmons, EDB, AEC
F. W. Davis, EDB, AEC
E. J. Wagner, NRB, AEC
A. Amorosi, APDA
J. J. Morabito, APDA
D. O. Leeser, APDA
R. A. Noland, ANL
F. A. Smith, ANL
W. R. Simmons, ANL
R. D. Wylie, Babcock & Wilcox
J. L. Van Ullen, KAPL
R. W. Dickinson, Atomics International
A. M. Stelle, Atomics International
W. C. Hayes, Atomics International
T. M. Hotchkiss, Southern California Edison
A. C. Werden, Jr., Southern California Edison
J. T. Waber, IASL

The meeting was called to order at 9:25 AM in Room 1062, Matomic Building, Washington, D.C., by Dr. Wensch.

Dr. Wensch explained that about 180 million dollars may be spent on sodium-cooled power reactors exclusive of the Naval Reactors Program. The remainder of the morning was devoted to classified discussions of past experience with sodium heat exchangers as background for future planning. The members present were to keep in mind the needs of their own projects and perhaps recommend what direction the future work on sodium heat exchangers should take. The CPRB believes that a coordinated program should be initiated.

Afternoon Session

The meeting was reconvened at 1:35 PM with about fifteen members present. While waiting for the others, Mr. Amorosi described some heat exchanger designs and tests pertaining to the APDA reactor.

The aim of APDA is to develop a steam generator to produce steam at 755°F and 600 psig from sodium at a maximum temperature of 850°F. One of their big worries at the moment is what happens if a serious tube failure occurs in the middle of a heat exchanger. Will the heat of reaction at the point of failure cause a chain of failures progressing through adjacent tubes? A seven tube heat exchanger with 1/2-inch diameter tubes is being designed to test this effect. The central tube will be intentionally failed and the results observed. This unit will probably use 2 1/4 Cr-1 Mo steel.

The proposed APDA steam generator will be a Griscom-Russell vertical bayonet-tube unit containing about 1100 tubes. The central tubes will be about 7/8 inch OD and will be insulated. Thus, all steaming occurs in the outer annulus. There will be no third fluid in this unit, although a gas space will be maintained on the tube sheet.

At this point, all members had returned to the meeting and the question period on the morning's discussion was resumed. Mr. Amorosi started off with a series of questions.

Q. Of the failures described this morning, to what extent have the units been carefully looked at?

A. Mr. Wylie: In Fig. 1¹ everything shown on the drawing has been carefully examined except as prevented by the tube bends. The units have been actually cut apart and given thorough metallurgical examination.

It is not clear from these examinations whether the primary trouble started from the sodium or the water side. Examination of undamaged tubes from these units does not show cracks or incipient failures.

Q. Do non-metallic inclusions in struts and non-stressed parts in liquid metal systems cause progressive troubles?

A. With reference to Fig. 2,¹ a void appeared in place on the inclusion, but a crack did not propagate. Porous zones do not seem to progress. Thus, it would seem that porosity, or inclusions, would not be harmful in unstressed parts, as long as they did not serve as barriers.

Mr. Wylie: Porosity of this sort is quite difficult, if not impossible, to determine in advance by any inspection methods available today.

Q. In Ref. 1, there is a big gap in caustic concentration between the data in Tables I and III. Is there any information available at intermediate concentrations?

A. There is no more information available, and no further testing is planned.

¹J. L. Van Ullen and R. D. Wylie, Metallurgical Problems with Liquid Metal Heat Exchangers, undocumented, Jan. 14, 1957. (Confidential)

Mr. Amorosi stated that APDA is running a rig at General Motors wherein a small amount of sodium hydroxide is injected into a sodium loop every two weeks and then part of it cold-trapped out. The material is type 347 stainless. As yet there have been no failures.

Mr. Morabito was asked to describe the APDA steam generator tests.

At the Quarry, APDA is running a seven tube model of an 871-tube steam generator. The tubes are full length. All material is type 304 stainless. NaK is on the shell side. This unit has now been operated for 1000 hours without failure. The main trouble has been with the oil-fired NaK heater which will not control satisfactorily at low output.

This heat exchanger is of the once-through type and is being controlled manually by the operators. There is some trouble with the automatic controls.

This unit has been shocked 450°F in about five seconds without failure.

Mr. Werden was asked to describe the Southern California Edison steam generator.

Southern California Edison has a building next to the SRE wherein they will receive sodium from the reactor at 900°F and return it to 440°F. In the process they will produce steam at 620 psi and 825°F.

The steam generator is 304 stainless throughout, with tubes of 80 ft development length. The tubes are duplex with the inner tube 1/2-inch ID and the outer tube about 11/16 inch ID. The third fluid is mercury pressurized to 190 psi.

Level measurement in the mercury expansion tank will be the primary means of leak detection. Other means are being tried. They would like to be able to detect 1 ppm mercury in the steam.

The choice of mercury over NaK as the third fluid was left to the manufacturer (B&W). The system contains about \$40,000 worth of mercury.

ANL representatives were asked to describe their steam generator development work. They replied that no new work was being done by them. They expect the equipment manufacturers to come through with suitable designs as they require them.

Mr. Wylie stated that B&W is doing a little work on their own, but that it is not very extensive. They are studying caustic corrosion, extra low carbon 2 1/4 Cr-1 Mo, and attempting to design heat exchangers with replaceable tube bundles.

Mr. Dickinson stated that AI is interested in higher temperature. They would like to make steam at 1050°F, a temperature where the ferritic Croloys

fall short in strength. What do we do for a steam generator design now? What do we do to insure something better two years from now?

ANL representatives stated that their steam generator designs call for 900°F sodium, and that final specifications for the units must be released by mid-1957.

Dr. Wensch re-emphasized the need for a coordinated program for steam generator development over the next few years. Delegates from each of the organizations represented were asked to draw up a letter to Dr. Wensch outlining the anticipated needs of their programs.

The following persons agreed to accept this responsibility for their organizations, and to submit the required letter by February 15, 1957:

W. R. Simmons, ANL
R. W. Dickinson, AI
J. J. Morabito, APDA
W. R. Wykoff, IASL

The meeting was adjourned at 4:40 PM.

Minutes taken by:

W. R. Wykoff, IASL, Secretary

Minutes of the Sodium Components Working Group

Meeting No. 1

February 27-28, 1958

AEC Headquarters

Washington, D.C.

(Official minutes of Meeting No. 1 apparently were not issued. In their stead, the notes of Kurt Goldmann, NDA, and Robert W. Dickinson, AI, have been summarized with their permission.)

The first meeting of the newly formed Sodium Components Working Group occurred February 27 and 28, 1958, at AEC Headquarters to discuss a proposed AEC-sponsored program on sodium component development:

The following persons were in attendance:

J. F. Kaufmann, AEC
H. H. Windsor, AEC
R. P. Schmitz, AEC
H. E. Dodge, AEC
J. M. Simmons, AEC (part time)
F. A. Smith, ANL
R. W. Dickinson, AI
T. Trocki, GE
J. J. Morabito, APDA
Kurt Goldmann, NDA

Items established for first priority development were heat exchangers (both sodium-to-sodium and sodium-to-water) and sodium flow control devices (both flow interrupting and flow limiting). It was agreed that preliminary functional specifications for these items should be forwarded to Kaufmann in Washington prior to March 14. Kaufmann will assemble these into specimen specifications, which will be reviewed by the group at the next meeting of the group March 27 at Atomics International.

The agenda for the meeting included:

1. functions and purpose of working group
2. organization
3. outline of proposed development program
4. review of status of sodium technology and experience of contractors with components.
5. establishment of component priorities for development effort
6. review and establishment of functional specifications for components based upon priorities
7. consideration of manufacturers to undertake work
8. methods of reviewing and analysis, proposed manufacturers design
9. discussion of location of test facilities and arrangements for test

10. dissemination of results and experience

11. future meetings

It was explained that functions and purposes of the working group would be as advisors to the AEC in a program of development of components which were common to all sodium reactor systems. The Working Group represented at this meeting would assist in contractor evaluations, specification writing, design review, and act as representatives of organizations which would probably eventually test the equipment developed.

It was recognized that some components might be of greater importance to one system than another, but at least there probably were applications for all of the components in everybody's program. The scope of the program was envisioned as costing about \$20,000,000 over perhaps three or four years. The program would largely be carried out by industrial contractors operating on CPFF contracts let by Washington directly. AEC indicated that there was no intention to combine any of the current development programs under way by the contractors represented budgets. This would be a new program and presumably funded by new money. This would permit each contractor to continue to present reactor concepts while cooperating on those parts of the system comprising the new program. The AEC considers that since the Working Group has been called together by the AEC and the program will be officially sponsored by the AEC, this will remove any possibility of an anti-trust law violation being raised.

Each of the contractors' representatives present reviewed briefly what their organization was doing along the components line. Morabito stated that APDA was concentrating on steam generators. A one megawatt model of a once-through U-tube, single-wall steam generator had been tested and removed from their loop. APDA was now in the process of installing a one megawatt once-through bayonet type unit manufactured by Alco. The free surface pump and check valve will be tested in one loop of their power plant which will be completed for this purpose in advance of the remainder of the plant.

Smith noted that ANL was concerned about boilers to the extent that they were planning tentatively to manufacture their own. This boiler would be based on a double-walled concept but with the two walls bonded together without a leak detector system. Smith also noted that their current major problem was the sealing of operating shafts penetrating into a sodium-vapor-filled space. Accumulation of sodium "frost" on mechanisms prevents reliable operation of these mechanisms. Intermediate heat exchangers had not been considered a serious problem, but only casual attention had been paid to it so far. This was partially because of the EBR-2 design, in which the exchangers are submerged in a pool of sodium, thereby alleviating many of the severe temperature transient conditions

expected in other types. Smith noted that the results of Argonne's work on sodium pumps and valves were well known and published.

Goldmann stated that NDA was concentrating on means of separating sodium and deuterium. They are expecting to use the results of developments by other AEC contractors as far as sodium system components are concerned. Trocki stated that no component work was presently being done at GE-San Jose but noted that they would be glad to undertake some under contract. Dickinson briefly reviewed the AI sodium components development program, covering the boiler test program, ball type valve program, structural materials research program, the system pre-heating work and bellows testing.

Kaufmann stated the objectives and purposes of the sodium components working group as follows:

1. To assist in the development of improved, less expensive and more reliable components for sodium and other liquid metal systems through:
 - a. Recommending components for development and establishing priorities of effort.
 - b. Critically analyzing and reviewing designs of components submitted.
 - c. Suggesting, reviewing, and commenting on proposed development programs for specific components.
 - d. Suggesting tests to be carried out on components and the places where these tests should be conducted.
 - e. Suggesting functional specifications and such other specifications as warranted for components to be developed.
2. To coordinate supplementary development programs on components which are under way at contractor sites.
3. To serve as a general technical advisory group to the AEC in the area of liquid metal system components.

He suggested that the committee set up a "master plan" with money estimates, and assign priority to those items for which immediate development was considered necessary. After considerable discussion, items suggested by the conferees were divided into those things which could be developed by industrial contractors and those which were properly the province of laboratories. The industrial items are as follows in order of priority:

1. sodium heated steam generators
2. sodium to sodium intermediate heat exchangers
3. sodium flow shutoff devices
4. sodium flow control devices
5. sodium instruments
6. inert gas compressors

Those items deemed suitable for laboratory investigation are as follows:

1. sodium "frost" and removal thereof
2. gas and sodium purification devices
3. decontamination of sodium systems (particularly in view of Argonne's statement that sodium could be absorbed into the surface of materials, including stainless steel, and the postulated existence of sodium-22)

Those present agreed to submit functional specifications including temperature, rate of change of temperature, flow pressure drop, etc., for the first two items on the industrial priority list by March 14. Kaufmann will then integrate these requirements into a single specification, presumably representing the most severe conditions of each contractor, and will mail these back to all the organizations represented prior to March 27. (The Group was also asked to prepare lists of prospective heat exchanger contractors and qualifications to be reviewed in selecting contractors for designing heat exchangers.)

The next meeting will be held March 27 and 28 at AI to discuss these items, the contractors who should be approached, and a time and money estimate for this portion of the program. This next meeting will also take up preparation of functional specifications for as many of the remaining items on the priority list as can be handled. Kaufmann stated that he had made a tentative estimate for the heat exchanger program as follows:

- \$510,000 for education of the contractor and design of the equipment
- \$150,000 for fabrication of a suitable model
- \$150,000 for test and evaluation of this model

This was not intended to be firm but simply to give an idea of the magnitude of the over-all program. In all probability, if funds could be made available, more than one contractor would be selected for each of the items to be developed. A wide disparity in design philosophy of components such as heat exchangers was apparent throughout the meeting.

It was suggested by NDA that Pratt and Whitney be contacted to see if they had any experience they could offer this program. Kaufmann said he would do this but advised that, because of the classification nature of Pratt and Whitney work, it might prove a considerable inconvenience to have them as a regular working member of the committee. The meeting was then adjourned.

Minutes of the Sodium Components Working Group

Meeting No. 2

March 27-28, 1958

Atomics International

Canoga Park, California

(Official minutes of Meeting No. 2 apparently were not issued. In their stead, the notes of Kurt Goldmann, NDA, and Robert W. Dickinson, AI, have been summarized with their permission.)

The second meeting of the Sodium Components Working Group took place March 27-28, 1958, at the Canoga Park, California, offices of Atomics International.

The following attended:

J. F. Kaufmann, AEC-Washington
 F. A. Smith, ANL
 K. Goldmann, NDA
 J. J. Morabito, APDA
 R. W. Dickinson, AI
 C. W. Richards, AEC-CP

The principal purpose of the meeting was to review the invitations which the AEC will send to potential contractors for their expression of interest in the development, design, manufacture and test operation of sodium heat exchangers and flow control devices.

It is expected that these invitations will be mailed to potential contractors within a week.

Contractor proposals are to be submitted to the AEC prior to May 15. The Sodium Components Working Group will meet in Washington toward the end of May to review the proposals and to act as an advisory group to an AEC contractor selection committee.

In arriving at a final set of operating conditions for the heat exchangers, the group looked toward the more distant future and specified the following:

	Steam Generator	Intermediate Heat Exchanger
Sodium inlet temperature	1140°F	1200°F (primary)
Sodium outlet temperature	640-850°F	700-900°F (primary)
Steam pressure	2200 psig	
Heat transfer capability	70 Mw	70 Mw

A five-year program is envisaged consisting of full-scale design, development, model testing, and construction of a full-scale unit.

The intermediate heat exchanger specification prepared by Kaufmann from submissions by committee members was reviewed. It developed that ANL and APDA transients were much more severe than any postulated for HNPF or SRE, and therefore their conditions were specified. EBR-2 expects transients at the rate of 70° per second for six seconds under some casualty conditions. The size of a reference design was taken up, and it was agreed that 70 Mw would permit scaling up to the largest unit currently expected (140 Mw, by PRDC). A unit of this size could be tested in a figure 8 loop with no particular difficulty as the heat in-put would only be that necessary to maintain gradients and make up losses. The specification was made completely general, and references to specific manufacturing procedures such as welding, cleaning, and inspection were deleted. The steam generator specification was then reviewed. Transient conditions comparable to those experienced by the heat exchanger were incorporated, and the reference steam pressure was raised to 2200 psi, 1050°F temperature in order to comply with modern steam plant conditions. Considerable discussion took place regarding methods of control, in order to insure that a recirculating, or a once-through boiler, were not implicitly specified by the means of control. This specification was also made as general as possible. While a rating of 70 Mw was established for the design of a boiler, although it was recognized that a boiler of this size could not be tested outside of a reactor. Possibilities of obtaining the 35 Mw sodium heater now stored at KAPL for use as a test facility were discussed. Kaufmann will look into this.

The group agreed that it would not be desirable to give a contract to a manufacturer for the design and construction of a large size sodium shut-off valve with zero leakage requirements. Efforts in this direction have failed in the past and it was generally agreed that such a device must be based on a new principle — therefore, it belongs in the laboratory development category rather than into a valve manufacturer contract category.

A set of specifications was prepared for flow control (or throttling) devices. Principal conditions are:

Pipe size	20 inches
Sodium temperature range	500-1200°F
Sodium pressure	0.5 psig to 100 psig

Smith noted that Argonne had a Hammell-Dahl throttling valve which had operated in sodium for over ten years with complete success. This is a 4 in. valve, and our requirements are for a 14 in. valve immediately and potentially a 20 in. valve. This would be tested in either Argonne's 7000 gpm loop or possibly one of AI's loops if they are available at the time a throttling device is produced.

A Griscom-Russell steam generator at MSA has gone through 150 hours of design full load operation. Performance is as expected so far.

AI spoke encouragingly of their work on cleaning sodium contaminated components with hydrogenated terphenyls. Apparently DuPont sells it as "HB-40" for something like 35 cents per pound. It forms an emulsion and does not react violently with sodium.

The next meeting of the group will be at ANL on April 24 and 25. The subjects for discussion then will be programs for solving sodium frosting, sodium and gas purification and decontamination problems.

Minutes of the Sodium Components Working Group

Meeting No. 3

May 1-2, 1958

Argonne National Laboratory

The Ad Hoc Working Group on sodium technology met at ANL on May 1 and 2, 1958. The following participated in the discussions:

J. F. Kaufmann	AEC, DRD, Washington - Chairman
T. A. Nemzek	AEC, COO
R. Dickinson	AI
K. Goldmann	NDA
J. Morabito	APDA
F. Smith	ANL
T. Trocki	GE

Mr. Kaufmann opened the meeting with a description of the status of activities by the AEC Sodium Components Selection Board. Letters of invitation and sample specifications for heat exchangers and steam generators had been sent to a number of prospective proposers. Copies of these invitations were to be sent to individuals present.

The subjects for discussions at this meeting were:

1. Sodium frosting.
2. Decontamination.
3. Purification devices and methods.

Mr. Fred Smith described the ANL program on the three subjects. He described their facility to test shaft seals. ANL believes that the basic nature of sodium vapor deposition should be investigated thoroughly. It was suggested that various coatings be applied to components to prevent sodium vapor or oxide deposition from sticking to the components. ANL is planning an experimental program in their sodium tank to test various parameters affecting frosting rate. On decontamination, ANL does not believe that the absorption of sodium by stainless steel should present an activity problem. Methods for decontamination were discussed. It was suggested that perhaps radioactive sodium should be oxidized, flushed with sodium, and then the oxide trapped out.

On purification, ANL has a program under way to study the properties of materials as a function of hot or cold trapping. They also pointed out that they have operated pump loops with no purification other than the use of large sumps.

The problem of sampling techniques for sodium analyses was discussed. The need for additional work was apparent. Discussion on specifics was delayed; to be covered in subsequent "instrumentation" discussions.

Work being conducted at NDA, APDA, and AI in the three areas being discussed was described.

In summary, it was concluded that an experimental program should be carried out to study frosting and that these studies should be fairly basic in nature rather than studies associated with a prototype mechanism. Schemes to design equipment such that condensing would occur where the sodium would run down without solidifying should be investigated. Coatings to prevent wetting of surfaces would be investigated. The use of calrod heaters should be looked at as a device to keep surfaces wet.

General conclusions on decontamination and purification devices were deferred until the next meeting. Each of the group agreed to prepare proposed programs on all three items.

The outline of the thermal stress book was reviewed briefly and it was concluded that inadequate emphasis was placed on plastic stress and plastic behavior materials. Although it was scattered throughout the outline, it would be appropriate to have a chapter devoted to this subject. The outline appeared to stress prototypes whereas it would be desirable to deal with basics. Members will receive more detailed outlines and agreed to submit written comments to the Chairman by May 26.

The use of a 34 Mw heat source, presently at KAPL, for the sodium component program was discussed. It was the opinion of the group that it would be desirable to have an impartial group such as a national laboratory operate such a facility. Such an arrangement, however, might be difficult to bring into being. The AEC Sodium Component Selection Board will take steps toward selecting an appropriate contractor to operate a component test facility.

It was decided that the next meeting would be held in Detroit, Michigan on May 26 and 27. Topics for discussion would include specific programs in laboratories and sodium components, particularly instruments. An agenda would be prepared and sent to the members.

Minutes of the Sodium Components Working Group

Meeting No. 4

May 26-27, 1958

Atomic Power Development Associates

Detroit, Michigan

(Official minutes of Meeting No. 4 were apparently not issued. Insufficient material is available to reconstruct "minutes" of this meeting.)

Minutes of the Sodium Components Working Group

Meeting No. 5

June 10-11, 1958

AEC Headquarters

Washington, D.C.

Attendance

The Sodium System Components Working Group met in AEC Headquarters June 10 and 11, 1958. The following persons attended:

Mr. John F. Kaufmann, AEC (CPRB) Chairman
 Mr. Kurt Goldmann, NDA, Member
 Mr. Robert Dickinson, AI, Member
 Mr. John Morabito, AFDA, Member
 Mr. Thomas Trocki, GE (APED), Member
 Mr. Fred Smith, ANL, Member
 Mr. William Henoch, AEC (CPRB)
 Mr. Walter Babb, AEC
 Mr. Irwin Jackson, AEC (CPRB)

Agenda

Major items discussed at this meeting were:

1. Determination of Phase I Scope of Work for Intermediate Heat Exchanger (IHX) and Steam Generator (STG) development contracts.
2. Determination of number of contractors and contractual responsibilities with respect to either heat exchangers, steam generators or both in 1 above.
3. Planning for contractor orientation meeting.
4. Status of development program on flow controllers.
5. Status of development program on instrumentation.
6. Plans for next group meeting.

Discussion and Conclusions

Mr. Kaufmann opened the meeting with a summary of the program objectives (see minutes of first Group meeting of February 27-28, 1958), and a status report. Specific agenda items were then taken up.

1. IHX/STG Phase I Scope of Work - Areas of work as outlined in the invitation for proposals were reviewed, and a more detailed statement of the Phase I tasks and the work to be done under each task were agreed upon (see attached Scope of Work).

2. IHX/STG Phase I Contractors - Fourteen proposals were received in response to the invitation. Each proposer expressed interest in both components (IXH and STG). Following an extended discussion, it was agreed that three contractors should be selected and that each contractor should be permitted to work on both components. (Note - The Sodium Components Selection Board has selected the following firms: Combustion Engineering, Inc., New York, New York, Alco Products, Inc., Schenectady, New York, Griscom-Russell Co., Massillon, Ohio). The proposals were not distributed among the group. Mr. Kaufmann sketched their common approaches and estimated that Phase I should cost about \$100,000 and required about eight months to complete. It was agreed that three designs for each component should provide a sufficient basis for selecting designs to be carried forward into Phase II.
3. Planning for Contractor Orientation Meeting - A meeting was planned for the orientation of the selected IHX and STG contractors. Brief summaries (20-30 minutes) of contractor and laboratory experience will be given covering AI, APDA, KAPL and ANL. Group members agreed to furnish lists of literature references to Mr. Kaufmann by June 20. The verbal presentations will be followed by question periods and stressing of items of major importance. A detailed discussion of the materials program (e.g., mass transfer, corrosion, decarburization) is anticipated.
4. Flow Control Mechanisms - The closing date for proposals on the design, development, manufacture, and test operation of improved flow control mechanisms was extended from June 16 to June 23. (Note - Nine proposals were received in response to this invitation. Proposers are:

Atwood & Morrill Co., Elizabeth, N.J.
 Copes-Vulcan Co., Erie, Penna.
 Ohio Injector Co., Wadsworth, Ohio
 S. Morgan Smith Co., York, Penna.
 Schutte & Koerting Co., Cornwell Heights, Pa.
 Stanford Research Institute, Menlo Park, Calif.
 Thompson Products, Inc., Cleveland, Ohio
 Walworth Company, New York, New York
 Worthington Corporation, Harrison, N.J.

The proposals being evaluated by the Selection Board.)

5. Instrumentation - Mr. Dickinson presented an AI proposal for work on process instrumentation, including -
 - a. Level gages based on new principles of operation (e.g., ultrasonic wave).
 - b. Na purity indicators capable of increased sensitivity and continuous indication.

- c. Flowmeters of increased reliability. It was agreed that AI and GE should review AI flowmeter experience and problems to determine the need for research and development on this component. Mr. Smith presented an ANL proposal to study sodium frosting using time-lapse photography. Problems related to the determination of vapor phase equilibria, wetting mechanisms, and friction coefficients in sodium were also discussed. Mr. Trocki stated that consideration was being given at GE to the submittal of a proposal to study mass transfer in sodium systems at 1200°F and 1,000 psi.
6. Next meeting — The next meeting will be in AEC Headquarters on August 5 and 6 in the absence of a call meeting in July.

SCOPE OF WORK TO BE UNDERTAKEN BY CONTRACTORS

PHASE I

1. Selection of a preferred conceptual or preliminary design for 70 Mw units [IHX and Steam Generator (SG)].

This will include:

- a. Drawings of dimension outline and assembly of unit.
- b. Conceptual details of any and all unusual features.
- c. Specifications to cover at least all points outlined in AEC functional specifications, including water quality control.
- d. Report of any other conceptual designs considered and reason for eliminations.
- e. Data sheet on predicted performance of unit.
- f. Methods of inspection after unit is in operation.

2. Delineation and analysis of preferred conceptual design to justify selection.

This will include:

- a. Optimization of division of surface between IHX and SG.
- b. Basis for sizing of unit.
- c. Preliminary stress analysis of critical points for mechanical and thermal stress under conditions in AEC functional specifications.
- d. Design basis for selection of allowable stresses.
- e. Basis for selection of material and justification for use of any unusual materials for this service.

3. Economic evaluation of preferred conceptual design.

This will include:

- a. Cost of first unit including all necessary ancillary components.
- b. Cost of any special tools required for maintenance.
- c. Cost of subsequent units.
- d. Expected operating costs. These will be based upon an equivalent capitalized cost of \$400/fluid H.P.
- e. Capital costs are to be broken down into the following elements at a minimum.

- (1) Engineering
- (2) Fabrication
- (3) Materials
- (4) Cleaning
- (5) Inspection and quality control

- f. Effect on cost of reduced top Na temperature.

4. Detailed outline of proposed research and development program required to develop and prove the preferred design unit. Each task of this program should be delineated in terms of --
 - a. Objectives
 - b. Detailed description of work to be accomplished
 - c. Time scale -- for accomplishment
 - d. Estimated costs

In accomplishing the above stated scope of work, the following limitations should be observed:

1. Reimbursed experimental work must be limited to such experimental work considered by AEC as aids in mathematical analysis of design.
2. Maximum time for accomplishment of above scope is to be 8 months after contract execution.

Minutes of the Sodium Components Working Group

Meeting No. 6

August 5-6, 1958

AEC Headquarters

Washington, D.C.

The Sodium System Components Working Group met in AEC headquarters, Germantown, Maryland on August 6, 1958. The following persons attended:

Mr. John F. Kaufmann, AEC-CPRB, Chairman
Mr. Kurt Goldmann, NDA, Member
Mr. Robert Dickinson, AI, Member
Mr. John Morabito, APDA, Member
Mr. Robert Lockhart, GE-APED, Alternate for Trocki
Mr. Fred Smith, ANL, Member
Mr. H. W. Savage, ORNL, Member
Mr. Thomas Nemzek, COO, Member
Mr. Irwin Jackson, AEC-CPRB, Member
Mr. Frank Legler, AEC-EDB
Mr. Charles W. Richards, AEC-CPAO

AGENDA

Major items discussed at this meeting were:

1. Status of development program on flow regulating devices
2. ORNL sodium technology program
3. General review of program projects and areas for currency, scopes of work, and surveys
4. New research and development proposals
5. Formulation of technical recommendation to Contractor Selection Board on flow regulator development
6. Plans for future meetings

DISCUSSION AND CONCLUSIONS

The unclassified information meeting for sodium component development contractors planned at the Group meeting in June was held at AEC headquarters on August 5, 1958. Although the meeting was originally set up for the benefit of the three heat exchanger-steam generator contractors, six prospective flow regulator contractors were also represented at the invitation of the Selection Board. Proceedings of this meeting are being prepared for limited distribution. An agenda is attached.

ORNL was invited to participate in the sodium component development program and to provide a representative on the working group. H. W. Savage

attended the August 5 information meeting and the August 6 group meeting as ORNL representative.

1. Flow Regulator Development Program Status - All proposals received under the Selection Board invitation of May 8, 1958 were reviewed and summarized by Mr. Kaufmann. The preliminary screening by the Selection Board at ANL on July 8-9 was reviewed.

Six contractors were eliminated, including S. Morgan Smith, Walworth, Stanford Research, Atwood and Morrill, Schutte & Koerting, and Liquid Metals, Incorporated. Meetings were scheduled with Westinghouse, Crane, Worthington, Ohio Injector, Copes-Vulcan, and Thompson Products in the week of August 4-8 to provide additional background for evaluation purposes. Proposals from these contractors were discussed later in the meeting.

2. ORNL Sodium Technology Program - Mr. Savage reviewed the history of liquid metal component development at ORNL from its inception in 1950 as part of the aircraft reactors program. Components were developed for 1500°F service, although the target service life was relatively short (about 200 hours). The major effort was on pumps, but also included heat exchangers, cold traps, etc. A considerable amount of classified information of value to the CPRB program is contained in the ORNL reports, particularly in the molten salt reactor development program. It was agreed that specific requests for information in this area would assist ORNL efforts toward declassification. ORNL sodium technology coverage includes specifically.

- (a) Welding and inspection specifications
- (b) Data on heat exchanger fabrication techniques
- (c) Mass transport and corrosion data
- (d) Materials compatibility with sodium
- (e) Shell side sodium heat transfer coefficients
- (f) Pump data on centrifugal types of 150-300, 600-900, and 1200-1500 gpm capacity
- (g) Instrumentation (level indicators, thermocouples, pressure indicators, leak detectors, and flow meters)
- (h) Oxide indication and removal

3. General Review - Mr. Kaufmann initiated a discussion of the overall component development program for sodium cooled civilian power reactors. The original list of industrial and laboratory projects was reviewed for currency and priority. It was agreed that development work on sodium shut off mechanisms and inert gas compressors should be deferred for the immediate future. It was also agreed that test facility requirements should be defined within the current year, and that inventories of available AEC-owned test equipment applicable to this program are necessary. Investigations of mass transport in sodium above 1003°F are also considered essential. Although a limited amount of experimental

information has been obtained in the 1200–1500°F range, the validity of interpolation between T 1000°F and 1200 T 1500°F is questionable. The following assignments were made:

John Morabito (APDA) will write proposed scopes of work on submerged sodium position devices, gas purification (demisting) devices, and leak detectors for sodium vapor entrainment in blanket gases.

Bob Dickinson (AI) will write proposed scopes of work on continuous O₂ indicators, Na flow meters, Na level indicators, and a composite scope covering engineering stress analysis, thermal fatigue, and general materials investigations.

Fred Smith (ANL) will write proposed scopes of work on fuel element failure indicators and sodium frosting.

Bob Lockhart (GE) will write a proposed scope of work on sodium purification devices (cold traps, etc.).

Wes Savage (ORNL) will survey thermocouple development for Na systems.

Kurt Goldmann (NDA) will prepare a preliminary scoping write up of the objectives of an adequate Na component test facility.

4. New Research & Development Proposals — NDA submitted a proposal for an experimental investigation of mass transfer in sodium systems at 1200–1300°F. The proposed program employs a number of thermal convection loops to provide quantitative data on mass transfer rate as a function of maximum temperature, system temperature differential, sodium purity, and other pertinent variables. At the June meeting, it was indicated that GE would submit a proposal covering the experimental evaluation of sodium systems with respect to oxygen control and mass transfer effects at 1000–1200°F. This proposal has not been submitted.
5. Recommendation to Selection Board on Flow Controllers — It was again proposed that one or more flow controllers should be purchased to the 1200°F performance specification with a minimum amount of research and development or without research and development, as an alternative to the selection of contractors for the proposed Phase I work. After an extended discussion, agreement was reached on the following recommendations.
 - (1) Purchase two or more flow controllers to the 1200°F performance specification with minimum R&D or no R&D.
 - (2) Select two or more contractors.
 - (3) Test these devices in sodium under AEC direction.
 - (4) Provide R&D funds for subsequent modification of flow controllers by contractors in view of test results.

6. Plans for Future Meetings — The next group meeting is planned for September 10, through 12. It will include visits to Griscom-Russell and Alco Products to review progress on their heat exchanger and steam generator development projects. A meeting is also planned for October 16 through 18, which will include a visit to Combustion Engineering.

Minutes of the Sodium Components Working Group

Meeting No. 7

September 10-12, 1958

Griscom-Russell, Massillon, Ohio

Alco Products, Schenectady, N.Y.

The Sodium Components Committee met on September 11 in the conference room of the Griscom-Russell Company. The recent action by the Sodium Components Contractor Selection Board was described to the Committee. Three contracts involving flow controllers were described briefly.

The desirability of having the Griscom-Russell Company do some heat transfer study work on internally finned tubes was discussed. It was decided that it would be to the advantage of the development program to have this work done under their present contract.

Committee members presented scopes of work on various topics agreed to at the last meeting. These were discussed as follows:

Oxygen analysis below twenty parts per million in sodium. NDA had previously submitted a proposal covering this work. It has been previously decided to include this work in their present program; however, approval has not been given.

An investigation related to oxygen exchange in sodium was proposed by AI, and this work is intended to be approved within their existing program.

Fred Smith, ANL, was to have developed a scope of work on sodium frosting. He was not present at the meeting. This item will be discussed at the next meeting.

A sodium components test facility utilizing as much as possible equipment at one time in the KAPL program was discussed. A Construction Project Data Sheet is being processed in Washington for \$2,500,000. The Committee agreed that the facility should be capable of generating sodium at 1200°F producing 35 MW of heat. It is recognized that the design of the facility will be affected by the design of the major components to be tested in the facility. The Committee agreed to review the facility scope and provide comments to Kurt Goldmann who would have a summary report for the next Committee meeting. It was recommended that preliminary design of the facility be undertaken as soon as possible.

The following areas of work were discussed and assigned a priority by Committee agreement:

1. Survey of sodium technology - low priority
2. Thermocouples for 1200° sodium - priority

3. Oxide concentration meter - priority
4. Flow meter - priority
5. Level gauges - priority
6. Sodium vapor detector in gas - priority
7. Water detector in liquid sodium - priority
8. Sodium detector in water and steam - out
9. Stress analysis of material studies - to be considered after Committee members review reports
10. Sodium vapor removal device from gas - priority
11. Mass transfer studies at 1200°F - high priority

It was agreed that the Chairman would recommend the above priority items be accomplished under the Sodium Components Development Program. It was expected that letters of invitation to interested companies would be sent out prior to the next Committee meeting.

New items which may be worthy of support were presented, and scopes of work will be developed for the next meeting - they are:

1. Stress work in 1200°F sodium
2. Shell-side heat transfer studies
3. A device for inspecting steam generators periodically

The Committee visited with the Griscom-Russell Company and later with Alco to review progress to date on steam generator and heat exchanger design studies. The Griscom-Russell design looked difficult from a thermal stress point of view, and it is generally agreed that they had not gotten far enough into their thermal stress analysis work to properly evaluate these difficulties. At Alco the Committee thought they too should get right into the thermal analysis problem which they had not done. They had not yet selected a design nor had made a material selection. They had to date analyzed a simple steam generator and heat exchanger design. Both contractors were requested to submit a report in November outlining their progress to date. It was agreed that the next Committee meeting would be held at Combustion Engineering in Chattanooga on October 16 to review Combustion Engineering's progress to date. The Committee would hold its meeting the following day at Oak Ridge.

Minutes of the Sodium Components Working Group

Meeting No. 8

October 16-17, 1958

Combustion Engineering, Chattanooga, Tenn.

Oak Ridge National Laboratory, Oak Ridge, Tenn.

The Committee met on October 17 at Oak Ridge Operations Office after visiting Combustion Engineering on October 16. The group toured ORNL facilities on October 17.

- I. Review of Statements of Work developed as a result of last meeting
 - A. Test facility
 - B. Mass transfer
 - C. Instrumentation
 - 1. Instrument for determining leak of water into liquid sodium
 - 2. Instrument for determining sodium vapor in gas
 - 3. Sodium oxide concentration meter
 - 4. Flow meter
 - 5. Level gage
 - 6. Thermocouples
 - D. Sodium vapor removal device

The review should result in Statements of Work which will suffice for letters of invitation to propose and for inclusion in the contract after selection.

- II. Discussion of work previously scheduled to be included under existing contracts.
 - A. Isotope exchange studies of sodium
 - B. Sodium oxide concentration measurement below 20 ppm
 - C. Sodium frosting (Fred Smith)
- III. New items suggested at last meeting
 - A. Material physical property tests in 1200°F sodium (specifications to be written by John Morabito)
 - B. Shell side heat transfer work on laboratory scale (specifications to be written by Bill McDonald)

- C. Boiler inspection device (specifications to be prepared by John Morabito)

IV. Items of questionable priority

A. Stress analysis and materials studies

1. Brief on Syracuse report by Bob Dickinson
2. Discuss additional work desirable

B. Sodium technology survey

V. Plan for next meeting

The IHX and steam generator specifications were reviewed at the last meeting. Changes to be forwarded to the contractor were reviewed and the results are shown in the attached letter which was sent to the contractors. It was agreed that these changes represented a more realistic approach to the problem and would permit more flexibility in design and material selection.

The proposed sodium components test facility was discussed and scope of work for an operating contractor was agreed upon. The facility will be designed to accommodate a 30-35 MW heat exchanger.

Items IB, C, and D listed on the agenda were reviewed and a scope of work for each agreed upon.

Isotope exchange studies and sodium oxide concentration measurement below 20 ppm was discussed and it was recommended that these items be included in the program. These two efforts will be contracted for as soon as possible.

Fred Smith agreed to prepare a purpose, scope, etc., for sodium frosting for the next meeting.

Statements of work for new items (Agenda Item III) were presented. Members will review and comment by October 31. A statement of work will be developed for discussion at the next meeting.

Bob Dickinson discussed the "Syracuse Report" indicating that the work done was primarily of use to water cooled reactor projects. It was recommended that the AEC attempt to arrange further support for the work and redirect the effort to better suit the needs of the sodium components program.

The Kellogg letter was discussed. The group would be interested in hearing about the Kellogg ideas in more detail but could not recommend that the AEC request a proposal or support Kellogg work at this time.

The next meeting will be held in Chicago Operations Office on November 14, 1958.

Members of the Committee were furnished with a list of equipment which could be available from the Seawolf in April. Comments on items which might be useful for the test facility or for examination after operation were requested.

Minutes of the Sodium Components Working Group

Meeting No. 9

November 14, 1958

Chicago Operations Office

Chicago, Illinois

The Group met on November 14 at Chicago with the following members present:

T. A. Nemzek	Chairman
T. P. Heckman	Member
I. E. Jackson	Member
R. W. Dickinson	Member
J. J. Morabito	Member
K. Goldmann	Member
R. W. Lockhart	Alternate
H. W. Savage	Member
F. A. Smith	Member

A brief discussion was held regarding the role of the Working Group in the program. The priority of projects within the program was discussed. From the list of fifteen desirable projects the order of priority for the first six projects was recommended as follows:

1. Low level oxide analysis
2. Mass transfer studies
3. Physical properties of materials
4. Shell side heat transfer
5. Oxide concentration meter (continuous; high range only during first part of program)
6. Hydrogen in sodium detector

At subsequent meetings the priority of the remaining items will be discussed.

Mr. B. J. Milleville of the Ohio Injector Company briefed the group on his company's approach to the design and fabrication of a flow controller under their contract in the Sodium Components Program. A discussion followed his briefing during which Mr. Milleville was able to take advantage of the collective experience of the Group. As the result of these discussions, Ohio Injector will submit a proposal to the AEC for early test of their torque tube seal arrangement.

A proposed approach for a literature survey by the Crane Company under their contract on flow control devices was reviewed. Members agreed to submit comments on the proposal answering as many of the questions posed in the proposal as they could. The Chairman will consolidate these comments and pass the information on to the Crane Company.

The use of equipment from the SEAWOLF program for the Sodium Components Test Facility was discussed. To date inquiries have been made of the Schenectady Operations Office of the availability and locations of this equipment.

It was decided that the next meeting would be held on December 12 at NDA in White Plains, New York. The main purpose of this meeting will be to review interim progress reports from the heat exchanger contractors.

The Group toured the Commonwealth Edison Dresden Nuclear Power Plant during the late afternoon.

Minutes of the Sodium Components Working Group

Meeting No. 10

December 12, 1958

Nuclear Development Associates

White Plains, N.Y.

Official minutes of meeting No. 10 apparently were not issued. In their stead the notes of H. W. Savage, ORNL, have been summarized with his permission.

Sodium Components Working Group Meeting, December 12, 1958

Meeting No. 10 of the Sodium Components Working Group occurred December 12, 1958, at the offices of Nuclear Development Associates, White Plains, New York. The following attended:

T. A. Nemzek, COO
R. W. Dickinson, AI
K. Goldmann, NDA
R. W. Lockhart, GE-APED
J. J. Morabito, APDA
H. W. Savage, ORNL
F. A. Smith, ANL

The agenda was as follows:

1. Brief description of activities of the Sodium Components Selection Board.
2. Review of interim progress reports by heat exchanger manufacturers:
(a) Combustion Engineering, (b) Alco, and (c) Griscom-Russell.
3. Discussion of procedure and timing on final review of work done by heat exchanger manufacturers.
4. Sodium Components Development Program scope.
5. Plans for next meeting.
6. Tour of NDA facilities.

At NDA the AEC Sodium Components Working Group was given a tour of facilities at 5 New Street, White Plains, New York, and the reactor and test facilities at Pawling, New York. Extensive tests of the fuel-Na coolant-D₂O moderator arrangement for the Chugach, Alaska reactor project have established that leaks of sodium and/or D₂O against an aluminum barrier separating coolant and moderated channels can be tolerated.

An experimental 10 kw D₂ moderated reactor is operating at Pawling. Hot cell space is available, but methods of using it are still under development.

The Working Group reviewed interim progress reports from each of three vendors (ALCO, Griscom-Russell, and Combustion Engineering), who have been awarded contracts to design 70 Mw Na-to-Na intermediate heat exchangers and 70 Mw Na-to-H₂O steam generators and superheaters. These contracts are due to be completed February 28, 1959.

Phase II of this project included the construction of these heat exchangers and steam generators in a test facility yet to be designed, constructed, or, if existing, selected. This phase has encountered a setback due to budgetary limitations for FY-1960. The opinion of the Group was that postponement meant essentially equal postponement of second generation sodium-cooled reactors. It was felt, also, that the heads of installations interested in sodium as a reactor coolant should be appraised of this situation with a view to obtaining stronger backing for the work.

AEC has also not released invitations to propose on (a) the heat exchanger test facility and program, (b) sodium mass transfer and corrosion studies at 1000-1200°F, (c) determination of sodium heat transfer coefficients in the shell side of heat exchangers, (d) sodium physical properties research, and (e) a small number of other lesser projects.

The situation with regard to dismantling and post-mortem examination of the sodium circuits of the Sea Wolf was also discussed. This ship will be de-commissioned about January 1, 1959, and the Working Group was unaware of any plan for competent close examination of these systems. The Chairman (T. A. Nemzek, Chicago Operations) will make appropriate overtures to guard against loss of what may be extremely valuable information and data.

Minutes of the Sodium Components Working Group

Meeting No. 11

February 18-20, 1959

Chicago Operations Office

Chicago, Illinois

The Sodium Components Working Group met on February 18, 19, and 20. All members were present. The primary purpose of this meeting was to get a report by the heat exchanger and steam generator contractors, Alco, Griscom-Russell, and Combustion Engineering, just prior to their submitting their final report to the AEC. Prior to hearing the three contractors' reports, a half-day meeting was held during which the status of acquiring Seawolf components for examination was discussed. It was agreed that arrangements had been made for acquiring an adequate number of components from the Seawolf for examination. The desirability of looking at the Seawolf boiler was discussed, and it was decided that the report put out through the Navy program on the operation of the Mark A boiler would be sufficient and that the information to be gained by examining the Seawolf boiler might not be worth the expenditure involved. It was decided not to examine the Seawolf boiler under our program.

The list of tasks to be carried out under the Sodium Components Development Program was re-examined and priorities were established beyond those established at previous meetings. The changes will be reflected in a change to the document entitled, "Sodium Components Development Program."

Alco Products gave their presentation on Wednesday afternoon, February 18. They indicated that they had recently selected a different design from that originally selected and presented the information they had on this design. They had switched from their once through sine wave tube unit in the steam generator to an integral but separate evaporator-steam drum-superheater arrangement all vertical. They described all phases of their program after which an open discussion between representatives of Alco and the Working Group took place.

On Thursday morning, Combustion Engineering presented the results of their study program describing the concentric tube and header type design. This design was selected by them early in the study and carried through to the conclusion. Hereto, after the formal presentation a discussion between Combustion Engineering and the Working Group took place.

Griscom-Russell appeared Thursday afternoon and described their designs. They initially had decided on a bent tube once through design and subsequently came up with an alternate design to this, a U tube type heat exchanger and an involute type steam generator. They, therefore, presented information on four units. The Griscom-Russell presentation was less formal and a great deal of discussion took place.

On Friday, February 20, the Working Group met and discussed criteria with which the three contractors would be evaluated. A tentative criteria was established, and it was agreed that each member would review and evaluate the final reports bringing his recommendations to a meeting on March 19-20 to be held in Canoga Park. There the Working Group would develop a recommendation to the AEC regarding further work on heat exchangers and steam generators under this program. During the course of the meeting, it was also decided that sodium frosting work, which earlier had been included in the program but had not been scoped, should be included in the program and given a reasonable degree of priority.

The meeting was adjourned at 4:00 P.M. on Friday.

Enclosure:
Priority Listing

SODIUM COMPONENTS DEVELOPMENT PROGRAMNEW PRIORITY RATING

1. Heat exchanger and steam generator
2. Facility scope
3. Flow control valves
4. Examination of Seawolf specimens
5. Low level oxide analysis
6. Mass transfer studies
7. Physical properties of materials
8. Shell side heat transfer
9. Oxide concentration meter (continuous)
10. H₂ detector in sodium
11. Sodium frosting
12. Na vapor removal device from gas
13. Na vapor detector in gas
14. Thermocouples
15. Level gage
16. Flow meter
17. Na isotope exchange
18. Inspection device (in Na)
19. Examination of used components and storage of equipment
20. Miscellaneous

Minutes of the Sodium Components Working Group
Meeting No. 12
March 19-20, 1959
Atomics International
Canoga Park, California

Members Present:	T. A. Nemzek	Chairman, COO
	R. Harris	DRD
	J. Morabito	APDA
	W. McDonald	ORNL
	H. W. Savage	ORNL
	J. R. Humphreys	ANL
	R. W. Dickinson	AI
	K. Goldmann	NDA
	R. Lockhart	GE
	T. P. Heckman	COO

The meeting opened with a short discussion of the plan for evaluating the designs submitted under the first phase of the heat exchanger and steam generator development program. Each member was asked to discuss and present his views on the advantages and disadvantages of each design. Wes Savage had made arrangements at ORNL for several people to spend two weeks reviewing the reports in detail with special emphasis devoted to soundness of assumptions made. They concluded that the assumptions used on the designs were sound. The sum of the opinions expressed are shown in the attached memorandum to the Manager, Chicago Operations Office regarding the Working Group review of these designs.

It was recommended by the Group that efforts on the priority items within the program related to sodium vapor removal, vapor detection, and sodium frosting be initiated as soon as possible.

The possibility of a revised or new handbook on sodium was suggested and discussed. It was agreed that much of the work being conducted under the Sodium Components Development Program would result in information which would be useful in developing or revising the handbook.

It was suggested that some work on general maintenance of sodium components be included in the intermediate heat exchanger and steam generator efforts.

A discussion of various efforts under way on continuous oxide measurement in sodium took place. It was concluded that all of the approaches now being pursued very definitely had serious problems and that our effort would compliment and extend present efforts. It was recommended that the effort be initiated as soon as possible.

It was suggested that in connection with our establishing the scope criteria for large sodium component tests that we might find the criteria developed at KAPL for their tests helpful. It was agreed that an effort would be made to acquire this information from the Naval Reactors Branch.

The next meeting of the Working Group was tentatively scheduled for April 23 and 24, 1959, at which time the Group would meet with the selected contractor who will develop the design criteria for the sodium components test facility and will conduct a survey of existing and available facilities in order that he might gain a better understanding of the test requirements. It is also planned to have the flow controller manufacturers present at this meeting to brief the Working Group.

The meeting was adjourned shortly after noon on Friday, and the remainder of the day was spent in touring facilities at Atomics International related to their sodium programs.

Enclosure:

Memo., 3-30-59, Nemzek to Dunbar

Office Memorandum • UNITED STATES GOVERNMENT

TO : Kenneth A. Dunbar, Manager
Chicago Operations Office

DATE: March 30, 1959

FROM : T. A. Nemzek, Chairman
Sodium Components Development Working Group

SUBJECT: REVIEW OF INTERMEDIATE HEAT EXCHANGER AND STEAM GENERATOR DESIGNS BY
SODIUM COMPONENTS DEVELOPMENT WORKING GROUP

SYMBOL: PR:TN

The Sodium Components Development Working Group met on March 19 and 20, 1959, to review the final reports of the Combustion Engineering Company, Alco Products, Inc., and the Griscom-Russell Company on their preliminary designs of intermediate heat exchangers and steam generators for use in a sodium system using 1200°F sodium into the intermediate heat exchanger and producing 1050°F steam at 2500 psi from the steam generator.

The Working Group discussed the advantages and disadvantages of each design and then, considering which designs would advance the art and have the best chance for reducing the cost of heat exchanger equipment for future reactor systems, evaluated the designs.

Briefly, the designs submitted were as follows:

1. Alco Products, Inc. - Intermediate heat exchanger; tube in shell heat exchanger with a sine wave in the tube.
Steam generator; recirculating type with boiler, steam drum, and superheater connected in one shell.
2. Griscom-Russell - Intermediate heat exchanger; tube in shell type with an offset tube.
Steam generator; tube in shell type with an offset tube. Griscom-Russell also presented alternate designs consisting of a U tube intermediate heat exchanger and involute tube type steam generator.
3. Combustion Engineering - Intermediate heat exchanger and steam generator were both of the double tube and header type.

The Working Group concluded that the objective of the Sodium Components Development Program would best be served by further effort on the tube and shell type intermediate heat exchanger with the sine tube

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March 30, 1959

and the recirculating type steam generator with integral boiler, steam drum, and superheater. A second effort on steam generators is warranted in that steam generator development is a far more serious problem than intermediate heat exchanger development. The second design recommended for further development was the tube in shell type steam generator with an offset tube. It was recognized that along with each component design an appropriate R&D program should be conducted. It was the unanimous recommendation of the Working Group that final designs of 70 MW units be started concurrent with the initiation of appropriate research and development programs for each design. It is expected that a recommendation will be made in the near future after further discussions with the heat exchanger and steam generator manufacturers regarding the prototype size which should be subjected to test. It was recognized that there was a great deal of merit in constructing full size units and testing at reduced capacity.

The following paragraphs summarize advantages and disadvantages of the various units:

The tube in shell type intermediate heat exchanger with the sine tube occupies a relatively small volume which, of course, must be a shielded volume. It can be shop fabricated thus assuring a greater degree of quality control. The unit can be scaled-up to larger sizes. The bottom side of the tube sheets contain crevices around the tubes which may present a problem and may have to be avoided. The unit is reasonably priced and probably can be reduced in cost after further development. An excellent job of design and analysis was performed on this unit.

The tube in shell type intermediate heat exchanger with the offset tube is low in cost and can be scaled up. It occupies a relatively small volume and also can be shop fabricated. The unit was not analyzed adequately and the tubes appeared to be too thin. Here again, crevices occurred on the under side of tube sheets and because of baffling design the heat transfer expected is questionable. A bent shell to accommodate the offset tubes could prove to be a slight disadvantage.

The U tube intermediate heat exchanger has a removable tube bundle but the tubes are not drainable. The unit can be scaled up to higher powers and it occupies a relatively low volume being a rather squat type unit. The unit can be fabricated in the shop. Here again, it appeared that the tubes were too thin and that the sodium entry at the bottom of the unit would cause rather high thermal stresses. The stress analysis on this unit was considered to be inadequate.

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The double tube and header type intermediate heat exchanger is probably the most reliable unit based on today's technology. It can be scaled up to any size simply by adding tubes to a longer header. The assembly of this unit would have to be done in the field thereby introducing a problem in quality control. The unit also requires a rather large cell space all of which must be shielded at considerable expense. The unit as designed indicated a flow area smaller than expected. The unit is somewhat more expensive than the others.

The tube in shell type steam generator featuring recirculation with separate boiler, steam drum, and superheater within the same shell appeared to be reasonably accessible for maintenance purposes. The material selection made for this unit was particularly good. The stress analysis was considered to be superior to that performed in other designs. The unit would be drainable and could be shop fabricated insuring quality control. Means for pressure release must be incorporated into this design. The unit is considered to be of moderate costs.

The tube in shell type steam generator featuring the offset tube appeared to have the advantage of very low cost. The unit could be fabricated in the shop and is completely drainable. The material selection for this design was questionable. Provisions would have to be made for adequate pressure release, and scaling this unit up could not be achieved easily.

The involute tube type steam generator has the advantage of having its tube sheet protected by a gas space which would prevent the severe thermal shocks. It can be fabricated in the shop, and the sodium side only would be drainable. Adequate relief for pressure is a feature of this design. Sodium inlet entering at the bottom of the shell probably would introduce severe thermal stresses at that point. The material selection in this unit was questionable as was the stress analysis.

The double tube and header type steam generator is, based on today's technology, the most reliable unit but by far the most expensive. It can be scaled up almost without limit but the cost would go up very nearly in direct proportion. Field fabrication would be required which could introduce a serious quality control problem. The methods of fabrication would need further development. Flow distribution in this design might be a problem.

The recommendation on steam generator designs was quite clear based on the review. The recirculating boiler, steam drum, superheater combination appeared to show the most promise from a development of the technology point of view and for achieving in our five year program a

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more economical, more reliable steam generator unit. The recommendation regarding the further work on the tube in shell with the offset tube type generator represents the "long shot" in the program. If this unit could be made to be reliable and so proved under tests, a great advance in reducing the cost of steam generating equipment would be made. It was believed that this approach warranted further investigation through prototype testing.

The evaluation of the intermediate heat exchanger designs resulted in the two tube in shell type exchangers and the U tube exchanger looking very much alike from a desirability point of view. The determining factor in recommending the tube in shell unit featuring the sine wave tube was by far the outstanding job done on selection and analysis of the design.

The recommendation to do further work on the tube in shell steam generator with the offset tube was made contingent on the submission by the contractor of a research and development program which would support the proposed designs in the following areas: material selection, control, pressure relief, welding development, inspection, stress analysis, and bent tube performance at either end of the unit. The development program presented in the final report was considered inadequate.

The research and development proposed to go along with the recommended intermediate heat exchanger design and the recirculating type steam generator design was considered to be more than adequate for those programs. It is recommended that this research and development program be modified from that which is presented in the report.

It is the recommendation of the Chairman that this information be transmitted to the Sodium Components Selection Board for their use in recommending the selection of the contractors to continue efforts on intermediate heat exchangers and steam generators.

Minutes of the Sodium Components Working Group
Meeting No. 13
April 30-May 1, 1959
Atomic Power Development Associates
Detroit, Michigan

Members Present:	T. A. Nemzek	Chairman, COO
	R. W. Dickinson	AI
	K. Goldmann	NDA
	O. Seim	ANL
	R. Lockhart	GE
	H. W. Savage	ORNL
	R. Harris	DRD
	J. Morabito	APDA
	T. P. Heckman	COO
Visitors Present:	F. D. Cotterman	Corwith Corporation
	W. S. Black	Corwith Corporation

The first item of business was a review of the status of the contract between COO and Corwith Corporation, a Division of Crane Company, for the development of a 6" prototype throttling device for high temperature sodium.

Mr. Black gave a brief summary of their literature survey and visits to various AEC sites actively involved in sodium work. He then proceeded to describe that particular design that they had chosen as being the most promising. This design is basically a gate valve. The proposed seal was a freeze seal copied directly from AI drawings with modifications to fit this particular size of valve, using tetralin as the freeze seal coolant. To meet the specifications of flow versus gate position, the openings in both the body of the valve and the gate had been shaped to approximate an equilateral triangle in cross section. The study report and drawings that were transmitted to the AEC, and

further distributed to the Working Group members, illustrated other various shapes and port openings that could be used and the effect that these shapes would have on the flow. Since this design is a preliminary study for a final product of 20" size, most of the effort to date had been on the analysis of flow through the body opening and the shaped gate. Comparisons have been made to standard gate valves, ball gate valves, and conventional globe valves. An open discussion among all of those present developed numerous other possibilities such as rotating disks with irregular openings serving as the flow passage, multiple openings as used in turbine throttle valves, and a succession of orifice holes in a conventional type of gate. Under questioning by the members of the Working Group, the Corwith representatives admitted that their proposed design would not stand up under continuous throttling use. It was also brought out that Corwith had not been making their calculations based on as high a pressure drop as indicated in the specifications of the contract. The Working Group indicated that in large power plants wherein several parallel loops may be used for transferring the heat from the reactor to the turbine, a throttling device may be in continuous use in order to balance the heat flow over the different parallel loops. The throttling device should also respond quickly so as to be able to minimize thermal transients following either a reactor scram or a load trip. Corwith Corporation admitted that they are now approximately two months behind their proposed schedule and that actual fabrication of a 6" valve of the design presented at this meeting would require approximately \$2,000 additional expense beyond the sum in the contract. Corwith Corporation asked for guidance regarding the next steps that they should be taking in this study. The Chairman offered to provide this guidance with a letter to them from the COO contract administrator.

Following the Corwith Corporation presentation the Working Group held a general discussion and evaluation of the work just presented. Mr. Seim of ANL related the discouraging experience that ANL has had with three 12" Crane angle valves

now installed in operating loops in the ANL 308 building. The Group generally agreed that Corwith had not directed their efforts closely in conformity to the specifications in the contract and felt that the contract should be terminated at this stage.

Sodium Components Information Meeting

The Chairman presented the general question concerning the need and type of information meeting that might be beneficial to the Sodium Components Development Program. After considerable open discussion, the Group generally agreed that the meeting should be of two days duration with the first day consisting of general broad subjects including formal introductions and presentations of papers. The second day could then be devoted to several seminars limited to subjects of special interest to those well-experienced with sodium problems. It was felt that such a meeting should be planned far enough in advance so that good publicity and good attendance could be assured. The Chairman agreed to take these comments under advisement and investigate the problem further within the AEC.

Griscom-Russell Company Contract

A brief discussion was held regarding the research and development of a once through steam generator superheater. The suggestion was made that if the Griscom-Russell Company does not have the facilities or manpower for pursuing a research and development program acceptable to the Working Group, that the Griscom-Russell Company might be requested to have this research and development work done as a subcontract with another company such as Franklin Institute or Battelle Memorial Institute.

PFBR (Plutonium Fast Breeder Reactor)

Messrs. Al Donnel and Al Amorosi of APDA then presented for the Working Group a brief technical review of advanced fast breeder concepts now under consideration by APDA. The PFBR has been a forty-man effort on the part of APDA and

their associates for the last several months and is intended to be the next project undertaken for detailed design and construction. This reactor is scheduled to be in operation in 1965, will have a mixed fuel containing $\text{PuO}_2 / \text{UO}_2$, and generate 300 MW electrical. The maximum sodium temperature will be 1000°F , will be shutdown every three months for loading, and will have an over-all thermal efficiency of 37 per cent. Mr. Amorosi then presented three parallel columns on the blackboard comparing the PFBR with EFR and a EFR of 300 MWe size. The columns illustrated those areas of design where considerable savings can be obtained and resulted in the following general conclusions:

<u>Reactor Type</u>	<u>Capital Costs for Installed KW</u>
PFBR (300 MWe)	$\approx \$230/\text{KW}$
FBR (300 MWe)	$\approx \$270/\text{KW}$
FBR-I (100 MWe)	$\approx \$350/\text{KW}$

Sodium Test Facility

The announcement was made that APDA had been selected as the contractor best qualified to proceed with the engineering study of a sodium test facility. Messrs. Al Amorosi, Bob Anderson, and Ralph Jones of APDA were present for the purpose of exchanging ideas and requesting general technical direction from the Working Group members. The following items were considered essential for this facility:

1. Ability to test intermediate heat exchangers, steam generators, and superheaters.
2. Electromagnetic pumps will be included as part of the facility.
3. Valves and flow controllers will be tested but on a lower priority basis.
4. The piping layout should be open and flexible to allow easy modification.
5. Capability of having two steam generators installed for test purposes at the same time. These test loops, however, need not be designed to test for intentional water leaks.

6. The cover gas will not require any special provisions.
7. Gas pressure shall be easily monitored and relief provided to allow the continual measurement and maintenance of intentional gas pockets.
8. APDA will specify the materials to be used that will be compatible with those of the test components.
9. Ability to subject the components to the thermal shock prescribed in the component specifications.
10. Cleaning provisions shall be considered but handled as an extra in this study.
11. The sites will be limited both in number and in degree of inspection for this particular study. APDA proposes to visit three or four AEC designated sites to check their capability of serving the required purpose.

A general discussion on excess and spare sodium components that might be available for installation in the test facility indicated that there are a considerable number of components available; however, a complete inventory does not exist. The Babcock & Wilcox oil fired sodium heater once installed at KAPL did not include the oil burners. The oil burners were to be of ship-board type and were to be supplied by the Navy.

Tour of Fermi Reactor Site and Quarry Test Site

On May 1, 1959, the entire Working Group visited the APDA test site located at a stone quarry on the edge of Detroit. The Group then proceeded to the Fermi reactor site, and during the noon lunch period entered the reactor containment shell and examined the progress of installation and construction.

The time, place, and subject matter for the next meeting was not made definite at this time; however, it was agreed that the next meeting should not be held sooner than the end of June or the first part of July.

Minutes of the Sodium Components Working Group

Meeting No. 14

September 16-18, 1959

General Electric Company

San Jose, California

September 16, 1959

Place: General Electric Company, San Jose, California

Present:

T. A. Nemzek, Chairman	COO
R. E. Harris	DRD
T. P. Heckman, Secretary	COO
W. R. Wykoff	LASL
R. W. Dickinson	AI
W. T. Morgan	AI
R. W. Lockhart	GE
K. Goldmann	NDA
H. W. Savage	ORNL
F. A. Smith	ANL
J. J. Morabito	APDA
R. Anderson	APDA

The Chairman opened the meeting at 9:30 A.M. on September 16 with a review of the past activities and a summary of the present status of the Sodium Components Development Program. The budget review held in Washington, D.C. during the summer resulted in favorable comments for this particular program including a general acceptance of the present schedule for design, fabrication, and operation of a sodium test facility. The purpose for this program and a brief history covering the last few years was presented for the benefit of the new people present at this meeting. In the order of importance a few comments were given on the contracts with Alco Products and Griscom-Russell for the development of steam generators and superheaters, followed by mention of the flow controller work now contracted with Crane, Westinghouse Electric, and Ohio Injector. The other contracts were listed and followed with a mention that there are still several items of important work to be assigned or contracted.

A letter from Mr. Gaines of Combustion Engineering in regard to an American Society of Mechanical Engineers meeting on the subject of heat exchanger work at high temperatures was brought to the attention of those present. This letter requested the submission of individual papers related to this broad subject matter from the members of the Working Group. Most of the members had been either contacted directly by Mr. Gaines or had received copies of his letter to Mr. Nemzek. The representatives from LASL, AI, NDA, and ANL were considering the submission of papers.

The representative from ORNL did not feel that at this time their organization would submit a paper. In regard to co-operation with technical societies, the position of the AEC was clarified for the benefit of those present. The AEC will participate and co-operate wherever possible with existing technical societies; however, the present policy does not allow the AEC to sponsor information meetings solely by itself.

The subject of the Working Group's status was presented for a brief discussion. The members were asked to consider the advantages and the disadvantages of this Working Group being either formal or informal. Their comments would then be asked for, either later in the meeting or by correspondence after they had had a chance to discuss the subject with their individual legal departments.

Mr. Heckman then reviewed the status of the work now being performed by Battelle Memorial Institute and Mine Safety Appliance, recently obtained from telephone conversations with representatives of these two companies. MSA reported that their contract had been divided into four separate problem areas, namely: (1) thermal shock of 1,000 cycles, (2) stress corrosion, (3) chemical corrosion, and (4) nitriding. At this time the assembly and layout drawings had been completed, and many of the detail plans were nearly completed. All of the material and major equipment items had been ordered, and the specialty items were now in the process of fabrication within the company's own shops. Present progress indicates that all of the equipment will be built and checked out by the end of October. These progress items and future data will be presented to the AEC and the Working Group on a bimonthly basis.

BMI reported that a committee had been established within BMI to discuss their contract for establishing a sensitive and rapid technique for the determination of low level oxygen. Of the many ideas presented by the committee, seven were considered worthy of additional investigation. These seven are as follows: (1) mass spectrometry, (2) sensitivity of other properties to the oxygen in the sodium, such as: (a) optical phase change of polarized light, (b) precipitation in a glass window noted by optical changes, (3) surface tension, (4) electrical resistivity, (5) polarography (the effect of samples added to a controlled electrolyte of an electrochemical cell), (6) refined plugging meter. The standard of reference for this development work will be the ANL distillation technique. This information will be presented in more detail in the standard BMI "red-back" reports starting with the August issue.

Mr. Robert Dickinson of AI reviewed the recent events of the SRE, starting with the operation in early July 1959. The subsequent explosion of August 16, 1959, of a test apparatus that contained both high-grade sodium and tetralin was described. At this time the explosion is attributed to the tetralin; however, a complete explanation of this phenomena is not readily available. Other chemical organizations such as the duPont Company have been approached for an explanation of this phenomena.

Mr. Dickinson then presented the status of the AI contract to develop a rugged and sensitive device capable of detecting hydrogen in minute quantities from a high temperature stream of sodium. At this time the most promising technique appears to be the separation of hydrogen from the sodium by means of a diffusion membrane and passing the hydrogen through a mass spectrometer.

Mr. Kurt Goldmann of NDA followed with a summary of the Seawolf examination contract which is nearing completion. The final report is due for delivery to the AEC September 30, 1959, and is on schedule. This date will be met unless additional work is requested by the AEC. The examinations were limited to the following three areas: (1) investigation of the transport of radioactivity, (2) sodium activity, and (3) component inspection.

[Classified data in official minutes, pp. 4 and 5, has been deleted].

Mr. W. R. Wykoff gave a brief description of LASL and of the K Division of which he is a member. The K Division has the assignment of developing experimental reactors with the present emphasis on LAMPRE I which is a 1/10 scale of a 20MW sodium cooled reactor planned as LAMPRE II. The K Division has a total of sixty-five people who are fully occupied at this time developing experiments to prove the feasibility of this design concept. The sodium heat transfer loop will operate at a minimum temperature of 1100°F with single wall tubes in the steam generator. This minimum temperature is essential because of the viscosity of the fuel which is a molten eutectic of plutonium and iron and must be pumped about within the fuel system of this design for the removal of fission products. The designs and progress to this date were presented along with descriptive slides. Copies of the LAMPRE first quarterly progress report were distributed to those present.

Mr. Robert Anderson, APDA, presented the status of their work on an engineering study of a sodium test facility. Copies of their report No. 1 entitled, "General Site Requirements" were given to each of those present. The building for containing the test facility and the general arrangement were based on the use of the Alco design of a steam generator and the existing Babcock & Wilcox oil-fired sodium heater. This resulted in a building with a maximum height of 75' and the use of an outside temporary crane for component installation. An air cooler on the outlet of the sodium heater was proposed as the method for producing the hot thermal shocks that will be imposed upon the component under test. Five different schemes were presented for the method of dumping the heat that will pass through the system as follows:

Schemes	Heat Dump	Estimated Equip. Cost
A	Condenser	\$158,000 - \$199,000
B	Evaporator	\$180,000 - \$208,000
C	Vent to atmo	\$132,000 - \$202,000
D	H.P. evaporator	\$263,000
E	Air Cooling	\$160,000 - \$230,000

The APDA member was excused and the Working Group discussed the work done to date. It was suggested that additional space be shown for future installation of test equipment in parallel. The general site requirements were also discussed, and the suggestions made that all utilities needed in the building be listed, and some minor re-arrangement of the requisites listed in their report No. 1.

The meeting was adjourned for the day at 6:00 P.M.

The meeting reconvened at 8:30 A.M. on September 17.

The Chairman introduced Mr. J. P. Thorel of Westinghouse Electric Corporation who presented the status of their work on development of a flow controller for high temperature sodium. He listed as prime importance in their consideration of this design: (1) a hermetically sealed unit with (2) a simple flow pattern and (3) a standard source of power including a manual over-ride. This design will not allow complete shutoff, but rather will only close to a minimum position of 5 per cent flow. Westinghouse has had little experience with components operating in high temperature sodium and has therefore relied heavily upon literature surveys for the selection of the materials and components used. The design as presently proposed was shown by the use of slides and drawings.

The Working Group discussed the design with Mr. Thorel and later recommended separate tests to prove the ability of ball bearings and ball nuts to perform in a high temperature sodium stream and the provision for heating, venting, and draining the components be included.

Mr. Robert Lockhart, GE, initiated the presentation of their contract for the investigation of mass transfer in high temperature sodium. He introduced Mr. George Billuris who used a series of sketches and charts to present the design and general arrangement of the test setup. Mr. Milt Lane followed with a description and discussion of the controls and instruments to be used for this same test equipment.

The GE member was excused and the Working Group discussed the information presented by the General Electric Co. The discussion covered the issues of a general versus a specific approach and the use of screening tests that would narrow the problem to a workable and practical number of specimens. From the discussion the Chairman concluded that: (1) The materials tested should be 316 stainless steel, 2 1/4 Cr-1 Mo, 5 Cr-1/2 Mo-1/2 Ti, a bimetallic loop containing 316 ± the 2 1/4 Cr alloy, and a

fifth bimetallic loop of 316 and the 5 Cr alloy. (2) The sodium should be of a reactor grade with specifications and constituents specified. (3) The velocity should be between 25-30 feet per second. (4) Tests for each of these materials should be run at temperatures of 1000, 1100, and 1200°F, and 1300°F for 316 stainless steel. (5) The temperature differential should be 500°F. (6) A close record of both the weight and the time of exposure should be kept for each specimen. (7) Radiochemical analysis should be made on the 316 loop. (8) Metallographic examination should be made on each of the loops and all specimens. (9) Radioactive tabs should be used at the high temperature only. (10) A continuous power supply with backup should be guaranteed. (11) Multiple tabs should be included in the cold legs. (12) The cold leg tabs should be chemically analyzed after exposure. (13) Unexposed samples, identical to the exposed ones, should be kept and analyzed for comparative purposes.

During an afternoon break in the discussions and presentations, the Working Group was taken on a conducted tour of the General Electric manufacturing facilities at the San Jose plant.

The meeting was adjourned at 7:30 P.M.

The Working Group assembled at the San Jose site of General Electric Company on the morning of September 18 and was taken to their Vallecitos Atomic Laboratories. A tour was conducted through the radioactive materials laboratory, the experimental physics laboratory, the boiling water reactor, and the General Electric test reactor.

After lunch the discussions reconvened at the Castlewood Country Club. Mr. Wes Savage reviewed his trip to the Alco Products, Inc. facilities at Dunkirk and Schenectady, New York during July 1959. Details of this visit were presented to each of those present in the form of a letter from Mr. Savage to Mr. Nemzek dated July 27, 1959. The Working Group was requested to review this trip report letter and forward comments to the Chairman for use in discussions with Alco.

Mr. Robert Lockhart then presented a recapitulation of his understanding of the Chairman's conclusions on the mass transfer work. A discussion of experimental technique followed.

The Chairman announced that the next Working Group meeting would be held in Chicago during late October 1959.

The meeting was concluded at 4:30 P.M.

Minutes of the Sodium Components Working Group

Meeting No. 15

December 10-11, 1959

Chicago Operations Office

Chicago, Illinois

Present: T. A. Nemzek, Chairman	COO
R. W. Lockhart	GE
K. Goldmann	NDA
G. Billuris	GE
R. Anderson	APDA
W. R. Wykoff	LASL
R. W. Dickinson	AI
W. McDonald	ORNL
T. Heckman, Secretary	COO
I. Spiewak	ORNL
J. Morabito	APDA
H. W. Savage	ORNL

The Chairman welcomed those present and offered the regrets of Mr. R. Harris who was not able to make the meeting. The original agenda for this meeting was referred to with several minor shifts and additions mentioned. Copies of the most recent Ohio Injector Company progress report and copies of the draft of the table of contents for Volume II of the Fast Reactor Handbook were distributed to those present. The members were requested to review this draft and offer their comments as soon as possible.

Both the advantages and disadvantages of this Working Group being made a formal AEC committee were discussed. The consensus of opinion of those present indicated that formalization would be an advantage both to the individual participating companies and to the AEC program in general. The details for instrumenting this formalization will be investigated and reported on at the next Working Group meeting.

Mr. Heckman gave a brief review of those status reports that would not be covered later in the meeting by contractor representatives or by recent progress reports that were mailed to each of the Working Group members. The most recent available BMI report on the determination of low level oxide in sodium covered the work performed in September and appeared to be satisfactory. The Group felt that this work should be reviewed with BMI to assure both the contractor and the Commission that both are in agreement as to the ultimate purpose of this contract. The work at MSA under the contract for investigating the physical properties of metals in high temperature sodium is in the stage of fabrication of test loops. The present rate of work indicates that these loops will be filled with sodium and checked out during the month of December and placed in operation during January 1960.

Mr. Dickinson briefly reviewed the philosophy of the present Sodium Components Development Program effort and proposed that the Working Group spend some time in considering and proposing advanced heat cycles and advanced designs of components to adequately support the proposed heat transfer systems. As examples of some of this advanced thinking now under way at this time, he made reference to some of the defense contracts and nuclear reactor systems proposed for use in space satellites. A sketch of a proposed binary system as developed by the General Electric Company several years ago which incorporated both mercury and water was presented. Similar efforts may be made by using sodium, mercury, and water to reach efficiencies as high as 50 per cent. All of the members present agreed that advanced ideas should be considered periodically and agreed to come to the next meeting prepared to present various new and advanced concepts and cycles for utilizing liquid metal as the coolant.

Mr. George Billuris of General Electric Co. distributed and presented the latest thinking of the GE Company in regard to their contract for determining the mass transfer between selected metals when subjected to high temperature sodium. In addition to the material presented in the recent progress report, Mr. Billuris offered for discussion detailed drawings on the sample holder of the mass transfer

test samples. The Group offered a few suggested changes that would improve the ability to withdraw test samples without disturbing the general loop characteristics. General Electric offered to consider these suggestions and will show the modifications or changes in the next progress report.

Mr. Savage gave a short presentation summarizing the discussions that he had held recently with specialists in the field of mass transfer at ORNL. One of these specialists, Mr. Jack DeVan, offered the opinion that the four most important parameters were temperature, flow rate, temperature difference, and oxide in a decreasing order of importance. Mr. DeVan felt that the flow rate was of such importance that velocity throughout the entire loop should be kept as nearly uniform as is possible including both the heater and the cooler regions. He was not experienced in the use of radioactive tracer techniques for mass transfer but did consider it worth trying. He considers that 1000 hour test was sufficient for alloys of less than 12 per cent chromium and temperatures under 1000°F. For austenitic steels under 1000°F the test should be for a duration of about 3000 hours. He also felt that the testing of crolloys above 1100°F should not be given serious consideration because their tensile strength was too low above these temperatures; also that throughout the test program the test samples should be maintained under their designed temperature differentials for at least 90 per cent of the total test time.

Mr. O. E. Dwyer of BNL was invited to speak to the Group regarding the accumulated experience gained by BNL in the field of liquid metal heat transfer. Mr. Dwyer limited his presentation to the work done with mercury, for both cross flow and in line flow performed with laboratory size test apparatus. Some work had been done at BNL with high temperature bismuth; however, he would not deal with this material at this time. By the use of several slides and the blackboard he covered the work performed by several Ph.D.'s and graduate students at BNL over a period of eight years with mercury. This work was intended for the purpose of developing basic theoretical equations and graphs that would be applicable under various engineering conditions. All of the BNL work was done with highly refined and

highly instrumented test arrangements designed for the purpose of developing equations that would fit these theoretical conditions for only cross flow and for only in line flow. By proper combination of these equations, an approach could then be made to equations that would closely simulate engineering components that have a combination of both cross and in line flow. For cross flow the equation he presented was $Nu = 4.05 + .228(P_1)^{.67}$. For cross flow there is also a variation of heat transfer with angular position as regards the direction of flow as illustrated by the following graph.

There was also a noted variation between the position of a particular row within its arrangement of the total tube bundle as illustrated by the following graph.

For parallel flow Mr. Dwyer offered the following equation.

$$Nu = 8.8 + 2.67 \left(\frac{P}{D}\right) + .0237 \left(\frac{P}{D}\right)^{.373} (Y_{Fe})^{.8}$$

In summarizing his presentation, Mr. Dwyer felt that considerable effort must be given to the cleanliness of liquid metal. Any scum or crud that formed in the test mercury tended to deposit out on the nonwetted heat transfer surfaces affecting the test results. Realizing that the effects of wetting or nonwetting of the liquid metal to the heat transfer surfaces plus the effects of gas entrainment in many practical applications, the graphs that have been plotted for heat transfer include separate curves covering these conditions of wetting, nonwetting, and gas entrainment. Although all of this heat transfer test work has been done with mercury in temperatures under 400°F, Mr. Dwyer felt

that the data could be directly applied to conditions using sodium or alkali metals as the coolant. Mr. Dwyer offered to send sets of reprints of the BNL report covering this work to those who are interested. (A list of names and addresses of those desiring reprints was sent to Mr. Dwyer on December 15, 1959.)

Mr. Irving Spiewak of ORNL had been invited to the meeting to present a moving picture in color and approximately twenty still slides covering the program of maintenance and rehabilitation of the HRE-II reactor. This presentation illustrated the tools and methods used to first examine the extent of damage to the reactor followed by the repairs necessary to put the reactor back into operation.

Mr. Anderson of APDA gave a presentation covering the material in their report APDA-134, "Sodium Components Test Facility under AEC Contract AT(11-1)-772," dated November 1959. After copies of the report were distributed to those present, the highlights within the report were reviewed and commented on.

The Chairman informed the Group that copies of this report together with a letter of inquiry had been sent on November 27, 1959, to the various AEC Operations Offices and prime contractors regarding the use of an existing site for this purpose. Replies to this inquiry were to be returned to COO by December 21, 1959. A summary of the replies will be given at the next Working Group meeting.

Mr. Goldmann of NDA reviewed the most recent work performed under their contract for the examination of certain Seawolf components. The disassembly of the primary sodium pump proved to be a very difficult job.

Mr. Morabito reviewed the status of the current test work now under way with the Enrico Fermi Fast Reactor. This work will use the actual reactor as a piece of test apparatus for a period of several months. The primary sodium tank and piping was heated by means of resistant and induction heaters to a temperature of 500°F. A period of three weeks was required for this heating operation to minimize the differential expansion and thermal stress that may develop from

uneven heating of the system. This operation revealed a few defects that will require modification and repair. The future schedule will include the following steps: (1) cool and repair, (2) heat to 500°F with air, (3) displace the air with inert gas, (4) purge with succeeding volumes of inert gas, (5) draw a vacuum on the primary system, (6) fill with sodium, and (7) operate the entire primary system without fuel at design temperature. Separate from the reactor several other development items are under investigation including examination of the B&W steam generator, testing the ability to trap sodium vapor from inert gas, and testing a 26' single tube crolloy once through superheater. This work under investigation at Alliance, Ohio, is primarily for the determination of corrosion on the water side of the tube. The tube is bent in the shape of a "U" and is heated by means of electrical resistance heaters and a sodium annulus between the heaters and the tube.

The first day's meeting adjourned at 6:00 P.M.

The meeting continued at 9:10 A.M. on December 11, 1959, with the following present:

T. A. Nemzek, Chairman	COO
C. S. Seabring	Alco
R. D. Seifert	Alco
J. A. Fabregas	Alco
L. E. Phillips	Alco
M. F. Sayre	Alco
J. A. McGowan	Alco
K. Goldmann	NDA
R. Anderson	APDA
R. W. Lockhart	GE
J. Morabito	APDA
W. R. Wykoff	IASL
R. W. Dickinson	AI
W. McDonald	ORNL

H. W. Savage	ORNL
F. Smith	ANL
T. Heckman, Secretary	COO

The Chairman welcomed the representatives from Alco Products, Inc. who were invited to give a status report on their contract for the design, and research and development phases of an intermediate heat exchanger, a steam generator, and a superheater that would satisfy the general scope of this program.

Mr. Seifert opened the presentation with a brief summary of the over-all contract covering the schedule for the separate parts of design, research and development, and fabrication. This schedule calls for the final design to start during March or April of 1960.

Mr. Sayre presented the R&D work that is now under way covering the mechanical design of the intermediate heat exchanger and the steam generator. The intermediate heat exchanger tests will attempt to resolve three basic problems: (1) the method of assembly of the tubes and the tube sheet, (2) the thermal expansion of the tubes which will be simulated by means of a hydraulic jack and a shortened tube under design temperature and pressure, and (3) the thermal shocks which will be both simulated and analyzed by theoretical statistical means.

Mr. Fabregas followed with an analysis of the heat transfer problems associated with the steam generator. A single tube test mockup will be constructed and be put in operation by mid-January 1960. This problem is also being analyzed by means of an analog computer.

Mr. McGowan presented the problem of chloride and hydroxide stress corrosion as related to the superheater and proposed the use of Kanigen nickel plating to solve this problem. At this time the test program is giving a basic evaluation to the plated material, the plating process, the precleaning and the activation as claimed for this method of nickel plating. Following this evaluation various samples and specimens will be plated and subjected to various tests such as heat treatment,

thermal shock, flexure, corrosion, stress corrosion, and the ability to provide anodic chemical protection. Further in the program will be the testing of full size and full length tubes and the correlation of this data to the smaller test samples.

Mr. Phillips presented the problem of instrumenting and detecting various types of leaks between the water and sodium in the steam generator together with the methods of protection that may be required. He classed the leaks into three sizes: (1) very small that would be detected by the oxide plugging indicator or by a hydrogen detector that is yet to be developed, (2) moderate size leaks that would readily be detected by changes in pressure in either the sodium or the water system and would require dumping the sodium to a tank and rapid shutdown of both the reactor and the water supply, and (3) large leak that would cause hazardous conditions not only in the steam generator but to the surrounding equipment and plant. This type of leak would require not only the scramming of the reactor but a complete shutdown of the turbine and bypassing wherever possible both the sodium and the water. From examination of the design drawings Alco felt that the most serious condition might develop from the spraying of water into the inert gas blanket immediately above the sodium surface in the steam generator. The possibility of the chemical reaction increasing the temperature to the point of rupturing several tubes was presented as possible. To evaluate the results of this incident plus others that may occur, Alco proposed an extensive test program that would satisfy the following objectives:

1. Determine the point of leakage that will cause the greatest pressure rise.
2. Determine the pressure rise versus rate of leakage.
3. Define a hazardous leak that would require a shutdown of operation in less than five minutes time.
4. Determine the sizing of the pressure relief valves and ruptured discs in the event of a hazardous rupture.

Mr. Fabregas presented the thermal analysis of their evaluation of the ability to scale-up or scale-down the prototype design of the components covered by this contract. He distributed copies of this analysis to all of those present and summarized for the Group the following highlights of the report. Changing the size or the number of tubes can be done reliably for a limited range. From known test data developed from the 70 MW design size reliable extrapolation could be extended either to 50 per cent or to 150 per cent of the 70 MW design. This would cover the heat range of 35 MW to 105 MW. The test conditions for obtaining this data must very closely simulate the actual design range of the final components. If the original design was for a 35 MW component, the data could only be reliably extrapolated up to approximately a 60 MW design.

Professor Sayre followed with the mechanical analysis of the same scale-up and scale-down evaluation. He felt that the weight and dimensions of the presently proposed 70 MW unit approach the maximum limit both for forging of tube sheets and for transportation of such a unit by rail. A unit larger than 70 MW heat size may require an entirely new design. From a mechanical analysis, this proposed type of steam generator superheater could be extended from as low as 20 MW to a limit of approximately 70 MW. A unit for less than 20 MW to 35 MW may also require a new mechanical design. The mechanical design of a 35 MW unit could be reliably extrapolated to a 70 MW unit. For testing purposes artificial means could be used to simulate 100 per cent load conditions in a test facility that was limited by the lesser capacity.

Mr. Seifert gave an economic analysis of the preceding scale-up and scale-down evaluations. He felt that the engineering cost would be the same regardless of megawatt size in the general range of 35 MW to 75 MW. The difference in cost between the two extremes would roughly be 12 per cent for the fabrication cost, 50 per cent for the tubing, and 25 per cent for the tube sheets resulting in an approximate savings of \$210,000 for the three units of the smaller capacity.

Mr. Seabring summarized the Alco presentation and mentioned that consultants qualified in statistical analysis have been called in to evaluate all portions of the complete design. The preliminary opinion of these consultants was that the good engineering design and testing as now proposed would be sufficient, and only in those cases of non-reproducibility of the test data would detailed statistical analysis be needed to help solve the problem.

Considerable discussion and exchange of opinions between the Alco representatives and the Working Group concerning the various parts of their presentation followed the formal portion of the meeting.

The Chairman thanked Alco for meeting with the Working Group and offered to summarize any changes in emphasis on their work by means of letter within the next few days.

The Working Group then met in a closed session to evaluate the complete Alco presentation. After considerable discussion among the members of the Group, it was agreed that the test program covering the sodium-water reaction was too extensive for this particular contract. Instead, full utilization should be made of that data that was obtained by test work performed at KAPL, APDA, and ANL covering the same general problem.

The question regarding the size of unit that should be selected for final fabrication was not resolved. The Group felt that Alco should be requested to extend their analysis of the scale-up and scale-down problem and to resubmit their report to the AEC. Analysis of this report will be made by the Working Group at their next meeting.

The Group was undecided as to what type of test data would be sufficient evidence to make the Kanigen process of nickel plating acceptable for use in the large size steam generator or superheater. Alco should be requested to do further investigation of this entire plating problem.

The Group decided to hold their next meeting on January 28 and 29, 1960, at Canoga Park, California, with AI acting as host. At this meeting the problem of shell side heat transfer should be given major consideration.

Minutes of the Sodium Components Working Group

Meeting No. 16

January 28-29, 1960

Atomics International

Canoga Park, California

Present: T. A. Nemzek, Chairman	COO
R. E. Harris	DRD
W. R. Wykoff	LASL
R. W. Dickinson	AI
R. W. Lockhart	GE
K. Goldmann	NDA
H. W. Savage	ORNL
F. A. Smith	COO
J. J. Morabito	APDA
L. Whynergy	LASL

The Chairman opened the meeting about 9:00 A.M. with some general comments on the status of the steam generator test facility. With the APDA Study, AEC Contract AT(11-1)-772 completed, the Chairman suggested the possibility of testing steam generators out of operating funds as an experiment and that the next step of this program is to get detailed proposals to cover the cost of this work from parties interested in doing this work.

The Working Group received a research proposal prepared by ALCO to conduct $\text{Na} \rightarrow \text{H}_2\text{O}$ reaction studies in connection with their steam generator design effort. It was the unanimous decision of the Working Group that ALCO should not engage in $\text{Na} \rightarrow \text{H}_2\text{O}$ reaction studies to determine the integrity of their bayonet and cap design. There are other means of determining the integrity of fabrication procedures and the more conventional means should be used.

Mr. Dickinson introduced members of the AI staff: John McDonald, Bill Hallett, R. Sygan, and L. Inglis who in turn presented the following aspects of an

Advanced SGR Component Development program:

Siphon Break

2" P.K. Ball Throttling Valve

Combination Valve Strainer Device

100 KW Concentric Cylinder, Spiral-Flow Heat Exchanger

100 KW Graham Helicoil Heat Exchanger

Experimental Stress Analysis of Large Bellows

Thermostatic Flow Regulator for Fuel Element Coolant

Cold Trap, cold trap and economizer with drain tank

Conoseal Mechanical Pipe Joints

AN-type Tule Joints

Valve Freeze Seals

Jet Pump

Following the discussion of the preceding items, Mr. Carl Davis presented the Working Group with preliminary data and status of work for the Na Components Development Program relating to the determination of H_2 in Na.

There are two methods of approach to make meaningful measurements:

1. Separation of H_2 from Na through a Ni or Pa membrane.
2. Thermal decomposition of Na and entrained H_2 where $NaH + \text{heat}$ yields $Na + H_2$.

To date most work has been done on the separation of H_2 from Na by diffusion of H_2 through a .015" Ni plate of approx. 5" dia. which is welded into a pipe assembly and submerged in Na. H_2 gas is introduced external to the immersed thimble, a vacuum is applied to the I.D. of the thimble and H_2 is collected and analyzed as it passes thru the Ni membrane. To date, there have been data taken on this apparatus to indicate that the method works. However, the time response is slower than the time response the Working Group specified as being desirable.

On Thursday afternoon Mr. Werner and Mr. Mausteller of Mine Safety Appliance Co. reported on the status of the Materials Study Program. Briefly the MSA program as presented breaks down as follows:

1. Corrosion with oxygen content varied at 1200°F
2. Corrosion influenced by stress, 200% of ASME code with oxygen content varied at 1200°F
3. Item #2 but with the effect of N₂ as a variable
4. Corrosion as effected by thermal cycling.

A loop facility to do items 1 and 2 is nearing completion and should be finished by February 8, 1960.

Another facility to do item #3 should be completed by March 8, 1960. A third facility has been started to do item #4.

Isometric flow diagrams and photos were distributed to the Working Group which graphically demonstrated the progress on this contract.

The Mine Safety representatives were excused from the meeting and the status of the Materials Program was reviewed by the Working Group.

Mr. Savage, ORNL, had prepared a written comment sheet discussing the scope of work covered and not covered by the MSA proposal. This interpretation points out that the MSA effort will determine the effect of stress on corrosion and that ORNL felt that the original scope should provide engineering design data on the effect of Na on the strength of the selected materials. The Working Group concurred that the MSA scope should be modified to try to obtain tensile strength and creep rate data making the minimum number of modifications to the existing loops nearing completion at MSA.

The Mine Safety representatives returned to the meeting and were notified of the changes which are desired in their study on structural materials. MSA

has agreed to study the engineering modifications necessary to increase their research program scope and will inform the Chairman by letter as soon as possible.

The Battelle representatives phoned the Chairman of travel difficulties in attending the Friday meeting and were excused. Battelle has offered to host the next Working Group meeting when they will present their status concerning "The Determination of Oxygen in Na at Concentrations of 10 ppm and Below."

The meeting opened about 9:00 A.M. on January 29, 1960, and the Chairman asked for a briefing of the status of work in current progress at each Working Member's organization.

Mr. J. Morabito gave a run-down on the non-nuclear hot dry test of core components on FERMI.

Mr. R. Wykoff, LASL, commented on the continuing program to resolve the container problem for the Pu-Fe fuel. Efforts are directed towards looking at fuel alloys which might reduce the liquidus temperature. Also they are investigating means of improving the fuel container by using alloys of Ta.

Mr. R. Lockhart reported that the Mass Transfer Study for the Commission is currently in the material procurement stage. All material should be in hand by March. Design work is completed. The first loop should operate in April.

GE is also getting some samples irradiated to get a better feel for the radio-active analytical work necessary for their program.

Mr. Kurt Goldmann reported that a final report is completed regarding the NDA inspection of components from the Sea Wolf. This reporter feels that this is one effort of the Na Components Program which is well done and successfully completed. The data on components might not have been collected had not the Working Group recognized the need before it was too late to get the data.

Mr. Dickinson discussed recent AI preliminary thinking on advanced heat cycles. The 1300°F Hg cycle does not at this time look too attractive as it would achieve cycle efficiency only about as good as a super-critical water cycle. It was pointed out that as a long range look we should remember that by increasing Delta-T's across reactors, heat exchangers, and steam generators, heat transfer area would decrease which, if successful in application, can lead directly to lower capital costs. The discussion terminated on the fond hope of Na gas vapor turbines operating at temperatures in excess of 1600°F at cycle efficiencies over 50 per cent.

On Friday afternoon members of the Working Group were conducted on an AI plant tour.

Minutes of the Sodium Components Working Group

Meeting No. 17

March 10-11, 1960

Battelle Memorial Institute

Columbus, Ohio

MARCH 10

Present: R. W. Dickinson	AI
K. Goldmann	NDA
R. E. Harris	DRD
T. P. Heckman, Secretary	COO
R. W. Lockhart	GE
J. J. Morabito	APDA
T. A. Nemzek, Chairman	COO
H. W. Savage	ORNL
W. R. Simmons	ANL
F. A. Smith	COO
W. R. Wykoff	LASL
D. R. Grieser	BMI
E. Simons	BMI
C. R. Tipton	BMI

Messrs. Simons, Grieser, and Tipton of BMI welcomed the Working Group to BMI and offered the use of their meeting room and other conveniences for the duration of this two-day meeting of the Sodium Components Development Program. Since the first day's meeting was devoted to Working Group discussions only, the BMI representatives retired from the room.

The Chairman opened the meeting at 9:25 A.M. and reviewed briefly the present status of the various contracts. He also summarized the recent changes in the AEC organization which now place the responsibility of all sodium cooled reactor programs plus the Sodium Components Development Program under a single Washington branch.

The response to the recent COO letter inviting an expression of interest on the part of national laboratories and industry concerning a sodium test facility was very favorable. Since the response of the Aircraft Reactors Branch was not definitive, the possibility of using their CANEL facility will be rechecked by the Civilian Reactors Branch of DRD in Washington. A memorandum from Pittman to Dunbar which will definitely decide the CANEL availability will be forthcoming in the near future.

The Chairman then brought up the first item of business on the agenda concerning a continuous oxide meter. The United Kingdom has developed such an instrument which in principle appears satisfactory. However, the reduction to practice of this principle has not been completely demonstrated. APDA, who now has a bilateral agreement with the United Kingdom regarding fast reactor development, is considering requesting complete drawings of this continuous oxide meter and also the possibility of fabricating and testing this meter in one of their test loops. The progress reports of EMI available up to this time have indicated that their work on determination of oxide at low level may result in a technique that would be readily developed into a continuous oxide meter. The Group, therefore, held this problem in reserve until after the EMI presentation scheduled for the following day.

The general discussion among the various members on determination of oxide impurities also generated the need of a technique and instrumentation for determination of other impurities that also may be present in sodium such as carbon, fission products and calcium. The Chairman, therefore, assigned each member the task of investigating what was presently underway within their own parent organization that related to the measuring and handling of any or all impurities in sodium. Each member is to report back at the next meeting of the Working Group.

A general discussion of the contract with Alco for the R&D design and fabrication of a steam generator was then initiated. A recent proposal by Alco for the evaluation

of the bayonet tube assembly end cap was discussed in considerable detail. Several refinements to their present test procedure were recommended, such as folding the test specimen at known temperatures while increasing the pressure hydraulically until rupture is caused in the specimen. In addition to the series of rupture tests proposed, it was felt that a close correlation of the test data must be made with the quality of weld of the end cap. Detailed procedures for checking the weld prior to test are needed, and correlation of these procedures with the rupture results should be a part of this R&D effort. A general discussion of Alco's report on the possibility to scale up or scale down their steam generator design was then held. The various members expressed numerous items of concern regarding this design. These items included cost per megawatt estimates and cost for dollars per square foot of heat transfer systems surface estimates. The problem of moisture carry-over by the steam impinging on the superheater tubes and on the superheater tube sheet was felt to be of major importance. The possibility of demonstrating this carry-over and other problems of recirculation by the use of an air-water test bottle was suggested. The problem of testing the steam generator of this design was also discussed in regard to the capacity of the test facility. Several members felt that the test facility should be capable of testing the steam generator beyond the 100 per cent design load, as only in this manner would the dynamic stability of the steam generator be correctly determined.

The Group felt that Alco should be asked to determine the limits to which this design can be extended with a clear definition of the limitations. In addition, Alco should be asked to give design data on several other sizes including 35, 70, 140, and the largest megawatt size to which this design can be carried. For each of these sizes the following items should be covered: length, diameter, cost for the various sizes and for using different materials of construction, baffles and their spacing, circulation ratio, steam separator effectiveness, stability under different load conditions, and the maximum stress and stress location during transients at different loads. The Group also would like to know the possibilities of operating the superheater with a reduced flow of sodium through the superheater thereby

limiting or reducing the demands on the test facility for test purposes. The Chairman offered to consider making this request of Alco. However, before undertaking this work, Alco will be asked to estimate the amount of manpower and dollar effort that would be required to complete these items.

The subject of shell side heat transfer was then generally discussed. A consensus of opinion was that the heat transfer coefficients now available in heat transfer handbooks concerning alkaline metals were made to empirically fit a specialized condition, and are, therefore, not applicable for general design use. This criticism also includes the data available in the Liquid Metals Handbook. The Chairman appointed a sub-committee for the investigation of the shell side heat transfer problem consisting of Mr. H. W. Savage, ORNL, Mr. K. Goldmann, NDA, and Mr. R. W. Dickinson, AI. These individuals agreed to do their initial work by correspondence and possibly hold a meeting after each had investigated the work underway within their own parent organization. A proposed program in detail will be submitted to the larger committee at the next Working Group meeting.

A brief review of the contracts with Westinghouse and Ohio Injector for development of flow controllers was then held. Estimates for undertaking the testing of these flow controllers are now being made by AI and should be presented to the AEC in the near future.

The meeting adjourned at 6:00 P.M.

MARCH 11, 1960

R. W. Dickinson	AI
K. Goldmann	NDA
R. E. Harris	DRD
T. P. Heckman	COO
R. W. Lockhart	GE
J. J. Morabito	APDA
T. A. Nemzek	COO
H. W. Savage	ORNL

W. R. Simmons	ANL
F. A. Smith	COO
W. R. Wykoff	LASL
H. W. Russell	BMI
H. R. Nelson	BMI
W. H. Goldthwaite	BMI
E. M. Simons	BMI
D. R. Grieser	BMI
J. W. Kissel	BMI
D. Ensminger	BMI
E. H. Hall	BMI
G. G. Cocks	BMI
J. McCallum	
J. Beach	

The second day's meeting was devoted entirely to the BMI presentation followed by a tour of the BMI facility. The Chairman opened the meeting by welcoming the BMI representatives and explaining for them the purpose and history of the Sodium Components Development Program, and the part that the Working Group plays in this program.

Mr. D. R. Grieser, BMI, acted as spokesman for the presentation and passed to each of the Working Group members an eight-page set of notes plus eleven pages of photographs, diagrams, and drawings that fit in with the presentation notes. The program notes were followed in close detail with Mr. Grieser making the introductions and giving the background. He was followed by Mr. Kissel who covered the purification loop, Mr. Hall covered mass spectrometry, Mr. Cocks and Mr. Ensminger on ellipsometry, Mr. Callum covered drop time and polarography, and Mr. Grieser handled the electrical resistivity. Mr. Eugene Simons covered the recap and general discussion. Following the formal presentation the Working Group met alone to evaluate the material presented and to formulate a reply of recommendations concerning the direction the work should take for the balance of

the time available under this contract. The Group agreed that the balance of time should be directed towards establishing:

1. A preferred method for an absolute determination technique
2. A preferred method for a continuous analytical technique
3. Possible techniques that may be evaluated in the future for the determination of other contaminants both on an individual and a gross basis

Following the closed meeting of the Working Group the BMI representatives were invited to meet again with the Group. The Chairman conveyed to the BMI representatives the general compliments and recommendations of the Working Group regarding their presentation. The formal meeting was then adjourned at 1:00 P.M. and was followed by lunch and a tour.

Minutes of the Sodium Components Working Group

Meeting No. 18

April 27-28, 1960

Los Alamos Scientific Laboratory

Los Alamos, New Mexico

April 27

Present: T. A. Nemzek, Chairman	COO
F. A. Smith	COO
W. R. Simmons	ANL
J. J. Morabito	APDA
K. Goldmann	NDA
J. McDonald	AI
R. W. Dickinson	AI
R. W. Lockhart	GE
W. R. Wykoff	LASL
L. A. Whinery	LASL
H. I. Bowers	LASL
E. C. Swickard	LASL
H. Barkman	LASL
T. P. Heckman, Secretary	COO

The first day's meeting was devoted to reviewing the work performed by LASL in regard to civilian power reactors with emphasis on their use of sodium as a heat transfer medium. Mr. Wykoff acted as spokesman and gave a brief review of the history of LASL and their civilian power works, and then introduced Mr. Larry Whinery, who described in detail the experiment that was then under way using a 2 MW gas fired furnace for testing a sodium to sodium steam generator that will eventually be incorporated with the LAMPRE. Through the use of charts, diagrams, and sketches drawn on the blackboard, Mr. Whinery answered the detailed questions asked him by the Working Group.

Mr. Howard Bowers followed and, by means of slides projected on a screen, diagrams, and the blackboard, illustrated the heat balance that was designed into the steam

generator and some of the actual test data that has been recorded to date.

	IHX	SUPERHEATER	THX
BTU/hr	3,920,000	726,000	5,790,000
U, actual	1300	156	1630
U, predicted L&K	1080	200	1220
U, predicted	1370	207	1590
U, predicted 100%	1560	240	1600

Mr. Swickard then presented a design for LAMPRE-I by means of slides and drawings. For a power of 500 KW the following design data was listed:

Sodium inlet temperature	450°C
Sodium outlet temperature	563°C
Sodium flow rate	133 gpm
Maximum fuel temperature	560°C
Fuel container Ta alloyed with .5% Tungsten	

The balance of the day was devoted to touring the actual test facility sites of LASL.

April 28

Present:	T. A. Nemzek, Chairman	COO
	R. W. Dickinson	AI
	H. W. Savage	ORNL
	R. W. Lockhart	GE
	R. E. Harris	DRD
	F. A. Smith	COO
	J. McDonald	AI
	D. Persons	ALOO
	W. R. Simmons	ANL
	J. J. Morabito	APDA
	K. Goldmann	NDA

W. R. Wykoff	LASL
R. Humphreys	LASL
T. P. Heckman, Secretary	COO

The Chairman opened the meeting with a few general remarks regarding the status and progress on the authorization from Washington AEC to proceed with a sodium test facility. He thanked the host for this meeting, LASL, for the very fine tour of their facility that was held the preceeding day.

The first of the business was a discussion of the shell side heat transfer by the subcommittee that was formed at the last Working Group Meeting held at BMI during March 1960. Mr. Savage, ORNL, acted as spokesman for the subcommittee which consists of representatives from ORNL, AI, and NDA.

Mr. Savage distributed to those present a four-page summary of the subcommittee's work to date. The scope of the work proposed was divided into four phases as follows:

1. Cross-Angular-In-Line flow heat transfer
2. Flow characteristics -- fluid dynamics
3. Flow and thermal characteristics
4. Verification program

Mr. John McDonald, AI, was then called upon by the subcommittee to present and summarize a more detailed report on the work proposed for determining shell side sodium heat transfer. Mr. McDonald distributed a twenty-five page report for all of those present and summarized the type of work that would be undertaken. This proposed program was also divided into four phases as follows:

1. Basic heat transfer experiments with sodium
2. Flow characteristic for experiments with water
3. Heat transfer and flow characteristic analytical studies
4. Verification experiments with sodium

The subcommittee requested that comments on this proposed program be directed to AI with copies to the other subcommittee members and COO. These comments

should be sent to AI within one week from the present date, May 5, 1960.

The very rough estimate of the funds and time required for completion of this investigation was \$200,000 per year and a time of several years.

Members of the Working Group felt that considerable effort should be directed to the problem of conduction verses local convection in the transfer from sodium to other materials. The understanding of heat transfer with liquid metals has improved considerably in the last fifteen years. Other members felt that the work under way at Brookhaven National Laboratory will be helpful in an academic sense but will be of limited usefulness to this particular program because of the lower temperatures and the small scale experiments that are now under way by BNL. There is also the possibility that the steam side of the heat transfer problem may introduce additional variable that will not be covered by work such as that under way at BNL. The subcommittee felt that satisfactory answers to this problem will depend largely upon qualifications of an organization to undertake a complete investigation of this problem plus the desire or enthusiasm on the part of an organization to do this work.

The subject of continuation of the Griscom-Russell contract for design, R&D, and fabrication of a once-through steam generator-superheater was brought before the Group by the Chairman. After considerable discussion it was agreed that a subcommittee should be formed for the purpose of visiting Griscom-Russell at Massillon, Ohio, for discussing the technical portion of the contract with Griscom-Russell representatives. The subcommittee would consist of Messrs. Fred Smith, Wallace Simmons, John Morabito, and Robert Lockhart. The subcommittee agreed among themselves to meet with Griscom-Russell on May 9, 1960, at Massillon, Ohio, assuming that this date was agreeable with the Griscom-Russell representatives.

Mr. Heckman was called upon to review the status of work at Westinghouse Electric Corporation for the design and fabrication of the sodium flow controller.

Mr. Heckman summarized his recent trip to Westinghouse Corporation of March 30, 1960, as follows:

On March 30, 1960, from approximately 9:30 A.M. to 4:30 P.M., he met with Messrs. J. P. Thorel, H. C. Flaton, et al, of Westinghouse Electric Corp.

to discuss the present status of work under Contract AT(11-1)-681 for a sodium flow controller.

The design is 95 per cent complete with only a few details on smaller parts, such as the thermal barriers, remaining. A recently requested addition by COO for the design, namely to allow for 100 per cent shutoff was not considered feasible because of the rigidity of the movable plug. However, the range of throttling will be increased so that in the closed position the flow will be no more than a "slow leak."

The reliability of the various parts of the total design was discussed, with emphasis placed on: (1) the ball bearings, (2) the permanent magnet drive, and (3) the prevention of crud deposits. Since the contract did not provide for an R&D effort to back up the choice of parts in the total design, Westinghouse has considered the total flow controller as a "best efforts" R&D component. The selection of parts, such as the ball bearings, was based upon vendors test reports on similar information in the open technical literature.

Mr. Thorel was confident that their design and choice of materials would perform according to specifications; however, Westinghouse does have alternate designs of critical parts such as the bearings. A sleeve bearing made of titanium carbide and tungsten carbide was submitted for his examination. This bearing appeared in perfect condition and reported to have been operated for over 3000 hours at 1350°F in sodium, including over 200 starts. This test work was performed by BMI for Westinghouse Electric Corporation and reported in the BMI monthly progress reports.

Provisions will be made in the design for keeping the permanent magnet temperature well within the range of magnet strength. Provisions will also be made to allow the purging with an inert gas prior to filling and also for draining the valve body for maintenance work.

Mr. Thorel estimated that 80 per cent of the items to be purchased outside of Westinghouse Corporation has been ordered. Two or three orders will exceed

\$2000 in cost and will, therefore, be submitted to COO for approval; the first one of these should arrive at COO by mid-April. Neither fabrication nor assembly of the purchased parts had started. A tour of the Cheswick shops did illustrate the capability of their facilities to handle this type of component.

Mr. Heckman was then called upon to review the current status of the Alco Products, Inc. for the design, R&D, and fabrication of a bayonet tube steam generator and separate superheater. He summarized his recent trip to Alco Products at both Dunkirk, New York, and Schenectady, New York, of March 31 and April 1, 1960, as follows:

On March 31, 1960, he was escorted by Mr. R. D. Seifert to the Dunkirk, New York, plant of Alco Products, Inc. where they met with Messrs. R. M. Church, J. G. Draves, et al, to discuss the status of work under Contract AT(11-1)-666. Four separate items of the total contract were being handled by the Dunkirk plant at this time, as noted on the attached schedule, as follows:

1. Ferrule Elimination R&D work:

Tubes of different wall thickness had been expanded into holes of different I.D. and then welded. The test section had been shipped to Schenectady for sectioning and examination. Following this preliminary work, a larger test section consisting of 644 holes and tubes of varying dimensions will be expanded, welded, sectioned, and examined.

2. Tube to Tube Sheet Welded Connection:

Tubes will be welded into a 12" diameter tube sheet using different types of joints such as: flat and trepanned. The possibility of protecting the joint by Kanigen plating and also by a buttered trepanned tube sheet will be investigated. This work was under way.

3. Samples of the Sine Wave Tubes:

These samples, made by the production shop techniques, were in transit to the Schenectady mechanical cycling test rig.

4. Transition Weld of $2\frac{1}{2}$ Cr . 1 Mo to 316 SS

The large massive test samples were in the welding rig. The first passes had been made.

On April 1, 1960, he was again escorted by Mr. R. D. Seifert to the Schenectady, New York, plant of Alco Products, Inc. where they met with Messrs Seabring, Ettinger, Phillips, Fabregas, et al.

In a general way the entire contract was reviewed, with attention given to the following:

1. Scale Up & Down from 70 MW Design

Alco was requested to give COO an estimate of the cost and time involved to examine this problem in more detail. Some of the details to be covered would be:

- a. Range of sizes to include 35, 70, 140 and largest MW units.
- b. What factors determine the limits in size.
- c. The stresses during transients and the stress locations.
- d. Should Kanigen plating not prove practical, what other metals would be specified. What effect would alternate materials have upon the total cost of a unit.

2. End Cap Weld Tests

The relationships of weld quality to the temperature and pressure causing rupture will be approached by the procedures outlined in their recent proposal. Should the results appear too erratic, a more refined way of applying the pressure, independent of specimen temperature, will be used. Testing of these specimens will be started by mid-April.

3. Kanigen Plating

A series of tests are under way to determine the capability of the Kanigen process of nickel plating to protect the **SS** superheater from chloride stress corrosion.

- a. A number of **SS** test bars (12-15) had been plated, heat treated, bent 180°, stressed by a bolt pulling on the two ends of the "U", and subjected to a boiling magnesium chloride solution. At different intervals of time the samples are withdrawn, washed, examined, and compared to unplated specimens subjected to the same treatment.
- b. A full length superheater tube had been sent to General American Co. for Kanigen plating of the inside surface. When the tube is returned (April) it will be closely inspected to determine the uniformity of plating.
- c. Corrosion tabs have been supplied to General American Co. for Kanigen plating. Return and testing of these tabs in high temperature steam are scheduled for mid-April. Specimens will be removed from the test loop after 500 hrs., 1000 hrs., and 2000 hrs. exposures and metallurgically examined.

4. Mechanical Flexure Tests

Several specimens of the sine wave end of the superheater tubes had been mechanically cycled to failure. The data obtained to date indicates that the design for thermal expansion of the tubes is adequate.

5. Thermal Shock of Tube Sheet Welds

A representative section of a tube sheet was under a continuous thermal cycling test to determine the effect of thermal stresses upon the tube to tube sheet welds. The data obtained to date indicates the welds are satisfactory.

6. Heat Transfer Test of a Single Bayonet Tube

The test rig was being heated for the first time during his visit.

The drawings of this equipment indicated that no heat would be transferred directly through the end cap of the bayonet tube. Alco agreed to modify the equipment to more closely simulate the actual conditions to be expected in the steam generator, wherein the hot inlet Na contacts the lower end of the bayonet tube first.

The reply of Mr. R. D. Seifert, Alco Products, dated April 20, 1960, to the questions left with them by Mr. Heckman regarding the scale-up and scale-down analysis was distributed to those present. The Group was not satisfied with the answers given in this reply, and after considerable discussion by the Group, the Chairman agreed to discuss this question further with Alco Products and determine to what degree of detail they can answer the questions put to them by Mr. Heckman on April 1, 1960. These questions were generated at the seventeenth meeting of the Working Group that was held in Columbus, Ohio, on March 10 and 11, 1960, and are summarized on page three of those minutes. Several members of the Working Group reiterated a feeling that the component that should be fabricated for test in a sodium test facility should be sized to a lesser capacity than the test facility itself. The Chairman agreed to take this recommendation under consideration and to investigate the possibilities and the cost of supplying a 30 MW combined steam generator and superheater of the Alco design.

The Chairman then brought to the attention of the Working Group the revised programs of MSA Research Corporation for the determination of the property of materials exposed to 1200°F sodium. After considerable discussion the Group agreed that specialists in metallurgy from within their own parent organizations would be consulted by members of this Working Group to compare the original proposal with the modified proposal also to consider the equipment being assembled at MSA, and to establish an integrated program that would solve the problem originally proposed by the Group. The representatives from ORNL, AI, and NDA agreed to

exchange among themselves their original proposals submitted to COO for undertaking this work. These members requested of the Chairman a copy of the original MSA proposal for doing this work. The Chairman agreed that if this were ethically and legally correct he would supply to the subcommittee copies of the technical portion of the MSA original proposal to COO.

The contract with BMI was then brought before the Group. It was agreed that this contract should continue for the balance of its contract time with emphasis on an analytical standard, or absolute technique, for the determination of oxygen in sodium at very low ppm. The subject of continuing this contract with BMI for the development of a continuous oxide meter was discussed without any decisions being made. Mr. Wykoff offered the comment that LASL is very seriously considering an investigation and development of the UK designed instrument for making this type of measurement.

A brief review of the entire program was then held. It was agreed that Item 10, Sodium Frosting, should be rewritten; that Item 11, Sodium Vapor Removal from Gas, could be eliminated since APDA has now performed this work and will report upon it; Item 13, Thermocouples, could be eliminated; Item 14, Level Gages, could be eliminated, and that those members who felt that their respective companies have developed a satisfactory level gage should report back on their development; Item 15, Flow Meters, was questioned and AI has agreed to report on their development of a satisfactory flow meter; Item 16, Isotope Exchange, was eliminated. New items recommended for adding to the work list are as follows:

1. Magnetic Aging Effect on materials, especially for flow meters.
2. Rotating seals, especially large diameter ones for shields.

The Working Group agreed to hold the next, and nineteenth, meeting in Detroit, Michigan, on June 9 and 10, 1960.

Minutes of the Sodium Components Working Group
 Meeting No. 19
 June 16-17, 1960
 Atomic Power Development Associates
 Detroit, Michigan

June 16

Present: T. A. Nemzek, Chairman	COO
R. W. Dickinson	AI
K. Goldmann	NDA
R. E. Harris	DRD
R. W. Lockhart	GE
J. J. Morabito	APDA
H. W. Savage	ORNL
F. A. Smith	COO
W. R. Simmons	ANL
W. R. Wykoff	LASL
T. P. Heckman, Secretary	COO
R. Anderson	APDA

The Chairman opened the meeting with a few general remarks concerning the activity within the AEC regarding the Sodium Components Development Program. The decision has been made to locate the sodium test facility at the Santa Susana site in California with AI as operating contractor. This decision was based largely on the installation and operating costs estimated for the facility at that location.

The Chairman then reviewed the agenda for this meeting, making note that there were three subcommittees to hear from. The first subcommittee to report would be the one assigned to visit the Griscom-Russel Company, consisting of Messrs. Fred Smith, John Morabito, Wallace Simmons, and Robert Lockhart. Mr. Smith acted as spokesman and reviewed those items

in the MSA modified proposal which G-R felt had been misquoted by MSA. Subsequent to the subcommittee G-R meeting, Messrs. Fred Smith and Phil Otten of G-R had met at a symposium sponsored by the International Nickel Company covering the subject of materials for nuclear and conventional power plants. At this meeting adverse information regarding the ability of Crolloy to withstand temperature and pressure conditions proposed in the sodium program was presented and discussed. In some instances $2\frac{1}{2}$ Cr - 1 Mo steel has exhibited very poor corrosion properties when subjected to steam conditions of 1050°F . A letter from Babcock and Wilcox to Mr. Smith regarding this subject was passed to members of the meeting. This letter cited several examples of similar results from this material; however, the letter noted the discrepancy in the water treatment by the various people reporting. The total evidence available at this time is not conclusive regarding the ability of $2\frac{1}{2}$ Cr - 1 Mo steel to stand up under conditions of 1050°F steam and needs further investigation.

Mr. Smith continued with a discussion of the subgroup meeting with the general conclusion that the G-R Company has the personnel and capabilities to undertake a research and development program on sodium-to-steam generators if given a certain amount of direction by this technical Working Group. He further felt that following the R&D effort a 30 MW unit of their design should be fabricated and tested in the sodium test facility. Mr. Simmons added that satisfactory stress analysis work is dependent upon the individual man doing the work, and that he feels that the G-R Company does have qualified stress analysis men.

Mr. Dickinson, at this time, presented two AI concepts for sodium-to-water steam generators and proposed that these be considered by the Group for possible fabrication. He also proposed that these concepts be shown to fabricators such as the G-R Company for their comments.

The Chairman then asked for general comments from the Working Group regarding Alco's steam generator design. Some of the Group felt that the steam separating surface appeared too small for the heat capacity claimed for this unit. The members agreed that a meeting should be held with Alco probably during August to review the data obtained from their current R&D program.

A lengthy discussion was then held among the members of the Working Group regarding new and improved concepts for steam generators. Some members expressed the opinion that the Group should hold frequent meetings with designers of steam generators to bring out all possible design that may, at any time, appear feasible, and the ideas originating from within the Group could be presented to these other designers for their comments and criticisms. However, before undertaking such a round of meetings, the Working Group agreed that they should establish a general set of requirements, or scope, that will give direction to the entire program. Mr. Morabito related the processes and procedures that APDA went through to select a satisfactory design of an IHX and to select a design for a steam generator.

Mr. Kurt Goldmann, co-ordinator for a subgroup to review the sodium components materials program, reviewed the June 10, 1960, preliminary draft made by the subcommittee consisting of Messrs. W. Anderson, AI; J. Divan, ORNL; and G. Stern, NDA; and submitted it to the Working Group. Following a summary of this draft Mr. Goldmann asked for comments and criticisms from the Working Group. Some members felt that the materials subgroup should have developed a broader program rather than one that was customized for the capabilities of MSA. Other members of the Working Group suggested that the individuals making up the subgroup should submit their individual comments to the Chairman in regard to how well this report covered the

essentials that should be covered in a materials project. The Chairman would then act as the arbitrator and resolve any differences that may exist between (1) the individual comments, (2) the preliminary draft coordinated by Mr. Goldmann, and (3) the proposals as submitted by the MSA Corporation. The Chairman agreed to review the individual comments from the members of the subgroup and also invited the comments from the Working Group not represented by this subgroup.

Mr. Savage then acted as spokesman for the subgroup studying the problem of shell side heat transfer. He referred to a 29-page report covering the heat transfer experiments specifications covering four phases of work. He summarized by expressing the opinion that this was a large program, that it would cost between \$350,000 and \$500,000, and would probably involve two scientists and four technicians over the period of 30 months, with a heat loop of approximately 1MW size. This heat transfer program would require a companion program to study the fluid flow data that may be of equal importance to the heat data in the total design of a particular component.

Mr. Morabito brought to the attention of the Working Group a report published by the B&W Research Center, Alliance, Ohio, dated April 23, 1957, titled, "Investigation of the Corrosion and Mass Transport Resistance of Structural Materials to Liquid Sodium".

June 17

Place: APDA, 1911 First Street, Detroit, Michigan, Basement Conference Room

Present: T. A. Nemzek, Chairman	COO
R. W. Dickinson	AI
K. Goldmann	NDA
J. J. Morabito	APDA
H. W. Savage	ORNL

F. A. Smith	COO
W. R. Simmons	ANL
W. R. Wykoff	LASL
T. P. Heckman, Secretary	COO
R. Anderson	AFDA

The Chairman asked each Working Group member to review briefly the work that has been accomplished by each individual's organization since the last Working Group meeting.

Mr. Goldmann indicated that activity at NDA had increased and that they are currently busy with a proposal on a small-sized mobile sodium cooled reactor that is at present classified.

Mr. Savage summarized the work at ORNL covering such projects as the EGCR, the HRE, and ORR, and the reactivation of molten salt reactor experiments. Mr. Dickinson reviewed the status of the HNPf and the modifications that will be made to the HNPf fuel handling mockup for conversion to a sodium test facility. He reviewed the present SRE status, indicating that the present schedule for reloading fuel would be July 13, 1960.

Mr. Wykoff reviewed the status at LASL covering the R&D work for the LAMPRE. He indicated that the ability to fabricate high purity Ta has been developed to a point where the capsules of .372 ID x 8 3/8 inches long x .025 wall can be accomplished satisfactorily. However, the addition of small amounts of tungsten to the Ta to improve the corrosion properties of this alloy has resulted in many difficulties in fabrication. The steam generator test loop had been operated at full power of 2 MW for approximately 10 hours when difficulty was encountered with the gas-fired heater. Design work is now under way for a core test facility for molten plutonium cores. This facility will be designed to handle an entire core to be inserted, tested, and withdrawn as a unit.

Mr. Simmons reviewed the status of EBR-II construction indicating that occupancy of the reactor building and the steam generator building will be given to ANL within a few weeks. Two steam generators have been shipped from the Argonne site to NRTS. Of the eight steam generators, four will be made with mechanically bonded duplex tubes, and four will be made with metallurgically bonded tubes. He estimated the cost of the complete steam generator system at about \$1,000,000 for a capacity of 62.5 TMW. ANL is also designing a core test facility in which the conceptual design will allow several cores to be connected to the common heat sink.

Mr. Morabito then reviewed the status of the Enrico Fermi Fast Reactor which the Working Group was later to tour. He mentioned that all the major components are either on hand or ready for shipment. The internals for the steam generators had been inspected by helium mass spectrometer in the vendor's shop and found to be leak tight. The core hold-down mechanism was being tested under cold conditions by the use of dummy fuel assemblies. The offset handling mechanism had been tested earlier, and at this time, parts of this mechanism had been sent back to their vendors for rework.

The Working Group was then escorted to the reactor site where a tour of all the principal buildings was held.

Minutes of the Sodium Components Working Group

Meeting No. 20

August 11-12, 1960

Alco Products, Inc.

Schenectady, New York

Present: T. A. Nemzek, Chairman	COO
R. W. Dickinson	AI
K. Goldmann	NDA
K. D. Kuczen	ANL
R. W. Lockhart	GE
J. J. Morabito	APDA
H. W. Savage	ORNL
F. A. Smith	COO
L. A. Whinery	LASL
T. P. Heckman, Secretary	COO

The meeting was opened at 9:30 a.m. by the Chairman who welcomed the alternates to the meeting from LASL and ANL and then summarized the current status on the design and fabrication of steam generators. An agreement could not be reached with the Griscom-Russell Company on certain contract terms regarding fee and allowable expenses; therefore, this contract will not be continued. Recent discussions between Alco, Inc. and COO have resulted in some changes to the contract which were discussed in detail later. The possibility of again making an open invitation to all manufacturers for a second steam generator unit was presented to the Working Group members for their consideration.

After several minutes open discussion between the members, the Working Group agreed that the cheapest design of a steam generator would basically be a straight tube in shell design with possibly a slight bend in either to allow for thermal expansion. Since such a design has been presented by both Griscom-Russell and Alco, the Group agreed that the logical step would be to

continue with fabrication of such a design. Additional R&D work would be allowed to resolve the stress problem associated with the tube sheet, to determine the advisability of lowering the inlet temperature, to consider the need for new alloys, the need for high quality water treatment, and the difficulties associated with the control of a once-through design.

At 10:00 a.m. the following Alco representatives joined the Working Group: R. D. Seifert, M. F. Sayne, J. A. Fabregas, G. P. Brown, L. E. Phillips, W. C. Aubrey, and W. D. Leggett. Mr. R. D. Seifert acted as spokesman for Alco, Inc. and gave a brief review of the R&D and the design work as of this meeting. The design of the 70 MW intermediate heat exchanger and 70 MW steam generator will be completed and reported to the AEC by September 1, 1960. The development work for providing a chemically deposited nickel coating on the inside of long, small tubes has not been successful. However, this method of protection for the outside of the tubes or for the tube sheet was felt to be satisfactory. Recent cost estimates for the intermediate heat exchanger indicated that an increase of \$140,000 would be necessary if the specifications for the material required an extra low cobalt content. A copy of the day's agenda was passed to each of those present and was followed very closely.

Mr. J. A. Fabregas followed with a brief statement that the thermal designs of all components under their contract including the intermediate heat exchanger, the steam generator, and the superheater were complete and that the analysis and write-up were under way at this time.

Professor Sayre stated that the stress analysis was basically complete for the original design. The time stress effects due to a Delta T appeared much less severe than originally predicted. This has been verified by the tube-to-tube sheet weld tests that are presently in the thermal-shock testing program, and which has indicated that this is not as severe a

problem as earlier thought. The sine wave tube test has resulted in very encouraging data, as the tubes broke when and where predicted from the theoretical calculations. Professor Sayre felt that should the contract be modified in any way, that the fatigue tests of other materials and at other temperatures could be made with the same test apparatus and would be of considerable usefulness to the general understanding of this problem or to any specific design.

Mr. Phillips summarized the chemical and metallurgical work on Kanigen plating and on the end-cap weld test. The Kanigen plating does not give a cathodic protection to small areas of uncoated base material; however, it does develop a protective oxide film when in contact with steam and has been tested for periods of five hundred hours at 1010°F. The evolution of gas during the chemical process of chemical deposition of the nickel has been the cause of unsatisfactory plating on the inside surfaces of small diameter tubes. The U-bend test samples in 42 per cent boiling magnesium chloride indicated that the Kanigen does give chloride stress corrosion protection to stainless steel. He recommended that bi-metallic tubes be used for the superheater with the tube ends and tube sheet protected by Kanigen plating applied to the tube sheet only. The actual testing of the end-cap weld test specimens had just started with the first specimen subjected to test. This specimen ruptured in the tube wall and not the tube end at a pressure of 11,000 psi.

Mr. Vawter discussed the advantages of and the problems associated with providing bi-metallic tubes in the superheater. An inter-liner, or tube, of a high nickel alloy was recommended for insertion in the stainless steel tube. The availability of this material had been discussed with various commercial suppliers such as the International Nickel Company and the Superior Tube Company. He concluded that an Inconel liner of

0.010" would prove satisfactory for both chemical protection and heat transfer purposes, since the higher pressure on the inside would produce the heat transfer bond.

Mr. Aubrey reviewed the design of the bayonet tube heat transfer test apparatus. Graphs were presented to show the effects of water velocity and steam flow rate versus various power levels for this particular geometry. The current tests that were then under way were to determine the effects of the water level upon the steaming rate.

Mr. G. Brown of the Dunkirk Production Shop of Alco, Inc. reviewed the ferrule elimination work. Since the Working Group earlier had considered that the number of crevices in a steam generator should be kept to a minimum, Alco had investigated various schemes for eliminating the ferrule which they had originally designed for the assembly of the tube bundle into the final tube sheet. Such schemes as casting the sine wave part of the tube bundle in a low melting alloy have been considered but discarded. As a result of this investigation, Alco recommended that the holes in the tube sheet be 0.020" larger in diameter than the tubes, that positioning rings be located approximately 18" back of the tube sheet, and that threaded bullet nosed plugs be inserted in the end of each tube to allow the tube to be pulled in case it should stick while being threaded through the tube sheet.

As indicated on the agenda, a tour was made to inspect the Kanigen plating, the welding development, the sine wave tests, the tube-to-tube sheet welded connection, the transition weld test, the bayonet tube test, and the end-cap weld test. Following the laboratory tour and lunch, the Group reconvened in the meeting room for discussion of the work completed to date on the bayonet tube design and to consider a new once-through design.

Mr. Seifert summarized Alco Products, Inc. feelings toward the bayonet tube design by saying that they would be willing to give the same assurances and guarantees for a component made to this design as they give on any of their other standard products such as feedwater heaters or locomotives. He recommended, however, that regardless of which design the AEC wished Alco to fabricate, he would recommend that additional Kanigen coupon tests be run for approximately three to four months. Also, he would recommend that additional heat cycles be made on the transition weld tests, and that over-run heat tests be made on the bayonet tube heat transfer experiment. The latter tests are very essential in determining the extent to which this type of design could be scaled up.

The Chairman initiated the discussion of a once-through design of a 30 MW size steam generator to meet the same general specifications as called for in the original contract. He summarized for the Working Group the discussions that had been recently held between Alco Products, Inc. and COO.

Mr. Seifert expressed the willingness of Alco Products, Inc. to make this change, indicating that much of the R&D work that was undertaken for the bayonet tube design would prove to be beneficial to a new once-through design. He indicated that actual design work for the once-through design would start about September 1, 1960, and would be very similar to the present design for the intermediate heat exchanger. If delivery of such a component were needed at the sodium test facility by August 1, 1962, they would be able to release shop drawings to the shop for actual fabrication by March 1, 1961. He also indicated that a change to the simpler design and the decrease in size from 70 to 30 MW would result in approximate savings to the AEC of \$250,000.

Mr. Fabregas outlined the procedures that would be followed in determining the thermal design for this once-through steam generator. Alco would like to

do a complete optimization of this design. Since heat transfer coefficients are not fully known, conservative values will be used. These heat transfer coefficients could be improved, or confirmed, with the present bayonet tube heat transfer test equipment after a few modifications have been made. These coefficients will also be verified by use of an analog computer. The problem of control of a once-through steam generator was considered by Alco to be a very important item, and that feedwater pumps that would respond closely to the demands of speed and capacity for a once-through steam generator, together with control schemes, should be closely checked immediately. He estimated that the over-all length of such a unit in a vertical position would approach 68 feet.

Mr. Phillips covered the chemical and metallurgical problems for the once-through design. Since any solids in the water would tend to deposit out at the transition from liquid to gas in the unit, the treatment of water must be closely controlled, keeping the total solids to one-half ppm total. The oxygen dissolved in the water would probably be scavenged by the use of hydrazine. This type of treatment will be similar to that used on the supercritical Eddystone Plant which is constructed of type 316 stainless steel. He recommended the use of welded tubing rather than seamless tubing indicating that quality control by the use of non-destructive testing could be as closely controlled for welded as for seamless and that the cost may be 40 to 50 per cent cheaper than for seamless tubing. The tubes would be bi-metallic with a 0.010" Inconel inner liner mechanically bonded to the stainless steel tubes. The protective valve of the Inconel would be continued to the tube-to-tube sheet connection and to the tube sheet itself by means of Kanigen plating.

Professor Sayre followed with a stress analysis of the design. He felt that the stress problem would be less than in the bayonet tube design. However, he was concerned with the problem of feedwater loss and the effects that this might have on the lower end of the component design.

The meeting adjourned at 4:45 p.m.

Time: August 12, 1960 9:00 a.m.

Present: T. A. Nemzek

R. W. Dickinson

K. Goldmann

K. D. Kuczen

R. W. Lockhart

J. J. Moribito

H. W. Savage

F. A. Smith

L. A. Whinery

T. P. Heckman, Secretary

The Chairman opened the meeting by asking the members present for their opinions of the presentation made by Alco Products, Inc. of the once-through design. An open discussion continued for approximately one hour during which the following points were emphasized. The industry needs a steam generator design that will cost less than \$10 per electrical KW installed. The simpler and less costly designs usually also have the highest stresses; or stated differently, the more complicated designs made to improve the stress and efficiency situation usually are more expensive. The present schedule given by AI for the installation and operation of the sodium test facility indicates that the intermediate heat exchanger should be on site by February 1962, and that the steam generator should be on site by August 1962. Based on this schedule it was agreed that Alco should start design of the once-through components by October of this year and to release the drawings to the shop for fabrication during the spring of 1961. Instructions to Alco should emphasize the fact that the Group would like to have cost estimates made by Alco's Dunkirk Production Plant. The Group agreed on the 30 MW heat size; however, they felt that a design with cost estimates should

be made using not only stainless steel but also using Croloy alloys, allowing Alco to adjust the temperatures slightly if required to make a workable design of Croloy. If Kanigen is to be used for protection of stainless steel against chloride stress corrosion, additional R&D work is necessary to prove that this type of coating will stand up to the erosion of wet steam. The R&D work now under way for the bayonet tube design should be brought to a rapid and logical conclusion. Wherever possible, the present testing equipment should be modified for use in R&D work essential for a once-through design. This R&D work, however, should be limited in both time and in areas of work that are considered critical.

The other items of the agenda were covered briefly as follows:

The Ohio Injector flow controller is on hand at AI and ready for tests. Westinghouse flow controller will be completed by October 1960. Since the water flow tests of the Westinghouse flow controller cannot be completed until late spring of 1961, the Group agreed to dispense with these tests and sent the component immediately to AI for testing in a sodium loop.

The contract with EMI for the determination of oxygen below 10 ppm has been extended and will allow EMI to consider using their developmental data for the actual designing of an instrument for the continuing reading of oxide concentration. NDA has been given a new contract to investigate the wet chemical technique for analysis of oxides at concentrates lower than 10 ppm.

Mr. Lockhart described the difficulties encountered in the preliminary startup and check-out of the first loops for the mass transfer investigation. Considerable trouble has been experienced with the conoseal gaskets, with valve bellows, and with the pump throat. Although

these problems are time consuming, he was confident that all of the loops would be in operation within the next few weeks.

The MSA proposal for undertaking the work outlined by the sub-group and co-ordinated by Mr. Goldmann regarding the physical properties of materials was presented to the Working Group. The Group felt that the two-loop approach presented by MSA appeared most consistent with the intentions of the sub-group and that the work should be continued with out undue delay. A copy of the technical portions of the MSA proposal was given to Mr. Goldmann, and additional copies will be sent to each member of the Working Group.

Copies of the 38-page report compiled by the sub-group to study shell side heat transfer were distributed to the members present. Mr. Dickinson gave an AI estimate for doing this work of approximately 30 months time and \$500,000, and recommended that the work be undertaken in the near future. The Chairman asked that each member of the Working Group review this sub-group report in detail and report back their recommendations at the next meeting.

Mr. Dickinson reported on the hydrogen detection in sodium saying that the technique has been demonstrated in the laboratory by the use of a nickel diaphragm which extracts the hydrogen, which is then in turn detected by a mass spectrometer. Additional work will be needed to reduce this principle to an actual instrument, satisfactory for reactor plant use.

Item 3 of the agenda was then brought to the Group's attention. Also at this time mention was made that an unsolicited proposal from B&W had been received for using the principle of flame photography for detecting sodium vapors. Also, a new work project proposal regarding the subject of the effects of magnetic and electrical fields on materials exposed to

high temperature sodium was distributed to each member present. The Group agreed that no work should be initiated upon those subjects listed on the agenda under Item 3. However, the effects of carbon and the methods of analyzing for carbon in sodium were brought to the Group's attention. Some members felt that the methods now available for the determination of carbon are very poor and very difficult to use, and that additional work is needed. The Chairman appointed Mr. Lockhart as chairman of a sub-group to investigate the effects and the analysis of carbon in sodium and to report his preliminary results at the next Working Group meeting. Mr. Dickinson brought to the attention of the Group a reference in KAPL-1450 to the possibility that erosion may be increased in areas of highest heat transfer in a boiler on the water side in the water zone. He then reviewed the current status of the SRE reactor and passed several photographs around the table showing a sectioned failed fuel assembly. A Washington-AEC committee had recently reviewed the SRE plant and procedures. If the present situation appears satisfactory, the loading of the reactor is estimated to start within ten days. The loading will require approximately one week to complete, which will be followed closely by low temperature and low power tests.

At 2:15 p.m. four representatives of Alco Products, Inc.: Messrs. W. D. Leggett, R. D. Seifert, J. A. Fabregas, and A. T. Lawrence, joined with the Working Group to summarize both the presentation and the discussion of the Working Group. The Chairman summarized the Working Group's opinion of the once-through proposal and recommended that the Alco program be modified as follows: the present efforts on the 70 MW bayonet tube design be brought to a rapid conclusion and summarized in a report with cost estimates; the design of a 30 MW intermediate heat exchanger and a once-through steam generator be initiated as soon as possible; these designs consider both type 316 stainless steel, and $2\frac{1}{4}$ Cr - 1 Mo materials for

both units. Alco Products, Inc. shall have the liberty of changing both the sodium temperature and the steam conditions to determine the optimum unit that can be made using $2\frac{1}{4}$ Cr - 1 Mo material. The Working Group would like to meet again with Alco about December 1960, to review their designs. The Dunkirk Production Plant should do the cost estimating, not only on an over-all basis but also on a detail parts basis, giving as much detail as possible. These cost estimates should include a 70 MW bayonet tube unit, a 70 MW once-through unit, and a 30 MW once-through unit. Alco was asked to look more closely at the specimens showing the tube-to-tube sheet weld, looking for incipient crevice corrosion. The Group would like Alco's recommendations on the phase-out of the bayonet tube heat transfer test and also on the end-cap weld test. The Group would like to know Alco's ability to scale-up the once-through design from the 30 MW size, to know if it is possible to build this type of design in a range of 140 to 200 MW.

For co-ordination purposes with the sodium test facility, the Chairman asked Alco to give approximate cost estimates on three separate 30 MW units as follows: (1) bayonet tube design, (2) once-through design, using either clad or bi-metallic stainless steel tube, and (3) once-through design, using $2\frac{1}{4}$ Cr - 1 Mo material. For administrative purposes, the Chairman asked Alco to also present their cost estimate for doing the total job according to expenditures in each fiscal year.

Minutes of the Sodium Components Working Group

Meeting No. 21

September 15-16, 1960

DuPont

Niagara Falls, New York

September 15

Present: F. A. Smith, Chairman (acting)	COO
R. W. Dickinson	AI
K. Goldmann	NDA
R. E. Harris	DRD
R. W. Lockhart	GE
J. J. Morabito	APDA
G. V. Packer	DRD
H. W. Savage	QRNL
W. R. Simmons	ANL
W. R. Wykoff	LASL
T. P. Heckman, Secretary	COO

DuPont

Ralph Elliott

Lee Greenberg

Frank Holt

Penn Lindsay

Don A. Miller

George Miller

Mr. Don A. Miller, Plant Manager, Niagara Falls, N. Y., of the DuPont Company welcomed the members of the Working Group to DuPont and offered the use of their conference room and other facilities for the meeting of this Working Group. He introduced the other representatives from DuPont listed above and passed out copies of the proposed agenda. The Acting Chairman for this meeting, Mr. Fred Smith of COO, thanked Mr. Miller and invited the DuPont representatives to sit

in for the first part of the Working Group meeting since the subject matter would be of a general nature. The DuPont representatives accepted the invitation, and the Chairman reviewed briefly the scope and purpose of the Sodium Components Development Program, and turned first to Item 2-A on the Working Group agenda, namely: status report on the work items under contract with AI.

Mr. Dickinson summarized the AI work to develop a hydrogen detector for use in a flowing stream of sodium. The principle of this instrument has been developed and proven out in the laboratory. It consists principally of a nickel membrane which alloys the hydrogen to diffuse and separate from the sodium. The hydrogen is then detected and measured by a catalytic hydrogen detector device. Continuation of this work to develop the principle into a working model has been deferred until the FY 1961 budget plan has been received by AI, with authorization to proceed with this work. AI is now summarizing the work under the hydrogen detection contract, and a report should be in the AEC and Working Group's hands in sixty days.

For the benefit of the guests, Mr. Dickinson then reviewed the current status of the SRE. This reactor went critical on September 6, 1960, following a long shutdown for the purpose of modification and recovery from a melted fuel element incident. The physics calculations estimated that the reactor would go critical with 26 fuel assemblies $\pm$ 2, and actually went critical with between 30 and 31 fuel assemblies needed. With the use of electrical heat, the sodium was raised to a temperature of 600°F and circulated for the purposes of wetting all heat transfer surfaces. Since flecks of material, considered to be carbon, were noted floating on the sodium, a hot trap operating at approximately 800°F has been in continuous operation with the intent of reducing the carbon content of the primary sodium to a desired level of 50 ppm $\pm$ 20. The hot trap now in the system is capable of withdrawing and holding approximately 13 pounds of carbon. Both AI and the AEC are concerned about the effects that excess carbon at high temperatures may have

on the thin-walled stainless steel. For this reason the reactor will not be operated beyond 10 MW and an upper temperature limit of 800°F until either the sodium is cleaned up, or interested parties are in agreement that the carbon does not constitute an unsafe condition. These hot traps, designed for the removal of carbon, consist of a filler of stainless steel foil and are heated so that the sodium can be raised to a temperature of 1300°F.

Mr. John Morabito of APDA then reviewed the recent past and the current status of the Enrico Fermi Fast Reactor. Several carloads of DuPont sodium were delivered to the Fermi site approximately one year ago, and after being pumped to the plant system the sodium was continually cold trapped for clean-up purposes. The first of a series of non-nuclear hot tests was performed earlier this year and required four weeks time to heat up the system. The second heat test is now under way and required one week for the heating to a temperature of 500°F, where it will be held for approximately three weeks to allow for the testing of various pieces of equipment such as the offset handling mechanism and control rod guides. After any modifications or repairs that may be required as a result of the second heat-up test, the system would be evacuated, filled with argon, evacuated, and filled with sodium heated to 400°F. He estimated that the primary system will be completely filled with the sodium in approximately four weeks and will be circulated in one test loop of the three loops.

Mr. Simmons of ANL then summarized the current status of the EBR-II as follows: The conventional power plant is approximately 99 per cent complete, the reactor plant (except for primary system) is 95 per cent complete, the boiler plant is approximately 35 per cent complete, and the processing plant is approximately 25 per cent complete. Work on the reactor proper inside the primary tank started this week. The schedule for dry criticality is now estimated to be in the spring of 1961 followed closely with filling the primary system with sodium, which will take place in either late spring or early summer of 1961.

For the benefit of the DuPont representatives, Mr. Simmons then reviewed the history of the model tank located in the ANL 206 building as a development step prior to the final design and construction of the EBR-II reactor.

Mr. Robert Lockhart of GE reviewed the current status of the mass transfer contract, up-dating the data and hours that are in the current progress report. He passed among those present a sample of the pipe taken from the Number 5 loop wherein a small leak had badly corroded the outside surface of the pipe below the leak, indicating that the sodium converted to a highly corrosive substance as it ran down the outside wall of the pipe. After viewing the sample and the photographs of the loop showing the sample in place, Mr. Holt of DuPont related similar experiences that DuPont had had with sodium and sodium hydroxide when permitted to leak through the container material and run down the outside surface of the containing pipe. He indicated that the corrosion increases very rapidly with an increase in temperature. Mr. Lockhart concluded by stating that the loops are still in the shakedown and start-up period of operations.

Mr. Robert Wykoff of LASL then summarized the history and current status of the LAMPRE. In this experiment the fuel alloy, consisting of the eutectic of plutonium and iron, will be kept constantly molten. Tantalum is the only known container material for holding this alloy, and even this material is considered marginal. Experiments to determine the compatibility of tantalum with this fuel alloy have shown leaks to develop after 2000 hours at 600°C. The minimum temperature that can be allowed once an experiment or the reactor is started up is 450°C, and must be maintained because the alloy expands upon freezing. Production of the tantalum container capsules is approximately 75 per cent complete at this time and will be 100 per cent complete by December. Loading of the first capsules with the fuel alloy is planned for about November 1, 1960.

The 2 MW steam generator loop continues to have trouble with the gas fired heater. This loop is a once-through single tube wall experiment designed to

operate at 925°F and 900 psi. The secondary loop has been operated for over 4000 hours, and the steam loop has accumulated approximately 2000 hours. The BJ pump bearing developed an oil leak of approximately 2 to 3 cc's of oil per day which is tapped off by an oil seal and has not caused any difficulty with the pumping operation. A differential temperature of approximately 35° has been noted between the top and bottom in the straight horizontal section of the steam generator immediately downstream from the cross flow section of the tubes. This differential temperature is reversed from what would normally be expected and is now being analyzed.

Mr. Kurt Goldmann of NDA then reviewed the contribution of NDA to the Sodium Components Development Program briefly summarizing the examination the the Seawolf specimens, wherein all the materials appeared to be in very good condition. He mentioned their current MCR contract, which is classified, and their contract for the analysis of oxygen in sodium at levels below 10 ppm by wet chemical techniques. This work has just started and will use the mercury amalgamation and titration approach.

After a coffee-break the DuPont representatives left the meeting, and the Working Group reconvened with the Chairman briefly reviewing the status of work by Alco Products, Inc. Mr. Dickinson then brought to the attention of the Working Group the AI inter-office letter No. 7519-4442 regarding a new 2 $\frac{1}{4}$ Cr alloy steel that has exhibited improved corrosion resistance properties to high temperature steam. He suggested that this material might be tested in the Alco bayonet tube heat transfer equipment, indicating, however, that this may involve the expense of two men per shift on a three shift per day basis. The Chairman then opened this subject of testing materials for their water resistant properties for general discussions by the Working Group as a part of the Sodium Components Development Program. Mr. Morabito stated that such an effort is not under way by the B&W Company at Alliance, Ohio, for APDA, and he would be willing to take specimens of this new alloy, supplied by AI, and have them tested as part of the APDA program. Mr. Heckman then mentioned an offer made by a staff employee of the ANL Chemical Engineering Division to test a few specimens of this material in a rig that they are now developing for the purpose of testing superheat fuel element cladding and structural materials for the EBWR Project. If AI could supply approximately 3 feet of this new material to COO; it would be forwarded to the proper personnel at ANL. Mr. Dickinson then brought to the attention of the Working Group the problem of the effects of

high heat flux on the surfaces of the transferring materials. Evidence of deterioration was obtained from the MSA tests performed for the HNPF; also, evidence has recently been obtained on a cal-rod type of heater in tests performed recently at Canoga Park. Mr. Kurt Goldmann explained some of the mechanisms that might be causing this deterioration by means of a graph on the blackboard, pointing out the type of violent reaction that takes place at the heat transfer surfaces; particularly at the reversal point on the heat transfer graph. The Chairman expressed interest in having these areas of work investigated but indicated that cost estimates would be needed from both Alco and B&W before the actual work could be authorized.

Mr. Heckman then summarized the progress reports of BMI as presented in the June report No. BMI-1448 and the July report No. BMI-1455. The July report implied that BMI was not adhering closely to the instructions of either the Working Group or COO and that this condition will be brought to BMI's attention in the immediate future. Since the BMI progress reports appear as part of a classified report covering all of the classified work under contract at BMI, the members of the Working Group were urged to request these individual reports from their own classified library. The numbers of these reports will be listed at the time other reports are transmitted to the Working Group members.

Mr. Morabito stated that APDA will receive a Blake type of oxygen determination meter during October 1960, as part of the bilateral agreement between APDA and the UK. APDA will then proceed to test and check-out this meter in an experiment loop prior to installation on the EFR. The first meter will be obtained without charge, and additional meters will be available either to APDA or to other interested organizations at approximately \$2000 each. Mr. Reuben Harris indicated that Washington Division of International Affairs has requested working drawings, prices, and availability of these meters for distribution to interested USA contractors.

Mr. Wes Savage of ORNL related that he had recently spent a day with MSA Research Corporation concerning the contract to determine the physical properties of materials exposed to sodium. He indicated that there was no disagreement between MSA and the subgroup report; however, actual construction of the loops is being delayed until the contract negotiations have been completed between COO and MSA. After reviewing MSA's proposal, he felt that there were several areas where savings could be made, such as programming the work so that the loops could proceed during the night shifts and possibly the weekends unattended except for periodic checking by the plant fireman. Also, this contract should not bear the full price for emergency or back-up diesel generator power. The service of such back-up power might be included as part of the overhead charge and spread over all of the MSA contract. Mr. Savage had discussed this contract with Mr. Jack DeVan, the ORNL member of the subcommittee, and they felt that this particular contract would produce data that would be supplemental and helpful to work that was already under way at such places as AI, ORNL, NDA, ANL, and elsewhere. However, it should not be considered as absolutely essential to the safe design or operation of sodium systems.

Mr. Dickinson stated that the Ohio Injector flow controller has been welded into the 14" loop. The bearing supplied by Westinghouse has been inserted in a loop of high temperature sodium and has been under test. Mr. Thorel of Westinghouse recently visited AI to check on the bearing test and also to review the specifications for the Westinghouse flow controller sodium test.

Mr. Smith then brought to the attention of the Working Group the list of new items on the agenda. The Working Group felt that the subject of magnetic effects on materials was of a minor nature and could be deferred until later.

The subject of shell side heat transfer resulted in a lengthy general discussion of the Working Group covering numerous questions such as: need for this work, cost of this work, organization best qualified to do this work, and details to be included in the scope of this work. Mr. Robert Dickinson asked

that any comments from the Working Group regarding the scope as developed by Mr. McDonald be sent to AI within the next week so as to allow Mr. McDonald to make corrections before the final copy is reproduced and distributed.

The subject of a third edition of the Liquid Metals Handbook brought out the following comments.

Publications in general are handled by a separate division of the AEC in Washington, D. C. A section of the "Fast Reactor Handbook," now under contract between AEC and APDA, will attempt to have current and up-to-date data in the sodium components section. However, this section will not be considered a substitute for a complete liquid metals handbook. The Group was not certain that enough new material was available or that the existing material was out of date so as to justify a third edition. The members will discuss this with their respective organizations and report back at the next meeting.

At 4:00 P. M. the DuPont representatives rejoined the Working Group to give a preview of the coming days agenda and tours and to answer some of the questions that were asked of DuPont during the coffee-break. Mr. Ralph DeSanis displayed a sketch showing the apparatus used for the determination of carbon at levels of ≤ 10 ppm and summarized the analytical techniques used in this apparatus. Mr. Holt agreed to have this procedure, along with descriptions of the apparatus, reproduced and distributed to the members of the Working Group before they departed.

Mr. Chuck Lempke of DuPont related a couple of experiences wherein a small sodium leak in equipment at 800°C continued for a considerable length of time without increasing in size or flow rate, implying that a small leak need not be an immediate emergency.

Mr. Stan Ekert stated that mild steel is used throughout most of their sodium production and processing equipment, and has continued to operate in the range of 400 to 450°C for periods up to eighteen years in length. However, during this

time some of the equipment had been repaired or patched. He mentioned that DuPont, after many years of experience, has found that soda ash is far better than other materials for controlling fire. CO₂, Metal X, and sand might be satisfactory for very small isolated fires, but definitely are not good for large spills. Mr. Morabito indicated that APDA has found silicon treated vermiculite to be very successful for their test operations.

September 16

Place: DuPont, Building 35, Conference Room, Niagara Falls, N. Y.

Present: F. A. Smith, Chairman (acting)	COO
R. W. Dickinson	AI
K. Goldmann	NDA
R. E. Harris	DRD
R. W. Lockhart	GE
J. J. Morabito	APDA
G. V. Packer	DRD
H. W. Savage	ORNL
W. R. Wykoff	LASL
T. P. Heckman, Secretary	COO

DuPont

R. DeSanis
 S. Eckert
 Ralph Elliott
 Frank Holt
 C. Lempke
 Penn Lindsay
 George Miller
 J. Rushmore

Mr. Lempke of DuPont, in answer to a question that had been asked earlier, discussed the solubility of nitrogen in sodium. He indicated that all of

their previous analyses show zero soluability even in cases where the sodium had been sparged with nitrogen followed by an additional sparging with argon. He agreed that calcium may have an effect on the nitrogen soluability in sodium, but he did not know what this effect might be. Mr. Dickinson expressed a feeling that possibly carbon also had an effect, not only on the nitrogen soluability but also on the oxygen soluability.

Mr. Stan Eckert, assisted by other DuPont members, discussed the items of sodium handling techniques, tank car loading and unloading, and safety precautions. DuPont prefers to take the samples by means of a large glass pipette from the tank car after the car is loaded, sampling from various positions in the 80,000 pound load, such as the 1/3, the 1/2, and the 2/3 points throughout the car. This pipette is introduced through a special plug in the gas blanket valve that controls the gas blanket over the sodium. The procedures for preparing, cleaning, and testing of the shipping cars were outlined. Commercial grade sodium, as sold by DuPont, differs from reactor grade principally in the ppm of calcium and chlorine that are contained. In commercial grade the calcium may go as high as 400 ppm and the chlorine as high as 50 ppm. Lowering the calcium content to meet reactor grade specifications adds approximately one cent per pound to the normal price of seventeen to eighteen cents per pound, F.O.B. Niagara. This additional charge covers only the additional processing, handling, and filtering through a micrometallic filter charges that DuPont incurs in producing sodium of this grade.

Mr. John Rushmore of DuPont described the process and techniques for the production of sodium, starting with a sodium chloride and calcium chloride fused salt bed that melts at a temperature of 580°C (1078°F) and is decomposed in a Downs cell by the process of electrolysis using iron and carbon electrodes. The raw materials are mined directly from deposits in the New York area, and the process requires 4KWH of eletricity per pound of sodium produced.

Mr. Lee Greenberg described the history of sodium production, emphasizing the pioneering work that DuPont had done - not only with sodium but with many of the other chemical products made by DuPont. The DuPont Company sells their "know how" to many other companies over the entire world. DuPont spends approximately 5 per cent of their sales revenue on research.

At mid-morning the Working Group was taken on a tour of the sodium production plant and the pioneering and supporting research laboratories.

After lunch the Working Group was introduced to representatives of the New York State Power Authority who conducted a three-hour tour of the \$720,000,000 Niagara Power Project.

Minutes of the Sodium Components Working Group

Meeting No. 22

November 2-4, 1960

Idaho Operations Office

Idaho Falls, Idaho

November 2, 1960

Present: F. A. Smith (Acting Chairman)	COO
R. W. Dickinson	AI
R. E. Harris	DRD
R. W. Lockhart	GE
J. J. Morabito	APDA
H. W. Savage	ORNL
W. R. Simmons	ANL
W. R. Wykoff	IASL
T. P. Heckman, Secretary	COO

Mr. Fred Smith, Acting Chairman, opened the meeting by welcoming all those present to this twenty-second meeting of the Working Group which will consist of one day of discussion and two days of tours of the sites at NRTS. He explained that Mr. Nemzek would not be present because of other business and that Mr. Kurt Goldmann would arrive one day late having been delayed at his office because of foreign visitors.

The Chairman then took up the first item on the agenda, reviewing briefly the AEC Sodium Components Development Program, emphasizing the fact that the budget has been limited which will require an even closer evaluation of each program before it is initiated and possibly requiring a stretch out in some of those programs now under way. Authorization for Phase-I of the sodium test facility has been given to Atomics International with the work to be scheduled so that the facility will be available to accept the steam generators and intermediate heat exchanger now under contract with Alco Products, Inc.

Mr. R. Harris reviewed the Sodium Components Development Program from the Washington, DRD, viewpoint. He emphasized the point that this program should make known through the means of the progress reports and technical meetings the successes and demonstrations that have been completed so as to keep people in the industry and within the AEC well informed of what has been accomplished with the funds expended. He also felt that the frequency of the Working Group meetings might be changed from an attempted once-a-month to quarterly or semi-annual meetings. The quarterly or semi-annual meetings could be of longer duration allowing a more thorough investigation of each problem area and proposed work for the future.

The DRD has received a proposal from AI concerning second generation steam generators for HNPF and has recommended that this work be delayed until after the HNPF has started up and given a preliminary indication of its capabilities.

Mr. Robert Dickinson of AI indicated that Nucleonics magazine will devote an entire issue to liquid metal reactors which will possibly be one of the next or near future issues. Both AI and Griscom-Russell are known to have made contributions for this special issue. Mr. Dickinson felt that there is a present need for advanced thinking, fabrication, and testing of advanced steam generators and liquid cooled reactors. In general, he felt that reactors of the 10 to 20 MW size, fueled with uranium carbide, designed to generate 1050°F steam could also in essence be considered a core test facility and would advance the nuclear technology more rapidly than by other approaches. He felt that the SRE has several limitations, especially in neutron flux, that detract from its use as a fuel test facility. He did indicate, however, that a few tricks, such as the insertion of converter plates, could result in thermal-peaking of neutrons and possibly producing a fast flux in a central area of the reactor for test purposes.

The Chairman then brought the Group's attention to the second item on the agenda pertaining to the MSA contract and asked for the Working Group's reappraisal of

the necessity for this work and the urgency of doing it as outlined by the subcommittee. He mentioned the possibility of incorporating this type of work, namely physical properties of materials subjected to high temperature sodium, in with the present General Electric mass transfer investigation. Mr. Lockhart of GE indicated that certain preliminary data could be obtained from the same test samples presently being used in the investigation of mass transfer. However, neither the samples nor the test loops are specifically designed for the type of data intended from the physical properties investigation. After a short discussion among the members of the Working Group, the Group agreed that the MSA contract should move ahead without any additional delay. They also agreed among themselves that their concern should be principally technical and that they would leave the budgetary and administrative problems to the AEC.

The Chairman then reviewed the BMI contract referring to the trip report of Mr. J. J. Purcell covering his trip to BMI on October 25, 1960, during which he visited with several of their administrative and technical personnel covering the subjects of (1) mass spectroscopy, (2) polarography, and (3) colorimetric technique. The Chairman then drew the Group's attention to a UK translation Number DEG-Info Series-46-D covering work done by French scientists headed by Mr. L. Champeix and others on the same subject as the BMI contract. The Working Group then expressed a desire to have separate BMI Progress Reports sent either directly to them or distributed through COO.

At 10:15 a.m. Messrs. S. Seabring and R. Seifert of Alco Products, Inc. joined with the Working Group to cover the Alco program status and future schedule. The Chairman introduced the Alco representatives and summarized the recent discussions between COO and Alco leading up to the information that would be presented at this meeting.

Mr. Seifert passed copies of their progress report dated November 1, 1960, to all the Working Group members present. He took several minutes reviewing the

contents of this report for the members. He then sketched on the blackboard a new scheme that is under consideration by Alco for avoiding the heavy sections of the tube sheet at the steam outlet end of a steam generator. This design would incorporate a double tube sheet with the tubes welded separately to each one. In this manner the high temperature of the sodium is separated from the high pressure of the steam resulting in thinner section tube sheets of approximately 6" in contact with the sodium and 10" to 12" in contact with the high pressure steam. Members of the Working Group felt that in cases where the Delta T was high and the diameter of the component was large, the stresses in the short section of tubes between the tube sheets might become excessive and, therefore, must be closely examined. Mr. Seifert felt that a preliminary analysis of this design would be completed and available for the next Working Group meeting.

The R&D effort at Alco is continuing on various items to back up the steam generator design. The Kanigen plating of test samples by the General American Company was not considered satisfactory by Alco, and negotiations are under way to see if the excessive porosity may be improved. The shock testing of Kanigen plated tube sheet sections has not indicated any flaking of the plating; additional tests will be made. Test coupons of Kanigen plated materials were subjected to 1050°F steam and showed no bond deterioration over those areas where the bonding or plating was intentionally removed. However, the opposite side of the test coupon was evidently affected by the removal process because the plating had raised over a considerable area indicating that the bond had been lost between the plating and the base material. The modified $2\frac{1}{4}$ Cr-1 Mo material proposed by AI has been investigated by Alco in co-operation with the U. S. Steel Corporation. Since the improved properties of this material are very dependent upon heat treatment, Alco felt that considerable investigation of the forming, welding, and other properties both before and after normalizing must be made before a definite decision could be made regarding the use of this material in a steam generator. After consulting with the U. S. Steel

Company, Alco felt that delivery of production amounts of this material to meet the proposed dates for the components could not be met, and, therefore, this material should not be considered for the first components. However, R&D work with the material should continue. Mr. Seifert proposed that Alco continue work with the modified $2\frac{1}{4}$ Cr-1 Mo steel in all of their present R&D setups such as sine-wave flexure tests, welding tests, corrosion tests, and a combination corrosion heat transfer test in the existing heat transfer loop. Although the normalizing of a large completed component made of this material does not appear practical according to Alco, Mr. Seifert felt that the potential promise to lower costs on future units should be justification for continuing the R&D effort with this material.

The Chairman then asked the Working Group the general question as to what degree the Sodium Components Development Program should be involved in new materials. Several members answered by saying they felt that any new material should be evaluated by the subcommittee established for the purpose of evaluating the physical properties of materials. The Chairman asked Alco to prepare a proposal addressed to Mr. Nemzek, Chairman of the Sodium Components Development Program, with copies to all Working Group members covering any work that they would consider doing in the evaluation of new materials such as the modified Croloy just under discussion. The Chairman also asked the members of the Working Group to take into consideration the possibility of inviting Alco to be a member of the materials subcommittee.

Mr. Seifert with assistance from Mr. Dickinson then drew on the blackboard a TTT diagram which is considered basic in the evaluation of the metallurgy of new materials and described how this diagram gives a graphic illustration of how a material can be expected to operate under certain temperature conditions following welding and heat treatment processes.

The Group adjourned at 12:45 for lunch and reconvened at 2:00 p.m. without the presence of the Alco representatives. Mr. R. Harris opened the meeting by

stating the need for another round of steam generator design evaluations with the intention of having alternate ideas, that have been well thought out, for use in a second contract for intermediate heat exchangers and steam generators for installation and testing in the sodium test facility. The fact that three reactors, namely EFR, EBR-II, and HNPF, will be in operation very shortly presents the needs for ideas both of alternate designs in case these reactors are not highly successful and also designs of advanced nature in the event these reactors are highly successful.

After a lengthy discussion among the various members of the Working Group, numerous ideas were presented as follows:

1. Raise the outlet temperature of the sodium from the reactor.
2. Lower the temperature of the outlet sodium from the reactor to a range of 950°F to 1000°F.
3. Raise the pressure of the steam side to 3500 to 5500 psi.
4. Make the best use of new materials.
5. Come up with better and improved mechanical designs.
6. Enlarge the present designs to units of larger capacity.
7. Limit the designs to units that will have a lower unit cost.
8. Invite all interested parties to a general Washington meeting.
9. Compile a bibliography or file of all existing steam generator designs.
10. Define our problem in considerable detail since we may now be chasing phantom problems
11. Where will we find these new ideas or answers to our problems--from national laboratories, from industry, from universities, or from special consultants in this field?

The Chairman asked each member of the Working Group to take the thoughts generated in this discussion back to his home organization and to come to the next meeting of the Working Group prepared with answers of what should be the next step with sodium steam generators.

The Alco representatives then re-joined the Working Group for the third item on the agenda, namely status of related sodium projects. Mr. Robert Dickinson of AI reviewed the test data obtained from testing the Ohio Injector flow controller indicating that this component performed very satisfactorily and closely to the predicted conditions when tested in the LCTL at 1200°F with a sodium flow of 780 gpm. The separate torque tube has been tested in a static hot gas set-up at 1200°F for 1200 cycles. The report on the hydrogen detection contract is still in process with an anticipated completion date of approximately November 16, 1960. The SRE is continuing with the physics tests, with the sodium at 350°F. During these physics tests the sodium is under a continual clean-up now revealing that the top surface is clean but still is not considered shiny. The carbon traps for the SRE sodium will not be used until the main sodium has been heated to a much higher temperature since the carbon traps themselves must operate at approximately 1300°F. Mr. Dickinson will have several capsules from the same batch of sodium prepared for shipment to any company who will volunteer to analyze these samples for carbon. He would like to have this analysis work done by several independent companies such as General Electric, AI, DuPont, and NDA to determine the reproducibility of the carbon analysis technique. AI has received instructions from the AEC to start work on the sodium test facility, and they hope to be able to issue orders on the long lead items very shortly in order to meet the 1962 startup date. The AI project engineer for the test facility is Mr. Jack Renard.

Mr. Wykoff of LASL then reviewed the status of the LAMPRE. Essentially all the fuel capsules have been made by this time. However, these still require a heat treatment and possibly several other nondestructive testing procedures. He anticipates that loading of the capsules into the reactor will start by mid-November 1960. The reactor now has sodium in the primary loop which is being circulated and cleaned. The mechanical handling device for the capsules has developed considerable trouble which is now being actively worked on. The steam generator has now accumulated 3175 hours of operation. The secondary

pump has accumulated 5575 hours and has worked fine. An identical BJ primary pump has had considerable trouble with the seal. This pump has been shut down and repaired once, and it appears that it must be shut down again for re-surfacing of the seal parts.

Mr. Lockhart of GE then covered the status of the mass transfer contract. He passed to those present a schedule dated October 30, 1960, to update progress report Number 14. He then summarized the material in the report. He passed among those present a section taken from of the loops consisting of a flanged joint that had started with a very small leak and had erroded away a considerable amount of material on the outside surface.

Mr. Harris brought to the attention of the Working Group the fact that Franklin Institute has a contract to write a text book on thermal stress analysis, and there now exists a need for competent reviewers of this text. He asked if any members of the Working Group would like to undertake this review work. The members present did not feel that they had time to undertake this review work. However, they gave to Mr. Harris, individually, the names of several people who were competent to do this work and might possibly agree to do so if approached by the AEC.

Mr. Smith then brought to the attention of the Working Group a draft of a multi-year review of sodium technology dated October 17, 1960, that had been prepared by AI. He asked that each member of the Working Group review this draft and reply in writing individually to the Chairman, Mr. Nemzek, their comments regarding this draft proposal.

Mr. Dickinson brought to the attention of the Working Group his feeling regarding the need for a new edition of the Liquid Metals Handbook. He asked for comments from those present.

Mr. John Morabito of APDA then presented the table of contents of the Liquid Metals Section of a new Fast Reactor Handbook that is now under preparation by APDA under contract with the AEC.

Mr. Smith, Acting Chairman, mentioned that any discussion on the subject of shell side heat transfer should be deferred until the next meeting when Mr. Nemzek, the permanent Chairman, would be present.

At 5:30 p.m. the meeting adjourned.

November 3, 1960 - Tour of ANL Facilities

The Working Group including the Alco representatives assembled in front of the Rodgers Hotel at 7:30 a.m. and were taken on a conducted tour of the EBR-II, TREAT, EBR-I, ZPR-III, and BORAX V facilities.

November 4, 1960 - Tour of other NRTS Facilities

The Group assembled at 7:30 a.m. in front of the Rodgers Hotel and was taken on a conducted tour of the MTR, ETR, and ICPP--all operated by the Phillips Petroleum Company. In the afternoon the Group toured the SL-1 being operated by Combustion Engineering and had a briefing of GCRE by Aerojet General Nucleonics. This was followed by a briefing and tour of the OMRE by Atomics International.

Minutes of the Sodium Components Working Group

Meeting No. 23

December 8-9, 1960

Chicago Operations Office

Chicago, Illinois

Present: T. A. Nemzek, Chairman	COO
R. W. Dickinson	AI
J. A. Fabregas	Alco
Kurt Goldmann	NDA
R. E. Harris	DRD, Washington
Ken Kuczen	ANL
R. W. Lockhart	GE
J. J. Morabito	APDA
J. J. Purcell	COO
H. W. Savage	ORNL
R. D. Seifert	Alco
W. R. Wykoff	LASL
T. P. Heckman, Secretary	COO

Mr. Nemzek, Chairman, opened the meeting by welcoming the members of the Working Group and the guests from Alco Products, Inc. to this twenty-third technical meeting of the Sodium Components Development Program. The discussion turned immediately to Item 1. on the agenda concerning the Alco intermediate heat exchanger and steam generator contract.

Mr. Roy Seifert of Alco distributed to those present copies of their progress report dated December 1, 1960. He then proceeded to summarize the report and to answer questions put to him by the Working Group. The discussion concerning the cost versus sodium flow graphs established the

assumption that the diameter of the components was kept constant and the length varied. Should a smaller diameter component be desired, the cost savings would approximate 6 per cent of the total cost for each reduction in diameter of two inches. A small change, however, in the length of the component should not affect the cost appreciably. This cost graph in effect consists of three graphs superimposed on the same paper, showing the individual costs for IHX and for the steam generator, and a total or summation of these costs including a pumping power cost. The stainless steel exposed to water would include an Inconel overlay.

Discussion of the development program brought out the following additional points. The Kanigen process of nickel plating does not appear practical because General American Company has not been successful in producing a nonporous continuous coating on the inside surface of small diameter tubes. Also, Kanigen is very sensitive at temperatures over 600°F and appears to erode very badly in the presence of saturated steam. Other metallic and ceramic coating such as aluminum and aluminum oxide had been considered but were rejected. A thin inner tube of Inconel is recommended for the steam generator tubes to protect the stainless steel from such effects as chloroxide stress corrosion. Inconel weld rods and weld wires have been developed for use in machine overlay of the tube-to-tube-sheet and the tube sheet proper. This recent development of Inconel weld wire that is not subject to age hardening will allow the application of an Inconel overlay by automatic machine methods.

Sections were taken of the test sample of the tube-to-tube-sheet weld sections that had been exposed to thermal shock. These sections showed considerable intergranular corrosion in the crevice area. Since the crevice was not subjected to either water or sodium, Alco is concerned about the method of hydrostatic pressure testing the finished component,

feeling that any fluid used for the hydrostatic testing may be forced into the crevice to remain and to cause corrosion. At this time Mr. John Morabito, APDA, brought to the attention of the Group the report titled "Examination of the AEJ-16 Steam Generator," B&W Report No. 7334.

Mr. Seifert expressed the opinion that the 30 MW design could be scaled up to 70 MW or greater with great assurance, if the unit were made of stainless steel. He could not offer the same assurance of scaling up units that might be constructed of Croloy or modified Croloy materials. However, the investigation of Croloy materials is continuing with two different type tubes being installed in the high temperature heat transfer experimental rig. The possibility of making a large diameter component using the principles illustrated in the EBR-II steam generator design was discussed. Some of the members felt that this principle could not be used for large diameter units without very close and critical examination of the thermal stresses imposed upon the tubes between the tube sheets.

Mr. Seifert then put the following time schedule on the blackboard: 30 MW design IHX-design release for fabrication and purchase of materials-February 15, 1961; steam generator design release for fabrication and purchase of material-April 15, 1961; IHX shipping date-March 1, 1962; steam generator shipping date-August 1, 1962. Although a cost estimate was not available immediately for these units, such an estimate could be put together in a matter of a few minutes. The Alco representatives, therefore, left the room to allow the Working Group to evaluate the information presented and returned after lunch to present the cost estimates.

A general discussion was then held among the members of the Working Group which brought out numerous conflicting points of view. Some members felt that Inconel has not been proven for this particular application and that the use of ferritic materials should be emphasized if economics is one of the primary goals of the Sodium Components Development Program. Other

members questioned the once-through concept of a combination steam generator and superheater, expressing an opinion that these should be two individual separate units. The Group adjourned for lunch and reconvened with the Alco representatives who listed the following cost estimates on the blackboard:

30 MW Components for 1050°F Steam

30 MW IHX stainless steel	\$186,000
Steam Generator-stainless steel	<u>176,500</u>
Total	\$462,500 (which equals \$15.42 per KW)

30 MW Components for 1000°F Steam

IHX stainless steel	\$180,000
Steam generator-2½ chrome-1 moly material	<u>254,500</u>
Total	\$434,500 (which equals 14.48 per KW)

The Alco representatives then left the room to allow the Working Group to continue with their discussion and evaluation.

The general discussion that then continued for approximately two hours, dwelt mainly on subjects of criteria for the program and on the materials the should be selected for the Alco contract to build an IHX and a steam generator. The criteria was narrowed down to four basic items, namely: reliability, economics, high temperature steam to 1050°F, and ability to scale-up.

In regard to the choice of materials, several members felt very strongly that stainless steel protected with Inconel was definitely the way to make the first unit. Whereas other members felt that any material other than stainless steel should be the choice, principally because of the experience the turbine manufacturers have had with stainless steel, and because Croloy would definitely lead to more economical units. Still other members felt

that the Group did not understand the metallurgical problems sufficiently well to establish a choice by themselves and therefore, metallurgical consultants should be brought in to assist with the decision. At 3:30 p.m. the Alco representatives rejoined the Working Group to be appraised of the decisions arrived at by the Working Group. The Chairman summarized the conclusions for Alco as follows: work should continue on both the IHX and the steam generator as outlined earlier by Alco. These units should be of the single tube sheet design. The IHX should be capable of receiving 1200°F sodium from the reactor and the steam generator should be capable of delivering 1050°F steam. Both units should be 30 MW in size. Stainless steel is acceptable as the material for the once-through steam generator, protected by Inconel, as outlined earlier by Alco. Prior to the time that Alco would release purchase orders for the material of these units, the Working Group would like to have all back-up information and test data that Alco has available regarding the capabilities of Inconel to stand up under the proposed conditions.

Mr. Seifert promised to deliver this information regarding Inconel. Also, he mentioned that an R&D report will be issued within a few days covering this effort up to this time. The Alco representatives then departed for their return trip to Schenectady, New York. Following a short recess, the Working Group started on Item 2. of the agenda, with Mr. Robert Lockhart, GE, summarizing the recent efforts on the subject of mass transfer, and distributing copies of their operating schedules dated November 5, 1960. The first day's meeting was adjourned at 4:15 p.m.

Place: Chicago Operations Office

AEC Conference Room

Date - Time: December 9, 1960

9:25 a.m.

Present: T. A. Nemzek, Chairman
R. E. Aronstein
R. W. Dickinson
Kurt Goldmann
R. E. Harris
R. W. Lockhart
J. J. Morabito
H. W. Savage
J. Simmons
F. A. Smith
W. R. Wykoff
T. P. Heckman, Secretary

The meeting reconvened with Mr. Dickinson of AI covering the various Sodium Components Development Program items being investigated by his company. Copies of a preliminary report titled "Detector Device of Hydrogen in Sodium" by K. A. Davis were distributed to those present. He summarized the information in this report and commented that the final copy would contain additional information such as other schemes considered and the approaches that were made but proved to be unsuccessful. All work except the report on this contract was stopped as of last June. Results, however, appear satisfactory enough that Mr. Dickinson recommended that this effort be carried into a second phase of producing an actual instrument that could be installed into an existing sodium cooled reactor system.

Testing of the roller assembly provided by Westinghouse Electric Company, similar to those to be incorporated in their flow controller, was terminated after 385 hours of operation at 1000°F, 85 rpm, and 870 pounds

of axial load. Although the torque did increase during the test, none of the parts failed nor did the parts appear severely damaged upon examination.

The Ohio Injector flow controller has been tested in a flowing stream of hot sodium up to rates of 6800 gpm. The flow controller operated satisfactorily from full open to full closed except for the range of full open, or 6800 gpm, down to 5000 gpm when the valve was continually noisy. The results of this phase of the testing have been summarized in the letter that has been mailed to the Ohio Injector Company dated approximately December 2, 1960. Mr. Dickinson suggested that Chicago Operations Office also write to the Ohio Injector Company asking for their comments regarding the AI letter that describes the testing and the noisy conditions at the upper ranges of flow.

Mr. Dickinson then distributed a five page draft of a table of contents for a proposed new edition of the Liquid Metals Handbook. A discussion of the AEC policy on procedures for publishing new books then followed. A suggestion was made that possibly Volume II of the proposed Fast Reactor Handbook could be renamed to serve the purposes of covering the properties of sodium and other liquid metals for all liquid metal cooled reactors. Mr. R. Harris offered to investigate these possibilities upon his return to Washington, D. C.

The Chairman then summarized the efforts now under way on the MSA Research Corporation contract regarding the physical properties of materials subjected to sodium. The contract is now being rewritten, and negotiations with MSA should be started within a few days. The suggestion was made that both MSA and the subcommittee of the Working Group should be invited to the

next Working Group meeting to make certain that all parties are in agreement as to the understanding of the work that should be performed.

The Chairman then announced that the duPont Company had offered to analyze samples of sodium that were being prepared by AI. Mr. Dickinson stated that the samples would be of approximately 55 cc size and that each participant will receive three separate samples. None of these samples will be radioactive and one of them will be of the highest purity available to AI. The organizations that have volunteered to make this analysis as of this time are: AI, GE, NDA, duPont; with ORNL and APDA as possible other participants. Mr. Robert Lockhart of GE will act as chairman of the committee that will collect the information of the analysis and correlate the data and prepare a final report.

The Chairman then announced that the shell side heat transfer contract had been assigned to AI. AI is presently working on the plans and specifications of the equipment that will be necessary. The Chairman then asked that any differences of opinion on how the program should be pursued that may exist between participants of the subcommittee for this contract, namely: AI, ORNL, and NDA should be continued by correspondence between these three organizations until the differences have been resolved.

Mr. Kurt Goldmann, NDA, then summarized the current status of the wet chemical approach to the determination of oxygen at low ppm in sodium. This work at present is in the purchasing and fabrication of equipment stage.

The BMI contract on determination of oxygen is continuing but will be terminated at the end of this fiscal year. A suggestion was made that BMI be invited to the next Working Group meeting to present their summary of the work up to that time.

Mr. Morabito mentioned that he will be attending the ANS meeting that will be held in San Francisco the following week, and will also attend the ASTM committee meeting for the purpose of discussing reactor grade sodium specifications. The Working Group viewpoint will be represented at the committee meeting by both Mr. Morabito and Mr. Lockhart.

The Chairman mentioned that APDA will have a contract with the AEC to test out a United Kingdom Blake-type oxygen meter. Mr. Morabito felt that the meter would be in the hands of APDA by the end of December 1960.

Mr. Dickinson then summarized the work under way at AI on the sodium test facility. He mentioned that the current thinking of AI is to run extra loops through the fire box of the sodium heater to provide the extra temperature, up to 1200°F, rather than install a piggy-back type of topping heater. He felt that the original equipment should not be operated much beyond 1000°F to assure continuity of operation over a reasonable lifetime of the test facility. The Title I report prepared by AI has recently been completed and submitted to Canoga Park Area Office for approval. He requested that authorization, which is needed to proceed on Title II, be expedited.

The Working Group members requested that copies of Title I be sent to each member for general information purposes together with a schedule of operation for each of the components that have now been designated for testing.

The Chairman then brought before the Working Group the broad subject of future programs on steam generators. The Working Group then carried on a heated discussion for one hour and twenty minutes covering the following general subjects: 1. need for new designs, 2. need for new materials, 3. need for parameter studies of the over-all program, 4.

need for at least one new design in detail for one year after the Alco units have been put in the test facility, 5. need for publicity of the unique properties of sodium, namely; high temperature at low pressure and superior coolant qualities for use in fast reactors, and 6. new system designs that might eliminate the use of water or steam as the final heat transfer medium.

Mr. Morabito, APDA, then summarized the recent activity at the Enrico Fermi Fast Reactor concerning the loading of the primary systems with 4500 gallons of sodium. The sodium was moved at approximately 500°F from the storage tanks, which were blanketed with a 25 psi argon gas atmosphere, to the primary system which was under a vacuum. Since the storage tanks did not contain quite enough sodium to completely fill the primary system, an extra tank car had been brought onto the site. Actual testing of any moving parts will be delayed until this additional sodium has been transferred to the primary system. He estimated that the secondary system will be filled with sodium in approximately one month. The Chairman then announced that the next meeting would tentatively be set for February 22, 23, and 24, 1961, held at AI, Canoga Park, California. The first day of the meeting will be optional and will be devoted to AI's experiences with components together with exhibits and demonstrations. He suggested that MSA and Alco and possibly BMI might be invited to the meeting if the contractors have developed sufficient information for bringing to the Working Group's attention. Between now and the next meeting, the Working Group members were asked to develop their written comments on ground rules to be used for parameter studies concerning future programs of the Sodium Components Development Program. At 3:30 p.m. four members of the Working Group departed for their return trip home.

Mr. Simmons, ANL, summarized ANL's recent experiences with the fabrication problems associated with steam generators and superheaters for the EBR-II. He exhibited several samples and sections of welds to illustrate the difficulty they are experiencing with the nickel bond that is present between the two duplex tubes of the superheater. ANL is attempting to develop non-destructive techniques for determining when the weld between the outer tube and the sodium tube sheet disturbs the nickel bond. Such a condition where the nickel is fused within the weld is considered detrimental because the nickel contains phosphorus which may be detrimental to the strength of the weld. The problem of welding the inner of the duplex tubes to the water tube sheet has been temporarily delayed until the other problem has been solved.

Minutes of the Sodium Components Working Group

Meeting No. 24

March 15-17, 1961

Atomics International

Canoga Park, California

Present: R. W. Atz	AI
R. Cygan	AI
J. DeVan	ORNL
K. Goldmann	NDA
W. J. Hallett	AI
T. P. Heckman, Secretary	CH
R. W. Lockhart	GE
W. Markert	B&W
R. Moeller	AI
J. J. Morabito	APDA
M. A. Perlow	AI
H. W. Savage	ORNL
S. Seigel (introduction only)	AI
W. R. Simmons	ANL
F. A. Smith	CH
W. Stern	NDA
R. C. Werner	MSA
J. B. Williams	AI
W. R. Wykoff	LASL

Mr. Seigel of AI welcomed the Working Group and guests to a one-half day presentation by AI covering the various activities of AI concerning the use of sodium as a coolant for reactors. He turned the meeting over to Mr. Hallett of AI who then distributed copies of an agenda. The first speaker was Mr. Perlow who discussed the subject of high temperature liquid metal corrosion research in the SNAP development program. Mr. Perlow read from a prepared paper which will later be issued under the number NAA-TDR-5708. His presentation was supplemented by several slides showing the cross section of the SNAP-II reactor, also showing corrosion loops to investigate the properties of materials subjected to high temperature sodium. In addition, charts of corrosion rates were shown, plus a graph showing hydrogen saturation versus temperature. Members of the Working Group expressed a desire to have copies of this paper when it is available.

Mr. Cygan was the next speaker who discussed the Ohio Injector Company's flow controller tests and the Westinghouse flow controller bearing test. The results of these tests were written up in the two reports, NAA-SR-TDR-6081 and NAA-TDR-5951; copies of both reports were distributed to those present. The separate torque tube seal supplied by Ohio Injector Company passed the test very satisfactorily. The flow controller, however, developed instability at openings greater than 80%. The Ohio Injector Company had not been consulted regarding this program as of this date; however, it was recommended that they should be. The Westinghouse bearing test was interrupted when the torque required to rotate the shaft increased significantly. Upon examination, the balls had a roughened surface; however, they were not in a badly damaged condition. There appears to be a difference of interpretation between AI and Westinghouse Electric Company regarding the significance of the results from this test.

Mr. Moeller then presented the recent information that was available on modified Croloy designated as 4S8 and 4S4. He passed out preliminary data sheets to those present. These particular alloys develop their unique properties as a result of heat treatment. Therefore, additional tests were under way to develop coatings to prevent surface defects as a result of the heat treatment or as a result of later high temperature environments. The advantage of these alloys will depend upon the long time retention of the heat treatment. Mr. Markert of B&W at this time expressed the opinion that the B&W Company had abandoned the use of any modified $2\frac{1}{4}$ chrome-1 moly steel for long time use. He indicated that the long term tests run by the B&W Company have not shown any advantages for the modified materials. Mr. Moeller then discussed the carburizing of austenitic steel subjected to high temperature sodium which has been reported in NAA-SR-5282. This report is in the rough draft condition and does discuss the vapor phase of oxygen, carbon, and sodium in relation to one another.

Mr. Atz then discussed the pump proof test for the HNPF. These tests considered types of seals such as free surface versus freeze seal, also considered various manufacturers such as Allis-Chalmers and Byron-Jackson and resulted in the selection of the Byron-Jackson free surface centrifugal pumps. This information will be available as an ASME Paper No. PB-588.

The meeting reconvened at 1:25 PM with three additional guests and the chairman as follows:

G. Billuris	GE
William Anderson	AI
C. Richards	CPAO
T. A. Nemzek, Chairman	CH

Messrs. W. Markert, B&W, and R. Werner, MSA, were absent from the afternoon session.

Mr. Nemzek opened the formal part of the Working Group meeting by calling on Mr. K. Goldmann, chairman of a subcommittee for the review of the MSA contract covering the physical properties of materials subjected to high temperature sodium.

Mr. Goldmann reviewed the problem and stated the conditions outlined for the subcommittee. He also reviewed the results of their investigation as presented in his letter of February 16, 1961. Except for a few minor details, Mr. Goldmann felt that MSA was conforming very closely to the technical intent and purpose outlined for them by the subcommittee and confirmed by the modification to their contract with CH.

Mr. Anderson of AI then explained a different method for doing fatigue tests that was suggested to MSA for consideration. MSA has subsequently based their program on the use of this technique.

Mr. Savage, ORNL, then presented the results of the review of the sub-committee designated to investigate the mass transfer work with the GE Company. He explained how the committee was formed and the timing, the purpose, and limits of their meeting with GE. He complimented the members of the subgroup for putting in two days of full, hard work of reviewing the GE work and writing a report. Mr. DeVan, ORNL, a member of the subgroup, presented some of the results from the data taken to date by GE, to illustrate how the data does not correlate with time.

A general discussion then continued for approximately two hours, considering the significance of oxygen to the data taken by GE, and what changes would be needed in the subsequent test to be run. The Working Group generally agreed that the future tests should be run at oxygen levels that could readily be maintained in a reactor plant, or about 10 ppm. An improvement in the techniques of maintaining a specific oxygen level and also instrumentation of this level was needed.

Mr. Billuris of GE then summarized the mass transfer test at GE up to this time. He mentioned that samples of the modified Croloy, 4S4 and 4S8, had been included in the cold leg of loop 3 for run 2. The Working Group then discussed the advisability of introducing these materials into the test program at this time. They did not arrive at a concerted opinion; however, they felt that further discussion of this subject should be held the next day.

Mr. Heckman, CH, briefly covered the BMI progress reports for December 1960 and January 1961 for the project to establish an absolute technique for the determination of oxygen in sodium in quantities less than 10 ppm. Mr. Grieser of BMI would be present the next day to discuss these progress reports in further detail.

Messrs. Lockhart of GE and Morabito of APDA reported on their meeting with an ASTM committee in an attempt to define reactor grade sodium. This committee did not feel that the need was great enough for the ASTM to establish a specification for this particular grade of sodium. Rather, they felt that an ACS, American Chemical Society, reagent grade of sodium may suffice for the present time. The meeting adjourned at 5:30 PM.

Place: Atomics International Conference Room, DeSoto Street, Canoga Park, California

Date-Time: March 16, 1961, 9:25 AM

Present: W. Anderson	AI
R. Beeley	AI
G. Billuris	GE
J. DeVan	ORNL
K. Goldmann	NDA
D. R. Grieser	BMI
W. J. Hallett	AI
R. Harris	DRD
T. P. Heckman, Secretary	CH
J. Holiday	SAN
R. W. Lockhart	GE
W. Markert	B&W
J. J. Morabito	APDA
T. A. Nemzek, Chairman	CH
C. Richards	CFAO
H. W. Savage	ORNL
R. D. Seifert	Alco
W. R. Simmons	ANL
F. A. Smith	CH
D. Sinizer	AI Subcommittee
J. Stern	NDA
R. C. Werner	MSA
J. Williams	AI
W. R. Wykoff	IASL

The first speaker of the second day's meeting was Mr. Lockhart, GE, who gave a status report of the mass transfer contract. He briefly summarized the physical arrangement of the test loops and the current data on each of the loops such as hours, samples being exposed, and difficulties to date. The loop No. 5 consisting of $2\frac{1}{4}$ chrome has given continuous trouble since startup. The summary of the data and trends gathered to date are as follows: The data is considerably scattered which makes analysis difficult. Loops 2

and 3 are identical in material except for a difference in oxygen level. Loop 5 has exhibited the highest corrosion rates in addition to its other troubles, especially with the mechanical couplings. The 316 samples have exhibited a ferritic layer on the boundary of the samples that is not of a magnetic nature. The $2\frac{1}{4}$ chrome-1 moly samples have exhibited a variation in the carbon content on the surface and have also exhibited a scattering of hardness measurements, however, no significant surface attack. The 5-chrome samples have not indicated any significant change except for a very slight surface attack. The flow in all of the loops has exhibited a decrease as a result of crud buildup at the sample locations. This has been checked out by a heat balance. The Croloy loops show the greatest flow decrease, as much as $2\frac{1}{2}\%$ per day, whereas the stainless steel loops have shown a .086% per day decrease in flow. This decrease in flow effect has been so appreciable in loop 5 that the sodium has been dumped to the dump tank approximately every five days in order to eliminate the crud buildup and to restore a normal flow rate. The oxygen level in all loops has decreased with time to the extent of 1 to 2 points per day. The problem of small leaks causing a rapid erosion or corrosion of the outside surface of the pipes is considered to be a very serious situation and should be investigated more thoroughly. In those loops having radioactive samples, after 700 hours exposure, the radioactive counts downstream of the source were traceable and graduated. The samples apparently gave up manganese 54 at a high rate with iron next, chromium next, and Cobalt last.

The Working Group then had an open discussion of this mass transfer phenomena with many suggestions and considerations of the effects of the various variables. The Ad Hoc Committee for this contract agreed to review the total program and recommend a sequence of future tests, considering the effects of velocity, oxygen, differential temperature, etc.

Mr. Werner, MSA, covered the status of the physical properties of materials contract. The thermal shock loop is practically finished; however, startup of this loop has been delayed because the operation will be performed by the same personnel that operate the other loops. The equipment for the other loops had been delayed until negotiations regarding the dollar amount that can be ordered without AEC approval had been decided. Mr. Werner passed copies of progress report No. 6 to those present and reviewed this report page by page. As a result of this review, the contractor agreed to have the tensile test performed by an outside laboratory. The longest delivery time for equipment would be the creep test machines with an approximate delivery date of eight weeks. Following the installation of these machines, startup would be approximately fourteen to fifteen weeks from this date; and data should start to be available by approximately eighteen weeks. The Working Group felt that the information that would be gained from this investigation was very essential to each of the larger reactor projects and that the assembly and startup of these experiments should be expedited. The samples to be tested in the thermal shock test were then discussed by the Working Group. Some members felt that the welds between the specimens would be extremely difficult to make and to examine, both before and after testing. Some members expressed the opinion that the defects would show up in the welds first, also that any results will be very difficult to interpret, especially in a manner that would be useful to other designs.

The next speaker, Mr. Markert of B&W, was invited by the Working Group to give a general review of the B&W experience with materials used for sodium steam generators, especially the $2\frac{1}{4}$ chrome materials. Mr. Markert explained that much of the work was done for the Navy and some for Westinghouse Electric Corporation. All of this work was done with water or with aqueous

solutions on one side of the test apparatus, and much of the data obtained has never been published. Accelerated stress corrosion experiments were made using chlorides, oxygen, and sodium hydroxide in contact with such materials as carbon steel, $2\frac{1}{4}$ chrome-1 moly steel, nickel, Inconel, Monel, and stainless steel. Samples subjected to sodium hydroxide solutions exhibited the most severe and the most rapid deterioration. The only test apparatus that seemed to give consistent results were U-bend heat exchangers of approximately 8 to 9 inches in diameter with a $1\frac{1}{2}$ inch thick tube sheet.

In those experiments made for the SEAWOLF, sodium hydroxide in concentrations of 50 to 3800 ppm were intentionally introduced into the water side. The Na-K primary was held at 600°F and the secondary at 500°F. Multi-radial cracks would often show up in as short a time as six hours under these conditions. As a result of these tests, the Navy program had completely abandoned type 304 stainless steel and had gone to Inconel, which is much more difficult to work and fabricate. Mr. Markert offered the opinion that the designer of any component that had alkali metal on one side and water on the other should assume that sometime during the history of that component a leak or accident would result that would introduce deleterious chemicals to the working fluids. He felt that the addition of magnesium phosphate to the water side might lessen the corrosive effects of sodium hydroxide. He also indicated that the work by B&W has shown a considerable difference to the extent of a factor of 2 in the decarburization rate between annealed and non-annealed materials even at the same temperature. Mr. Markert then distributed to those present reprints of articles from the magazine "Power," 1960, and "Corrosion" magazine that covered much of the information that he had just presented. He also referred to the B&W Report No. 1796.

Mr. Morabito, APDA, then covered the work they are doing on oxide analysis by means of a UK Blake meter. The meter arrived in Detroit about March 13, 1961, and is being installed in a test loop by APDA. In this loop, various contaminants such as oxygen, carbon, and possibly hydroxide will be introduced and the ability of the meter to determine and discriminate the contaminants will be checked. It is estimated that it will be approximately four months before any data will be available from these experiments.

Mr. Stern of NDA presented the status of the wet chemical methods of analyzing for O_2 in sodium that is being performed by a Mr. Steinmetz. The March 1 progress report was used as the reference. The apparatus had been assembled and placed in operation and was currently making shakedown runs. He estimated four to six weeks time before reliable data is available.

Mr. Grieser, BMI, then discussed their work to establish an absolute technique for the determination of oxygen at low levels. Two techniques are now under development by BMI, mass spectrometry by Dr. Hall and coulometry by Dr. McCallam. Neither technique has proven very successful by this time. However, Mr. Grieser felt that the mass spectrometry technique has possibilities for considerable refinement and improvement, whereas the coulometric approach may not be able to distinguish between the sodium contaminants; and, in the event free calcium was present, the oxygen would not be distinguishable. A new approach called arc emission spectroscopy has some possibilities. However, to date, the background emission has been too extensive.

Mr. McDonald, AI, then gave a presentation on their work covering shell side heat transfer. By use of a bar graph and drawings, he presented the schedule and the types of test apparatus that are being considered in

this investigation. The Working Group felt that they would like to consider this program in more detail and had arranged for a evening meeting on this subject. Representatives of the Ad Hoc Committee covering the subject of shell side heat transfer felt that there were several items where agreement had not been reached and that considerable review and discussion was still necessary before the program should be actually started.

Mr. Seifert, Alco, then summarized the work being done on the intermediate heat exchanger and steam generator. He reviewed the progress report, which had been mailed directly to the Working Group members, and distributed at the meeting the progress report dated March 15, 1961. He stated that the Alco's schedule called for releasing shop orders by April 1 and would be requesting AEC approval immediately for doing so. More development work was needed on the concentric bi-metallic tubes consisting of a stainless steel outer tube and an Inconel inner lining before a decision could be made between choosing either a mechanical bond or a metallurgical bond bi-metallic tube. He also stated that additional development work was needed on the mechanical expansion of the bi-metallic tube into the tube sheet. The tests to date have shown that the Inconel was overworked and had the tendency to extrude.

Mr. Seifert indicated that the modified $2\frac{1}{4}$ chrome tubes that had been ordered from U. S. Steel Company had been delayed for the third time for another four to six weeks. If the high temperature, high pressure test loop is delayed until this material is available, actual operation of the loop will not start until May 1961.

After considerable discussion, the Working Group expressed the opinion that the metallurgically bonded bi-metallic tubes were preferable to the

mechanically bonded tubes for the reason that the ASME code would allow the design to take credit for the strength of the inner liner. The price, however, may be as much as 80¢ per foot extra.

Place: Atomics International Conference Room, DeSoto Street, Canoga Park, California

Date-Time: March 17, 1961, 9:30 AM

Present: R. Beeley	AI
R. Cygan	AI
J. DeVan	ORNL
R. W. Dickinson	AI
K. Goldmann	NDA
W. J. Hallett	AI
R. Harris	DRD
T. P. Heckman, Secretary	CH
J. Holiday	SAN
R. W. Lockhart	GE
J. Mallmeister	AI
J. J. Morabito	APDA
T. A. Nemzek, Chairman	CH
C. Richards	CFAO
H. W. Savage	ORNL
R. D. Seifert	Alco
W. R. Simmons	ANL
F. A. Smith	CH
Spencer	CFAO
J. Williams	AI
W. R. Wykoff	LASL

Mr. Savage, ORNL, started the third day's meeting by reviewing the mass transfer investigation. He recommended that the modified Croloys be removed from Loop 3 run 2, and that the conditions for Loop 3 run 3 be made the same as for Loop 2 run 1 with the same samples as were in Loop 3 run 1; also, that Mr. Lockhart of GE consult with other people of his firm to decide the best arrangement of the specimens so as to easily and quickly determine the velocity effects; also, that the temperature of Loop 1 be dropped from 1300°F to 1200°F; also, that the possibility of additional loops made of other materials such as the modified Croloys might be appropriate in the future; also, that the same batch of sodium,

such as DuPont's "best," be used in both the GE and in the MSA work under the Sodium Components Development Program.

AI personnel, in regards to additional materials to be tested, expressed a preference for the 4S8 modified Croloy over the 4S4 material. Whether the additional loops should be bi-metallic or of one material was not definitely decided.

Mr. Wykoff of LASL then expressed the opinion that, at this time, the laboratories did not know which contaminants were being removed by a cold trap at any specific temperature.

The question of a definition for "reactor grade" sodium was brought before the Working Group. The Group did not feel that a definitive answer was available at this time.

Mr. Cygan of AI then made the presentation covering the status of the sodium components test installation that was given the "go ahead" February 24, 1961. The present schedule indicates that the site preparation will be finished and the foundation drawings will be available during April. Bids for doing the site work will be let out about April 10. Bids for many of the main components are in the hands of the suppliers at this time and are due back in the immediate future. By May 1, most of the existing surplus equipment that is now in storage in New York will be on hand. By July 1961, all final construction drawings will have been finished and by December the field construction will have started. The only major changes that will be in the final drawings as compared to Title I drawings will be the elimination of a topping heater and the addition of heating surface within the heater proper.

A discussion between members of the Working Group and AI concerning the capabilities and the limitations of the sodium components test installation

indicated that a thermal shock of 11°F per second would be available on an increasing temperature and a 35°F per second available on a decreasing temperature.

Mr. Morabito, APDA, expressed the opinion that a 10 MW cooler in the system would allow for testing of IHX's independent or separate of steam generators in this installation.

Mr. Harris, DRD, then discussed the possibilities of initiating a new addition of the liquid metals handbook. The Fast Reactor Branch of DRD was opposed to giving the second volume of the fast reactor handbook a new name, even though this volume would be devoted principally to liquid metals. Other people within DRD are advocating that a new broader and deeper handbook be prepared with a possible title of "Fluids Metals Handbook." Mr. Harris supplied to the AI representative an outline developed by the AEC for the preparation of material to be published by the Office of Technical Information, Scientific Information Publications.

The chairman then announced that a Sodium Reactors Technology Symposium would be held in Lincoln, Nebraska, May 24 and 25, 1961, and that all members of the Working Group were invited, also that possibly the next Working Group meeting would be held in conjunction with this larger meeting.

Mr. Wykoff, LASL, then distributed the quarterly status report on the LAMPRE sodium test facility for the period ending February 20, 1961. LASL plans to take the steam generator apart and inspect it after it has operated 9000 hours. The wet and dry criticals for the reactor have been run with the fuel solid in its capsules. Following these experiments, the electrical heaters will be turned on to melt the plutonium and additional physics tests will be made.

Mr. Simmons, ANL, gave the current status report on the EBR-II reactor. He indicated that the blanket loading will be made in early May of this year and that the dry critical of the reactor will follow closely.

The welding problem associated with the fabrication of the superheaters had not been solved at that time. The alternate decision was made to fabricate three additional steam generators which would be installed and used as superheaters. This will result in a slightly lower steam exit temperature and a lower efficiency in the EBR-II system.

Mr. Savage, ORNL, gave the current status on the EGCR, the HRE, the molten salt reactor, the high flux test reactor, the PBRE, and the boiling potassium work. Mr. Savage is in charge of the experimental loop installations in the EGCR which will contain several loops for various fuel tests. The heavy assembly work on this reactor should be finished by late this summer.

Mr. Goldmann, NDA, discussed the new work under way with his company, such as the MCR (which is classified), a new boiling sodium reactor concept under study for NASA, and a sponge fuel in sodium concept.

Mr. Dickinson, AI, then covered the recent developments at the SRE. This reactor developed 3 MW thermal on March 16, 1961. Unexpected reactivity effects, however, have prohibited them from going to higher power. An analysis of these reactivity effects indicates that the fuel pins are bowing as the result of both flow and temperature. The fuel rods are unsupported over a length of six feet and a movement of .167 inches is possible in a radial direction. AI has initiated an experiment on the removal of fission products by the means of activated charcoal.

The Working Group then presented their individual recommendations for future programs. The suggestion was made that the AEC take these separate

contributions and compile them into one composite recommendation. Several members made additional recommendations as a result of hearing the rather alarming results of the B&W work as presented by Mr. Markert on the previous day. Some members felt that this information was so essential to the success of the Alco steam generator design, soon to be released to the shop for fabrication, that authorization to fabricate be delayed until single tube intentional leak tests have been made to understand the water sodium hydroxide sodium tests that Mr. Markert described. All possible methods of preventing crevice corrosion, such as the use of back brazing, should be investigated before fabrication has been started. The chairman offered to take these suggestions under advisement and to discuss them with the Alco Company.

The chairman then thanked the Atomics International for acting as host for this 3-day meeting of the Working Group and invited the Working Group to be present at the Sodium Reactors Technology Symposium, May 24 and 25, 1961, Lincoln, Nebraska.

Minutes of the Sodium Components Working Group

Meeting No. 25

May 25-26, 1961

Hallam Nuclear Power Facility

Lincoln, Nebraska

Present:

T. A. Nemzek, Chairman	CH
G. Billuris	GE
J. D. Cochran	CPPD
R. W. Dickinson	AI
K. Goldmann	NDA
R. E. Harris	DRD
T. P. Heckman	CH
R. W. Lockhart	GE
J. J. Morabito	AFDA
L. R. Nichols	NASA
H. W. Savage	ORNL
C. S. Seabring	Alco
R. D. Seifert	Alco
F. A. Smith	CH
G. Stern	NDA
J. B. Williams	AI
W. R. Wykoff	LASL
R. E. Aronstein, Secretary	CH

The Chairman, Mr. Nemzek, opened the meeting and introduced the guests, Messrs. J. D. Cochran, CPPD, and Landon R. Nichols, NASA Lewis Research Center, Cleveland, Ohio.

MSA Research Report No. 8, April 1961, covering the MSA Materials Program and the most recent report on the low level O₂ determination work at BMI were distributed to the group members.

Mr. R. D. Seifert of Alco gave a report on the status of the Alco steam generator and intermediate heat exchanger program. The intermediate heat exchanger design and fabrication is proceeding well. Fabrication drawings are nearly complete, material is being ordered, and detailed shop schedules are being worked out. Alco does not anticipate any problems with this unit.

As a result of information on caustic stress corrosion presented at the last meeting, Alco was requested by CH to hold the steam generator fabrication and to examine means of protecting the tube sheet against possible caustic stress corrosion damage in case of a leak. The steam generator design has been released to the shop for preliminary work. No material will be ordered until the fabrication hold is released.

Mr. Seifert said that AI was sent the drawings of the units and was informed that Alco must have preferred nozzle orientations and other special requirements by June 15. Mr. Dickinson, AI, said that a reply with AI's comments had recently been sent.

Mr. Seifert reported Alco has been unable to obtain modified croloy from U.S. Steel. U.S. Steel Research has not been able to produce satisfactory material. U.S. Steel believes this is due to the small batch size. U.S. Steel Research is unable to supply larger batches and will require long preliminaries before the production group could supply it. Alco was unable to get a satisfactory answer from U.S. Steel as to when they could get the required material. Alco recommended to CH that they be given approval to produce an experimental heat at their own mill. Alco has been given approval by the AEC and will make about 3000 pounds of modified 2 1/4% Cr-1% Mo steel. They will make about 250 feet of tubing from the heat and the remainder will be retained in ingot form for other possible uses.

Mr. Seifert said that back brazing might be a promising way of overcoming the caustic stress corrosion problem. Alco has proposed to the AEC a program to investigate back brazing and diffusion bonding of the tube-to-tube sheet using Kanigen plate as a bonding material. As part of this work, they propose to make full size heating tests using a tube sheet available from previous work.

They have reviewed brazing with ORNL personnel who have had experience in brazing similar joints in small heat exchangers with Kanigen. ORNL expressed the opinion that brazing of these units would be feasible but very difficult because of the large sizes. Diffusion bonding appears to be the more desirable process if it proves satisfactory because it can be done at 1000°F to 1100°F range versus 1800°F for brazing.

Mr. Dickinson suggested that Alco contact Mr. Cartinhour of Foster Wheeler. Foster Wheeler has done similar work on the STR steam generator program.

Mr. Seifert pointed out that the brazing investigation as now scheduled would not delay the steam generator work; however, it must be realized that very few development programs go exactly as scheduled. The AEC must be prepared in case the brazing program schedule slips or the program is unsuccessful.

There was lengthy discussion of the Alco program and means of protecting the tube sheet against caustic stress corrosion.

The Chairman concluded that Alco should continue their current program of intermediate heat exchanger and steam generator fabrication. The problems of caustic stress corrosion will be evaluated. Alco was requested to submit a revised and more general proposal for brazing or bonding to avoid stress corrosion.

Mr. Seifert presented a preliminary layout of test instrumentation on the intermediate heat exchanger for Working Group comment. This plan utilizes thermocouple tubes to obtain tube side temperature distributions axially and radially. Thermocouples to measure shell side temperatures are also planned. It is expected that steam generator instrumentation will be similar but there will be no penetrations of the steam (tube) side. Alco will also consult their structural people to provide instrumentation necessary to evaluate structural design.

There was a general discussion of the information presented. The Working Group felt that the general direction was proper but more detailed plans are required to completely evaluate the instrumentation.

The Chairman said that Alco will be instructed to work out a recommended test program and detailed instrumentation for both units. Mr. Seifert stated that Alco expects to have the program details worked out by early July and will need approval for fabrication by August.

Mr. W. R. Simmons, ANL, brought to the attention of the Group a French article describing stress corrosion of an Inconel. It could not be determined if the Inconel used by the French is the same as the U.S. Inconel. This was discussed by the Group. No one knew of any evidence that indicated there would be a stress corrosion problem with U.S. Inconel in the steam generator.

Mr. R. W. Dickinson, AI, reported on the status of the SCTI. Ground was broken on May 22 for foundations. The condenser arrived in the L.A. harbor on May 20. The ANL free-surface pump for the primary is on hand and is in good condition. Most auxiliary equipment is on order. The switch gear has been released for fabrication and fabrication has begun on the feed-water pump. The cooling tower has been delivered but is not yet assembled.

A 3 MW cooler is being obtained from MSA. This cooler is not big enough to permit figure eight full power operation with the intermediate heat exchanger. A cooler of approximately 11 MW would be required to permit this type of operation. The cost of a new 11 MW cooler is estimated to be about \$100,000. CH will attempt to locate a surplus cooler known to be in existence.

Babcox and Wilcox has stated that adding an economizer in the stack of the sodium heater will increase its operating capability to 1300°F at 35 MW with a lifetime of 10,000 hours. Mr. Dickinson said that the heater is capable of supplying a hot shock of +11°F/sec and a cold shock of -35°F/sec.

Mr. J. J. Morabito, APDA, presented the report of the SCTI subgroup. The objective of the subgroup was to determine how well the facility, as being designed by AI, conforms to the specifications and criteria established by the Commission. The subgroup members are J. J. Morabito, R. W. Lockhart, GE, H. W. Savage, ORNL, W. R. Wykoff, LASL, and R. E. Aronstein, CH.

The subgroup found that the Title I report does not describe the facility as it is presently designed. The subgroup would like a brief description of the existing design of the facility and a description of how the test program will be accomplished.

The Chairman stated that the subgroup should consider: (1) All aspects of the facility in its evaluation as well as the specifications set up in APDA-134. Flexibility for future use should be carefully considered. (2) Alco has the responsibility for establishment of the test program in co-ordination with the Commission and AI.

Mr. Morabito listed all the following questions on the facility:

1. Concern about using the heater to produce hot shocks and the adequacy of the cooler.
2. It appears that pump head and flow are marginal. Adequate margin should be available for future tests.
3. Concern about the reliability of the freeze seal pump which AI plans to use.
4. Is adequate space available to test different type units or for expansion of the facility?
5. What methods will be utilized to detect steam generator leaks?
6. What is the heater material?

There was discussion as to what the capabilities of the facilities are and should be for testing the intermediate heat exchanger by itself and coupled to the steam system.

The day's meeting was adjourned at 6:45 P.M.

Place: Consumers Public Power District, Conference Room,
14th and O Street, Lincoln, Nebraska

Date-Time: May 26, 1961, 8:45 A.M.

Present:

T. A. Nemzek, Chairman	CH
G. Billuris	GE
J. D. Cochran	CPPD
R. W. Dickinson	AI
K. Goldmann	NDA
R. E. Harris	DRD
T. P. Heckman	CH
J. Holiday	SAN

R. W. Lockhart	GE
J. J. Morabito	APDA
L. R. Nichols	NASA
H. W. Savage	ORNL
G. Stern	NDA
J. B. Williams	AI
W. R. Wykoff	LASL
R. E. Aronstein, Secretary	CH

The Chairman opened the meeting with a brief status and objectives of the Sodium Components Development Program for Mr. Nichols of NASA who was not familiar with the program.

The Chairman summarized the unresolved problems on the SCTI listed by the subgroup for Mr. Dickinson's benefit. In addition, he requested that AI provide the following:

1. Updated drawings, specifications, system descriptions, and design data sheets.
2. A listing of the range of test conditions the facility can provide and the limiting factors or specific equipment items that limit the facility to these operating conditions.
3. A determination of the test limits on the intermediate heat exchanger imposed when the steam generator is used as a heat dump and whether the intermediate heat exchanger can be given a maximum test under these conditions.

Mr. R. W. Lockhart, GE, discussed the GE mass transfer report for the month of March. GE has taken the following action on items discussed at the previous Working Group meeting.

1. Commercial grade sodium will be replaced with du Pont's reactor grade before the next run is started in each loop.
2. The maximum temperature for Run 2 of Loop 1 will be reduced from 1300°F to 1200°F.
3. The installation of a hot trap for extra low oxygen operation in Loop 2 will be postponed.
4. All 4S8 samples will be removed from Loop 3 after 700 hours.
5. A cost estimate will be supplied the AEC for two additional loops to obtain mass transfer data on 4S8.
6. GE recommends the use of an Na₂O immersion capsule for adding oxygen to the loops.

7. GE recommends modified test conditions for Loops 2 and 3 to tie down the velocity effect. The following summary of the proposed program was presented.

Time	700 hr		2800 hr	
Loop	2	3	2	3
High Velocity (20 ft/sec)	2-2	3-4		3-5
Low Velocity (7 ft/sec)	2-3	3-3	2-4	

There will be seven samples in each loop.

There was a discussion of the number of variables and the design of the test program to obtain significant information from the program on these variables.

Mr. Lockhart pointed out that the samples farthest downstream from the heater in the 1200°F sample holders have a lower corrosion rate than the samples closest to the heater. This phenomena should be investigated.

Mr. G. Billuris, GE, reported on the status of the loops.

<u>Loops</u>	<u>Run</u>	<u>Status</u>
1	1	Has radioactive foil. Samples have been cleaned and sent to laboratory for radiochemical analysis.
2	2	Under way about 200 hours.
3	2	Run will be complete within a few days (700 hours).
4	2	Pre-test operation
5	2	Maintenance and flushing for fill with reactor grade sodium.
6	2	Will be ready for new run as soon as flange replacement is made.

GE has been attempting to determine oxide content in the sodium as a function of loop operating time. It appears that the oxide concentration levels out after a period of operation. They suspect this is due to Na₂O giving up oxygen to the pipe walls.

Mr. Lockhart reported that the first samples of modified 2 1/4 Cr were not properly heat treated after being cold worked.

The carbon-in-sodium analyses were received from du Pont, GE, and AI. NDA's results are expected in about one month. ANL did not set a completion date.

Mr. H. W. Savage, ORNL, said the subgroup on mass transfer would like to meet at GE again at a time when the information available is comparable to that available at the last meeting. Mr. Lockhart said this would probably be August or September. This was acceptable to all. Subgroup recommendations on oxide control are discussed in the letter from H. W. Savage, ORNL, to R. W. Lockhart, GE, of April 12 and in the letter from R. W. Dickinson, AI, to R. W. Lockhart, GE, of April 20. It was recommended that the oxide concentrations for Run 2 (~10 ppm) be maintained constant by use of second cold trap or oxide wafers.

The Chairman reported that BMI is concluding their oxide analysis studies and will write a final report.

Mr. T. P. Heckman, AEC, reported on the MSA materials work. The procurement of some equipment has been held up to enable the AEC to check to see if any of the equipment was available at other sites. The thermal shock tests were discussed. Mr. Heckman pointed out that the setup to be used for these tests was constructed early in the program and very little additional equipment expense beyond sample manufacture was required.

Mr. Lockhart suggested that MSA be requested to participate in the carbon-in-sodium analysis work as carbon determination will be important to their program. It was suggested that they not be included until the second round of samples is sent out.

Next, Mr. G. Stern, NDA, reported their progress on oxygen determination in sodium by wet chemical methods. The primary disadvantage of their present method is that it requires a very highly trained chemist to perform the analysis and only two runs a day can be made. They would like to simplify the method so it can be performed by a technician. They are working on a method of removing the oxide film from the sample with alcohol. They have tried one alcohol (ethyl cellosolve) which removed the oxide film but left an oxygen containing residue. NDA believes this method has promise and wants to try other alcohols.

Additional oxide runs are needed to obtain better statistics.

Mr. J. J. Morabito, APDA, reported on the status of the Blake Meter test. The meter has been received by APDA but was damaged. It has been repaired and is scheduled to be installed in a 1 inch loop about June 1.

Mr. J. B. Williams, AI, reported on the status of the shell side heat transfer project at AI. The shell side heat transfer subgroup has been given the plan of action, drawings, P and I's, and the structural and heat transfer analysis for the shell side experiment. A mathematical expression has been developed to utilize the results of the experiments.

There is a need for tube side data near the tube entrance. AI has a loop to do this work available and suggests this be done.

The heater from Pratt and Whitney arrived with the lining broken. The coolers from MSA have been shipped and other equipment is on order. The lowest responsible bidder for fabrication of the tube bundles has been selected with AEC approval. The selected vendor will fabricate one bundle first to prove his ability to do the job. Unit 12 (cross flow) has been selected for test fabrication and is about 50% complete. (This is a correction from the meeting where it was stated that Unit 1 would be fabricated first.)

AI is negotiating a contract with Professor Short of the University of Texas for consulting services.

The installation of the cold trap in the loop is complete and loop cleanup will start soon. Flow meters will be calibrated. AI expects to be able to maintain an accuracy of 1%.

By making changes in the details of the plenum design, the calculated flow distribution difference has been reduced to 1% between any tube and the mean. This information will be added to the information previously distributed.

The Working Group discussed the reported work on shell side heat transfer. Means of calibration flow meters was discussed at length. It was concluded that the flow meters calibration would have to be watched very carefully. Methods of determining the tube side heat transfer coefficient and difficulties involved were also discussed.

The Chairman brought to the attention of the Group the fact that several members had been requested to review papers on sodium components work for presentation at a forthcoming ASME meeting. He requested that those involved clear through him as he did not believe that more than one Working Group member should comment on a given paper.

The Chairman requested that the members of the shell side heat transfer subgroup meet with him during the lunch break. The Chairman advised AI that the approach to the shell side program should include an effort to develop a general theory which would describe the mechanics of shell side heat transfer. It was recognized that this had been attempted before without success; however, this program should try since it represents one of the best supported programs of its kind in the field. Further, the cross flow tube bundle designs should be redone to assure an appropriate flow distribution in the model at the points where measurements would be made. AI agreed to reconsider both the approach and tube bundle design and submit reports to the Working Group.

The first report after lunch was from the steam generator subgroup. Mr. W. R. Simmons, ANL, reported. The recommendations of the subgroup were:

1. There is need for a continuing program of development of steam generators and intermediate heat exchangers. The design of subsequent test units should not be delayed until the present units operate.
2. The Alco units will not supply all the information needed nor are they ultimate in design. Planning and design for the second test units should be initiated in the near future.

The subgroup suggested that the second units be made of a material more resistant to stress corrosion than stainless steel. A review of materials should be made to determine suitable materials and establish design limits based on material properties and not subject to code requirements. The design conditions should be carefully reviewed to assure ourselves that the best choice is being made. Detailed studies are required to set optimum design conditions. Study conditions should be limited to those for foreseeable plants. Economics should be a major consideration.

The subgroup report was discussed. The Working Group members were in general agreement with the report. The Chairman requested that the Group meet to establish a scope of work for a study to set design conditions for the next steam generator.

The Chairman told the Group that the date for the next meeting would be September. The location has not been chosen.

Mr. Heckman described his visit to the Patent Office in Washington. The purpose of his trip was to review patents on heat exchangers that might have application to sodium plant heat exchangers. He found that most of the sections he was interested in were being reclassified and, therefore, were not available. Mr. Heckman said he believes that the Patent Office should not be overlooked as a source of information. Mr. Dickinson said he believed that AI made a search of heat exchanger patents at one time and he would check and determine what information is available.

Mr. Morabito, APDA, was asked by the Chairman to give a status report on Fermi activities. Mr. Morabito reported that all the sodium circulating pumps have been run and perform satisfactorily. Pump No. 1 has run the most and has accumulated about 1500 hours of operation. They are cold trapping for about an hour a day. There was very little oxygen contamination of the sodium during the filling operation. The system was held at about 500°F for several months and then the temperature was raised to 1000°F to make high temperature tests. After about a week at 1000°F, it was noticed that the plugging temperature was rising and there was CO₂ in the cover gas. It is believed that the high oxide content and the CO₂ is due to outgassing of graphite in the rotating plug. The secondary storage system has been filled with sodium, but the remainder of the secondary system has not been filled.

The fuel handling equipment has been checked out at 500°F and has performed very well. One of the dummy elements stuck and could not be removed with the regular handling equipment. Special equipment was fabricated and the element removed within three days without draining the sodium from the system.

APDA has completed their test program on the primary system and will turn it over to the PRDC operating crew.

Mr. Dickinson, AI, reported on the status of SRE. The recent work at SRE has shown that fuel element geometry changes do have an effect on the reactivity of thermal reactors. It has been fairly conclusively shown that the positive coefficient of reactivity in the SRE is due to fuel element bowing. A number of unwrapped elements has been replaced with wrapped elements, and the positive coefficient was reduced significantly.

Mr. W. R. Wykoff, LASL, reported on their work on pumping heat transfer experiments with plutonium alloy and sodium in direct contact.

The Chairman advised the Working Group that subgroup activities should become more formal. In the future, all subworking group meetings will be attended by an AEC representative. This action is being taken to avoid any possible criticism of the Working Group members' relationships with the AEC and to each other. All correspondence should be through the AEC.

The meeting was adjourned at 5:00 P.M.

Minutes of the Sodium Components Working Group

Meeting No. 26

General Electric Company

San Jose, California

Present: T. A. Nemzek, Chairman	AEC-CH
T. P. Heckman, Secretary	AEC-CH
C. A. Barrett	NASA-Lewis
R. W. Dickinson	AI
Kurt Goldmann	UNC
W. J. Hallett	AI
R. E. Harris	AEC-DRD
C. H. Hauser	NASA-Lewis
R. L. Hudson	Ethyl Corporation
R. W. Lockhart	GE-APED
B. F. Love	Alco
J. J. Morabito	APDA
J. S. McDonald	AI
J. M. McKee	UNC
J. Paul Peterson	GE
W. W. Sabol	GE
H. W. Savage	ORNL
R. D. Seifert	Alco
Prof. Short	University of Texas
W. R. Simmons	ANL
F. A. Smith	AEC-CH
B. G. Voorhees	GE
R. C. Werner	MSA
W. R. Wykoff	LASL
F. L. Yaggee	ANL

Mr. Nemzek, the chairman, welcomed the members of the Working Group, members of the Ad Hoc Committees, and guests to this twenty-sixth meeting of the Sodium Components Development Program and gave a brief summary of the program.

Mr. McKee of the United Nuclear Corporation then reported on the status of the oxide analysis work being performed by Mr. Steinmetz of the same company. He felt that the effort to date had been very satisfactory. The eight test samples had given very consistent results and are reported in the final report, NDA 2154-6. However, he feels that there are limitations to the present method and that additional work would be needed to reduce the present technique to a standard laboratory approach that anyone could use with consistent results.

Mr. McKee then presented a new proposal entitled, "Continuous Reading Meter for Determination of Oxygen in Sodium," UNC-NDA 3-730. The principle of the proposal was presented by means of chemical equations and diagrams on

the blackboard. Mr. Werner of MSA volunteered the information that the principle was very similar to the one used in fuel cell work performed at MSA and that he feels this approach is a very acceptable one for the determination of oxygen in sodium.

Mr. Lockhart of GE then presented the results of the carbon analysis. The samples that had been provided by AI and were analyzed by AI, ANL, DuPont, Ethyl, GE, and UNC had been tabulated by Mr. Lockhart. The results did not prove very consistent especially in the lower range of ppm of carbon in sodium. He felt that a second round of samples should be prepared and analyzed; however, prior to this work a meeting should be held to settle on standard techniques and procedures for preparing, handling, and analyzing the samples. Mr. Simmons of ANL felt that the chemists who do the actual analytical work should also be invited to such a meeting.

Mr. Dickinson of AI then summarized the work they had completed on the detection of hydrogen in sodium, reported in their internal memorandum 796-41-379. He felt that the completed work was very successful and the topical report is now under preparation; a report number was not available. He then summarized the testing of the Ohio Injector flow controller reported in internal memorandum 796-41-380. This component which is very simple in design proved to be highly successful in operation in the test loop.

Mr. Heckman reviewed the hot gas testing of the Westinghouse Electric Corporation flow controller performed in the WEC shop at Cheswick, Pennsylvania. The hot gas test did not prove satisfactory and the negotiations between the AEC and Westinghouse regarding the next step in the program had not been resolved as of this date.

Mr. Lockhart then covered the background of the mass transfer project and summarized the current status with a few general conclusions and comments. He deferred discussion of the details until after the Ad Hoc Committee, headed by Mr. Wes Savage, would give their report later in the day.

Mr. Simmons of ANL summarized the status of the EBR-II reactor, mentioning that the reactor had reached dry criticality on Saturday, September 30, 1961, with 87 elements, of an estimated 90, required to reach criticality. The steam generator that had developed a leak had been removed and returned to the Illinois ANL site for repair.

Mr. Werner of MSAR reviewed the status of their contract to investigate the physical properties of representative ferritic and austenitic steels subjected to various environments. The test equipment is still in the stages of fabrication, and the discussion dwelled on the proper procedures and philosophy of testing so that the results would be easily understood and correlated for actual designs of sodium cooled reactors.

Mr. Savage, ORNL, summarized the work of the Ad Hoc Committee studying the mass transfer contract of GE. This committee consisted of Messrs. McKee, UNC; DeVan, ORNL; Sinizer, AI; Savage, ORNL; Aronstein, Chairman, AEC; and Holliday, AEC observer. Various GE personnel participated when called upon by the Ad Hoc Committee, including Messrs. Lockhart, Billuris, Hetzler, Epstein, Brush, and Gaylor. Considerable data were presented on the blackboard by Mr. Savage which will later be presented in the Ad Hoc Committee report and, therefore, is not repeated in these minutes. Preparatory to the visit of the Committee, GE had compiled all of the progress reports and other pertinent data within one set of covers, approximately $1\frac{1}{2}$ inches thick. A few of the general conclusions as a result of the discussions and meetings are as follows:

The operation of the loop has become more routine. The appearance of fouling within the loop continues to require shutdown and dumping of the sodium and then re-startup. The oxygen level within the sodium continues to change and the explanation of a model for this phenomenon needs examination and explanation. The corrosion rate is known to be both velocity dependent and oxide dependent; whereas the time dependence of corrosion has yet to be analyzed. There seems to be a temperature dependence upon the corrosion; however, further analysis is needed of this effect as well as the effect of carbon and other contaminants in the sodium on the corrosion of the test samples. Considerable time has been spent on the analytical models of this mass transfer work and also on statistical analysis; however, an extension to this work is still needed. The present choice of loop materials and test samples does not show a widely divergent set of results. To assist in the analysis of the data, an additional effort to establish more precise solubility curves of materials in sodium may be necessary. Reference was made to the BML-1538 summary report of the BML work to determine oxygen in sodium at concentrations below 10 ppm. This report does summarize the oxygen solubility in sodium versus temperature from six different experimental efforts. This report also gives a current history of the analysis problem together with a bibliography of other similar work.

The chairman excused the GE representatives and the guests and held a separate meeting of the Working Group together with the Ad Hoc Committee of the mass transfer investigations. This meeting indicated that there were two alternate courses for future work, and that the problem was one of basic research. These alternates are: (1) to establish a model and then attempt to prove the model or (2) to attempt to test all variables considered significant and then to correlate the results of the variables. Mr. Savage recommended that the Ad Hoc Committee meet separately later that evening in order to prepare for the Working Group their technical conclusions and recommendations for use by the AEC in instructing General Electric on the future course that this work should take.

Mr. Lockhart of GE then joined the Group to discuss the MSAR contract dealing with the physical properties of materials subjected to sodium. Those present agreed that the Ad Hoc Committee appointed for this contract should meet, preferably in the latter part of November, to review the approach of MSAR and to meet with their consultant Professor Freeman of the University of Michigan to make certain the intentions of the Working Group were being followed. A suggestion was made that the Ad Hoc Committee be allowed to also investigate the thermal shock tests that are part of this same contract with MSAR.

Mr. Dickinson of AI mentioned that discussions had been held with Mr. Grotten of AEC Headquarters in regard to a new edition of the liquid metals handbook, and that he would send an outline of the proposed handbook to all members of the Working Group.

The representatives of UNC were then excused while a discussion was held regarding the analysis of oxygen in sodium. The Group was in agreement that solubility curves should be attempted and that the work proposed by UNC should be continued. The meeting adjourned at 6:05 PM.

October 5, 1961, 9:00 AM

Mr. Seifert of Alco Products, Inc. then presented the status of their contract on the intermediate heat exchanger and the steam generator. All of the materials for the IHX are on hand except for the nozzles, and progress is satisfactory. The detailed drawings for the steam generator are nearly complete, including the material take-off. Twenty-five per cent of the material is now on order and the present progress seems to be on schedule. Approval is needed from the AEC for the location of the thermocouples in both of these components, also the approval of the proposed test program.

The high temperature-high pressure loop has been delayed because of difficulty in obtaining the specimens of modified Crolloy tubing. The company that has attempted to pierce and draw the tubes has been unsuccessful; however, additional tries will be made with closer attention given to the temperatures of all operations.

The crevice corrosion study program was then presented by sketches on the board and discussed in considerable detail with the Working Group members. The Group was agreed that this problem should not delay the schedule of the steam generator now being fabricated by Alco. They did not agree, however, that additional research or development work should be undertaken at this time to prove out the proposals for new materials or new designs that might solve the admitted crevice corrosion problems.

Mr. Cygan of AI then presented the status of the Sodium Components Test Installation. The bid package for the erection of the sodium heater has been completed and sent to the area office of the AEC. Since this installation is made up of components and parts obtained from other installations that have been made surplus, there was considerable discussion about the incompatibility of sizing of the various parts; for example, the surplus Navy condenser that was now on hand is 400% over size, whereas some of the piping and pump capacity in the primary and sodium loops would not be sufficient to subject the test components to an overload.

Mr. Morabito, APDA, Technical Co-ordinator of the Ad Hoc Committee, reviewed the Sodium Components Test Installation. He discussed the complexity of the control system and the need for the ability to test independently various test components. This Ad Hoc Committee meeting had been short and had covered a large amount of territory; therefore, he felt that an additional meeting was needed to resolve many of the questions.

Mr. Love of Alco Products, Inc. reviewed the test program for the IHX and presented a pattern of thermocouples that they felt would be needed to understand the test data obtained from these components. The Working Group then discussed the subject of thermocouples and strain gauges for a considerable length of time.

Mr. Savage, Technical Co-ordinator of the Ad Hoc Committee, reviewing the shell side heat transfer work, summarized the numerous variables that would be present in the problem and the various steps that would be necessary to properly correlate all of the information so as to be useful to the designer of heat exchangers.

Mr. McDonald of AI then presented their latest proposal for undertaking this heat transfer work. He introduced Professor B. E. Short of the University of Texas, Austin, Texas, who has been retained as a consultant to AI for this project. Professor Short presented approximately 12 slides illustrating the flow pattern of water when intercepted by various tubes through the means of plastic models and the injection of colored ink into the water.

Mr. Nemzek then brought to the attention of the Working Group a letter from Mr. Kaufmann of Headquarters concerning the need for work on a binary cycle system and for higher temperature sodium up to 1400 F. The Group agreed that at this time such systems may be technically feasible but not necessarily economical. Therefore, the Group would not recommend such an effort be undertaken at this time.

Mr. Simmons of ANL presented a paper entitled, "Cost Study - Influence of Steam Conditions on Steam Generator Cost for 800 MWT Sodium Cooled Nuclear Power Plants." At this time Mr. Dickinson presented to

Mr. Simmons an AI memorandum 7519-4410-838 entitled, "ASGR Steam Cycle Optimization Report." Mr. Simmons suggested that the Working Group read and comment on his paper; however, he wished to defer further recommendations until reading and studying the AI memorandum.

Mr. Morabito, APDA, then summarized the current status of the EFR. He brought the Group up to date with the various technical problems they have been having including graphite, the offset handling mechanism, the number 2 steam generator bundle, and the oxygen and carbon contamination of the sodium.

Mr. Wykoff of LASL then summarized the work under way at LASL including the disassembly of the steam generator, the operation of LAMPRE I, the design of a fast reactor core test facility, and the renewal of the turret reactor under a different name, UHTREX.

Mr. Barrett of NASA, a new member to the Working Group, summarized the work of their organization that relates closely with the Sodium Components Development Program covering such items as the SNAP reactors, investigation of boiling sodium system, and investigation of properties of structural materials.

Mr. Hauser of NASA discussed the various systems now being investigated for the propulsion of space vehicles.

Mr. Hallett of AI discussed the current status of the SRE experiment, followed by a brief summary of the HNPF status.

Mr. Savage of ORNL summarized various projects at ORNL including the EGCR, the pebble bed reactor, the flux trap reactor, the molten salt reactor experiment, and various supporting activities.

The Working Group then met in an executive session to discuss the future of the Sodium Components Development Program. The Group was agreed that various Ad Hoc Committees should be combined such as the Sodium Components Test Installation, together with the test program associated with this installation.

October 6, 1961, 9:00 AM

The chairman introduced Mr. R. L. Hudson of the Ethyl Corporation who was a guest at this meeting and who had volunteered to tell the members of the experience of the Ethyl Corporation in the manufacture and handling of sodium. Through the use of a number of flip charts, Mr. Hudson illustrated the following:

- a. Manufacture of sodium in a Downs cell.
- b. Impurities in sodium manufactured by this means.

- c. Methods of purifying sodium by filtering.
- d. Specifications for reactor grade sodium.
- e. Diagrams showing how carbon in sodium is selectively deposited, dependent upon the freezing rate of the specimen. (This chart illustrated how the carbon tends to migrate to the liquid phase and is usually concentrated in the center of a solid cylindrical sample which is solidified slowly.)
- f. A chart showing the spectrographic method of detecting various impurities in sodium.

Mr. Hudson concluded by saying that the Ethyl Corporation would like to know what impurities are of greatest importance to the reactor people when used as a coolant for reactors and that his company would be very glad to co-operate in the analysis and in the determination of methods to eliminate these impurities.

Mr. Nemzek thanked Mr. Hudson for participating in the meeting of the Working Group and for offering the experience of his company to them. He then announced that the next meeting of the Working Group was tentatively set for the 10, 11, and 12 of January 1962 to be held at the Chicago Operations Office, Argonne, Illinois.

Mr. Lockhart then outlined the details of a tour that would be given for the members through the various San Jose and the Vallecitos, California, facilities. The balance of the day was taken up with touring these various General Electric facilities.

Minutes of the Sodium Components Working Group

Meeting No. 27

January 10-12, 1962

Chicago Operations Office

Argonne, Illinois

Present:	T. A. Nemzek	AEC-CH	Chairman - 1 & 2 days
	R. E. Harris	AEC-HQ	Chairman - 3rd day
	T. P. Heckman	AEC-CH	Secretary
	W. F. Anderson	AI	
	R. E. Aronstein	AEC-CH	
	C. A. Barrett	NASA	
	M. H. Barsky	ANL	
	R. Cygan	AI	
	R. W. Dickinson	AI	
	K. Goldmann	UNC	
	I. Johnson	ANL	
	R. W. Lockhart	GE	
	J. J. Morabito	APDA	
	L. E. Phillips	Alco	
	V. J. Rutkauskas	ANL	
	H. W. Savage	ORNL	
	W. R. Simmons	ANL	
	A. Smaardyk	ANL	
	W. R. Wykoff	LASL	

The meeting was opened by Mr. Nemzek, Chairman, who welcomed the Working Group members to this 27th meeting, and turning immediately to Mr. Kurt Goldmann, technical co-ordinator for a meeting with MSAR in Callery, Pennsylvania, on January 9, 1962, for his report. The subgroup that reviewed the MSAR contract consisted of Messrs. T. P. Heckman, Chairman; K. Goldmann, UNC, Technical Co-ordinator; W. F. Anderson, AI; J. H. DeVan, ORNL; and G. Stern, UNC.

Mr. Goldmann briefly summarized the discussions that took place and then listed the various technical opinions and recommendations made by the subgroup as follows:

The contract between the MSAR and the University of Michigan should allow Professor Freeman to dispense with the testing of croloys at 1100°F in air because of Professor Freeman's statement that the surface to volume geometry of these specimens would result in such a large degree of corrosion that the data would not be significant. Professor Freeman has had considerable experience working with stainless steel on an ASME committee, and has become aware of the wide variation in the properties of 316 stainless steel throughout a large sheet. Therefore, he should be allowed to select at random, approximately 12 samples from a sheet, and test to determine the reproducibility of results from the test material prior to the material being exposed to the various test

environments. Should the variation be considerable, the sheet material should be annealed in an attempt to eliminate cold working as a variable in these tests.

Professor Freeman should also be allowed to test more specimens than outlined in the contract in order to establish a stress rupture diagram; however, attempting to stay within the time and the dollars of the contract. He should also be allowed to test the samples at three different stress levels rather than three samples at a single stress level since he expressed the opinion that the scatter along a curve would mean as much to him statistically as a bunching of data around a single point.

Mr. Goldmann expressed the subgroup's opinion that the testing of stainless steel at room temperature would be more significant than testing at 1100°F in order to show up the presence of any sigma phase that may have developed during the high temperature exposures in sodium.

The subgroup also noted several items about the test setup that should be brought to the attention of MSA and corrected or minimized so as not to add additional variables to the test data. These included the noting of a spread of temperature in the specimen pots as compared to the outlet temperature of the loop; the variation of the ambient temperature at the support of the testing machine; the tare and temperature effects of the bellows of the test specimen support rod; the need for photomicrographs both before and after the specimens have been tested; the recommendation that the present stress fatigue mandrel be used plus the additional two that will be required for the three test conditions; and that there be a closer co-ordination between the test specimens of the GE Mass Transfer work and the MSA work.

Mr. Goldmann summarized his impressions of viewing the test loops and the procedures being followed by the testing personnel and estimated that test samples would not be under way before six weeks from this date.

Mr. Wes Savage then suggested that the Chairman establish a joint meeting between the two subgroups for review of the MSA and GE contracts.

Mr. Goldmann then reported on the thermal shock work and summarized with his impressions that the present setup of the equipment and specimen could not result in a satisfactory job. He then turned the review to Bill Anderson, AI, who is a specialist in thermal fatigue work. Mr. Anderson spoke briefly on the experimental setup and design of the test specimen and also expressed the opinion that the results from the program as now outlined would not result in understandable data. He made a strong plea that an investigation of thermal fatigue work be initiated. He felt there may be certain correlations between the pressure cycling work which is now being done under AEC direction at Southwest Research Institute and at Polytech Institute in Canada.

Mr. Robert Lockhart then referred to the Working Group's original specifications for this work, which were to determine whether a few very severe thermal shocks could cause a fracture in either a specimen or in the weld between sections of a component.

Mr. Wes Savage, ORNL, Technical Co-ordinator for the subgroup reviewing the mass transfer work, then briefly summarized the results of the second Subcommittee review, reported in the subgroup minutes dated November 22, 1961, as follows:

All of the loops tend to foul with crud over a period of time. The fouling effect indicates a need of additional loops to allow the investigation of geometry. The data does not indicate a best material for sodium loop construction. A relation or interdependence of two or more variables was not detected. Computer work had been developed so that empirical data could be fed into the mathematical equation presenting a numerical answer for certain variables and an answer given in a very short time.

The third meeting of the subgroup was held in December, 1961, the minutes are not yet issued. Mr. Savage summarized the discussions that were held at this meeting under the subject of fouling phenomena, geometry effects, statistical plans for interpretation of the data, the effects of carbon, the effects of oxygen, and interrelationship of carbon and oxygen. Mr. Savage recommended to AEC that this work be continued until the mass transfer phenomena can be analytically explained. Also the program be expanded to include geometry effects, fouling effects, and a complete understanding of the contribution of contaminants such as carbon and oxygen to the corrosion or mass transfer phenomena.

Mr. Robert Lockhart expanded on the previous speakers comment by saying that fouling increases directly with velocity in the loop; that the material causing the fouling is alpha iron which is magnetic; that the capturing of representative samples of the material causing the fouling is extremely difficult because the process of cleaning the samples or the holders or screens of sodium also seems to eliminate whatever is causing the fouling. The location of where the fouling or stoppage of flow occurs, has been determined through the means of pressure indicators. The data collected to this time indicates that corrosion is directly related to the velocity of the stress.

By the use of slides, Mr. Lockhart then presented the mathematical equation attempting to interpret the effects of each of the variables, the sketches of the schematic loop diagram, and isometric view of the loop, the sketches of the sample holders, and plots of the different variables resulting from that data that has been obtained. Mr. Lockhart recommended to the AEC that more runs be made with the existing equipment

to allow an extension to the degree to which the present variables are being investigated. In addition, that replicas of the present runs be made, that the effects of a hot trap of linear analysis, and of curve-linear analysis be made to the additional runs.

Mr. Larry Phillips, Alco, then reviewed the status of the intermediate heat exchanger and steam generator contract. He indicated that the locations for the thermocouples in these two components are still a problem. Purchase orders for the thermocouples have been written and given to the AEC for review and approval, with delivery of the actual thermocouples estimated for six or seven weeks after approval. The twelve inch nozzles for these components have been re-designed to allow the use of ring forgings which has caused slight slippage in the schedule, but should be available by April, 1962. The shipping date for the IHX is now estimated for September, 1962.

The Working Group then held a lengthy discussion with Mr. Phillips regarding the procurement and the reliability of various types of thermocouples especially brazed versus welded types. Mr. Phillips then described the progress being made on the procurement of tubes for the steam generator. Superior Tube Company was the only company to respond to an invitation to bid on the co-extruded inconel-croloy 40 foot length tubes. The first test run of this material was tested and closely examined and found to be defective. Mr. Phillips recommended that there be a joint meeting between the AEC, Alco, Superior Tube Company, and Allegheny Ludlum to determine the next steps that should be taken in the development and procurement of this tubing material. Several alternate materials for the tubing were mentioned including straight stainless steel and high nickel super alloys.

Mr. Phillips then described the status of the high temperature, high pressure test loop implying that a shutdown would be needed in the near future to make modifications to the controls and instrumentations. It was hoped that during the modification, samples of modified croloy and of the co-extruded inconel croloy material could be installed for testing.

January 11, 1962

Mr. Cygan, AI, presented the status of the Sodium Components Test Installation. He passed to the Working Group members copies of the proposed construction schedule dated 12/7/61, and reviewed briefly the status of the various items such as: re-winding of the present feedwater pump motors to allow a higher capacity. Bids for valves have been invited from the various vendors. The sodium storage tank is due for delivery in 30 days. Stubs have been provided in the piping system to allow the 30 MW IHX to be tested separately from the steam generator. As of this time, surplus coolers for putting in the primary system have not been found and new coolers have not been ordered; however, a cost estimate for new coolers will be supplied to the AEC within 30 days.

The Working Group then entered into a general discussion with Messrs. Cygan and Phillips regarding ability of testing the components separately, also the ability to subject either component to the maximum thermal shock of 350°F per second for twenty seconds. Mr. Phillips felt that if the IHX and steam generator were tested together, it would not be possible for the Sodium Components Test Installation as now designed to subject these components to a shock as severe as 350°F per second. However, if they were tested separately this thermal shock might be achieved. Also, if the steam generator were to be tested separately, under thermal shock, the AEC should be aware of the possibility of causing damage to the sodium heater. The Working Group discussed the time cycle for performing thermal shocks; for example, if immediately after a shock, the temperature of the sodium was raised, the component may never see the full temperature differential, rather, only the sodium and the thermal shield in the component would see the maximum temperatures.

Mr. Cygan stated that the present design of the test installation does not allow the testing of the steam generator separately, and additional guidance would be needed from the AEC to incorporate this flexibility into the test installation. Should AI be requested to include this flexibility, an additional 30 days in the schedule would be necessary to install the by-pass around the IHX. Mr. Harris then reviewed the original specifications for the thermal shocking of the IHX and steam generator for the Working Group. Mr. Morabito then read from AFDA-134 the various maximum thermal shocks estimated for reactors that were either being built or planned for the future.

Mr. Phillips then stated that Alco will independently rewrite a test program and operating manual for the two components they are supplying. They will then meet with AI for adjustments or modifications that will be needed in the Sodium Components Test Installation to meet these performance specifications. The operating manual will be written as though it were for components that would be a part of an actual reactor system. A separate test manual will then be written to allow for the testing of these components in the Sodium Components Test Installation in the attempt to meet the original specifications as outlined by the Working Group.

Mr. Simmons, ANL, then reviewed the status of the steam generator optimization study. This subgroup met in October, 1961, and submitted an outline for the Working Group's comments which have now been included. This ANL study, which is limited to showing trends in the cost of steam generators, will be completed and provided to the AEC within a few weeks. Mr. Simmons suggested that the AEC use the study for letting a contract to do the investigation. He estimated such an investigation or study would require an architect-engineer type of contractor a period of three months to complete.

Mr. Dickinson, AI, then reviewed the status of the hydrogen detector. The report on this work is in final draft form and a draft copy will be sent to CH within a week. The report numbered NAA-SR-6986 will be in printed form within three to four weeks and will then have patent review before general distribution. CPAO has inquired of AI regarding the desirability of installing such instruments in the HNPF and SRE. Mr. Dickinson did not feel that these two reactors were in need of this instrument because they have the necessary protection built into a gas detection annulus within the steam generator. However, such an instrument will be installed in the Sodium Components Test Installation, and he estimated the prices for this instrument to be \$1,500 for the sensor and \$3,300 for the associated equipment for a total of \$4,800 for the installation of a hydrogen detector.

Mr. Dickinson then reviewed the status of the shell side heat transfer work. One bundle for this study has been fabricated. However, work was brought to a stop when directed to do so by the AEC because of lack of funds. No one at AI is now working on this problem. However, Mr. Dickinson proposed that the testing of one bundle be allowed the check-out, the instrumentation, and the loop. Mr. Goldmann and Mr. Savage at this point expressed their opinions that considerable theoretical work was needed. They felt that the complete program should be designed and laid out prior to collecting test data, otherwise, the analysis of the test data would be extremely difficult.

Mr. Morabito, ADPA, then reviewed the status of the Enrico Fermi Fast Reactor. The reactor was subjected to a 1,000°F non-nuclear check-out during 1961 which resulted in the discovery of several problems which are now being resolved. One problem is with the graphite in the rotating top shield of the reactor tank. This graphite was bonded with phenolic resins which outgassed to as much as 20 volumes at the test temperature. The graphite on the outside of the reactor tank was subjected to air during the test run which caused some of the plain graphite to deteriorate in mechanical strength, and the boron from some of the borated graphite to react with the water in the air causing a depletion of the boron. This phenomena has been established in laboratory tests and noted to occur at as low a temperature as 350°F. Other laboratory tests wherein graphite has been allowed in contact with sodium have shown that the graphite expands, but without exerting much force. APDA, therefore, felt that any canned graphite that developed a leak to sodium would be restrained by its container.

Mr. Morabito then reviewed the past history and present status of the steam generator problem. The steam generators were shipped from the vendor, Griscom-Russell Company, in a dry condition. Upon arrival at the Fermi site they were installed, cleaned, and put into long storage with pure water containing hydrozene additives. During this storage period, some of the tubes in the number two steam generator developed severe corrosion pits and cracks to the point that this bundle must be

completely re-tubed. The current interpretation for this corrosion is that natural circulation of the water which contains hydrozene continued for the five months of testing the sodium system at 1000°F. This testing caused local boiling at the top of a few of the outer tubes of the number two steam generator, thereby, concentrating the inhibitor salts at certain locations, which in turn caused the corrosion cracking. One tube in the number three bundle has been analyzed as straight carbon steel which will be removed. The number one tube bundle was found to be in satisfactory condition except that unidentifiable oil was found on the tube sheet when the head was removed. This oil has been analyzed, however, the origin or source is not now known.

The offset handling mechanism has been damaged as a result of rotating it while a subassembly was out of the normal position, which in turn has damaged some of the other dummy subassemblies. This mechanism will be removed from the primary tank and repaired. The problem of the stuck subassemblies will then be reviewed.

The Chairman then called a meeting of the Working Group only, to review the previous presentations by the contractors. Part of this meeting consisted of an exchange between the Chairman and the members of the Working Group regarding the relationship of the Working Group to the AEC. Members of the Working Group expressed several opinions regarding improvements of the administration of this program, such as an improvement in informing the Working Group members of the decisions arrived at by the AEC following this type of Working Group meeting; to have the contractor personnel present only for their particular presentation, or for an occasional general review of the total sodium problems. Some members felt that the industrial participation should be limited to technical information whereas the national laboratories should be requested to recommend to AEC on the adequacy and technical competence of the contractors to perform the work. Other members felt that the subgroups of the Working Group should concern themselves only with the broad general scope of the contractors work.

The Chairman advised that the minutes should be turned out in a rough draft form within two weeks of the Working Group meeting to allow comments to be sent back by the members. In addition, a monthly progress report might be submitted by the AEC to the Working Group and the other interested parties, summarizing the correspondence and the decisions that have been made during the preceeding months.

The Chairman mentioned that AEC Headquarters had asked for a formal review of the sodium components development program with contractors present for the first days agenda and the Working Group present for the first and the first half of the second day of the two-day meeting. The tentative dates that have been set for this meeting are March 21 and 22, 1962.

The Chairman then summarized all of the recommendations and comments presented by the various members covering the presentations made as follows:

1. To ask MSAR to eliminate creep rupture tests of $2\frac{1}{4}$ Cr - 1 Mo at 1100°F in air.
2. Include a series of tests to determine the variability of 316 stainless steel from a single supply of materials.
3. Attempt to anneal or to get another sheet of supply if the specimens show great variability.
4. Allow the creep rupture specimens of 316 stainless steel and of $2\frac{1}{4}$ Cr - 1 Mo to be tested at different stress levels as determined by Professor Freeman so as to establish stress rupture diagrams for these materials.
5. To run room temperature tensile tests of the 316 stainless steel specimens exposed at 1200°F in sodium.
6. To call to the attention of MSAR, the three degree temperature control required on their test specimens.
7. To calibrate the testing machines for ambient temperature.
8. Calibrate the specimen test setup for the tare and temperature effects of the stem bellows.
9. Support the test data with photomicrographs taken before and after the specimens have been subjected to the test conditions.
10. The subgroup should be invited to visit MSA again at a time when the first data was ready for analysis.
11. An exchange of information and specimens between the two sodium component contractors, GE and MSAR. This should also be extended to an exchange of information between the two subgroups.
12. Fatigue tests should be run at three strength levels rather than two levels. This would require only two additional fatigue mandrels as the present one is still acceptable.
13. To recommend that the thermal shock tests be discontinued.

Mr. Lockhart, representative of GE, was asked to leave during the discussion which followed on the mass transfer work. The Working Group suggested to the Chairman that this mass transfer work continue on the present schedule. In addition, GE should be requested: (1) to make a proposal for additional extensions to this present work to investigate

the geometry and fouling effects; (2) that the linear statistical approach should be continued on the data to a completion of the analysis; (3) that the analysis of the mass transfer data should show particular attention to carbon transport.

Mr. Lockhart rejoined the Working Group for discussions on the subject of the IHX and steam generator being fabricated by Alco. The Working Group suggested to the Chairman that: (1) the thermocouples be purchased based on good technical judgement with schedule considered as secondary to reliability of this particular item; (2) Alco Products, Inc., be allowed to shutdown their high temperature-high pressure test loop for the purposes of modification to the controls and instrumentation, and insertion of new materials.

The subject of carbon analysis was then brought to the attention of the Working Group. Mr. Lockhart of CE will collect the names of people associated with the carbon analysis problem and will supply these to the Chairman with the recommendation that a meeting be called of these people, with a suggested date of mid-February, 1962.

The Chairman then requested that Mr. Dickinson leave the room while the Working Group discussed the Sodium Components Test Installation and the shell side heat transfer work. After considerable discussion, the Chairman decided as follows:

1. That AI be instructed to provide a primary system by-pass of the IHX with the purpose of testing the steam generator independently at the end of the normal test period.
2. That the controls and instrumentation be closely inspected to assure the AEC of reliability and ease of operation of this test installation. A meeting of the subgroup for the purpose of reviewing the test installation would be appropriate for February, 1962.
3. That all pipes and valves and connections to the components should be designed so as to meet the specifications of flow as outlined in the report APDA-134.

The Chairman returned to the subject of shell side heat transfer. He requested that Mr. Kurt Goldmann act as technical co-ordinator to outline a complete program for the investigation of shell side heat transfer including the technique for the analysis of the resulting data. The meeting adjourned at 6:30 PM.

January 12, 1962

The third day of the Working Group meeting No. 27 opened with Mr. R. E. Harris acting as Chairman. The first item on the agenda was a report by the various Working Group representatives to the NASA-AEC liquid metals meeting of December 14 and 15, 1961, held at Brookhaven National Laboratory. Mr. C. Barrett of NASA-AEC who had attended all three of these meetings reported first. He stated that most of the work under this program is aimed at the use of liquid metals in the range of 1800 - 2200°F. This included the attempt to have boiling liquid metal systems. The results as of this time have not been very successful and some of the original choices of materials for the loops have not proven to be the best. The present indications are that the niobium 1% zirconium alloys may prove more successful, and that the test operations could be performed in a vacuum environment rather than an inner gas environment because of the corrosion to the outside surfaces of the test materials.

The second day of the Brookhaven Meeting was devoted to the analysis of the various liquid metals for the presence of various additives and contaminants. There was considerable difference of opinion among those people reporting on the progress of their work as to what is happening between the liquid metals and the containing materials and how to measure the phenomena that is occurring. Mr. Barrett mentioned work being done by Aerojet General in boiling rubidium at 2000°F. This apparently has been the only successful loop to date and will continue for 2000 hours, at which time the loop will be shut down and inspected.

Mr. Dickinson then volunteered the information that AI is doing boiling sodium work under a project of safety studies with a Mr. R. C. Noys in charge. This work is attempting to reach heat fluxes of 500,000 Btu per square foot-hr. and is having considerable difficulty with the heaters. Messrs. Savage, Goldmann, and Heckman, who had also been present at this meeting, gave their general impressions of what occurred. Their comments agreed closely with the prior speakers plus adding a few related comments regarding the meeting, such as, the old-timers in the business of liquid metals expressing a disappointment in the fact that the newcomers have not read the existing literature thoroughly enough to know that much of their work has already been done in the past.

Mr. Lockhart then reviewed the paper that he had presented at this meeting and mentioned that there was a certain amount of conflict between his work and the work presented in the AI paper.

Mr. Savage then described the tour of the BNL facilities following the meeting and some of the new equipment that has been installed for liquid metal investigation. He then referred to some of the space work now being performed at ORNL under Messrs. Hoifman and DeVan. He mentioned that a Finley pump developed for pumping high temperature

potassium has functioned satisfactorily. He also indicated that the cobalt alloys such as Haynes 25 have developed considerable difficulty in high temperature liquid metals work. Several attempts have been made at ORNL to make bearings that operate in high temperature liquid metals, and after attempting several different special alloys, one at a time, they have found that stainless steel when machined to very close tolerance has functioned satisfactorily. ORNL has been working a boiling heat transfer loop for approximately one year and has started work on a potassium vapor turbine.

Mr. Dickinson volunteered the information that similar work at AI under Mr. Roger Moore has developed a moly-silicide coating for the protection of columbium against the atmosphere at high temperatures.

Mr. Barrett then mentioned a contract that NASA has with GE to develop new materials and to determine the solubility of various materials in liquid metals. Also to develop vapor pressure diagrams. He is of the opinion that the high temperature loops should be operated under as good a vacuum as necessary, thereby avoiding the necessity of wrapping the loops or coating them with materials such as those referred to by Mr. Dickinson.

Mr. Barrett brought to the attention of the Working Group a meeting of the AIME who will hold their third meeting in New York City, February 22, 1962, related to high temperature liquid metals and their containment materials.

The Chairman then turned to the next item on the agenda, namely, reports by the various members of activities at their parent organizations.

Mr. Savage then reviewed the status of the molten salt reactor which is continuing at a slow pace. Considerable difficulty is being had with the container materials and in the welding of alloys such as hastelloy and Inor-8. Work is also continuing on the high flux reactor which will be used for making transuranic isotopes. The EGCR is at this time approximately 6 months behind schedule with operation planned for 1963-1964. Much of the effort at this time is in the consideration of hazards of this type of reactor. Many of the component parts for this reactor are on hand but have yet to be tested at high temperature.

The fuel elements which will be supplied by Westinghouse Electric Company are being studied by a fuel management group. There is also a study and evaluation of the pebble bed reactor of the Sanderson and Porter design, wherein the pebbles are actually one to one- $\frac{1}{2}$ inches in diameter graphite, pyrolytically coated. The gas or helium blowers for this reactor have been operated in test loops and appear to be satisfactory.

Mr. Dickinson summarized the work at the SRE, HNPF, and his recent trip to Japan. The stability problem on the SRE is solved as of this time. The hot traps for the removal of carbon seemed to be operating satisfactorily with an indication of control tabs showing 46 ppm on the inlet side and 26 ppm of carbon on the outlet side. These hot traps are filled with Type 304 stainless steel operating at 1200°F with a flow of approximately 30 gpm. Since new sodium contains approximately 18 ppm of carbon, he feels that the sodium in the SRE will soon be at a level of carbon to allow higher power level operation. He described one occurrence of a leak in the hot trap which resulted in a fine stream of sodium that cut through the insulation, hit the pipe gallery wall, and sprayed. Since the pipe galleries contain inert gas, there was no fire, however, the spread of fission products, especially cesium, caused some difficulty in repairing this defective leak. One moderator can in the second row of the SRE reflector has developed a cladding leak causing the graphite to swell. This is detected by an increase in height of this particular moderator can over the adjacent ones. The present AI thinking is to continue operation with this defective moderator can and observe the rate which any change might take place. The once-through B&W steam generator is now being operated with the SRE.

The HNPF at this time was being loaded with new fuel assemblies for the dry criticality run. He indicated the physicist calculated that 25 subassemblies would be required for criticality and 41 subassemblies would be loaded to check controls and instrumentation. Following the dry critical physics experiments, the reactor will be loaded with sodium and the criticality experiment repeated. It is estimated that approximately 151 subassemblies would be loaded for actual operation with sodium. The present schedule calls for the loading of sodium in the primary system in March, 1962, followed by raising the temperature by auxiliary means to 500°F to checkout the operation of the system. If this schedule can be held, power will be generated in June and the reactor will be turned over to Consumers Public Power District operation in November, 1962.

In December, 1961, Mr. Dickinson was invited to a joint Japanese, AIF Meeting in Japan. This meeting was attended by approximately 250 people of which 50% were from Asia and the other 50% from the USA with a few people from the UK and other countries. He mentioned that Japan is quite interested and needs nuclear power, however, they feel that the cost must be competitive before they will initiate the building of large central station power plants.

Mr. Simmons, ANL, then summarized the current work at the EBR-II. The reactor has been unloaded and preparation is now under way for high temperature gas testing. The turbine generator has been operated on auxiliary steam and the startup of the reactor for purposes of generating power is scheduled for the fall of 1962. The defective steam generator has been repaired and returned to Idaho

and is now in the process of being installed in the system. The attempt to weld the tubes in the header of the superheater design for the EBR-II has stopped, however, planning is going ahead on other ways that this might be performed. ANL at this time is putting together a boiling sodium experiment. They are also thinking of using the EBR-I facility, following the plutonium loading, for boiling sodium experiments.

Mr. Lockhart then summarized the work at GE in regards to the FOB reactor. A design of a critical experiment has been completed. Ceramic fuels have been tested in the TREAT reactor and mixed Pu oxide and uranium oxide capsules that were exposed in the GETR are under examination.

Mr. Goldmann, UNC, then summarized some of the work going on at the NDA Division of UNC, including design studies of fast reactors, of fast safety, of the use of Pu carbide fuel elements and the development of sponge fuel which consists of uranium metal spheroids compacted by vibration into tubular cladding and the remaining space filled with liquid sodium.

Mr. Wykoff, LASL, passed to those members present, the K-3 monthly progress report for November 21 to December 20, 1961. This summarized the results of the dismantling and inspection of the steam generator test loop. This inspection showed a very definite destructive effect of thermal cycling, almost to the point of fatigue failure. He circulated among the members, six photographs taken of the piping that had been cut open longitudinally.

He summarized the present status of the LAMPRE-I which has been kept at a temperature of 480°C for the last four months. The reactor had operated to a total of six MW days and during this time lost as much as eight dollars of reactivity due to frothing within the fuel capsules. The reactor is not running at this time because of sticking controls. However, the results have demonstrated that a container material for the plutonium iron eutectic is possible. Further planning and development work is going ahead to prevent the frothing effect noted and checked by radiography. Additional cores are now under development with the hope of reaching 500 watts per gram of fuel whereas LAMPRE-I is designed for only 40 watts per gram. LASL is now busy with the design of a fast reactor core test facility of 20 MW size. The title one work has been completed by Norman Engineering and title two work has started. The start of construction is scheduled for August of 1962.

Mr. R. Harris then made a few brief remarks about the AEC and stressed the need for additional work on the part of the Sodium Components Development Program for advanced steam generators.

Minutes of the Sodium Components Working Group

Meeting No. 28

March 21-22, 1962

AEC Headquarters

Washington, D.C.

Present:

C. A. Barrett	NASA-Lewis	Cleveland, Ohio
G. Billuris	GE (APED)	San Jose, California
R. Cygan	AI	Canoga Park, California
J. P. DeKany	USAEC	Canoga Park, California
R. W. Dickinson	AI	Canoga Park, California
J. J. Dissler	USAEC	HQ
O. E. Dwyer	BNL	Upton, New York
J. W. Freeman	University of Michigan	Ann Arbor, Michigan
A. G. Fremling	USAEC	CH
W. A. Glaeser	BMI	Columbus, Ohio
K. Goldmann	UNC	White Plains, New York
W. J. Hallett	AI	Canoga Park, California
R. E. Harris	USAEC	HQ
T. P. Heckman (Sec.)	USAEC	CH
J. P. Holliday	USAEC	SAN
R. H. Jones	APDA	Detroit, Michigan
J. W. Kissel	BMI	Columbus, Ohio
R. W. Lockhart	GE (APED)	San Jose, California
J. J. Lynch	NASA HQ	
W. B. McDonald	ORNL	Oak Ridge, Tennessee
J. J. Morabito	APDA	Detroit, Michigan
S. G. Nordlinger	USAEC	HQ
G. V. Packer	USAEC	HQ
L. E. Phillips	Alco	Schenectady, New York
R. D. Seifert	Alco	Schenectady, New York
W. R. Simmons	ANL	Argonne, Illinois
F. A. Smith	USAEC	CH
H. Steinmetz	UNC	White Plains, New York
D. C. Thomas	USAEC	HQ
G. W. Wensch	USAEC	HQ
R. C. Werner	MSA	Callery, Pennsylvania
J. B. Williams	AI	Canoga Park, California
W. R. Wykoff	LASL	Los Alamos, New Mexico

Dr. Wensch, Chairman, opened the meeting by welcoming all the contractors and members of the Working Group to this Washington review meeting. He very briefly summarized the Sodium Components Development Program by mentioning that it had started in 1958, had spent to this time

approximately 4.6 million dollars at a rate of \$200,000 per month. The DRD, therefore, felt that it was appropriate to hold a Washington review to ask questions such as how well the program is doing and to determine whether it is appropriate to make any changes in how the Program is progressing. Copies of an agenda were passed to all of those present and this agenda was adhered to closely. The first speaker was Mr. Phillips of Alco Products, Inc. who discussed his company's work on the design, R&D, and fabrication of a steam generator and intermediate heat exchanger. This work, which is part of the over-all Sodium Components Development Program, was being undertaken for the development of economical and more reliable heat exchangers and steam generators for use in sodium cooled reactor plants. The prototype units are to be tested in a sodium test facility to evaluate performance and obtain basic design information.

During FY 1962, the final design for a 30 MW intermediate heat exchanger and a 30 MW steam generator was completed. Fabrication of both of these units was initiated and will be approximately 50% completed by the end of FY 1962.

The R&D program associated with the intermediate heat exchanger and steam generator designs will also be approximately 50% completed. This R&D program includes the following items: welding development, operation of a high temperature high pressure loop, evaluation of composite sine wave tubing, and the testing of a proposed new, modified 2 1/4 Cr-1 Mo alloy steel.

The welding development included: (1) procedures for joining 20 gage type 316 SS tubes to type 316 SS tube sheets, (2) development of welding procedures for depositing a nickel chrome iron alloy overlay on the type 316 SS tube sheets and channels which are to be exposed to water or superheated steam in the steam generator, (3) development of welding procedures for joining composite type 316 SS and nickel chrome iron alloy tubing to tube sheets which have been overlaid with nickel chrome alloy, avoiding exposure of bare stainless steel on the tube side of the steam generator, and (4) thermal cycling tests to evaluate the integrity of the developed tube-to-tube sheet joints with weld overlay deposit after exposure to anticipated service.

Work has also been initiated on preparation of a test program for the 30 MW units. A preliminary test program was prepared for the purpose of obtaining comments from the Working Group. This test program will be refined and completed in co-operation with Atomics International who will operate the test facility. This work has been published under the number AP&E-1112, "30 Megawatt Heat Exchanger and Steam Generator for Sodium Cooled Reactor System" in four volumes.

Volume I	Thermal and Mechanical Final Design
Volume II	Chemical and Stress Analysis
Volume III	Material and Welding Specifications
Volume IV	Operation and Maintenance Procedures

A separate publication will cover the Inconel weld overlays on type 316 forged stainless steel.

After Alco has made delivery of the units to the test site, Alco will continue to follow closely the progress of the test program in order to gain all the test information which will be pertinent to post test evaluation of the units and to act in an advisory capacity on the test program.

At this particular time, Alco Products, Inc. is having difficulty in obtaining delivery of the bimetallic tubes required for the steam generator unit. These tubes are a joint development among Alco, Superior Tube Company, and Allegheny Ludlum. The test run of this type of tubing did not prove satisfactory for metallurgical bonding and continuity in the Inconel inner tube. The vendors for this tubing have been reluctant to accept an order with a specified price and delivery date. However, Mr. Phillips was confident that additional development work and improvement in the procedures will result in satisfactory tubing being delivered in time to allow Alco to deliver a completed unit to the test facility by January or February 1963.

Mr. Cygan of AI then made the presentation covering the Sodium Components Test Installation. This project is to provide a high temperature sodium components installation suitable for the operational proof testing of large prototypes sodium components. The installation will be designed to provide for the testing of sodium heated steam generators and sodium-to-sodium heat exchangers. Other advanced sodium components can be tested in conjunction with the above.

The installation shall be capable of simulating various operational steady state and transient conditions that would be experienced in large nuclear power electric generating stations. In addition, some basic instrumentation to evaluate performance of components will be provided.

This installation is necessary since no other installation exists which can satisfy the same final objectives. It will provide necessary data, provide operational proof of structural reliability, verify the integrity of sodium components under transient conditions, and finally demonstrate that certain component designs can be guaranteed as sound investments for large nuclear power electric generation stations. During 1961, the site for the test installation was prepared by clearing equipment and other items of previous work from the proposed site. The analytical evaluation of the steady state and transient performance of the facility was approximately 50% completed. Flow diagrams for all process systems had been prepared and the control and instrumentation diagrams were finalized in conjunction with the analytical evaluation of the system. Working drawings necessary for the erection of the installation were started. The writing of final specifications for equipment and construction installation was initiated and procurement action was initiated for the following long delivery items: boiler feed pump, feedwater heaters, cooling tower, electrical switch gear, sodium instrumentation, and high

pressure steam valves. Contracts were let for the site preparation for foundation work and for the control room erection.

During FY 1962, the analytical evaluation of the steady state and transient performance of the installation will be completed and all necessary working drawings and final specifications will be completed.

The 35 MW sodium heater is installed and the installation of major systems including steam and sodium equipment and piping, electrical and instrumentation work and control boards will be continued. The operating procedures for the installation will be prepared and a test program will be written in conjunction with Alco Products, Inc.

For FY 1963, it is planned that all installation will be completed during the second quarter. The test and checkout of the installation, as far as possible, prior to installation of the test units, will be carried out. This work can proceed concurrently with the installation of test units which is not part of this program.

Mr. Cygan felt that the schedule has been hindered to some degree by several conditions, such as the method of funding and spending of money according to Government fiscal year, also the original vendors of some of the used equipment that will be part of this facility have not been very co-operative. Some of the original designs for the surplus equipment were not adequate and redesign was necessary. Selection of burners for the sodium heater was delayed by discrepancies in one vendor's specifications. The order for burners has now been given to the Peabody Burner Company. As a result of reviews by the Working Group, some of the specifications in the Title I design have been changed, such as the 6" pipe was later changed to 8" size and the drive motor for the primary pump has been increased by 50 hp.

By the use of flip charts, Mr. Cygan then showed several time-versus-temperature charts of transients and also flow-versus-time. Because of changes, the schedule for the sodium piping will be delayed from September to November. He stated that the purchase order for the control panel was recently given to the AEC for their review and approval or comment.

Mr. Phillips of Alco Products, Inc. then made a brief presentation on the preparation of the test program for the intermediate heat exchanger and steam generator to be tested in the Sodium Components Test Installation. This test program will allow either unit to be tested separately or the two units to be tested as a composite part of a system for both thermal performance and stresses. The calculations and analysis work are now proceeding at Schenectady, New York, and are scheduled for completion by the end of the summer of 1962.

Mr. Williams of AI made the presentation of the project to test one torque tube shaft seal and one 10" flow controller manufactured by the Ohio Injector Company to demonstrate whether these components meet the functional specifications called out in the AEC contract with the Ohio Injector

Company. The torque tube shaft seal was installed in the HNPF 12" valve test loop. This unit was operated for 1000 mechanical cycles. Of these, 500 cycles were performed while the seal was at 1000°F and another 500 cycles were performed at 1200°F. During this project, five leak checks were accomplished at 100 psig. Satisfactory performance was achieved.

The flow controller tests were performed in the HNPF free surface pump loop. Flow control characteristics were determined at 600, 825, and 1000°F and at flow rates from 3000 to 6200 gpm.

After modification of the LCTL, the controller was installed and the first series of thermal shock tests were made. This series of tests required 500 cooling cycles from 1000°F at 30°F/sec for three to five seconds. The thermal shock test program consisted of subjecting the unit with gate full open to a total of 1000 cycles. Of these, 500 cycles from 1000 to 850°F, plus one-half of those specified for 1200° to 1025°F have been completed. Following 400 cycles from 1000 to 850°F, it was found that warpage of the valve body had occurred. The unit was disassembled and machined to provide the original .015" gate to body clearance. After reinstalling the valve in the LCTL, residual strains were relieved by holding the devices at 750°F for 24 hours. This stress relief process was carried out in order to assure that any future warpage observed during the program would have been caused by thermal shocks and not by residual stresses initially present. Cycling was then resumed. Torque and flow tests as described above were conducted following 0, 50, and 100 of the last set of 1000° to 850°F cycles and at 0, 25, 50, 75, 100, and 200 cycles from 1200° to 1025°F. Results from the torque and flow tests showed no change, indicating little if any warpage in the valve due to repeated thermal shocks.

It is planned to complete the remaining 300 thermal shock cycles at 1200 to 1025°F. At the end of this test program, an attempt will be made to determine the strain-versus-time profile through the wall of the controller under conditions of the 1200 to 1025°F shock. Following this, the valve will be taken apart and gate and valve bore dimensions will be remeasured to determine whether distortion occurred.

A topical report will be prepared summarizing results obtained during the entire test program of the torque tube shaft seal and flow controller. The preliminary results indicate that the valve operates quite satisfactorily up to 5000 gpm and over the range from 1% to 100% of this flow capacity.

Mr. Williams then described the project titled "A Device for Continuous Detection of Hydrogen in Sodium," Report No. NAA-SR-6986, copies of which were passed to the AEC members. By the use of flip charts, Mr. Williams illustrated the drawings that are present in this report and the scheme by which this device works. The device employs a nickel diaphragm to separate hydrogen from flowing sodium and was developed at AI under a previous study. One side of the diaphragm is contiguous with

flowing sodium and the opposite side forms one side of a vacuum chamber. Hydrogen diffusing through the nickel diaphragm causes an identifiable increase in the rate of pressure rise on the vacuum side of the diaphragm when the vacuum pump is isolated from the system. Spectrographic analysis of collected gas verifies the presence of hydrogen. The pumping rate of the vacuum system is adjusted to just maintain a preset pressure of approximately 5 microns Hg pressure. When hydrogen diffuses through the nickel tube, the resultant gaseous mixture has a higher thermal conductivity causing a sharp rise in the pressure indication given by a Pirani vacuum gage. By recording the output of the vacuum gage as a function of time, it is possible to determine when hydrogen was introduced and also to obtain a measure of the amount of hydrogen or water involved. The commercial instrumentation incorporated with the sensing device can be equipped with an alarm to indicate the presence of hydrogen in the sodium.

At this time, there was an open discussion among members of the AEC, the Working Group, and the contractors regarding the extent to which the Sodium Components Development Program should be involved in strictly hardware items and to what extent they should be making basic research investigations. Participating in these discussions were Messrs. Wensch, McDonald, Nordlinger, Dwyer, Dickinson, Smith, Harris, Goldmann, and Heckman.

Mr. Jones of APDA then made the presentation on their investigation of a Blake Meter for the determination of contaminants in sodium. By the use of slides, he showed the actual installation, the schematic diagrams, and the various components of the Blake Meter. As of this date, there had been a 2-week period of shakedown of the installation with two actual days of operation. The preliminary data indicate that the Blake Meter is highly temperature sensitive and that a calibration curve for temperature effect may be needed.

Dr. Werner of MSAR, assisted by Professor Freeman of the University of Michigan, then made the presentation of the Physical Properties of Materials. Dr. Werner distributed to those present a 12-page collection of photographs, drawings, and tables to illustrate the work that he subsequently described. His presentation followed very closely the information present in their Progress Letter No. 18, dated March 13, 1962, numbered MSAR 62-23. Dr. Werner related that the thermal shock work has been stopped by the AEC, that there have been meetings between MSAR and GE for the purpose of correlating the two contracts under this program, and that subsequent progress reports will contain more actual test data.

Mr. Dwyer of BNL then made a presentation on the Measurement of Heat Transfer Rate to Alkali Metals Flowing Through Rod Bundles, and distributed to those present a paper with this title, dated February 27, 1962. He briefly mentioned discussions that he had with Russians at an international symposium on heat transfer held last January, and how there seems to be very close correlation between the Russian and the USA data. Mr. Dwyer felt that theory of heat transfer will very likely outrun experimental

data for a considerable length of time, and illustrated this opinion by writing a few equations on the blackboard and pointing out the amount of work necessary in order to prove out the theoretical equations.

Mr. Billuris of GE then made the presentation on the Mass Transfer Investigations in Liquid Metal Systems at Temperatures up to 1300°F. By means of slides, he covered the subjects of: objectives and specifications, schematic diagrams, component part design, test results, and a proposed program for FY 1963 and 1964. The experimental determination of Mass Transfer and corrosion of steel systems containing sodium and operating at a maximum temperature from 1000° to 1300°F are necessary to design a nuclear reactor heat transfer system utilizing these conditions. The use of higher temperature coolant systems will provide a plant with higher thermal efficiency.

The data and results obtained under this program are fundamental to other contractors of Sodium Components Development Program by providing improved materials and component designs. He stated that this information will also be beneficial to operators of reactors that are cooled with sodium but operating at lower temperatures such as the HNPF, Enrico Fermi Plant, the EBR-II, and test facilities at LASL.

Over 50,000 loop hours of operation had been completed on the six specially designed Mass Transfer test loops which were fabricated with five different combinations of type 316 SS, 2 1/4 Cr-1 Mo and 5 Cr-1/2 Mo-1/2 titanium alloy steels. All loops have been operated with 1200°F maximum and 700°F minimum temperature with sodium velocities from 1 to 30 ft/sec and oxygen impurity at 10 and at 50 ppm. Corrosion rate data and metallographic examinations have been obtained from over 600 samples. To date, two runs have been completed of a 5 run 1/2 replicate, two level test program for the three primary test condition variables (maximum temperature, delta T, and oxide level). The third run for each loop has been initiated.

Preliminary data indicate that none of the observed metallurgical changes are serious enough to eliminate from the program any of the materials tested. Corrosion rates from essentially 0 to about 1 mil/year have been observed. The available corrosion rate data have been analyzed by the statistical least squares multiple regression method. The corrosion in the increasing temperature regions of the test loops has consistently indicated a loss of material whereas all parts of the loop in the decreasing temperature zone have gained material. The corrosion rate is a function of material, temperature, oxide level, velocity, and downstream effect. The latter two items were not identified as being significant variables in previous tests below 1000°F. The downstream effect indicates an exponentially decreasing corrosion rate as one moves along the flow path in an isothermal region. Other variables such as time and temperature are not as significant or else data have not been obtained as yet. Two persistent conditions that have been observed with increasing time are the decrease of the oxygen level in the sodium and the increase in flow resistance or fouling.

Mr. Billuris felt that this program should continue into FY 1963 and 1964 to allow additional materials to be tested, to extend the statistical analysis, and to provide an opportunity to investigate other variables such as geometry, fouling, and the downstream phenomenon.

Mr. Steinmetz of UNC then made the presentation on low level oxide analysis. Since the corrosion rates in sodium are related to the oxygen content of the sodium, instruments for continuously monitoring the oxygen content of sodium are needed. The aim of this work is the development of an instrument based on an electrochemical principle for monitoring oxygen in the sodium. This instrument will attempt to be specific for oxygen and have improved sensitivity over existing instruments. The electrochemical oxygen monitor when developed could then be incorporated into liquid sodium systems. This could serve then as a supplement or replacement for plugging meters and chemical analysis. The test apparatus for demonstrating the feasibility of the method has been built. The tests performed as of this date have demonstrated a response of the electrochemical device to varying oxygen content in the sodium. Refinements are required in the details of the device and calibration against chemical analysis of the sodium. Further studies will be initiated on the effects of temperature and other impurities besides oxygen in the sodium.

Mr. Steinmetz proposed that this work continue into FY 1963 to allow complete tests on effects of impurities and temperature with the present research apparatus. This would be followed by design and fabrication of a breadboard model, and experiments with the model, which will develop the information needed for the design of a prototype unit. He proposed that this work then be extended into FY 1964 to allow the design, fabrication, and testing of an actual prototype unit that could be incorporated into a large sodium cooled reactor system.

Mr. Steinmetz of UNC then wrote an equation on the blackboard

$$E = E_0 - 10^{-4} T \log_{10} (\text{Na}_2\text{O})$$

and a diagram of this cell with sodium as one electrode and either copper oxide or nickel oxide as the other electrode. He then presented some very recent data obtained within the last few days that make this type of instrument look very encouraging. Mr. Dwyer offered the name of Mr. Bernhard, Schelten-Petterson of Ispra, Italy, who is doing work very similar to that of Mr. Steinmetz.

Mr. John Kissel of BMI then gave a presentation on friction and wear of sliding surfaces in sodium and in sodium environments through the use of approximately 25 slides. This program is to develop basic principles which may be applied to the selection and application of engineering materials for sliding conditions in liquid sodium. This type of information is needed in the design of liquid metal cooled components which have bearings for valves, control rod guides, seals, etc. operating submerged in liquid sodium.

Slow speed rubbing experiments were carried out between ball and plate specimens of the following materials: 304 SS, 2 1/4 Cr, nitrated steel, 52-100 steel, chromalized 52-100 steel, and stellite No. 6. These experiments provide coefficients of friction records between specimens exposed to argon environments, both dry and with sodium lubrication, and at temperatures ranging up to 1300°F. With one exception, the results indicated improved friction and wear characteristics resulting after a few drops of molten sodium had been added at the rubbing interface. Only stellite No. 6 demonstrated unstable and somewhat increasing friction with sodium. A new method of friction analysis, that of recording the oscillating decay rate between rubbing specimens, was successfully employed and this shows promise of providing direct evidence of surface film changes. Studies involved apparatus and techniques for measuring the rate of formation of sodium molybdate in systems containing sodium, molybdenum, and oxygen (as a contaminant).

Dr. Wensch then summarized the meeting and thanked those who had made presentations. He expressed the great concern of his management at Headquarters concerning the schedules for the steam generator and for the Sodium Components Test Installation, and the fact that the two schedules might not be closely matched because of delays in either one or the other of these projects. He also expressed concern over the fact that some of the contractors expressed the opinion that they were not getting all the progress reports and information from all of the other contractors, and that an improvement should be made in the exchange of information and reports.

Meeting was then adjourned at 5:30 P.M.

Place: 1717 H Street, Washington, D.C., Room 1146

Date - Time: March 22, 1962, 9:00 A.M.

Subject: WASHINGTON REVIEW WORKING GROUP MEETING

Present:

C. A. Barrett	NASA-Lewis	Cleveland, Ohio
J. P. DeKany	USAEC	Canoga Park, California
R. W. Dickinson	AI	Canoga Park, California
A. G. Fremling	USAEC	CH
K. Goldmann	UNC	White Plains, New York
W. J. Hallett	AI	Canoga Park, California
R. E. Harris	USAEC	HQ
T. P. Heckman (Sec.)	USAEC	CH
J. P. Holliday	USAEC	SAN
R. W. Lockhart	GE (APED)	San Jose, California
W. B. McDonald	ORNL	Oak Ridge, Tennessee
J. J. Morabito	APDA	Detroit, Michigan
S. G. Nordlinger	USAEC	HQ
G. V. Packer	USAEC	HQ

D. E. Pollock	USAEC	HQ
H. W. Savage	ORNL	Oak Ridge, Tennessee
W. R. Simmons	ANL	Argonne, Illinois
F. A. Smith	USAEC	CH
D. C. Thomas	USAEC	HQ
G. W. Wensch	USAEC	HQ
W. R. Wykoff	LASL	Los Alamos, New Mexico

Dr. Wensch welcomed the members of the Working Group and the field office members of the AEC to this Washington Review Meeting of the Working Group. He gave a very brief history of the Sodium Components Development Program and an outline of his understanding of Chicago Operations Office's plans for the next few years. Since a formal agenda had not been prepared and distributed, the next ten minutes were devoted to preparing an agenda that would bring out the thoughts and questions from the minds of all the participating members. The suggested items included the following:

- a. A summary of the March 20 Ad Hoc Committee Meeting on Carbon Analysis.
- b. The present need for a new edition of a Liquid Metals Handbook.
- c. The role of the Working Group in relation to Mr. Nordlinger's Branch.
- d. The current ideas of the AEC in regard to funding for the Sodium Components Development Program.
- e. The AEC's plans for a new steam generator.
- f. The AEC's purpose and goals for the Sodium Components Development Program.
- g. R&D items that fit within the Sodium Components Development Program charter that need attention in the immediate future, such as larger pumps, larger diameter piping systems (30" diameter), and shell side heat transfer work and its relation to Mr. Dwyer's project at BNL.
- h. An AEC statement to establish the role of the subcommittees.
- i. The most pressing current problems existing within the Working Group members' organizations.
- j. A review of the Working Group minutes of meeting No. 27.

Dr. Wensch then undertook to explain the role of the Sodium Components Development Program within the AEC structure. He related how this program, and its membership, originated as an advisory group to the total sodium reactor industry. He pointed up several cases of either misunderstanding or abuse of this advisory capacity, and emphasized to all those present that the Working Group was at no time to advise the contractors

directly or to give direction to their work. The responsibility for directing the contractors rests strictly with the AEC. He then drew an organization diagram on the blackboard as follows:

Dr. Wensch stated that both verbal and written comments have been received from the contractors implying that the Working Group has been directing their efforts. He felt that the legal procedures for conducting business as outlined in the AEC manual should be observed at all times. These included invitations by the AEC to industry to submit bids for doing work. However, it is proper for the Working Group as an advisory technical group to help establish specifications prior to the invitation for bids and to review the technical proposals presented by industry. However, the actual selection of the contractors remains strictly an AEC function.

Mr. Dickinson of AI then presented his case wherein at times he acts in three capacities as follows: one, as a Working Group member; two, as a Sodium Components Development Program contractor; and three, as a sodium graphite reactor contractor. There are times when these three capacities cause administrative uncertainties and cause delays in meeting certain project schedules. In general, the work being done under the Sodium Components Development Program moves much too slowly to be relied upon to supply data in answer to a specific problem for a closely scheduled project.

Mr. Harris, DRD, then asked the question: Is the Working Group reviewing the contractor's work in too great a detail? This resulted in a general open discussion involving most of those members present which can be summarized as follows: Sometime, the Working Group's comments do tend to redirect the original work scope. At an open meeting when the contractors are making a presentation, the contractor should not be openly criticized or embarrassed. A separate contractor-AEC meeting should give any redirection to the contractor's work. The Ad Hoc Groups attempt to limit their work to strictly technical problems and they do attempt to work very closely with contractor personnel to search out and improve the technical investigation. The meetings have maintained formality by having the subgroups chaired by an AEC employee and any summaries, redirection, or comments coming to the contractor from the chairman. Mr Harris then summarized this discussion by stating that the Sodium Components Development Program has not had many new starts of new work within the last one and one-half years. Rather, the work has been one of looking in greater detail at the things that are basic rather than at the hardware or components. He thought that the program should be either renamed, or redirected in the future to move more toward the hardware type of effort.

Mr. Savage, ORNL, then expressed an opinion that a more definitive list of the problems, and the schedules at which the work should be done, should be prepared by the AEC to focus attention on these problems. Mr. Packer then stated that Headquarters AEC is revising the Form 1025 which are broad program assumptions. These will be sent to Chicago for review, comment, and contribution in the very near future.

Mr. Simmons, ANL, then stated that more emphasis should be placed on the word "economics" in arriving at working specifications of a steam generator.

Mr. Morabito, APDA, then commented that conventional utilities are always attempting to reach higher levels of performance, but are ruled by economics on the actual design of large plants.

Mr. Dickinson of AI then stated that sodium cooled reactors may be greatly different from conventional utility plants. The present feeling within AI is that the steam conditions should be 3500 psi and 950°/950° F. He also felt that approaching a particular problem from different directions would very likely result in differing answers.

Dr. Wensch then stated that DRD will support any study of economics of sodium graphite reactors and steam cycles as a part of the broad sodium cooled reactors program.

Mr. Nordlinger was then allowed the final hour of this meeting to explain the Components Branch of the AEC and how it hopes to help contribute to solving the problems within the Sodium Components Development Program, and how the work at BMI and BNL that was presented the prior day does relate to this Program. The Components Branch attempts to work on

basic R&D work and avoiding the project type. He would like very much to have the Chicago Operations Office give technical direction to the work of Mr. Dwyer at BNL and Mr. Glaeser of BMI as part of the Sodium Components Development Program and he offered to have any of their reports properly distributed to the members of the Working Group.

In the absence of the permanent chairman, Mr. Nemzek, Mr. Fred Smith then offered to take these suggestions and offers into consideration.

The Working Group was then asked to express their comments and corrections on the minutes of the Working Group Meeting No. 27. The following corrections were made.

a. On page 8, under item 12, the second sentence should be changed from "This would require only two additional fatigue mandrels" to "This would require no additional fatigue mandrels."

b. On page 10, line 14, the word "inner" should be changed to "inert."

Mr. Goldmann of UNC then wished to correct the last paragraph of page 9 which stated that "The Chairman returned to the subject of shell side heat transfer. He requested that Mr. Kurt Goldmann act as technical co-ordinator to outline a complete program for the investigation of shell side heat transfer including the technique for the analysis of the resulting data." Mr. Goldmann did not recall this request being made of him and was of the opinion that Mr. Savage of ORNL had been the technical co-ordinator of a subgroup to investigate this work. Mr. Savage was not certain whether he was the technical co-ordinator for the shell side heat transfer work but, if he were at one time appointed, he wishes to resign. However, he agreed to continue to act as a member of the Shell Side Heat Transfer Ad Hoc Committee. Mr. Savage then summarized for the benefit of Dr. Wensch and Mr. Harris the past history of the shell side heat transfer project and briefly its relation to the BNL work now being performed by Mr. Dwyer.

Mr. Wykoff, LASL, then expressed the opinion that more, rather than less, work should be done under the Sodium Components Development Program. He was very thankful that this program had undertaken to pursue steam generator work rather than requiring LASL to do this. He did not, however, feel that it was necessary to be investigating large sizes of the 30 MW capacity.

A brief discussion of where and when to hold the next Working Group meeting tentatively selected Lewis Laboratories of NASA for May 23 and 24, 1962, subject to confirmation by Mr. Barrett.

Dr. Wensch then thanked all those Working Group members that were present and called the meeting adjourned.

Minutes of the Sodium Components Working Group

Meeting No. 29

June 5-6, 1962

NASA Lewis Research Center

Cleveland, Ohio

Present:	C. A. Pursel, Chairman	AEC-CH
	C. A. Barrett	NASA
	R. Cygan	AI
	W. A. Dupraw	Chemistry Unit
	J. E. Farmer	NASA-Lewis Advanced Development & Evaluation Division
	A. Ginsburg	NASA-Lewis Advanced Development & Evaluation Division
	K. Goldmann	UNC
	J. W. Graab	NASA-Lewis Analytical Chemistry Unit
	P. T. Hacker	NASA-Lewis Fluid System
	W. T. Hallet	AI
	R. E. Harris	AEC-DRD
	C. H. Hauser	NASA-Lewis Fluid System
	T. P. Heckman (sec)	AEC-CH
	I. R. Humphrey	LASL
	J. P. Lewis	NASA-Lewis Fluid System
	R. W. Lockhart	GE
	T. P. Moffitt	NASA-SEPO Lewis
	T. A. Moss	NASA-SEPO
	R. S. Norman	NASA-Lewis Advanced Development & Evaluation Division
	A. M. Nosek	NASA-Lewis Advanced Development & Evaluation Division
	L. Rosenblum	NASA-Lewis Materials Division
	H. W. Savage	ORNL
	W. R. Simmons	ANL
	F. A. Smith	AEC-CH
	W. L. Stewart	NASA-Lewis Fluid System
	J. Yevick	APDA

Mr. Pursel, temporary Chairman, called the meeting to order at 8:50 A. M., and welcomed the members of the Working Group, and visitors from NASA, to the 29th meeting of the Working Group of the Sodium Components Development Program. Mr. Pursel made a few introductory remarks and explained, for the NASA personnel, the purpose of the Sodium Components Program and the Working Group.

The agenda, dated May 18, 1962, and mailed to all those present, was closely adhered to. Mr Barrett made a few introductory remarks and then introduced the first NASA speaker, Mr. Rosenblum of the Liquid Metals Branch Materials and Structures Division. He first described the organization of NASA, and how it is divided into two parts, Research and Development. Under Development, is the Space Electrical Power Office which is presently involved in developing nuclear reactors for generating electrical power to be used in space vehicles, and on a full scale test facility for the SNAP-8 reactor. Under Research, the NASA effort is directed to basic items, giving assistance to the development work, and searching for new materials, new fuels, and new methods of control,

The work on space electric power systems was described by the means of several graphs and charts projected on a screen. The first one was entitled, "Space Power Requirements, Watts vs. Years", the second, "Estimated Specific Weights of Power Generator Systems", the third, "Schematic Piping System", and the fourth, was a comparative chart of pressure vs. temperature for the liquid metals, mercury,

cesium, rubidium, potassium, and sodium. Much of the present effort is on the determination of compatibility of structural materials to these liquid metal coolants, with the first investigation being done for mercury. Following mercury, the three most potential liquid metal coolants appear to be cesium, rubidium, and potassium. In contact with these selected coolants, cobalt base alloys will be tested in the boiling and superheating range through the use of capsule tests. Following the capsule test, the more promising materials will be tested in pumped loop tests in which the entire loop will be the corrosion sample. The proposed method for analyzing for oxygen in the liquid metal will be by radioactive tracer techniques. Sodium is also being investigated by a Mr. Saroff, who is investigating into the critical range of sodium vapor, estimated to be a temperature of 2500° to 2600°C at a pressure of 5000 to 10,000psi.

Mr. Stewart, of the Turbo-Drive Section, Fluid System Components Division, then presented a schematic of the power generation loop, using a direct condensation system. By means of slides, he described the present development work on a turbo pump and on the heat transfer unit.

Mr. Hacker then explained the development work being performed with their 100kw two phase flow loop. The first step of this effort will be to gain experience, to study the problems, and to do research on sodium vapors. The second step will involve a sodium turbine vapor loop. Several slides were projected, showing the schematic of the facility and the various problem areas, such as mechanical, instrumentation and process. The future plans for this loop are to install improved components, to make improved layouts, and to make improvements on the instrumentation.

Mr. Moffitt then explained the schematic power loop and the attempts to optimize or minimize the weight of the system. By means of graph, he illustrated the problem areas in an alkaline metal vapor turbine. The high temperature of the coolant will require a close analysis of the material selection, of the stresses, and of the mass transfer caused by the coolant. High thermal efficiency is essential; however, will be limited by the stress developed in the turbine blades, the aerodynamic design, and the effects of condensate on the turbine blades. For this reason, separate investigations will be made of the effects of erosion and corrosion by wet alkaline metal vapors. He then drew a temperature-entropy diagram on the blackboard to illustrate why they are working in the range of saturated vapors in the turbine. Although improved thermal efficiency might be obtained by including superheat and reheat in the cycle, the increased weight and complexity introduced may not justify the use of superheat or reheat.

Mr. Hauser then described the pumps for the liquid metal loops and the problems that are now being investigated. The main problem, at this time, is cavitation of the saturated liquid; and at the Lewis Research Center, both theoretical and experimental evaluations, plus experimental studies are being performed. A subcontract for basic studies of cavitation has been given to the University of Michigan, and another subcontract for the design and experimental evaluation of electro-magnetic pumps has been given to Electric Metals, Inc. The pump research facility will be capable of testing sodium pumps at low pressure, sodium pumps at high pressure, jet assisted centrifugal pumps, and a water tunnel for studying the simulated sodium condition by the use of water.

Mr. Lewis then described the problems associated with mechanical parts in a boiling liquid metal system. Since a space vehicle must operate from one to two years, unattended, all mechanical parts, such as bearings and seals, must be thoroughly proven out in a mockup or simulated situation. A schematic diagram of the system was presented, and the various trouble points involving seals and bearings were described.

Mr. Nosek discussed the heat rejection system for the space vehicle. This system will be required to reject, by radiation, approximately 80% of all heat

generated. Since the reactor will be started after the vehicle is put into orbit by chemical means, the heat rejection system will be in a folded position for take-off; it must be capable of unfolding, and protected against meteorite puncturing while keeping the entire weight to a minimum. A simulated liquid metal radiator condenser test facility was shown wherein simulated startup, and other problems, will be performed using water.

Mr. Farmer presented the support development work for the SNAP-8 vehicle. Atomics International has the responsibility for developing the power plant under a contract with the AEC, and will utilize Na-K in the reactor. Aerojet General will develop the power conversion unit, under a contract with NASA, and will utilize mercury in the turbine. Slides were projected showing the SNAP-8 simulated system and the test facility which was adapted into an existing wind tunnel.

Mr. Norman then presented the test facility for the simulated space testing of the SNAP-8 vehicle, to be located at Plum Brook Center in Sandusky, Ohio. This facility will simulate actual space conditions for the SNAP-8 reactor in larger vehicles. The environment will allow testing at temperatures as low as -320°F , pressures of 10^3 to 10^{-8} millimeters of mercury, and sun radiation from a point source. This facility will also allow testing for a very short time, the chemical powered takeoff of the vehicles. This facility will be supplied with shielding to allow the actual testing of nuclear reactors at a later date. Funds of \$25,000,000 have been authorized for the initial test work, and the facility for this initial testing is scheduled for 1966. A sketch of this proposed space propulsion facility is as follows:

Mr. Moss then presented some of the work that the Space Electric Power Office is performing; and, by the means of four slides, showed the SNAP-8 system diagram. A pictorial view of the finished vehicle, diagrams of subsystems and the components facility status, also a loop test being performed by Aerojet General. Considerable work is being done on mass transfer and corrosion of materials subjected to high temperature liquid metals. The greatest concern in regards to mass transfer and corrosion is the accumulation of the crud in sensitive locations of the flow system, which could cause a reduction or blockage of the flow. Contracts will eventually be let on such vehicles as SNAP-8, SNAP-50 or 60, and the Sunflower Project. Some of the existing contracts are as follows:

<u>Contract No.</u>	<u>Contractor</u>	<u>Subject</u>
NAS5-417	AGN	SNAP-8
NAS3-1925	AGN	Mercury Loop
5-462	TRW	Sunflower
5-681	GE-FPLD	Liquid Metal Heat Transfer
5-1143	GE-FPLD	Potassium Turbine
5-2111	GE-FPLD	Journal Bearing Development
	TRW	Wetting of Mercury
5-1253	GA	Carbide Cathodes for TI
5-828	GE-MSVD	TES
3-2140	GE-FPLD	AS-55
5-1234	WE	Alternator Design
3-1929	NB Associates	High Voltage Gun
NTF-92	NRL	Physical Properties of Sodium
3-584	BMI	Physical Properties of Potassium
W-104	P&W	Emissivity Studies

The NRL contract, with work being done by Mr. Solomon Weiss, was described in more detail. The specific heat of sodium in the range of 1500° to 2200° will be investigated. A PVT diagram will be developed, the density and the viscosity will be investigated at higher temperature ranges. The solubility of Columbium and Zirconium in sodium will be more thoroughly investigated, as well as the surface tension at higher temperatures. The BMI contract will investigate, in the range of 1500° to 2200°F, the specific heat of potassium, establish a PVT diagram, investigate the thermal conductivity and the viscosity of potassium. For further details, and for copies of progress reports by the above contractors, Mr. Henry Sloan of NASA should be contacted. This completed the presentations by the NASA scientists; and, following a break, the Working Group then continued with their portion of the agenda.

Mr. Heckman gave a brief summary of the March meeting of the Carbon Analysis AD-HOC Committee, followed by Mr. Lockhart, GE, who reviewed report #1 of the subcommittee dated June, 1962, and the conclusions of the March meeting. Several members then commented on the necessity for an improved technique and method of analysis for carbon in sodium. Mr. Hallett, AI, described some of the problems of carbon in the SRE and their attempts to both measure and remove the carbon from the primary sodium. Mr. Harris suggested that, under specification 2, set 2, the container used for the addition of carbon be closely weighed before adding the carbon, also after exposure to the sodium after the sodium had been removed from the container. Mr. Yevick, APDA, then described some of the experiences that they were having with the Fermi Reactor. This reactor has approximately 65,000 sq. ft. of stainless steel surface in the primary system. The Ledoux Company is under contract to PRDC for doing the carbon analysis of the sodium for the Fermi Reactor. Mr. Yevick did not have the details of the analysis with him; however, he stated that there is no positive indication that the Fermi Reactor primary tank stainless steel has experienced any carburization.

Mr. Pursel then stated that he would accept the AD-HOC committee report for the Working Group, that the AEC would send copies of this report to various organizations that would be willing to perform analysis of prepared samples asking for their comments; and following receipt of the comments, the AEC would then arrange for the preparation of samples and the delivery of samples to the participants.

Mr. Smith, AEC-CH, then reviewed the status of the Alco Products, Inc. work on the intermediate heat exchanger and steam generator. He had recently visited the Dunkirk, New York, plant of this company, and described the situation as he saw it at the plant; both in regards to the assembly of these components and the management situation. The bimetallic tubes for the steam generator are still being developed, and the Superior Tube Company does not wish to accept an order until they are assured of receipt of qualified billets from the Allegheny Ludlum Company. The estimated schedule, as of the first part of June, for these tubes, was eleven weeks for Allegheny Ludlum to prepare the starting material, and a subsequent six weeks by Superior Tube to draw the material into tubes. If Alco Products were allowed to continue the fabrication of the steam generator in their factory, this unit would be shipped by approximately March, 1963. Atomics International has made available an employee, to report to CPAO, to act as inspector of the steam generator in the fabricator's factory. Atomics International and Alco Products has had two meetings since the last Working Group meeting to discuss the test program for these particular units.

Mr. Cygan, AI, then discussed the status of the SCTI. AI has sent a letter to the AEC recommending that the Alco Products Company Steam Generator Test Program be accepted. Following discussions with Alco Products, he was of the opinion that strain gauges should be included in the units. Further discussions between Alco and AI, concerning the detail of strain gauges, will continue. The first tests of the Alco units will be for the purpose of checking their guaranteed performance for balanced load, and then for unbalanced loads. The subsequent tests will check the units for balanced load and reduced flows, starting at 100% flow and going down in steps of 20%. Overload tests will be performed with balanced loads, starting at 105% design capability and going up to 125%. Since the original calculations of the heat transfer for the steam generator were made with single wall tubes, these calculations will be redone, taking into consideration the thicker wall of the bimetallic tubes. Prior to loading the steam generator with sodium, this unit will be heated up and checked out at 350°F, using hot water. AI is at present studying the stratification problem to verify that any trouble, if encountered, will be in the shell side of the heat exchanger. Additional testing of the steam generator unit will be under lower temperature conditions starting at normal conditions, and reducing the temperature until wet steam will exit from the unit. The present plan will be to test the steam generator starting at 2200 psi, then going down to 1800, 1400, and 1000 psi. Transient tests will also be performed on both the combined units, and on the individual IHX and steam generator. At present, there is no heat dump installed in the facility for testing the IHX alone. Before such a heat dump can be estimated, or bids obtained, AI will need to know from the AEC the minimum operating temperature and the minimum load that the units will be subjected to. Mr. Cygan estimated that, if the minimum temperature were 700°F, the cost for an air cooled heat exchanger dump would be approximately \$200,000. All of the equipment bid packages for the SCTI have been completed or sent to the AEC for review. The piping contractor will start in July, and the modifications to the primary and secondary pumps for meeting the recommended differential pressures of the system will all be scheduled for a November 1962 completion. Construction, with the exception of the control panel, which is scheduled for November delivery, will be complete by the end of November 1962. The checkouts of the complete SCTI, less the test units, is now scheduled for January 1963. This presentation was concluded by showing five slides of the present status of the construction.

Mr. Pursel then reviewed the recent activities within the AEC for obtaining a new steam generator to be tested in the SCTI following the Alco unit. The Contractor Selection Board, made up of members from the Chicago Operations Office and one member from Headquarters, has been announced, and the first meeting of the board will be June 7, 1962. At a later date, an invitation to industry for proposals will be sent out, together with a public announcement. Following the receipt of proposals, the selection board will review and evaluate the proposals and make a recommendation to the manager of Chicago Operations Office for the selection of a contractor to perform this work. The invitation to industry requesting proposals will include the performance specifications and limitations of the SCTI.

A general discussion was then held regarding the need for an air cooled dump for the SCTI to allow separate testing of heat exchangers. The general consensus of opinion was that a separate heat dump was needed. The Chairman summarized the discussion by saying that Chicago Operations Office will ask AI to submit their recommendations to the AEC for the inclusion of an air cooled heat dump. He also mentioned that AI has been requested to put the scheduling of the SCTI construction and operation in a PERT format. This discussion also brought up the need for additional work on the solubility of metals in sodium. Mr. Heckman then offered the information, obtained at the BNL eleventh annual AEC corrosion meeting held at BNL May 22-25, 1962, that BNL is now doing this type of work using mercury, with the intention of investigating the solubility of metals in other alkali metals at a later date. The equipment for performing the solubility tests are described in TID-7626, page 29.

Mr. Smith presented a film produced by the Du Pont Company on the subject of corrosion of type 316 stainless steel.

Mr. Goldmann, UNC, reviewed the second annual heat transfer meeting, held at BNL May 17-18, 1962, which he attended. The proceedings of the first heat transfer meeting are included in ANL-6507. BNL has undertaken to publish a bimonthly report on heat transfer which will start in 1962. One of the papers reviewed by Mr. Goldmann pointed out that the heat transfer co-efficients for the pot boiling of liquid metals may not be any superior to the heat transfer co-efficients for water under pot boiling.

Mr. Savage, ORNL, reviewed the trip report of the 1962 Fast Reactor Team that visited Europe. This team was led by Dr. Wensch, DRD, and included five members from ANL, one member from ORNL, and one member from GE. This was the fourth trip under an exchange agreement between the USA, the UK, and France. The complete trip report, WASH-1036, is classified confidential. Mr. Savage offered a few personal unclassified comments as follows:

The UK has a renewed interest in fast reactors for the purpose of burning the plutonium that will be made in the thermal reactors, with a target date of 1970 for large scale operating fast reactors. The Dounreay reactor is very badly contaminated with oxygen, and the scientists at this installation are fully occupied with the problems of trying to make the reactor run, with little time allowed for doing basic R&D work.

Mr. Humphreys, LASL, offered the information that most of the scientists in England who are working with sodium seem to be satisfied with the distillation technique for the determination of oxygen in sodium. They have extended the solubility curves for oxygen-in-sodium to both the high and low ranges, and appear to get very good reproducibility of their data.

MINUTES OF THE MEETING OF JUNE 6, 1962

Place: NASA Cleveland Ohio Administration Building

Subject: WORKING GROUP MEETING

Present:	C. A. Pursel - Chairman	AEC-CH
	C. A. Barrett	NASA
	R. Cygan	AI
	K. Goldmann	UNC
	W. T. Hallett	AI
	R. E. Harris	AEC-HQ
	T. P. Heckman (sec)	AEC-CH
	J. R. Humphreys	LASL
	R. W. Lockhart	GE
	H. W. Savage	ORNL
	W. R. Simmons	ANL
	F. A. Smith	AEC-CH
	J. Yevick	APDA

The Chairman, Mr. Pursel, opened this members-only Working Group meeting, and turned to item one on the agenda. Announcements and instructions were given by Mr. Barrett regarding transportation, and the tour of the Lewis Research Laboratories for the afternoon.

In turn, the members were then called upon to give the latest status on liquid metal work at each of the member's organization, and to relate any recent experiences that would indicate a need for attention under the Sodium Components Development Program.

Mr. Goldmann, UNC, then described the current status of the continuous oxygen monitor being developed by Mr. Steinmetz at UNC. Following tests with this meter up to 900°F, when the meter had ceased to function, the electrodes were withdrawn and examined. The zirconium oxide electrode presented a black appearance on the surface. The development work of this meter is continuing. UNC is not doing any work on developing a solubility curve for oxygen in sodium, nor are they continuing work on an absolute technique for the determination of oxygen in sodium. Mr. Goldmann expressed the opinion that this work is very important and would be a contribution to the whole field of sodium technology and should be continued. Mr. Pursel replied that he will take up these subjects with other people within the AEC and give a definite answer to UNC concerning whether the works will be supported by the AEC. Mr. Goldmann continued by describing the work that UNC is doing on the subject of fast reactor safety which includes coolant studies under transient conditions. The sequence of events, starting with a power surge, are being closely analyzed for generalized cases for both the fluid and the heat flow of two-phase conditions. Also included will be physics and doppler effects during such a power transient. These studies will be covered by a UNC unclassified typical reports. UNC is also performing some in-house work, under John McKee. He is extending the earlier corrosion studies with sodium, to include potassium in the range of 1200° to 1600° F. The two sodium loops where this earlier work was done are still in existence and in good condition. Specimens will be withdrawn from the loop every 500 hours during a test that will be run for a period of several thousand hours.

Mr. Yevick, APDA, then described the work being done on the resistivity meter supplied by the UK. This meter has given very reproducible results down to levels of 10 ppm of oxygen in sodium. This meter appears to be very sensitive and will allow extrapolation of the data down to zero ppm of oxygen in sodium. Mr. Yevick expressed the opinion that every nuclear reactor plant will have a sampling and analytical laboratory as part of the plant. He felt that the techniques and equipment being developed by UNC for the analysis of oxygen in sodium might be rather costly to include in a reactor plant as standard equipment. He then described some of the problems and status of the Fermi reactor.

The sticking of the dummy fuel assemblies in the reactor core is now thought to be related to the nitriding of the mated metal surfaces of the subassembly, and of the lower grid plate. The sodium level in the primary tank will be lowered to a point where these surfaces can be examined. The temperature will be lowered, and personnel in special protective clothing with special breathing apparatus will enter the primary tank to make an examination. The first hot trap, which was filled with stainless steel foil, operated at 1200°F for approximately 1000 hours, has been removed and is now being taken apart and analyzed. Dependent upon this analysis, a second hot trap may be installed.

The badly damaged steam generator is now in the fabricators shop, and is being completely retubed with 1200 tubes. The two steam generators now installed at the reactor site will be heat treated in place. By September or October, 1962, all three steam generators will be in place and operating, according to the present schedule. Several problems that are now under study by APDA are as follows:

- a. How to detect a leak in the sodium heated steam generator
- b. How to inspect mechanical parts under sodium
- c. How to readily detect fission products in the primary sodium
- d. How to measure the flow through each fuel subassembly

He felt that many of the existing devices and procedures in the Fermi reactor are in need of improvement; such as, the level indicators, a hydrogen detector, and the procedures for cleaning sodium from components after they have been withdrawn from the sodium system.

Mr. Savage, ORNL, then described the work now going on at Oak Ridge National Laboratory. Having just returned from the fast reactor team trip to Europe, he felt that all of the countries, and all of the sodium cooled reactor installations are having problems that are very similar in nature. The present ORNL liquid metals work is limited to potassium, for which data is beginning to accumulate in the range of 1600°-1800°F. Starting in fiscal year 1963, an investigation of the refractory metals containing boiling potassium will be started. At this time, one boiling pumped-loop of potassium has accumulated 750 operating hours. A second similar loop is in the fabrication stage and will be installed in a low-pressure vessel. All of this work is pointed towards a 500 kw reactor for space application.

Mr. Hallett, AI, then summarized the status of the HNPF. Both the primary and secondary systems have been filled with sodium and held at temperatures of 350°-500°F for cold trapping purposes. From the performance of the secondary pumps there appears to be a gas entrainment problem at greater than 60% design flow rate. This will be corrected by by-passing a present flow-through expansion tank. Discussions will be held with DL&R on June 8, concerning a license for performing a wet critical.

The SRE is presently shut down for the purpose of removing two moderator cans that apparently have failed; allowing sodium to enter into the graphite and causing the graphite to swell. The present schedule indicates that the reactor will be back in operation in July, 1962.

Unit 12, of the shell side heat transfer facility has been installed, together with instrumentation, and is ready to start operation.

The Westinghouse Electric Company flow controller was received in five boxes, plus manuals and reports. At this time AI is not prepared to answer the AEC request to evaluate this flow controller and make recommendations as to whether it should be tested or not. There followed an open discussion of the advantages

and disadvantages for performing tests on separate parts of the Westinghouse flow controller.

Under the subject of reactor safety, AI has performed absorption tests of certain fission products in sodium. The test performed with iodine indicates that approximately 98-1/2% of the iodine remained in the sodium. These studies will also investigate secondary effects in the event that sodium that contains absorbed fission products should leak out and either chemically react or burn. AI feels that the entire subject of sodium chemistry needs review and further work. This might include a basic study of the growth of sodium oxide crystals.

Mr. Hallett then discussed the AI studies of next generation reactors and scale up factors. They are considering reactors in the range of 750-1000 mw electrical, which will require pumps of the 60,000 gpm size, pipes of 30-40" diameter and a completely new type of flow meter. Dr. Dwyer of BNL, has been consultant concerning the shell side heat transfer work, with a tentative schedule for his visiting the AI facilities and discussing the program with AI during July.

Mr. Simmons, ANL, then described the present status of EBR-II. Corrective work to the reactor vessels is nearly complete, and the estimate is for July filling of the primary system with sodium. The secondary sodium system will be checked out independently of the primary system and is scheduled for filling with sodium during July. The steam system is nearly complete and will be ready for shake-down during this summer.

Mr. Humphreys, LASL, distributed to those present a two page summary of the status of liquid metal work within the LASL K division. This report covered the following subjects: LAMPRE, hot trap evaluation loop, instrumentation test loop, pit test assembly, steam generator evaluation, oxygen solubility loop, fission product control studies, solution getter studies, circulating fuels compatibility loops, and new work areas.

Mr. Lockhart, GE, distributed to the members present a five page summary of GE's sodium mass transfer project, which included the status of test loops as of May 31, 1962. The analysis of samples tested as of that time, the topical reports that are now being issued, and a list of proposed future work as follows: Geometrical effects on corrosion rate, flow rate analysis, air side corrosion, saturation of impurities in sodium as a function of temperature, and effect of surface and gross composition changes.

Mr. Pursel then brought to the attention of the Working Group the fact that ATR will have two positions in the reactor for the insertion of sodium cooled loops, and will be ready for operation in 1965. The members should be thinking of ways that these two sodium loops may be best utilized. Mr. Pursel then made a few general remarks concerning this Working Group meeting with a summary that more time might have been spent on results and data.

Following lunch, Mr. Barrett conducted the members of the Working Group on a tour of the NASA facility, visiting the following laboratories: The Liquid Metals Branch of the Materials and Structures Division, the Turbo Drive Section of the Fluid System Components Division, the SNAP-8 Support Development at Lewis Research Center, and the Space Heat Dissipation Mockup of the Space Electric Power Office.

The meeting and tour were adjourned at 4:30 P. M.

Minutes of the Sodium Components Working Group

Meeting No. 30

Oak Ridge National Laboratory

Oak Ridge, Tennessee

Present:

T. A. Nemzek, Chairman	AEC-CH
R. B. Abderhalden	BLH
R. Cygan	AI
J. H. DeVan	ORNL
D. A. Gardiner	ORNL
R. E. Harris	AEC-DRD
E. E. Hoffman	ORNL
R. H. Jones	AI
R. W. Lockhart	GE
R. E. MacPherson	ORNL
W. B. McDonald	ORNL
J. J. Morabito	APDA
P. S. Otten	BLH
H. W. Savage	ORNL
W. R. Simmons	ANL
F. A. Smith	AEC-CH
W. R. Wykoff	LASL
T. P. Heckman, Secretary	AEC-CH

The Chairman, Mr. Nemzek, opened the meeting by welcoming those present to this 30th meeting of the Working Group. He drew the Group's attention to the prepared agenda and requested that all speakers attempt to adhere closely to the time indicated on the agenda because of the large number of subjects to be covered. He announced that, if anyone cared to discuss specific subjects in more detail, arrangements can be made to stay over and visit ORNL on Friday. He then introduced Mr. Savage of ORNL who, in turn, welcomed the group, discussed travel arrangements, and distributed additional copies of the agenda. The Laboratory had arranged a dinner for the evening of October 10 for the Working Group and gave a list of names of ORNL personnel who would also be present.

J. C. Amos	ORNL
J. H. DeVan	ORNL
A. P. Fraas	ORNL
D. A. Gardiner	ORNL
G. Goldberg	ORNL
A. G. Grindell	ORNL
H. G. MacPherson	ORNL
R. E. MacPherson	ORNL
W. R. McDonald	ORNL
A. J. Miller	ORNL
P. G. Smith	ORNL
Dunlap Scott	ORNL
A. Taboada	ORNL
Jim White	ORNL
Gale Young	ORNL
D. Cope	AEC-OROO
W. I. Larkin	AEC-OROO

Mr. Cygan, AI, then presented the SCTI status report and test program. The engineering work is 95% complete at this time. One of the remaining items, the design of the rupture discs for the steam generator piping, is nearly complete. Mr. Cygan drew a sketch on the blackboard to illustrate where rupture discs are proposed at both the top and the bottom ends of the steam generator. In the event either disc should rupture, large tanks will be provided to capture the released steam and/or sodium. The Black Sivalls & Bryson, Inc. will design and supply the rupture discs. Installation of the fuel gas piping and control system for the sodium heater is 80% complete. The treated water storage tank and pumps have been installed together with the high pressure flash tank and the condenser cooling water piping which is 70% complete. Installation of instrument air piping and cable trays from the instrument lines and thermocouples is under way with approximately 15% completion. Modification of steam condenser water boxes is complete and the units are now installed. The analog computer work on the steam generator-feedwater control system has been completed and indicates that the extremely flexible system utilized for this installation is fully justified. A contract for the installation of sodium and inert gas system piping is now in effect. Delay in the delivery of several important items by suppliers such as valves is delaying the completion of this work. The supplier of the sodium preheater and the sodium cooler has moved the delivery of both of these items to about the first of February 1963.

A short discussion was then held among the members regarding the design and reliability of rupture discs and the problems associated with recovering from the rupturing of such a disc in this particular SCTI. Considerable efforts should be made to prevent inadvertent ruptures.

A brief discussion was held on the need in the test program of a separate sodium-to-air heat dump for the SCTI to allow independent testing of the intermediate heat exchanger. A recent AI letter outlining the limitations of the SCTI under different test conditions was circulated among the members present.

Mr. Cygan stated that the IHX can be installed in the SCTI at the time it is delivered. However, the system as a whole will not be complete until late March of 1963. Over-all construction as of this time is 50% complete, based on dollars expended.

Mr. Smith, AEC-CH, then gave the status of the steam generator and IHX work still under contract with Alco Products, Inc. The shop work on the IHX shell is complete and is ready to receive the tube bundle except for minor construction details. The upper tube sheet is in the machine shop with only the making of a radius on all tube holes still needed. The tube bundle is being fitted with its full length heat shields and will then be inserted into the shell. Upper and lower channel heads are in the process of final machining and will be attached to the tube sheets. After the shell and bundle are mated, the upper tube sheet will be put in place.

The welding development of the tube-to-tube sheet welds of the composite tubes to the Inconel overlaid tube sheets is being reviewed. The weld configuration which had been subjected to thermal shock tests developed some cracking. A new weld configuration appears to have considerable promise and Alco expects to have a formal weld procedure developed by the end of October.

Mr. Otten of BLH, formerly of Griscom-Russell, then reviewed the status of the steam generator fabrication. The BLH Corporation was awarded an AEC contract to complete certain portions of the steam generator work under the AEC-Alco contract. These portions included the completion of manufacturing and assembly of the steam generator and the erection and operation of the Alco test loop. Two shipments of manufactured parts have been shipped from Dunkirk, New York, to the BLH plant near Philadelphia, Pennsylvania, and the balance of parts together with drawings, calculations, and manuals is expected within the very near future. BLH was represented at a meeting in August among the AEC, AI, and Alco to resolve the final test program as proposed by Alco in their document APAE-122 titled "Test Program for 30 MW Prototype Sodium IHX and Steam Generator" to be performed in the SCTI at Santa Susana, California.

All material for the steam generator is on hand at either BLH or Alco with the exception of the tubing. The purchase order for the tubing was placed by Alco with the Superior Tube Company with a delivery promise of February 1963. The tube rounds, in turn, were ordered by the Superior Tube Company from the Allegheny-Ludlum Company.

The engineering drawings are complete; however, changes may be necessary for the location of the rupture disc nozzle and for additional instrumentation.

The agreement was made that the tubing will be bent into sine wave configuration and hydrotested at BLH with arrangements yet to be made for the use of the Alco dies and bending equipment. A firm delivery date for the steam generator has not been established by BLH. However, a critical path planning chart has been made except for time and exact dates. These dates and times will be established in the very near future; however, the entire plan will be dependent upon the delivery of satisfactory tubing.

An open discussion was then held among the members regarding the subject of performing ultrasonic tests on bimetallic tubing and also on the subject of stress calculations that may have been made by Professor Sayre, consultant to Alco Products, regarding the rupture strength of various sections of the steam generator.

Mr. Nemzek then reviewed the status of the second steam generator and the invitation to bid package that was mailed to industry on August 20, 1962. Mr. Nemzek asked that all persons at this meeting who represented companies that intended to propose in response to this invitation please excuse themselves for the balance of the morning's presentation. At this time Messrs. Otten and Abderhalden of BLH and Messrs. Jones and Cygan of AI departed. Mr. Nemzek then continued by mentioning that a Contractor Selection Board had been appointed by the Manager of the Chicago Operations Office to prepare an invitation package for a second steam generator of a 1000 MW size plus a 30 MW prototype that would include specifications and a model contract. A press release was also made at this time to inform those companies who did not receive an invitation directly. Copies of this invitation to propose were sent to those Working Group members only who did not represent companies that received an invitation directly to propose. Following the direct mailing and the press release, a pre-proposal conference was held September 20, 1962, at ANL to answer questions for all interested companies. The meeting then adjourned for lunch.

Following lunch, Mr. Simmons of ANL gave a brief status report on the EBR-II and related research and development. He distributed to those present portions of the ANL monthly progress letter for the month of August 1962 which contained several drawings and a detailed description of the difficulties that ANL was having at this time with the large rotating seals that are part of the rotating shield plugs. This problem has set the schedule back at least three months. However, the necessary corrections are nearly complete and retesting of the various working parts will be initiated and repeated within a few weeks.

Mr. Wykoff of LASL then gave a summary of the LAMPRE-I work and the related research and development. Early in 1962, a new core made of new materials was installed in the LAMPRE. This core ran for about 2,000 hours accumulating a total reactor power of 40 MWD. During one of the operating tests, a loss of reactivity of approximately \$1.00 over the time period of one hour was noted which was conjectured to be caused by a leaking fuel capsule. The reactor was shut down and a search was made for a defective capsule. This fuel capsule has been removed and examined and a hole was noted approximately one-third of the way down from the liquid level in the capsule which allowed approximately 75 grams of the plutonium iron eutectic fuel to leak into the sodium coolant. Mr. Wykoff then drew a diagram on the blackboard illustrating the design of the fuel capsule together with the reactor inlet and outlet temperatures of 460° and 610°C respectively. This reactor has a very serious flow pattern and he estimated that the defect was caused by overheating of this particular capsule. He then reported on a very strange phenomenon that occurs randomly among the seven thermocouples in the LAMPRE-I, wherein a temperature flop of approximately 30°C continues to occur without any easily rationalized reason. He stated that LASL has considered all credible and incredible causes for this temperature flop without any success as of this time.

Mr. Wykoff then described the metallurgical examination of material used in a small circulating sodium loop wherein sodium peroxide was added by the use of a "teabag" after 9,000 hours of exposure at a temperature of 1050°F. The type 316 SS tubing of .050" wall thickness was sectioned and examined metallurgically. Photographs of the metallurgical samples were passed among those present. The LASL metallurgists interpreted these specimens as showing severe intergranular corrosion completely through the structure and advised against the use of type 316 steel for this application.

Mr. Morabito of APDA then reported on the status of the EFR and the related research and development. The various rework and modifications necessary for the EFR are on schedule and a license to operate the reactor will be applied for in late 1962. By the means of sketches drawn on the blackboard, he described in some detail the cause of the damage done to the offset handling mechanism and to the holddown mechanism, and the modifications now under way to prevent a recurrence of these accidents. Photographs were passed among those present showing the cavitation caused to the lower core plate. Close examination of the sleeves between the two bottom core plates showed extensive cavitation around five of the 159 holes. Stellite bushings are being inserted in the lower of the two bottom core plates for the purpose of preventing this cavitation. He then referred to a report on cavitation performed approximately ten years ago that estimated that sodium may be 20 times worse than water in causing cavitation under similar hydraulic situations.

Mr. Morabito then described the attempts made to clean up the sodium that was contaminated by the offgassing of the binder used to make the carbon blocks inserted in the top rotating shield plugs. Filters of different size openings down to five microns and the use of a hydroclone were not successful in removing large quantities of suspected carbon in the sodium. A hot trap similar in design to the one used on the SRE was operated at 1200°F without removing any appreciable carbon. The method of sampling the sodium has been changed to a simple glass thief. Analysis of the sodium taken in this manner showed only normal carbon present in the sodium which casts suspicion on the former method of sampling. APDA is also of the opinion that the cold trap removed much of the carbon that was noticed as a crust on the sodium shortly after the incident that released the carbon from the blocks in the rotating shield plug.

Mr. Jones of AI substituted for Mr. Dickinson who could not make this meeting and reported on the SRE and HNPF status and related research and development. AI has been preparing a report describing the cause of carbon being released into the sodium of the SRE and the subsequent work of removing and analyzing for this carbon in the sodium and in the materials of the primary loop of the SRE. He is of the opinion that this report will answer the questions submitted by the AEC and will relieve the concern over running the SRE at a higher temperature than 800°F.

The HNPF is now undergoing low power physics tests with 125 fuel subassemblies in place and 11 more to be inserted. All of the systems are operating satisfactorily except for a gas entrainment problem in the secondary sodium loop. One of the two cold traps used to clean up the sodium is known to be loaded and will be bypassed or removed. There is also some indication that some of the 2" vent lines have become plugged and must be opened up. A meeting with the ACRS is scheduled for January 1963 for review of the power operations up to 15% of full power prior to requesting a license to go to full power.

Mr. Lockhart of GE then reviewed the mass transfer status. The Ad Hoc Committee appointed by the Working Group for the review of this contract met with GE on September 19, 20, and 21. The first two days of this meeting consisted of presentations by GE of the accumulated loop history and test results as of September 1962. The third date was spent by the Ad Hoc Committee evaluating this presentation and preparing a report to be presented to the Working Group. At this time, Mr. Savage distributed draft copies of the part of the report titled "Conclusions and Suggestions" which is summarized as follows:

General Comments

- a. Carbon migration rates have been relatively high in 2½ Cr-1 Mo loops. In bimetallic 316 SS-2½ Cr loops, the transfer of carbon from the 2½ Cr-1 Mo material to the 316 SS makes the use of this combination questionable. In the case of monometallic 2½ Cr-1 Mo loops, decarburization has generally been observed at all loop positions above 1000°F. However, carburization is not felt to seriously affect the potential use of this material, particularly since loss of strength with temperature limits its use to about 1000°F.
- b. In bimetallic 316 SS-5 Cr loops, no significant carbon transfer has been observed in 2,800 hours. This combination is promising if austenitic

steel is required in the hot leg. However, fabrication difficulties exist with this air hardening 5-Cr material.

- c. In bimetallic loops of 316 SS-2½ Cr and 316 SS-5 Cr, mass transfer of substitutional constituents appears to proceed at about the same rate in both material combinations under the loop conditions tested so far.
- d. In monometallic ferritic systems, no great differences in corrosion behavior have yet been shown except that carbon is transferred from 2½ Cr-1 Mo steel and not from 5-Cr steel. Both appear to be equally satisfactory for sodium containment to their maximum allowable service temperatures. Fabrication difficulties with 5-Cr may limit the choice of this steel for some applications.
- e. Monometallic 316 SS systems appear satisfactory from the standpoint of both metallic and carbon transfer over the conditions investigated.

Specific Comments

- a. Carbon transfer effects are potentially the most serious because of the possible changes in mechanical properties of austenitic steels after excessive carburization.
- b. Metal transfer effects on mechanical properties appear relatively minor for normal cross sections although fuel cladding may be an exception. Effects of metal transfer on flow characteristics may be of greater significance.
- c. The empirical model has been studied with good success. Its use is probably restricted to interpolation within the specific system and condition study.
- d. The analytical model for some processes involved in mass transfer has been studied. Application of these processes to formulation of a system model still remains to be done.
- e. The empirical model appears to have great value in analyzing mass transfer effects in the particular GE loops, but the analytical model is potentially more useful since it can permit extrapolations to other systems and system conditions.
- f. The effect of oxygen is suspected to be a potent factor in mass transfer, but no direct evidence is available at this time because oxygen studies are not complete.

At this time, Mr. Heckman who acted as AEC Chairman for the Ad Hoc Committee expressed the AEC's thanks to the contractor and to the members of this particular committee for their contributions to this very important investigation. He made reference to the Eleventh Annual AEC Corrosion Symposium held May 23-25, 1962, at Brookhaven National Laboratory. At this symposium, reported in BNL-728, several papers were delivered in the attempt to relate test data to theoretical models such as "Fundamentals of Stress Corrosion Cracking" by H. H. Uhlig of MIT and "Stress Corrosion Cracking in Liquid Metals" by R. Rostoker of ARF.

Mr. Goldmann of UNC, who just arrived, then proceeded to give the status of the oxygen analysis work now under way at UNC by H. Steinmetz. Using the latest progress report UNC-5032, the results from the use of different materials for the cell and of different materials for the electrodes were presented. These data indicate that certain combinations of material are far more stable under different oxygen and temperature conditions than are other materials. Graphs of the latest test results were passed among the members present.

Mr. Heckman then made a presentation of the status of the physical properties of materials in sodium performed by MSA. He used the MSA Progress Report 19 to describe the background and program for the testing of representative specimens of type 316 SS austenitic and $2\frac{1}{4}$ Cr-1 Mo ferritic steel to compare the stress to rupture, creep, tensile, and fatigue strength of specimens of these two steels in 1200° and 1100° F sodium and also in air and helium atmospheres. A chart was drawn on the blackboard to show the number of samples of each type of steel that would be subjected to these four types of tests. The tests will be repeated for different degrees of purity of sodium. The first tests will be performed using "as is" reactor grade sodium. The second series will include a high level of carbon as a contaminant in the sodium, and subsequent tests may utilize contaminants such as high oxygen and a nitrogen atmosphere.

The latest results as reported in the MSA Progress Report 24 were summarized as follows:

The operation of Loop No. 1 was continuous except for three interruptions caused by failure of the electrical leads to immersion heaters and of a temperature controller. These interruptions resulted in 20° F drops for durations of 30 minutes in one pot, three hours in another pot, and four hours in a third pot.

A total of seven stainless steel specimens has been tested for failure in fatigue and, with the completion of the helium and air tests, curves can be drawn showing the relative effects of cyclic strain ranges and different test environments. The sixth and final stress rupture of stainless steel in air was still in progress. The results of these rupture tests conducted in sodium and air are in close agreement and are shown graphically with the drawing of curves planned for the next report. The present data for stainless steel creep tests indicate that creep rates in sodium may run three to four times higher than in air. However, any final conclusions are withheld until all the data have been processed and carefully studied.

For the $2\frac{1}{4}$ Cr-1 Mo specimens, the creep rates in sodium are also much higher than in air with only the 6,000 psi specimens comparable. Since this difference is so great, an extra 8,000 psi specimen has been started. The preliminary results for the Cr-Mo specimens under stress rupture tests also indicate that sodium has a definite effect on the stress rupture properties.

MSA is preparing a preliminary topical report summarizing all of the information in the progress reports up to and including September. This report should be available for distribution to the Working Group during the month of October.

Mr. Nemzek then asked those persons who were not members of the Working Group to please be excused. He then held a discussion concerning semiannual liquid metal information meetings and the future relations of the AEC and Working Group under the Sodium Components Development Program. He stated that certain working arrangements could be improved and is suggesting that semiannual information meetings be held in place of the more frequent Working Group meetings. For these information meetings, only participants in the program would attend. Informal drafts of information to be presented would be given to the Secretary at the meetings, and these together with information added at the meeting would form the basis for comprehensive minutes of the meeting. These minutes would be published and distributed for the benefit of nonparticipating parties. He also felt that many of the functions now performed by the Working Group would in the future be handled by Ad Hoc Committees. This would include the planning and evaluations that were performed by the Working Group during their first meetings. Many of the same individuals who are now on the Working Group and on the Ad Hoc Committee would be requested to participate in the future Ad Hoc groups to assure continuity of participants in the process of assistance to the AEC in review and planning.

Mr. Harris then stated that DRD had considered the status of the Working Group and basically agreed with CH and the program just outlined by Mr. Nemzek.

Mr. Nemzek then asked for any questions or comments that the Working Group members might wish to make. These comments can be summarized as follows:

- a. Concern was expressed that the change in method of operations would effectively eliminate this type of Working Group activity and have a similar effect on the desirable program now in effect.
- b. Ad Hoc groups would tend to lose the continuity maintained via the present Working Group.
- c. Activities of the Ad Hoc groups subjected to the general review of the Working Group tends to assure the objectivity of the Ad Hoc Groups.
- d. By agenda established by the AEC, the Working Group meetings have tended to become status review meetings rather than planning assistance to the AEC. The latter function was preferable.
- e. The Working Group concept was good and should be continued. More formal meetings would tend to decrease the interest of the participants.

Mr. Nemzek thanked all the members for their questions and comments and adjourned the meeting at 6 p.m.

Place: Y-12 Conference Room No. 118, Oak Ridge National Laboratory

Date: October 11, 1962

Present:

T. A. Nemzek, Chairman	AEC-CH
R. B. Abderhalden	BLH
C. A. Barrett	NASA
G. Goldberg	ORNL
K. Goldmann	UNC
R. H. Jones	AI
R. W. Lockhart	GE
J. J. Morabito	APDA
P. S. Otten	BLH
H. W. Savage	ORNL
W. R. Simmons	ANL
F. A. Smith	AEC-CH
W. R. Wykoff	LASL
T. P. Heckman, Secretary	AEC-CH

The Chairman, Mr. Nemzek, opened the meeting and turned to Mr. Savage for a discussion of the afternoon's tour and for travel arrangements for returning home after the meeting. Attached is a list of facilities toured.

Mr. Heckman then described the purpose and background of the second-round analysis for carbon in sodium. He summarized the first-round results compiled by Mr. Lockhart of GE which displayed widely divergent analytical results. Because of the disagreement in results, an Ad Hoc Committee was formed which held a meeting March 1962 in Washington, D. C., to establish the procedures and specifications for a second round. The AEC then requested AI to prepare the second-round specimens and invited a total of 17 organizations to participate in the analysis of these specimens which will be carefully prepared so as to have three different levels of carbon contained in the sodium. The latest estimates received from AI indicate that the specimens will be ready for shipment in December 1962. Mr. Jones, AI, then distributed to those present copies of drawings of the specimens and a schematic of the loop for preparing the specimens. He stated that AI had decided to fabricate a new loop for this specific purpose of preparing the sodium specimens. The design of the loop was complete. All materials have been ordered and fabrication is under way. The personnel in charge of designing the loop and producing the specimens are working closely with the analytical chemists to establish the procedures that will assure that all specimens will be uniform for three different carbon levels.

Mr. Jones, AI, then reviewed the status of the shell side heat transfer work being performed by AI. The test runs have been delayed by difficulties with various components. The original pump used in the loop developed bearing troubles and was replaced with an experimental helical flow passage electromagnetic pump. As recent as October 10, extensive intergranular corrosion was detected in the sodium-to-air cooler installed in this loop, and it must be replaced; this will delay the test program. The Chairman asked that AI make an attempt to examine this component and explain the corrosion that was detected.

Mr. Morabito, APDA, then reported on the status of the Blake meter test. With certain limitations on the temperature compensation and on velocity, this meter has operated satisfactorily. The original zero set point for temperature compensation was 560°F. APDA has made additional adjustments to the electrical circuitry to extend the flat point of the curve of temperature compensation to beyond $\pm 40^\circ\text{F}$. The results of the carbon contamination experiments which terminated on August 8 were inconclusive. The results of analysis of sodium samples taken from the surge tank on July 24 at maximum contamination as well as during subsequent cold trapping and filtering operations through August 8 were reported. The concentration of both elemental carbon and carbonate was reported as parts per million of carbon. Samples were filtered through a five micron metallic frit placed into the tip of the sample thief for the purpose of segregating solid particles of carbon entrained in the sodium loop.

Carbonate determinations were rational and consistent with solubility and examination of deposits on the filter frit showed them to be 90% carbonate and 10% metallic particles of 10 micron size. Carbon determinations were erratic, indicating that the solid phase carbon passing through the frit was not homogeneously distributed in the sodium. Until the problems of 2-phase contamination are resolved, calibration of the meter will not be possible. The final report on this resistivity loop project is scheduled for completion on October 15, 1962.

Mr. Jones, AI, then made a presentation on the status of the modular steam generator study. A drawing of the steam generator was mounted on the wall, and photographs of sections of the steam generator were passed around for inspection. The evaporator module will be constructed of 5-Cr steel in the shell and head and $2\frac{1}{2}$ Cr-1 Mo tubes. Each module will contain 37 tubes of 32' lengths. The superheater module will be of the same physical dimensions; however, it will be constructed of type 347 SS for a temperature of 1050°F and 3500 psi. Each module will be capable of generating from 8 to 10 MW(t) and will be incorporated into a design of a large plant of a 400 MW(e) capacity.

Mr. Barrett, NASA, then reviewed the status of liquid metal research and development work at NASA. The SNAP 8 system has undergone a major re-evaluation because of difficulties encountered with the original materials. Haynes type 25 will be eliminated because of the severe crud problem that was encountered with this material. NASA is attempting to find a material from which monometallic tubes can be constructed. At the same time, they are investigating bimetallic tubes wherein the 300 series stainless steels will be used on the outside with columbium-zirconium liners incorporated. Nuclear Metals is the only supplier of this type of tubing at this time, and they are having considerable difficulty in inspecting this type of tubing material. Whereas the present SNAP 8 work is utilizing mercury, advanced systems are being investigated which will utilize boiling potassium and possibly at a later date boiling sodium. A new type of tilting furnace is being designed and built for the capsule testing of materials in various environments at high temperature with emphasis on the refractory metals such as columbium base alloys, tantalum base alloys, and Cobalt base alloys. The National Laboratories and the Lewis Laboratory will be involved in the attempt to fabricate tubing from those materials that pass the capsule corrosion tests. The furnace will operate with a pressure of 10^{-6} mm of mercury and in the temperature range of boiling potassium and sodium. The electron beam welder that will be used for

fabricating large corrosion test loops is due for delivery at the Lewis Laboratory at this time.

Mr. Savage of ORNL then made a brief presentation summarizing the work of interest to the Working Group that is taking place at ORNL. These activities include the Molten Salt Reactor, the Gas Cooled Reactor, the High Flux Test Reactor for making of transuranic isotopes, consulting services on the Savannah Nuclear Ship, desalting of sea water by the means of large reactors, the Pebble Bed Reactor program which at the present time is in a deferred status, and supportive efforts such as development of pump components and materials.

Mr. MacPherson of ORNL then described the experimental work active in Building 9201-3 that would be visited later on a tour of this building. There was a total of 23 different tests being performed in this facility which were briefly described. A list of these test facilities is attached to these minutes.

Following the tour and lunch, the Working Group reassembled in Conference Room 9704-1 in the Y-12 area where the subject of space reactor experiments was covered in brief presentations by four ORNL scientists, Messrs. Fraas, Grindell, Hoffman, and Amos. Those people whose clearances did not include this category of information and tour access were excused (Messrs. Abderhalden, Otten, and Jones).

The Molten Salt Reactor was then reviewed by the four ORNL scientists. Mr. McDonald described the over-all project and then by means of slides illustrated the entire reactor complex and the various components that will be included in this reactor system.

Mr. Smith described the experiments being performed on centrifugal pumps for high temperature potassium.

Mr. Taboada covered the various materials that had been considered and detailed the properties of Inor-8 alloys that had been selected for the fabrication of the Molten Salt Reactor. He estimated the cost ratio of the various materials investigated as follows:

	<u>Dollar Ratio</u>
304	1
347	1.14
316	1.16
Inconel	1.86
Hastelloy-C	4.60
Inor-8	5.40

Mr. Scott then described the core of the MSRE and the provisions provided for the performance of remote maintenance.

Mr. McDonald then summarized the ORNL presentations by saying that the MSRE was for the purpose of demonstrating: (1) low cost of heat from a

nuclear reactor, (2) the ability to have direct fuel reprocessing, and (3) the lifetime of components subjected to this combination of fluorine salts. He concluded by saying that this type of reactor has the capability of becoming a breeder reactor.

The Working Group was then conducted on a tour of the Y-12 shops and the MSR installation by Mr. McDonald and the other ORNL scientists.

Meeting adjourned at 5:00 p.m.

Attachment:
List of Test Facilities at ORNL

TOUR

Engineering Facilities - 9201-3

<u>Facility</u>	<u>Engineer Present</u>
MSR Pump Test	P. G. Smith
Graphite Oxidation Loop	A. M. Smith
Forced Convection Loop	A. M. Smith
Rankine Cycle Loop	H. C. Young
Control Rod Drive Test Facility	W. F. Ferguson
Continental Compressor Test Facility	D. L. Gray
Bristol Siddeley Compressor Test Facility	D. L. Gray
PK Pump Test	P. G. Smith
Molten Salt Bearing Test	P. G. Smith
CRDT Compressor	I. K. Namba
HECT 2 Compressor Loop	W. R. Huntley
Vacuum Facility	J. C. Amos
Heater Tests	J. C. Amos
Boiling Potassium Compatibility Loops	J. C. Amos
Freon Loop	S. Kress
Potassium Bearing Test	H. C. Young
EGCR Dummy Flow Tests	R. E. Helms

Mechanical Joints	R. E. Helms
Water Mockup	C. H. Gabbard
Single Rod Heater Test	C. H. Gabbard
Jet Pump Test	L. W. Evers
Compressor Shop	W. F. Boudreau
Hydrogen Autoclaves (not observable for safety reasons)	

Minutes of the Sodium Components Working Group

Meeting No. 31

(Review Group No. 1)

May 13-14, 1963

AEC Headquarters

Washington, D.C.

Present:

May 13 and 14

Glen W. Wensch, AEC-DRD, Chairman
T. A. Nemzek, AEC-CH
F. A. Smith, AEC-CH
A. Fremling, AEC-CH
T. P. Heckman, AEC-CH
J. V. Levy, AEC-CPAO
C. W. Richards, AEC-CPAO
J. P. Holliday, AEC-SAN
Jules Wise, AEC-NY
R. E. Harris, AEC-DRD, Secretary
H. W. Savage, ORNL-Consultant
W. R. Wykoff, LASL-Consultant

May 14 only

W. R. Simmons, ANL-Consultant

The meeting was called to order by Dr. Wensch at 9:00 A.M. The first topic on the agenda was a discussion of the functions of the new Review Group and of the procedures which would be followed in the performance of those functions. The group was advised that changes in administration of the SCDP review procedures were made because the rapid growth pattern in the Commission's liquid metal cooled civilian reactor programs has made it necessary to bring other operations offices into the program to reinforce and assist Chicago Operations Office. Also, to remove any possible restraint on submission of proposals and avoid any shade of conflict of interest, contractor representation was eliminated from the review function; the former SCDP Working Group was reconstituted to eliminate industrial representation and to create a new review group, the SCDP Review Group, consisting of AEC employees and National Laboratory consultants only. As a matter of record, the membership of the new SCDP Review Group is:

Dr. Glen W. Wensch, DRD, Chairman
Reuben E. Harris, DRD, member

Fred A. Smith, CH, member
T. P. Heckman, CH, alternate
C. W. Richards, CFAO, member
J. P. Holliday, SAN, member
C. V. Backlund, SAN, alternate
Jules Wise, NY, member
Robert E. Behmer, NY, alternate
H. W. Savage, ORNL, consultant
W. R. Wykoff, LASL, consultant
W. R. Simmons, ANL, consultant

The chairman explained that future meetings will be of two types, e.g., meetings during which the SCDP work of each contractor will be reviewed and appraised by the SCDP Review Group and information meetings open to all contractors working in the liquid metal cooled reactor field. An informal atmosphere and active participation by attendees will be encouraged during all meetings.

In addition to maintaining cognizance over SCDP efforts through participation in the review meetings and study of reports, the SCDP Review Group will be concerned with developing plans for the system and component needs of the Commission's liquid metal cooled reactor programs. It is hoped that the members of the group will be alert for possible imbalance within the program and present recommendations concerning the correction of program deficiencies to the chairman. Informal discussion of such matters is encouraged at all times; formal recommendations should be routed to DRD through established channels of communication.

The routine business procedures for the SCDP will continue to be handled by the cognizant AEC Operations Office. Proposals covering new work will be submitted by the contractor to the appropriate Operations Office, which will evaluate the proposal and send recommendations to DRD. New work proposed by the national laboratories will be submitted via the standard project proposal route. In no case will new projects be initiated or the scope of existing projects be broadened without the written approval of DRD.

After several minutes of discussion, the decision was made to invite Brookhaven National Laboratory to designate a consultant to work with the group. Dr. Dwyer was specifically suggested as a qualified individual for position.

The chairman asked Mr. Nemzek if CH would continue to gather information and publish the monthly SCDP Coordination Report. Mr. Nemzek agreed that CH would do so. The chairman requested that more emphasis be given to causes and effects in the document.

During a discussion concerning the continued use of ad hoc committees, Mr. Nemzek asked whether the intent was that the SCDP Review Group would perform all evaluation in the SCDP program. Responding, Dr. Wensch stated that the operations offices will continue to be responsible for the detailed administration of individual SCDP projects, including independent evaluation. If the operations office desires to utilize ad hoc committees to assist in this evaluation, DRD has no objection so long as the committee is chaired by an AEC employee. It would be preferable for membership for such committees to be restricted to AEC and national laboratory employees.

Mr. Savage pointed out that among the advantages of ad hoc groups were that more specific, detailed program reviews could be made by expert personnel over a more adequate period of time and that such reviews yield more exact answers concerning whether program activities are proceeding according to plan and, also, whether the plan remains valid. As chairman of the ad hoc committee which has worked with the GE-Mass Transfer program, Mr. Savage stated that the GE program will need two more ad hoc reviews; one of these would occur during the fall of 1963 and the other during the spring of 1964. He also suggested strongly that membership of the committee be maintained without change during the two future reviews in order to maintain continuity. This point was reinforced by Mr. Richards.

It was agreed that the membership of present ad hoc committees would continue until the subject projects are completed, but that the membership of all future committees will be drawn from the AEC and national laboratories. Current ad hoc committees exist for the following programs:

1. GE-Mass Transfer
2. MSA-Mechanical Properties
3. AI-Shell Side Heat Transfer
4. Various participants-Carbon in Sodium

Mr. Holliday said that need for a future ad hoc committee might develop in conjunction with a program aligned toward standardization of analytical procedures for sodium.

United Nuclear Corporation
Continuous Oxide Meter
George Stern and H. Steinmetz

George Stern reviewed the history and objectives of the Continuous Oxide Meter program. To date, the most reliable electrode found is copper-copper oxide. UNC is continuing to search for an acceptable electrolyte. Notwithstanding the fact that a reference electrolyte has not been selected, UNC proposes to freeze design of the prototype cell design in July, based on copper-copper oxide electrode and probably ThY_2O_3 electrolyte.

Dr. Steinmetz reviewed the progress and problems to date in the program. An upper temperature limit of 500-600°F has been imposed on tests by the fact that the ZrCaO_2 electrolyte disintegrates at higher temperatures. Recently a loop (about 50 gallon sodium capacity) was put into service to investigate cell sensitivity to step changes in oxygen concentration and the effect of flow variation. Past observations have revealed that serious effects upon the response and sensitivity of the cell occur with the passage of time.

Recent efforts in the program have been aligned toward explaining the time-related change in cell response. The cause has not been

determined; the possibility that the ZrCaO_2 is slowly reacting with sodium at the 500°F operating temperature is being considered. Concurrently, UNC is investigating a different electrolyte, ThY_2O_3 , in an attempt to overcome the present unfavorable effect of time on cell response. One problem area which has been encountered in the ThY_2O_3 investigation is sealing the material to metal. Various sealing methods are being investigated.

A lengthy discussion of the technical features of the various cell combinations followed. Steinmetz concluded his presentation with a statement that the time delay effect on cell behavior appeared to take place during the first two weeks of service. On the basis of present data, the response of the cell after six weeks of service appears to be identical to cell response after two weeks of service. The difference between initial cell response and cell response at the end of two weeks is that after the two week soaking period the cell responds more slowly to a change in oxygen concentration and the voltage produced for a given oxygen concentration is lower.

In response to a direct question from the chairman concerning the value of continuing the program, Mr. Stern stated that UNC believes that freezing the design and proceeding with testing of prototype cells would produce meaningful data.

In closing, Mr. Stern told the group that UNC is preparing and will submit a proposal for development of a meter capable of continually measuring the carburization potential of a sodium system.

After the UNC representatives left the room, the chairman asked for opinions from the Review Group concerning continuation of the program. In general, the response from the group favored continuation of the work, with due recognition to the importance of developing the ability to

monitor sodium purity. Messrs. Holliday and Harris questioned going ahead with design and fabrication of a number of prototype cells until the theoretical aspects of the cell are more completely understood.

Atomic Power Development Associates
Resistivity Meter
John Morabito and Peter Lindsey

Mr. Lindsey stated in his opening comments that the Blake resistivity meter is sensitive to changes of 1 ppm of oxygen in sodium and that this oxygen concentration reading is obtained without penetrating the sodium system. The most significant problem associated with use of the device is that of temperature compensation. A change of 0.04°C produces the same effect on the output of the instrument as a change in oxygen concentration of 1 ppm.

The first phase of the program, which was to evaluate the meter as an oxide detection device, was completed in February 1963. This phase demonstrated that:

1. Changing the sodium pressure did not affect the meter output.
2. The meter is extremely sensitive to changes in temperature.
3. A flow rate effect was observed and was found to be related to heat transfer and heat dissipation characteristics of the meter at low flow rates and to cavitation effects at high flow rates. The useful flow rate range was found to be 3 to 7 gpm.
4. Varying the voltage caused objectionable drift. Constant voltage is required.
5. The meter was satisfactorily calibrated for oxide concentration.
6. Attempts to calibrate the meter for carbon concentration were unsuccessful, probably due to inability to dissolve enough carbon at sodium temperatures within the temperature range of the instrument.

Attempts to inject oxygen directly into the test loop were unsuccessful. The injection hardware always plugged or was destroyed by oxidation and corrosion.

Phase II of the program started in February. This phase will investigate the ability of the instrument to detect various contaminants in the system and will also develop an improved temperature compensation device for the meter.

The first test performed was a hydrogen injection run during which 4 cubic feet of hydrogen gas was injected directly into 1000 pounds of sodium circulating in the loop, upstream from the meter. Part of the hydrogen reacted with the sodium and part came out in the cover gas. The meter performed well.

An interesting observation was made during cleanup of the loop following the hydrogen injection run. After heating the loop to 800°F, with the expectation that the sodium hydride would dissociate at that temperature, the investigators found that only about 20% of the hydride followed the expected behavior pattern and broke down. It was necessary to remove most of the hydride in the cold trap.

A satisfactory temperature compensation modification has been completed and the modified instrument is working well.

The next step in the program will be to inject sodium hydride and various impurities and gases which have been found in contaminated sodium systems. Later sodium carbonate will be injected. Finally, in about September, water will be injected directly into the loop.

In conjunction with the work performed under this project, APDA has developed an instrument capable of detecting 2 ppm of hydrogen in cover gas.

Summarizing the results of the project to date, Mr. Morabito stated that the Blake resistivity meter has proven to be a reliable device for detection and measurement of contaminants in sodium; oxygen and hydrogen contaminants are detected almost instantaneously. The lower limit of sensitivity for oxygen appears to be about 10 ppm, but this limitation may be apparent rather than real since APDA had no accurate method for measuring oxide below 10 ppm. At low concentrations, the meter readings do not follow the predicted curve based on plugging meter results.

Mine Safety Appli-cance Research
Mechanical Properties in Sodium
R. C. Werner, J. W. Mausteller
R. C. Andrews, Fred Tepper

Dr. Werner briefly described the project history. He stated that the best definition of the program scope is presented in "Review Report No. 4 of the Material Subcommittee" (the pertinent ad hoc committee) dated January 25, 1963. Quoting from that document, the following information is presented for the record even though Dr. Werner did not discuss it in detail at the meeting:

"1.2 Purpose and Scope of MSA Program

The physical properties research program at MSAR was initiated for the purpose of determining the effects of reactor grade sodium, and normally anticipated contaminants, upon representative types of structural steels of interest for the construction of sodium systems. Type 316 stainless steel was selected as representative of the austenitic steels, and 2-1/4 Cr-1 Mo was selected as representative of the ferritic steels. The maximum temperatures selected were 1200°F for the austenitic and 1100°F for the ferritic. The contaminants to be intentionally introduced into the sodium after the reactor grade sodium tests were completed would be oxygen, carbon, and nitrogen. The types of tests selected for revealing any possible effects of the environments upon the materials were tensile, creep, stress-to-rupture, and fatigue. In addition to these physical tests, appropriate chemical analyses and metallurgical examinations were designated for assisting in the interpretation of the physical properties "

Mr. Andrews outlined the progress which has been made in the program to date. Pertinent figures and tables from progress report #31 were

distributed to the group and served as the basis for Mr. Andrews' presentation.

Dr. Mausteller discussed the analytical aspects of the project. MSA has been one of the participating organizations in the program for investigating analytical procedures for carbon in sodium. In the work which MSA is doing, the greatest analytical problem is that of determination of carbon in sodium. After outlining the method used for carbon determination, Dr. Mausteller said that MSA continues to note severe variation between the carbon content of sodium specimens and the analytical results obtained.

In response to a question from the group, Mausteller said that sodium samples are taken from the loops for analysis once or twice a week.

Fred Tepper discussed the metallurgical aspects of the MSA program. Samples from stressed and unstressed specimens are being examined for changes in grain size and differences in corrosion effects. Long exposure specimens will be subjected to microprobe inspection to investigate possible phase changes. In the fatigue test specimens, differences in mode of failure as a function of environment are being sought. Most of the metallurgical work to date has dealt with inspection of failed fatigue specimens.

One interesting observation which has come out of this work is that examination of 316 SS specimens pre-exposed to sodium, but water washed before fatigue testing, has revealed what appears to be stress corrosion cracking.

Dr. Wensch requested that future reports include a summary section. He also asked when the program was expected to be completed and was told that completion of the entire proposed program was scheduled in the spring of 1966.

Babcock & Wilcox Company
Steam Generator
Paul B. Probert & J. Schlichting

This was the first time that B&W representatives have appeared before an AEC review group since the contract was signed for conceptual design of a 1000 Mwt steam generator and design, development and fabrication of a 35 Mwt prototype unit for test. The contract was signed on April 3, 1963. Probert distributed copies of a list of design criteria, then discussed the importance of each criteria. A summary sheet evaluating seven different steam generator concepts against the criteria list was then distributed, and the group was informed that B&W selected an integral superheater steam generator design for their proposed and accepted design.

B&W has asked the AEC for permission to size the large unit design on the basis that three units can produce sufficient steam to generate 1000 Mwe. The thermal rating of each such unit will be 777 MW based on the efficiency associated with a 2400 psi/1050°F/1000°F steam cycle. B&W also asked for and received permission to change the steam pressure from 2200 psi to 2400 psi to match preferred steam turbine standards.

The specification for the steam generator was based on 600°F feedwater. B&W pointed out that this feedwater temperature would require a high pressure feedwater heater, which would be expensive. Discussion brought out that the 600°F temperature had been specified on the basis of reactor and sodium system considerations rather than steam cycle considerations, and that it, indeed, might be higher than desired from the steam cycle standpoint. B&W intends to perform an economic analysis to determine the effect of lowering the feedwater temperature to 530°F rather than 600°F. Following completion of the analysis, a recommendation will be made to the AEC.

The group was advised that B&W is comparing the data from MSA's "Mechanical Properties" project with existing data on the same materials in air and is attempting to extrapolate the MSA data to 30 year plant life.

The tubing for the Fermi steam generators was supplied by B&W. Based upon the type of failures which have occurred in the Fermi units, B&W is concerned about the destructive effect which a leak might have on the unit. The Alliance R&D Division of B&W is developing a program for investigation of this effect and will submit recommendations to the AEC.

Mr. Savage asked how long fabrication of a prototype unit would take after completion of design. Mr. Probert stated that 4 months would be required for procurement of materials and 9 months for fabrication - total time from design to completed hardware 13 months.

Alco Products, Inc.
Steam Generator & IHX
Roy Seifert & Robert Bennett
Note: Messrs P. S. Otten, R. Tidball,
and R. B. Abderhalden, representing
Baldwin-Lima-Hamilton Corp., were present
during the Alco presentation.

Mr. Seifert described the history of the project in detail. After describing the integral evaporator-superheater steam generator originally proposed by Alco, Seifert told the group of receiving instructions from the AEC, in September 1960, to shift to a different concept and proceed to design and fabricate a 30 MW prototype steam generator and IHX.

Fabrication of the IHX has been completed and the unit is now in place in the Sodium Components Test Facility at Santa Susana, California. In closing his presentation, Seifert showed a number of slides depicting various stages in fabrication and assembly of the IHX.

Mr. Bennett reviewed the current program at Alco for the group. Major design features of the steam generator were described. Under

existing arrangements, responsibility for fabrication of the steam generator has been assigned to Baldwin-Lima-Hamilton; Alco has the responsibility for procurement of all materials and parts for the unit and for completion of all related R&D except operation of the water side test loop.

Procurement of the special inconel-lined, 316 stainless steel tubing for the steam generator has encountered quality control difficulties. At present, Superior Tubing has 230 tubes which have been accepted and 60 more undergoing inspection. Allegheny-Ludlum has completed sufficient tube blanks to complete the order, but some of the blanks are imperfect. Only a few tubes, for use in the experimental program, have been shipped to B-L-H by Superior.

The welding development program for the tube-to-tube sheet joint was discussed by Mr. Bennett. This particular part of the R&D program proved to be the most significant and required the most time. With the aid of slides, Bennett reviewed development of the Inconel overlay for the tube sheet and development of the tube-to-tube sheet joint. In order to overcome a tendency toward thermal shock cracking, the weld design adopted by Alco is a very complex 15 pass weld. Tests have demonstrated that the design will satisfactorily withstand thermal shock. A topical report on welding procedures will be issued by Alco toward the end of May.

Plans have been completed for supplying the tube welding gun to B-L-H for assembly of the unit.

Baldwin-Lima-Hamilton
Completion of Alco Steam Generator
P. S. Otten, R. Tidball, R. B. Abderhalden

Mr. Otten stated that the contract between B-L-H and the AEC covers three phases:

1. Completion of fabrication of the Alco prototype steam generator to Alco's design.
2. Completion of the steam test loop, operation of the loops, and reporting results of the tests.
3. Participate in testing of the Alco units at the SCTI at AI, and evaluate and report on the performance of the prototype units.

Discussing each of these phases in turn, Otten explained that the first task performed during fabrication of the steam generator involved welding large nozzles to the shell. Delay was encountered during inspection and correction of some deficiencies. There is still reasonable assurance that the unit can be shipped to SCTI in November 1963, though the probability of schedule slippage was increased by recent design changes such as changing from a 9 pass tube to tubesheet weld to a 15 pass weld.

B-L-H has requested permission to reduce the diameter specified for tube holes through the sodium side baffles in order to avoid possible flow induced vibration problems. A B-L-H expeditor was recently assigned to the project in an attempt to increase the rate of progress on the project.

The second phase of B-L-H's assignment, e.g., the high temperature, high pressure steam loop, is currently centered around completion of the test loop. The loop has been moved to B-L-H and assembled. By the last week in May, testing should commence. The objectives of the test program will be to determine the effect of high temperature, high pressure steam on a number of different alloys, to obtain information about water side heat transfer at various locations in a tube mocking up the evaporator Section of the steam generator, and to determine the effect of thermal shock conditions on the sine wave section of the tube. The tube will be thermally shocked by intermittent operation of electrically heated sections of the loop.

A schematic diagram of the loop was drawn on the blackboard by Mr. Otten; the group was advised that a final flow sheet for the loop will be prepared by the end of May.

Materials to be tested in the loop include the duplex 316 S.S.-Inconel tube specified for the prototype steam generator, Incolloy 800, 304, 347, 316 stainless steel and 2&1/2 Crolloy.

In response to a query from Dr. Wensch, Mr. Otten stated that the loop program should be completed, with metallurgical examination of loop specimens the last effort, in April 1964. The test loop program will investigate water side problems; Dr. Wensch suggested that B-L-H consider how the loop could be used for further study of water side effects.

The third phase of the B-L-H contract will consist of analysis of the test data when the Alco units are tested at SCTI, followed by interpretation and reporting of the test results.

Atomics International
Sodium Components Test Installation
and Test Program for Alco Units
Jim Leppard, Don Eggen, D. F. Casey

SCTI

Mr. Leppard advised that the objectives of the SCTI program are (1) to design and build a non-nuclear test facility generally capable of testing prototype sodium heated intermediate heat exchangers and steam generators and specifically capable of testing the IHX and steam generator prototypes produced under the Alco contract and (2) to prepare for test of the Alco units.

Construction of the SCTI was about 75% complete as of the middle of May, 1963. Work is underway on steam and sodium piping and the instrument air system. The final bid package, covering electrical work and insulation, is out for bids; bids were due on May 17, 1963.

AI intends to start developing an operating staff for SCTI in July. An 18 man crew will be required for operation on a 24 hour per day, 5 day per week schedule. Discussion with the group developed a consensus of opinion that plans should be made to operate 7 days per week, around the clock.

In response to a query from Dr. Wensch, Mr. Leppard stated that the test program to be performed is described in detail in an Alco report (see APAE 122 "Test Program for 30 Megawatt Prototype Sodium Intermediate Heat Exchanger and Steam Generator", September 14, 1962, Alco Products, Inc.).

In conjunction with design of the control system for SCTI, AI recently completed a computer study designed to match the control system characteristics as closely as possible to the test conditions specified for the IHX and steam generator. A topical report covering the computer study will be issued shortly.

Shell Side Heat Transfer

The history of the project was briefly reviewed. During this review, recognition was given to the fact that the program has suffered delay and setbacks because of disagreements concerning the program content and scope between the SCDP Working Group and AI and because of budget and hardware problems. The first test unit has been completed and is in place in the test loop and some tests have been performed. However, the program is now inactive and AI does not plan to reactivate during FY 1964 under presently proposed funding levels.

Modular Steam Generator

Don Eggen reviewed the status and history of the modular steam generator project. As a matter of record, the project was initiated at AI for the primary purpose of providing a back up advanced steam generator

program at the time Alco management announced the decision to withdraw from the nuclear field. At that time, the fate of the Alco prototype equipment was uncertain, no second steam generator effort had been initiated, and construction of SCTI was underway. Added advantages were also seen in the AI proposed modular steam generator. Due to its design features, such equipment can be designed for supercritical steam conditions and plant availability should be high due to ease of replacing the modular units.

In December 1962, a design package, based on completed stress analysis and weld development, was completed and mailed to a number of vendors for review and quotations. Quotations were received from the vendors in January 1963. A summary report was submitted to the AEC in April 1963. Topical reports on the weld development program, the stress analysis, and the design of the units will be prepared.

The group was advised that the basic 61 tube steam generator is rated 10 to 13 MWT and is sized to use standard 8" pipe for the shell of the unit. Fabrication of the unit is expected to require 10 months; the most uncertain item for procurement is the special drawn tubing.

At various times, AI has claimed proprietary rights to some of the design features of the modular steam generator. This point was brought up by Messrs. Smith and Harris, and AI representatives agreed to secure and submit a firm statement of AI's position to the Commission.

When asked for AI's priority concerning the steam generator and the shell side heat transfer program, Dr. Eggen stated that the steam generator definitely has higher priority than the Shell Side Heat Transfer program, and that AI is recommending subcritical steam generator units now as a backup for the Alco steam generator; fabrication and testing of supercritical units should follow according to AI's recommendations.

Analysis for Carbon in Sodium

AI is contributing one of the major efforts in the AEC's program for investigation of the analytical procedures for determination of carbon in sodium. Following collection and comparison of analytical results from the first round of carbon contaminated specimens analyzed under this program, it became apparent that either the specimens were not homogeneous or the analytical procedures used by American laboratories to measure carbon in sodium were inaccurate and non-reproducible. In an attempt to determine the reason for the wide variation in the first round results, a special loop was constructed at AI for the express purpose of assuring tight control over sample homogeneity. Using this loop, homogeneous specimens containing carbon concentrations at three levels, e.g., as received (18 ppm), 40 ppm, and 100 ppm, were to be prepared and distributed for analysis. Samples of the first type (as received) were prepared and distributed several months ago, but a cloud of uncertainty was cast over the homogeneity of that set of specimens when it was discovered that the MoS₂ lubricant used to lubricate the closure fittings was carbon contaminated. Subsequently a new set of Type I specimens was prepared and, on April 22, distributed.

In mid-May, AI was producing type III (100 ppm carbon) specimens by operating the loop at 950°F while dissolving carbon into the system at 1150°F. After the type III specimens are obtained, AI plans to utilize hot trap techniques to reduce carbon concentrations to 40 ppm for preparation of type II specimens.

At the close of AI's presentation, questions were asked which disclosed that the SCTI, as it now exists, is not capable of performing all of the tests required to meet the conditions specified by the Alco steam generator specifications and the Alco test program. The AEC staff is

aware that lack of a large heat sink at the SCTI will prevent testing the steam generator alone, as specified.

The meeting adjourned at 6:15 P.M. on May 13, 1963. On the following morning, May 14, 1963, the meeting reconvened at 9:07 A.M.

Westinghouse Electric Corporation
Pump Study and Cold Trap Inspection
Jim Wright, Paul Kohen, Clint Randall

Pump Study

Dr. Wright outlined the background and objectives of the pump study. The objectives of the first phase of the study is formulation of a recommended program for development of large sodium pumps for service in future liquid metal cooled power reactors. In performance of the first phase, four tasks will be completed:

1. Pump requirements for 1000 MWE liquid metal cooled fast and thermal reactors will be identified.
2. The current status of sodium pumps will be determined and clearly described.
3. The need for further developmental work on large sodium pumps will be evaluated and, if the evaluation indicates that further work is necessary, a coordinated sodium pump development program will be formulated.
4. Establish and define the technical and functional requirements for a test facility capable of supporting the development program and of proof testing prototype pumps and related flow measurements and control devices.

The second phase of the Westinghouse study will cover:

1. Conceptual design of the Pump Test Facility.
2. Evaluation of designated Government owned sites.

3. Development of PERT system and cost estimate for construction.
4. Development of annual operating and maintenance cost estimates for the facility.

Mr. Randall outlined progress on the project to date. He advised that work on Task 1, Phase I was complete except for report preparation. Problem areas in current sodium pump technology have been identified and Westinghouse is currently outlining a research and development program designed to attack these problems. Work is also underway on establishment of requirements for the test facility. Little work has been completed on Phase II of the program.

Mr. Randall displayed a chart of the parameters for sodium pumps and a tabulation of the pump characteristics which will be required for the target plants toward which the Commission's Liquid Metal Cooled Reactor Program is directed. On the basis of these pump characteristics, Westinghouse is proceeding to development requirements for the test facility.

From the work which Westinghouse has done to date, the most likely candidate for pump service in future large sodium cooled reactors is a centrifugal, free surface pump with variable speed drive. The major problem areas appear to be seals, bearings, scale-up of dimensions, thermal shock, and speed or flow control.

Discussing the type of testing which Westinghouse envisions, Mr. Randall mentioned:

1. Steady state characteristics
2. Parallel flow characteristics
3. Flow control response
4. Component evaluation
5. Pressure variation on both the discharge and suction side
6. Cavitation and gas entrainment studies

At present, the facility is expected to have the following capability:

1. 60,000 gpm per loop, in each of two loops
2. Operating temperature variation 400 to 1200°F
3. Variation in Net Positive Suction Head up to 50 psi
4. Shock rate 10°F second for 30 seconds
5. Pump power 10 MW maximum
6. Discharge head to 350 feet of sodium

A schematic flow diagram was displayed and the anticipated mode of operation was explained. Specific mention was made of the need for large flow measurement and flow control devices.

Summarizing the Westinghouse presentation on the Sodium Pump Test Facility, Dr. Wright stated that Westinghouse is commencing conceptual design of the facility, is proceeding with more detailed description of the associated R&D program, and is sensitive to the need for developmental work on large flow measurement and control devices. Some of the design problems which Westinghouse envisions in the design of large sodium pumps are expected to be directly related to the sodium systems in which the pumps will be used. Economic considerations for the pump would favor the larger impeller and pump size, but for large impeller sizes the NPSH increases. Increased NPSH would require very undesirable system pressurization which in turn would impose additional problems with seals and closures. Thus, the economic advantage of the large pump size may be offset by increases in system cost. A careful optimization is necessary by the reactor designer to attain minimum costs for the system.

During his closing comments, Dr. Wright asked for comments from the group about the size pumps which should be tested. Westinghouse has found that very little sodium experience has been acquired by the architect-engineering firms of the United States. Therefore, Westinghouse has tentatively selected an A-E for the Sodium Pump Test Facility conceptual design work on the basis of a key A-E staff individual who worked on the

conceptual design of the steam generator facility while an employee of APDA.

Dr. Wensch discussed the timeliness of proceeding with a survey of potential sites for the Sodium Pump Test Facility with Jules Wise. The conclusion of the discussion was that extensive surveying of sites at this time could not be justified. It was agreed that NYOO and Westinghouse would survey the CANEL site only at this time, and would delay further surveys until a construction line item for the Sodium Pump Test Facility has been approved.

Dr. Wensch asked the group whether, to the group's knowledge, any bearing development applicable to the pump program was underway. The response was negative. Dr. Wright suggested that Westinghouse would be pleased to undertake such a program based on use of hydrostatic or pivoted pad bearings if the Commission were interested.

The next item on the agenda was a presentation by Dr. Paul Kohen on the work which Westinghouse is doing to try to determine the mechanism of trapping sodium oxide. The project involves removal of samples from a cold trap used during cleanup of the Fermi reactor sodium systems. Attempts are being made to collect samples axially and radially throughout the mesh packed trap. The first sampling procedure attempted by Westinghouse involved use of a core drill. In order to try out proposed sampling techniques without damaging the Fermi cold trap, a mock-up was devised which used the same type mesh loaded into the Fermi trap and pot metal, to simulate frozen sodium. Core drilled samples were then taken from the mock-up without difficulty. Confident that the mock-up operation had demonstrated the feasibility of the sampling technique, Westinghouse proceeded to set up a dry box, charged with dry, oxygen free, nitrogen atmosphere. Using this dry box, attempts were made to take samples from

a mocked-up trap using frozen sodium rather than pot metal for the mesh filler. These attempts were unsuccessful; even when liquid nitrogen was used to refrigerate the cutting area, the sodium filled mesh proved to be too spongy to resist drill pressure and the resulting samples were extremely twisted and distorted. Attempts were then made to take samples using a hole saw cutter. Samples were obtained, but again were unsatisfactory. In all cases to date, the difficulty has been caused by the flexibility of the mesh. Westinghouse plans to try an oscillating scissor-like device next.

General Electric Co.-APED
Mass Transfer
Robert Lockhart

During a brief outline of the history of the project, Mr. Lockhart emphasized the importance of material selection for service in high temperature sodium systems. After briefly discussing the objectives of the project, he stated that time has shown that the objectives selected at the start of the program four years ago are still valid. Six loops were constructed initially for the project; operation of all six loops continues.

For the benefit of the new group members, the design, material combinations, and specimen distribution and numbering were explained. The program variables are material, temperature, velocity, and oxide content. Close to 100,000 hours of cumulative operating time has been achieved with the six loops.

Discussing results of the program to date, with a note of caution in interpretation of data to the effect that the actual rates of mass transfer or corrosion have not been severe enough to limit service life, Mr. Lockhart stated that:

1. The monometallic loops have experienced more trouble and downtime.
2. As expected, over the years the hot leg in each loop has lost weight and the cold leg has gained weight.
3. Increasing the hot temperature from 1100 to 1200°F causes the corrosion or mass transfer effect to increase by a factor of 4.
4. Considering the velocity effect, the temperature effect, and the downstream effect, the total mass transfer effect at 1200°F might be as much as 50 times that at 1100°F.
5. The results of the program confirm that oxide content is a very definite factor affecting the mass transfer effect.
6. Based on relatively short time exposure to carbon contaminated sodium, 316 stainless steel displays a carbon case. With the passage of time, the case becomes thicker as carbon diffuses into the parent metal.
7. In the 316 stainless steel/2&1/4 Crolloy loop, the Crolloy displays a carbon loss while the 316 SS displayed a carbon gain. A definite layer was deposited on the surface of the cold leg (2&1/4 Crolloy leg). Through the use of x-ray and electron microprobe analyses, it has been determined that the hot leg (316 SS) has suffered a chromium and nickel depletion. Apparently the corrosion rate is dependent upon diffusion of chromium and nickel out of the parent metal to the surface, leaving a thin ferritic layer on the exposed surface of the austenitic 316 SS.

Outlining plans for the next two years, Mr. Lockhart mentioned the following items:

1. The current five run fractional replicate program will be completed to achieve statistical validity in the program.
2. The data will be collated and analyzed for third order effects.

3. Additional work will be undertaken to improve carbon-in-sodium analytical techniques.
4. Loop components will be examined for long term metallurgical effects.
5. Further refinement and development of theoretical models, designed to permit extrapolation of data from the program to large engineered systems, will be undertaken.
6. Continued analysis and resolution of operating anomalies.
7. Loops of different geometry and size will be constructed to permit further investigation of velocity, downstream, scale-up, and fouling factors.
8. Experiments will be devised and proposed which will permit detailed investigation of the effects of fouling deposits on system flow and heat transfer characteristics.

In response to a question from Dr. Wensch concerning GE's estimate of how long the original six loops should be operated, Mr. Lockhart explained that analysis of the data taken to date indicates that the corrosion rate vs. time curve is following the expected shape, that recent data indicates that the loops are now operating in the expected knee of the curve which is the transition region between the initial high slope portion of the curve and the expected flatter and essentially straight portion of the curve which represents the long service life effects. The slope of the long service life portion of the curve is the engineering data which the program was designed to obtain. From data collected to date, production of the ferritic layer in the hot portion of the loops appears to be a function of the square root of operating time; hence long time periods are required for the investigation. Mr. Lockhart explained that GE is utilizing all of the facilities available in the GE-San Jose complex to analyze data from this program.

In preliminary investigations of carbon-in-sodium, GE has added carbonate to an operating loop. Upon doing so, a drastic increase in plugging temperature was observed which could be interpreted as an "apparent oxygen increase". The investigators also found that reduction in the upper system temperature, with no change in system composition, resulted in a reduction in the plugging temperature. The plugging temperature appeared to stabilize after maximum system temperature was lowered to about 750°F.

The results of the first round of carbon analyses under the broad carbon analysis program were discussed. Mr. Lockhart stated that there was such wide variation in the analytical results that no one analytical procedure could be ruled as the most accurate. A second round of samples was prepared and distributed by AI, but was found to be seriously contaminated. Further work will be undertaken.

Mr. Heckman asked Dr. Wensch to endeavor to interest John Hague, National Bureau of Standards, in participating in the development of a reliable and accurate analytical procedure for carbon in sodium. Chicago Operations Office has advised Mr. Hague of the program and invited his participation. So far, however, Mr. Hague has declined to participate because of a personnel shortage in his unit.

Executive Session
Sodium Components Review Group

Immediately following the lunch break, an executive meeting of the Review Group was held. Dr. Wensch opened the session with a request for comments and questions from the group. Mr. Savage requested that the distribution lists for all reports generated by contractors in the AEC's civilian liquid metal cooled reactor program, including those under the Sodium Components Development Program, be reviewed to ascertain that the group's national laboratory consultants receive copies. He also raised

a question about continuation of existing Ad Hoc committees, with specific reference to the GE Mass Transfer Ad Hoc Committee. Dr. Wensch stated that he prefers to draw the membership of future ad hoc committees from the national laboratories; through this device, he intends to stimulate participation of the national laboratories in the sodium programs. After further discussion, a decision was made to continue the GE Ad Hoc Committee with its present membership; CH agreed to encourage AI to permit Dave Sinizer to participate in the program as a specifically requested individual.

Mr. Smith asked whether the same reasoning and decision applied to the MSA Mechanical Properties Ad Hoc Committee. After discussion, it was agreed that continuity of the original MSA Ad Hoc Committee was not as important as continuity of the GE Committee. On the basis of this agreement, some change in composition of the MSA Ad Hoc Committee is expected. With respect to this committee, Dr. Wensch mentioned the need for a broad long range program for investigation of the properties of materials in a sodium environment and requested that the committee prepare a detailed work scope for such a program. This work scope should be of sufficient breadth to cover all foreseeable material needs for high temperature sodium systems and components.

From discussion of the specific materials program, discussion shifted to development of an even broader program for the sodium components and systems themselves. Comments were received from the group to the effect that:

1. A national laboratory should be selected to develop the program.
2. Appointment of a special planning group to develop program plans.
3. The Sodium Components Development Program Review Group should develop program plans.

After rather thorough discussion, Dr. Wensch assigned Mr. Harris to serve as a coordination point for development of program plans, drawing on the services of the Review Group and the national laboratories. The limits for this phase of planning were established as all parts of the power extraction system from the reactor vessel nozzles outward.

Shifting from a discussion of plans to discussion of the individual projects, Mr. Savage suggested that the high temperature test loop program at B-L-H appears to be growing beyond any reasonable scope for the existing program at B-L-H. He also pointed out that the results of the GE Mass Transfer program will be specific to the existing GE loops unless the larger loops which GE has proposed are built. With these new loops, at least some data will become available concerning extrapolation of the GE results to reactor size loops.

The suggestion was made that the work at MSA on mechanical properties should be phased out concurrent with completion of the Alco work. Mr. Smith suggested that the MSA work should be judged by the data which is being produced and that only after evaluation of that data should a decision to terminate the project be made.

Looking beyond the scope of the present Westinghouse Pump Program, Dr. Wensch stated that the operator of the Sodium Pump Test Facility (SPTF) will be selected through a competitive procedure. After some discussion of site surveys for the SPTF, it was agreed that site selection activities should be held in abeyance until a construction budget line item for the SPTF has been approved. Continuing, Dr. Wensch stated that the intent for the prototype pumps is that an invitation will be extended for the design, development and fabrication of two large prototype pumps. He expects New York Operations Office, with the assistance of SAN and CH, to develop and submit a plan for implementation of a vigorous pump

development program. Mr. Wise advised the group that a report covering Phase I of the Westinghouse program will be issued in about two months.

Mr. Nemzek stated that B&W has suggested that the feed water temperature specified for the steam generator which that company is now designing be lowered. The specified 600°F feed water temperature would require design of an unusual pressurized feed water heater for the final stage of feed water heating, and would impose unusual turbine design conditions. B&W intends to write a letter to CH which explains the exact situation and requests authorization to design for more conventional feed water conditions. During the discussion which followed Mr. Nemzek's statement, Messrs. Smith and Harris indicated that the 600°F feed water temperature was selected on the basis of sodium system considerations rather than steam side considerations, and that lowering the temperature to match good steam cycle design practice would not be objectionable.

A question was raised concerning the need for supporting the proposed B&W work on water reactions with sodium in steam generators. The group was strongly in favor of proceeding with this work, particularly after the experience which the Fermi project has had with steam generator leaks.

During discussions of the continuous oxide meter program at UNC, Mr. Wise was asked how NYOO plans to implement distribution, installation and test of prototype units which the program is expected to produce. He replied that each prototype would be checked out in the pump loop at UNC before being installed at other locations. Firm plans for the program of prototype fabrication, installation, and testing have yet to be developed; NYOO intends to do so in the near future.

At the close of the session, Dr. Wensch discussed the general procedures for generating and starting new work. DRD intends to continue

to work through the field offices. Due to elimination of the A-B office relationships, the Sodium Components Development Program will no longer be handled through one central field office, though in general specified field offices will be relied upon to handle all of the work in major areas. For example, CH will continue to be the center for steam generator development and NY will continue to work in the sodium pump field. It is the desire of DRD that all of the field offices develop competence to handle liquid metal reactor assignments. To that end, DRD requests cooperation between field offices in the exchange of information.

In general, the procedures which were outlined in the Sodium Components Development Program procedures document developed by CH in 1958 will continue to be used. Shortly a memorandum concerning procedures to be used will be distributed to affected field office managers.

In final, instructions were issued to the acting secretary to invite Dr. O. E. Dwyer to become a member of the Review Group and to invite NASA-Lewis Laboratory to attend information meetings only. The meeting adjourned at 4:20 PM.

Reuben E. Harris
Acting Secretary

Minutes of the Sodium Components Working Group

Meeting No. 32

(Review Group Meeting No. 2)

August 20-21, 1963

Palo Alto, California

The Sodium Components Working Group met in executive session for several hours on August 20-21, 1963, with the following persons in attendance:

O. E. Dwyer, BNL	W. R. Simmons, ANL
T. P. Heckman, COO	F. A. Smith, COO
J. P. Holliday, SAN	G. W. Wensch, DRD, HQ (Chairman)
A. E. Mravca, COO	J. Wise, NYOO
C. W. Richards, CPAO	W. R. Wykoff, LASL
H. W. Savage, ORNL	

Round Robin Carbon Analysis

Mr. Heckman reported on the 8/19/63 meeting of his ad hoc committee to review the program for carbon analysis in sodium. Only MSA, GE, and AI, of the 17 companies receiving sodium samples, have reported the results of their analyses. The ad hoc committee recommendations were:

1. The fourth set of samples which have high oxygen and carbon contents are to be sent to all participants with a request that results of analysis for all sets be returned within 30 days of the receipt of sample set #4.
2. AI is to cold trap the sample preparation loop down to 10 ppm oxygen and take sample set #5 if the carbon content remains high. No further sample preparation by AI for round robin analysis is contemplated after sample set #5.
3. General Electric Company, San Jose, is to take bulb-type samples of sodium from one of their aged loops and send to AI, MSA, and ANL as a further check of the total carbon analysis as done by these groups.

The carbon analysis ad hoc committee report will be sent to all Working Group members in about three weeks.

O. E. Dwyer requested that BNL be added to the list for a complete set of AI prepared samples for analysis.

It was the consensus of the group that the original purpose of having AI prepare 17 sets of carbon contaminated sodium samples of varying carbon content had been achieved. Further work on sample preparation

or analysis should be the responsibility of individual contractors and laboratories.

Ad Hoc Committees

G. W. Wensch reviewed membership of ad hoc committees. Each committee will have an AEC chairman and the committees as presently organized will continue in effect for continuity purposes. Future committees will have no contractor personnel as members. Chairmen of the ad hoc committees should send a write-up including the charter for their group, future plans, a schedule for future review meetings with the contractors, and membership to G. W. Wensch.

Committees as presently constituted are:

1. General Electric Company - Mass Transfer Programs

Chairman - J. P. Holliday

Members - H. W. Savage, ORNL J. H. DeVan, ORNL
 D. E. Sinizer, AI J. H. McKee, UNC
 * An ANL Metallurgist to be named by W. R. Simmons is
 to be added to the committee.

Next Meeting - January 1964

2. MSA - Mechanical Properties Program

Chairman - T. P. Heckman

Members - J. DeVan, ORNL
 J. McKee, UNC
 W. F. Anderson, AI

Next Meeting - Fall, 1963

3. Steam Generator Testing Program

Chairman - A. E. Mravca

Members - ORNL, BNL, and ANL will be asked to each nominate a member.

One of the first objectives of this committee will be to review the SCTI capabilities and tie steam generator effort together with the SCTI testing program. Committee is to be formed by September 30, 1963.

*See Appendix A for later membership lists.

Structural Materials Test Program

In the last meeting of the Working Group, the necessity for a testing program for structural materials exposed to sodium was mentioned. ANL and ORNL members expressed an interest in such a program, and G. W. Wensch suggested that the laboratories send a proposed work scope of such a program to DRD for review.

Pump Testing Loop Study

Phase I of the Westinghouse Pump Loop Study is complete and copies of the report will be sent to the Working Group. A very preliminary effort has been made by J. Wise to determine what sites might be suitable for the pump test loop.

Steam Generator Projects

The B&W feedwater temperature question mentioned in the last meeting has not been resolved because B&W has not submitted its optimization study. COO is to follow up on this. AI has indicated in a letter to CPAO that AI has no proprietary rights in the modular steam generator concept.

Continuous Oxide Meter

The chairman indicated that this work at UNC is included in the FY 1964 financial plan and that he was disappointed that NY had terminated or deferred this activity since doing so was not to the best interests of the AEC.

Sodium-Water Reaction

The B&W proposal to study sodium-water reactions was reviewed by Smith, Wykoff, Simmons, and Dwyer. This would be a full scale engineering series of tests at a cost of about \$700,000. The reviewing group recommended that:

1. R&D of a basic nature to determine procedure for operation of the steam generator in case of a small leak during the test in the SCTI is worthwhile and should be supported.
2. It was believed that the long range study of the steam generator safety was not a necessary part of the steam generator fabrication contract work. B&W should not do this portion of their proposal.

G. W. Wensch indicated that the Chicago Operations Office had recommended acceptance of a long range program to study sodium-water reactions from small leaks which had been submitted by APDA prior to B&W's proposal and which was quite similar. The APDA project is to be accepted. COO will discuss the acceptability to B&W of conducting only the short term R&D *applicable to the 30 Mwt test unit. Then COO will advise DRD of a course

of action to approve the B&W work scope before proceeding with this phase of the work at B&W.

The availability of ANL's two spare superheater sections for sodium-*water reaction studies should be investigated by CH.

Carbon Transfer

The work scope of the B&W proposal to study carburization-decarburization and film-nucleate boiling is to be sent by COO to Savage and Dwyer for *review. Review recommendations are to be sent to COO and Dr. G. W. Wensch.

Reports

Distribution of all applicable reports is not being made to all members of the Working Group. COO is to prepare distribution lists and send them to all contractors to correct this.

Next Meeting

The next meeting will be held approximately December 3-4. Tentatively, the meeting will be a two day information meeting open to the contractors and followed by a one day executive session with certain of the contractors.

Suggestions by the Working Group members as to the type of meeting and items for inclusion on the agenda are to be sent to G. W. Wensch as soon as possible.

Richards will coordinate with Wensch in making arrangements for the meeting.

May Meeting Minutes

The Chairman requested written comments on the minutes of the May meeting.

Future Projects

The Chairman requested that the Working Group members Dwyer and Wise review the areas of sodium component development where additional work or new work should be done, and to put together in a preliminary way a proposed program for review at the December meeting. It is planned that this information can be worked up into a report such as WASH-1025. (COO will send copies of WASH-1025 to all Working Group members.)

APPENDIX ASODIUM COMPONENTS DEVELOPMENT PROGRAM
Working Group

October 1963

Members

Glen W. Wensch, Chairman, DRD
C. A. Pursel, CH
C. W. Richards, CPAO
J. P. Holliday, SAN
Jules Wise, NY

Consultants

W. R. Simmons, ANL
O. E. Dwyer, BNL
H. W. Savage, ORNL
W. R. Wykoff, LASL

Ad Hoc CommitteesMechanical Properties of Materials in Sodium

J. J. Purcell, COO, Chairman
J. H. DeVan, ORNL
J. H. McKee, UNC
Unnamed, BNL

Mass Transfer in Sodium

J. P. Holliday, SAN, Chairman
H. W. Savage, ORNL
J. H. DeVan, ORNL
D. E. Sinizer, AI
J. H. McKee, UNC
Unnamed, ANL

Analytical Techniques for Sodium

Vacant, Chairman
R. W. Lockhart, GE
R. W. Bane, ANL
C. F. Metz, LASL
J. C. White, ORNL
D. T. Eggen, AI

Steam Generators and the SCTI

A. E. Mravca, CH, Chairman
G. Gower, CH
K. Kuczen, ANL
K. Hoffman, BNL
R. MacPherson, ORNL

Minutes of the Sodium Components Working Group

Meeting No. 33

(Review Group No. 3)

January 16-17, 1964

AEC Headquarters

Washington, D.C.

Members Present -- January 16 and 17:

O. E. Dwyer, BNL	H. W. Savage, ORNL
R. H. Jones, HQ (Secretary)	W. R. Simmons, ANL
A. E. Mravca, CH	G. W. Wensch, HQ (Chairman)
C. A. Pursel, CH	J. Wise, NY
J. J. Purcell, CH	W. R. Wykoff, IASL

Members Absent:

J. P. Holliday, SAN
C. W. Richards, CPAO

Guests -- January 16 and 17:

G. C. Gower, CH
L. Redecke, CH

Visitors -- January 16th, a.m.:

N. Grossman, HQ
R. M. Scroggins, HQ
A. Van Echo, HQ

Introduction:

- 1.1 Dr. Wensch called the meeting to order at 9:10 a.m. and introduced each of the members with a brief resumé of his background.
- 1.2 For future Information Meetings each speaker will be instructed to submit a written abstract of approximately 1000 words covering the substance of his presentation for inclusion in the Minutes.
- 1.3 As a means of improving the committee meetings, Dr. Wensch passed out evaluation sheets based on the Department of Agriculture Guide and Source Book. Since this is an effective and essential instrument in making these and other meetings more fruitful, a copy of the Guide is being attached to these minutes.

Minutes of Palo Alto Meeting:

- 2.1 The Minutes of the Palo Alto Information Meeting were omitted due to the absence of both Mr. Holliday and the final Minutes.

- 2.2 The Minutes of the Palo Alto Working Group Meeting were presented by Dr. Wensch and accepted unanimously as written.

ACTION - C. A. Pursel will resolve item on Page 4 of these Minutes concerning carburization and carbon transfer.

Organization:

- 3.1 As an introduction to the effectiveness required of the various committees working on SCDP, Dr. Wensch passed out resumés of Rep. Melvin Price's "The Honeymoon in R&D is Over." Every effort should be made in the SCDP to see that contractors are performing; if they are not, correct the situation or recommend phasing out the work. Dr. Wensch commended CH for taking such action just recently in the case of the HTHP loop at BLH.
- 3.2 Each Ad Hoc Committee Chairman should submit a charter of the function of his group. The charter should list the members, their resumés and indicate that the committee follow the work of the contractors, analyze and evaluate the results obtained, and recommend a course of action with respect to this work. Their charter is to be broadened, moreover, to encompass cognizance of all work being done in the area of the committee's interest and recommendations based on this broader knowledge. It is expected that this new basis will guard against unnecessary duplication of work.
- 3.3 To assist the Ad Hoc Committee in arriving at more definitive programs, without duplication of effort, the following devices were proposed:
- a) Proposals for initiation of new work, or extending work, should be made through the Field Offices (rather than HQ). The Field Offices will keep Dr. Wensch informed of desirable programs so that he can make the necessary budgetary provision.
 - b) The Ad Hoc Committees will assist the Field Offices in evaluating proposals.
 - c) Contractors submitting proposals should be required to keep the Field Office informed of similar submissions to other Divisions and Agencies. This would help to avoid duplication of effort, funding and acceptance of more than one group.
 - d) Attendance at NASA technical review meetings would help to eliminate duplication and assist in keeping informed on their programs.

ACTION - G. W. Wensch will request that SCDP members be invited to NASA technical review meetings.

- e) O. E. Dwyer's "Technology Review" is a good source of information for the committees to use in avoiding duplication.

- 3.4 Every effort should be made by the committee chairman to phase out industrial members of their committees as opportune break-off points arise. It was recommended that with William Anderson's (AI) present workload as a professor and also obtaining his doctorate, it would be a good time to relieve him of the duties with the Properties of Materials Committee; Carl Klamut of BNL is a likely replacement.
- 3.5 Distribution of SCDP reports is being supervised by J. Purcell. Committee members were of the opinion that this service has been considerably improved since J. Purcell started handling this problem — several hastened to add that it is difficult to determine whether they have received all reports where they have no means of knowing how many reports they should have received.
- 3.6 References — The following were passed out to all members:
- a) Meeting agenda
 - b) Liquid Metal Cooled Reactors Branch-Functional Areas of Responsibilities
 - c) Liquid Metal Cooled Reactors Branch-Specific Program Project Responsibilities
 - d) Sodium Components Development Program Working Group Membership — dated December 1963.

Review of European Programs:

- 4.1 Mr. Savage reviewed the European sodium component development based on the changes he had noted in his recent visit compared to his visit about a year and a half earlier. Although he did not make a complete tour each time his impressions were that:
- a) Their rate of development of components is not impressive.
 - b) They are not taking full advantage of extrapolating existing technology.
 - c) Their present technology is of limited assistance to us but promises to be of future value, and their safety practices are poor. One area that was particularly impressive was a French innovation of an automatically controlled cold trap by an automatic plugging meter.
- 4.2 Mr. Savage recommends that in the next couple of years the European work should be watched carefully because of their very interesting approaches to many problem areas. He also recommends that an average of one week be spent at each European installation.

- 4.3 He further recommended that Mr. Hallett (AI) be asked to report on his experiences during the one-year stay he had in Europe.

ACTION will be taken on this by Dr. Wensch.

- 4.4 Reference - Further information on Mr. Savage's European trip is contained in "Trip Report on Visits of H. W. Savage to the Fontenay-Aux-Roses, Saclay, and Cadarache Centers, CEA, France, and to the Casaccia Center, CNEN, Italy" by J. A. Swartout and H. W. Savage, January 6, 1964, ORNL Files Number 64-1-9. Several copies of this publication were passed out at the meeting.

Dr. Pittman's Long Range Fast Breeder Reactor Program:

- 5.1 Dr. Wensch gave an abbreviated presentation of Dr. Pittman's speech at Detroit and a summary of the range of comments that have come in following this speech.
- 5.2 Discussion by the Committee raised the question of whether a 1000 Mw(e) reactor plant would be a realistic size of capacity addition in 1989. CH and NY both have information on projected turbine-generator units showing much larger units are anticipated in the next 25 years. There were varied opinions as to whether these projections of turbo-generator design and manufacturing capability had any direct reflection on electric utility practice in the next 25 years. It was pointed out that TVA is presently installing a 1000 Mw(e) turbo-generator.

ACTION - C. A. Pursel and J. Wise will send Dr. Wensch the projection data they have available.

- 5.3 Reference: "Fast Reactor Program" by Dr. Frank K. Pittman, December 3, 1963 at Detroit, Michigan. Copies of charts passed out to all members.

Long Range Sodium Components Development Program:

- 6.1 Mr. Jules Wise presented a parallel to Dr. Pittman's Fast Reactor Program for the components development that would be necessary to support fast reactors and other sodium cooled reactors. In this components program, he limited the forecast to the next ten years.
- 6.2 One of the specific facilities which Mr. Wise discussed was the Large Sodium Pump Test Loop which, it was decided, should be renamed to reflect its more generalized use as a facility in which all hydraulic components and instrumentation could be tested.

Due to lack of time, the detailed report on the Pump Facility was not given. However, it was recognized by the membership that a meeting had been held in New York at which the Phase I portion of the Westinghouse Pump Study was presented to representatives from industry.

ACTION by Mr. Wise will be taken to present to Dr. Wensch the NY recommendations on how this facility is to be implemented.

- 6.3 It was recommended that, when Mr. Wise has produced the revised version of the Long Range SCDP, copies of it should be sent to all Committee members for them to identify and delineate the problems, and to estimate the time, cost and approach to solving them.

ACTION will be taken by Mr. Wise to revise and mail the long range program to the membership.

ACTION will be taken by the membership in sending to Jules Wise their detailed comments on his revised version of the long range program.

- 6.4 Reference: "Research and Development Program for Civilian Power Reactors Sodium Components" by J. Wise and Dr. O. E. Dwyer, January 1964, NYO-10725. Copies were passed out to membership.

Mechanical Properties of Materials in Sodium:

- 7.1 Mr. John Purcell reviewed MSAR's progress; Tests 1 and 2 have been completed and Test 4 loop work is completed. Test 3 ran into trouble with carbon plugs forming in the OCI system and in the economizer. The Ad Hoc Committee is contemplating rescoping Test 3 and future tests for the following considerations:

- a) Lowering the carbon pot temperature below 1200°F saturation.
- b) Whether highly carburized materials represent meaningful or useful test data.
- c) Re-arrangement of tests so that both loops do not become carbon contaminated.

- 7.2 Although it was originally assumed in setting up the test program that 316 SS was representative of the 300 series stainless steels, it now appears that the question of sigma-phase formations in 316 SS invalidates this assumption. With the interest in using 304 SS for such projects as FARET, the Ad Hoc Committee should review the test program to determine whether:

- a) The present program represents reactor environment conditions, particularly in oxide content, carbon content, and cover gas selection.
- b) The N₂ tests could be replaced by 304 SS tests.

ACTION will be taken by the Ad Hoc Committee on rescoping this program.

- 7.3 Reference: 6 pages of Tables and Figures dated January 15, 1964 were passed to all members.

Sodium-Water Reactions:

- 8.1 Mr. A. E. Mravca reviewed the status of research and development requirements in the Babcock & Wilcox steam generator contract. B&W has now submitted a program (\$93,000), which will satisfy their design requirements, consisting of:

- a) An analytical study of sodium-water reactions by APDA.
- b) Corrosion of Cr-Mo in reaction products by B&W.

Independent of B&W requirements, APDA proposes a 3-year large-scale reaction study for \$588,000.

- 8.2 Mr. W. R. Wykoff presented a historical review of the rather sketchy work that has been done on sodium-water reactions by MSA, GE, NDA and APDA. He pointed out that there has been no significant work done on the subject since about 1957. From the available information, Mr. Wykoff concludes that:

- a) Oxygen must be excluded from the reaction area.
- b) Hydrogen must be vented by a rupture diaphragm.
- c) If the sodium and water are both cold, there is a possibility of auto-catalytic action.
- d) At temperatures above 600°F, the reaction proceeds rapidly, but smoothly.

- 8.3 A review of the current status and proposed work on sodium-water reactions was given by Dr. O. E. Dwyer. He finds that in steam generators:

- a) Small leaks result in corrosion problems.
- b) Medium leaks result in a combination of corrosion and hazard problems.
- c) Major leaks are expressly a hazards problem.

In his opinion he proposed analytical study of the reaction by APDA is worthwhile and that the proposed 3-year large-scale test by APDA be undertaken even though there might be some duplication of conditions with the work being financed by ESADA at AI in that the comparison of results would be beneficial.

- 8.4 Discussions of whether or not a sodium-water reaction analysis had ever been made for the Alco steam generator led to Mr. Savage assuring the committee that such an analysis had been made by Alco but he could not attest to its accuracy.

Mass Transfer in Sodium:

- 9.1 Mr. H. W. Savage (substituting for Mr. Holliday) reviewed the mass transfer program. The half replicate is about finished for the following conditions

<u>Top Temp</u>	<u>500°F Δt</u>	<u>250°F Δt</u>
1200°F	50 ppm oxide	10 ppm oxide
1100°F	10 ppm oxide	50 ppm oxide

in the 6 loops covering 316 SS, 2-1/4 Cr, 5 Cr individually and in paired combinations; metallurgical results are not as yet completed. Data from the tests are being computer analyzed in an attempt to develop equations for the parameters. The following general observations were made:

- a) The all-316 SS loop has a slightly higher corrosion rate than the other loops.
 - b) After a short initial period, the corrosion rates appear to become constant with time.
 - c) Oxide appears to have the greatest influence on corrosion rates; there are also flow and temperature-dependent factors.
- 9.2 Mr. Savage recommends that the Ad Hoc Committee meet every three months until evaluation of the data is completed and a new program is formulated.
- 9.3 Mr. Savage is of the opinion that the GE loops have produced all of the information that is required of them and that the Ad Hoc Committee could design loops that would be much more economical in both capital cost and operating cost and yield much more data.

In discussing this, a number of members feel that this type of work should be continued at GE because of their competence in this area; if necessary, the work scope and design of the loops could be changed.

ACTION will be taken by Ad Hoc Committee to evaluate the GE mass transfer results and recommend on future work on mass transfer, factoring in the possible necessity of tests in 304 SS.

- 9.4 Since GE is presently designing two additional loops of about the same configuration as the existing loops, the membership expressed the opinion that the design and materials for these new loops be appraised and that possible continued use of the existing equipment be determined.

ACTION will be taken by Mr. C. A. Pursel in organizing and chairing a group of experts to review this matter.

Analytical Techniques in Sodium:

- 10.1 Mr. Wise reported that the scatter of results from the carbon analyses from the First Round Robin (6 labs) have continued in the results so far reported by about half of the 21 laboratories involved in the Second Round. Since the results of the analyses were supposed to have been received by November 1963, the membership expressed the necessity of pursuing this problem more vigorously. If necessary, the Ad Hoc Committee should be strengthened and should meet more often until a strong plan of action has been formulated for oxide and carbon analysis; when this has been accomplished, the attack should be carried to other contaminants. It was pointed out that much of the research and development programs presently being performed are dependent on known contamination levels - without reliable analytical results these programs may have to be repeated in the future.

ACTION will be taken by Jules Wise to strengthen the Ad Hoc Committee and pursue the solution to the analytical problems.

- 10.2 Mr. Wise explained the UNC proposal for developing a continuous carbon meter; he explained that UNC was unwilling to contribute any of their own funds to establish proof-of-principle. The membership was not enthusiastic to pursue this proposal.

Steam Generators and SCTI:

- 11.1 Mr. A. E. Mravca reported that Mr. Whinery of IASL will join this Ad Hoc Committee.
- 11.2 SCTI construction is to be completed in February 1964 and AI has been instructed to proceed with a 4-step program of instrument and control checkout which will take about 6 months. Mr. Widors has been named by AI to be plant supervisor. AI is currently going out for bids on the installation of the Alco/BLH steam generator.
- 11.3 BLH is presently about 2 weeks behind the revised schedule for the Alco steam generator (showing a shipping date of May 18, 1964). Mr. Mravca and Mr. Gower passed around photographs of the assembly of the unit and samples of tube-rolls and welds; the assembly procedure prompted some discussions from the membership due to the alignment ring at the hot end with one row of tubes rolled into it and the second and third rows tack-welded to it. Since this operation has

already been passed in the assembly, there seemed to be no point in continuing the discussion. The problem of welding 600 tube-ends, 15 passes each, is yet to be encountered in the assembly.

- 11.4 The HT-HP Test Loop Program at BLH has been discontinued due to slippage and non-phasing with the need for this information in producing the Alco steam generator. CH is now investigating re-use of this equipment at other facilities.
- 11.5 Mr. G. C. Gower described the AI modular steam generator design, 21 Mw of which is now being procured for testing in the SCTI; this step in procuring another steam generator was taken, on the recommendation of the Ad Hoc Committee, to insure that a steam generator is available for SCTI in the event that the Alco/BLH unit runs into further schedule trouble. The consultant members were quite disturbed to find that the modular units had become part of the program without them being aware of it and without their review of the design. The minutes of the May 13-14, 1963 meeting of the committee indicated that Dr. Eggen had, in fact, made a presentation on the modular design.

ACTION will be taken by Mr. C. A Pursel to send each of the four consultant members a package on the AI modular design.

- 11.6 Mr. G. C. Gower also made a presentation on the Babcock & Wilcox steam generator contract. During Phase I, B&W will produce designs for a 1000 Mw(t) unit, a 30 Mw(t) prototype, and research and development (some of which was previously mentioned in Section 8) for the prototype. The additional research and development consisting of (a) a test of two-phase flow and heat transfer in curved tubes and (b) the removal of slag inclusions by chemical methods, both drew considerable discussion from the committee; particularly in regard to item (b), it is not clear just what application this investigation has to the design of the B&W steam generator.

Upon completion of Phase I, the B&W design will be evaluated before approval is granted to proceed with the Phase II production of the prototype for testing in SCTI.

- 11.7 References: The following were passed to all members:

- a) "Sodium-Heated Steam Generator Program," with Outline, dated January 16-17, 1964.
- b) Cost Data - B&W.
- c) Steam Generator Test Program, Ad Hoc Committee Report No. 1, dated November 19, 1963.
- d) Steam Generator Test Program, Ad Hoc Committee Report No. 2, dated December 23, 1963.

Miscellaneous Items:

- 12.1 A list of proposed meetings of the committee for 1964 was passed out to the membership for their comments.

ACTION will be taken by members to submit their comments to Dr. Wensch on the proposed 1964 meetings.

- 12.2 Mr. R. Jones is to meet with the Steam Generator Ad Hoc Committee to discuss sodium-water reactions.

ACTION will be taken by Messrs. Jones and Mravca to set up this meeting.

- 12.3 Dr. Wensch asked that CH review and revise the "Black Book" procedures which govern the Working Group activities.

ACTION will be taken by Mr. C. A. Pursel.

- 12.4 The secretary for the meeting reviewed the action items.

- 12.5 Mr. W. R. Simmons summarized the meeting. He expressed satisfaction with the meeting in being both helpful and enjoyable. In his opinion, the Long Range SCDP review will uncover some new areas of research and development which may require committee attention before the next scheduled meeting.

- 12.6 Mr. Wykoff expressed his praise of the work being done by the standing committees.

- 12.7 Analytical chemistry of sodium should be stressed in the next scheduled meeting.

ACTION will be taken by Dr. Wensch.

- 12.8 The meetings for these two days ran from approximately 9:10 a.m. to 6:30 p.m. on the first day and 9:00 a.m. to 5:20 p.m. on the second day.

Prepared by R. H. Jones
Meeting Secretary

Attachment:
Guide and Source Book

Minutes of the Sodium Components Working Group

Meeting No. 34

(Review Group No. 4)

April 17-18, 1964

Hollywood, California

Members Present:

R. H. Jones, RD-HQ, Acting Chairman
O. E. Dwyer, BNL
J. P. Holliday, SAN
A. E. Mravca, CH
C. A. Pursel, CH
J. J. Purcell, CH

C. W. Richards, CPAO
H. W. Savage, ORNL
W. R. Simmons, ANL
J. Wise, NY
W. R. Wykoff, LASL

Members Absent:

G. W. Wensch, RD-HQ

Alternates:

G. C. Gower, CH - April 15 and 16
J. A. Bailey, SAN - April 15
R. E. MacPherson, ORNL - April 15

Secretary:

D. P. Kuntz, RD-HQ

Introduction:

- 1.1 The meeting was opened with the announcement by Mr. Jones of the inability of Dr. Wensch to be present because of more pressing matters in Headquarters, that he had been requested to preside at the meeting, and that Mr. Kuntz would act as Secretary and prepare meeting minutes.
- 1.2 The minutes of Meeting No. 3 held at HQ (Germantown) on January 16 and 17, 1964, were discussed. The Review Group approved the minutes with corrections as noted on original copy without reissuing.

SCDP Informing Meetings:

- 2.1 Mr. Jones expressed to the Group Dr. Wensch's desire to complement Mr. Richards on the excellent manner in which he handled the arrangements for Sodium Components Information Meeting. The Committee unanimously agreed with the commendation and also expressed its thanks for the fine help provided by CPAO and AI.
- 2.2 Standardization of slide presentations at future information meetings was discussed with the interest of improving clarity of presentation of data and to keep required projection equipment to a minimum. The group favored eliminating the use of opaque projections, large transparencies or view-graphs on the basis of equipment simplification; they agreed to limiting the projections tentatively to standard glass slides and 35 mm slides. It also favored furnishing advice to attendees of meetings as to just what projection equipment would be available.

ACTION - Mr. Richards agreed to take on the task of preparing, and distributing for approval, standard specifications for slide preparation patterned after AI and ASME standards.

Minutes of Palo Alto SCDP Information Meeting:

- 3.1 Mr. Holliday stated that the minutes of the Palo Alto meeting were now at the printers and should be distributed to the Committee by the end of April.
- 3.2 The manner of reporting minutes of future information meetings was discussed. The suggestion was made that abstracts should be prepared for inclusion in minutes. No decision was made, however, the group was advised that no minutes would be prepared for the meeting of April 13, 14, and 15, since distribution was made of all presentations at the meeting.

Organization and Procedures:

- 4.1 The initial meeting of the SCDP Review Group was held at 4:30 p.m. on April 15 attended by members, consultants, and several guests and alternates. On April 16, the meeting was limited to members and consultants only. Considerable discussion was held on the question of having alternates attend meetings with the consensus being that alternates are needed at times for backup in certain areas. Several alternative suggestions were made, such as having alternates attend but not participate or making arrangements to have certain alternates or other individuals participate on a particular subject. However, in the interest of keeping attendance limited in order to expedite discussions and accomplish the work of the group, Mr. Jones stated that it would be expected that members be fully acquainted with the subjects assigned to them and meetings should be limited to members and consultants only. Nevertheless, further consideration will be given to that question and more specific rules will be developed for application in particular circumstances.

ACTION - Mr. Jones will develop rules for approval of the group.

- 4.2 The time and place of the next meeting was discussed. It was decided that the meeting would be held in New York on June 11 and 12, 1964, to avoid conflict with the ANS meetings to be held in Philadelphia the following week. Mr. Jones stated it will be an executive meeting with members only with no contractors present.

ACTION - Mr. Wise will make all arrangements for hotel reservations, meeting rooms, etc.

- 4.3 The next information meeting for the SCDP will be held in September or possibly October. The place and time will be announced by Dr. Wensch at a later date.
- 4.4 Mr. Jones discussed the approach to be used regarding acceptance of unsolicited proposals. He explained that DRD will continue to accept unsolicited proposals provided the ideas presented are attractive to the particular program, are original, and/or comprise, in part, company confidential information. Such proposals should

be submitted to AEC by the operations office with full justification as to why the proposal should be accepted rather than soliciting competitive bids. However, Mr. Jones stated that in-so-far as practicable there should be a positive approach taken by field offices to having new work undertaken on a competitive basis. CH, NY and SAN will be the offices to prepare and issue invitations.

- 4.5 Mr. Jones presented the proposal of Dr. Wensch that consideration be given by the group to recommending the establishment of a permanent contractor selection board for work on the SCDP. Discussion centered on the difference between permanent technical versus permanent non-technical members of such a board. Mr. Wise was of the opinion that permanent non-technical members might cause some local problems in operations offices. Mr. Pursel felt that a board with permanent non-technical members could work all right. Following considerable discussion, the board agreed to support Dr. Wensch in his proposal for constancy in membership of selection boards for the SCDP to the extent that technical representatives from each operations office having an interest in the SCDP be selected as permanent members of such a board and that non-technical members be selected from the operations office which would have programmatic responsibility.

ACTION - Mr. Jones will follow up on this suggestion and advise members of the action taken on this matter.

- 4.6 Mr. J. Purcell discussed his activities in the preparation and distribution of the "Project Coordination Reports." Mr. Jones expressed Dr. Wensch's desire to commend Mr. Purcell on his good reports and the improvement in the distribution of technical reports relating to the SCDP. Mr. Savage suggested that a listing of reports received by Mr. Purcell be included in his report so all members could know what reports should have been received.

ACTION - Mr. Purcell stated he would do that and in addition he would distribute a list of names and addresses of all working group members to contractors preparing reports of interest, thereby assuring direct distribution. This will be coordinated with AEC policy, re: reports distribution.

- 4.7 Mr. Jones requested a volunteer to prepare and distribute a monthly newsletter covering items of interest in the Fast Breeder Reactor Program (SCDP). Mr. C. Pursel stated he would undertake that job.
- 4.8 On the matter of charters for Standing Committees, Mr. Holliday stated he had prepared a draft charter for his committee on Mass Transfer. It describes its functions, responsibilities, and procedures, and lists present membership. He requested approval to include members from outside the Commission and National Laboratories. Mr. C. Pursel stated that the updated "black book", requested by Dr. Wensch, had been completed and its recommendations should take care of the charter problem. The "black book" entitled, "The Sodium Components Development Program - Objectives, Organization, and Procedures for Implementation" was distributed. Comments were deferred until members and consultants had an opportunity to review it. Mr. Jones requested that comments on the contents of the paper be sent to Mr. C. Pursel.

ACTION - Each Ad Hoc Committee chairman was requested to submit to Dr. Wensch resume's of all of their committee members.

- 4.9 NASA has been requested to invite SCDP Committee members to attend their technical review meetings when items of interest to the SCDP are discussed, along with the suggestion that NASA participate in the SCDP. It was hoped that some duplication in development work could be avoided and a mutual exchange of information accomplished. However, to date, no support on this proposal has been received from NASA.

Liquid Metal Technology Building

- 5.1 Mr. Jones advised the group that IASL had requested funds for a Liquid Metal Technology Building to be built at Los Alamos. He asked Mr. Wykoff to bring the group up to date as to the general purposes of the project and its relation to SCDP. Mr. Wykoff explained that the project was one which had been proposed for several years to take care of work now being done under crowded conditions in other buildings. The work being done on liquid metals is in conjunction with the IASL fast breeder program responsibilities. He stated that the estimated cost of the facility was \$1,300,000 and emphasized it was to house existing work in sodium loops and was not a proposal to do new work or expand present efforts.

Long Range SCDP

- 6.1 One action item of the last meeting, namely the revised version of Mr. Wise's and Dr. Dwyer's Long Range SCDP, was not completed. The program was to be sent to group members for comment, but all comments have not yet been received. Mr. Wise says it should be distributed very shortly.

Sodium Pump Facility

- 7.1 Mr. Jones requested information on the status of the recommendations of Mr. Wise on the Sodium Pump Facility which were to be sent to Dr. Wensch. Mr. Wise stated that the NY recommendations to HQ were prepared and indicated that further conceptual design be carried out to optimize on a lower cost facility. Every effort would be made to obtain industrial support of this facility.

Reports of Standing Committees

Committee on Mass Transfer in Sodium

- 8.1 Mr. Holliday discussed the report of the Standing Committee on Mass Transfer in Sodium on its fifth review of the project at GE under USAEC Contract AT(04-3)-189, Project Agreement No. 15.
- 8.2 The program of originally planned experimental work for the five loop, five run fractional replicate program is almost complete. The Commission's position is that the original scope of the GE Mass Transfer Program will be met by three additional loop operations: (1) a 1300°F, 500°F, 10 ppm operation of all 316 SS loop 1; (2) long term (>20,000 hours) operation of bimetallic loop 2 at present operating conditions;

and (3) completion of the last fractional replicate run, 6-6, with all 5 Cr Croloy loop 6.

- 8.3 An estimate of up to one year will be required for data reduction, analysis, and evaluation remaining for this program. Both empirical and theoretical approaches to data analysis have revealed some unexpected or undefined variables or parameters.
- 8.4 The conclusions of the previous report are still relevant with minor modifications. The additional comments of the present report concern the technical output from the program and comments on program planning and execution.
- 8.5 The continuing evaluation of the data from the complete Fractional Replicate Program may indicate additional exposure data will be required to resolve interactions of test variables. There may also be a need to re-run tests to resolve questionable data. If some interaction is noted, consideration should be given to running the other half of the program on Types VI, VII, and VIII.

Type VI run : 1100°F T_{max} , 500° ΔT , high oxide

Type VII run : 1200°F T_{max} , 250° ΔT , high oxide

Type VIII run: 1100°F T_{max} , 250° ΔT , low oxide

- 8.6 Any future tests such as those above should retain the primary objective of preserving the structures for complete examination for the present program. The question of dismantling and cutting up the loop for examination was discussed. Mr. Savage was of the opinion that destructive examination should cover everything including pumps, et al. Determination of the time and extent of destructive examination will depend upon the need for re-runs in the present loops.
- 8.7 Mr. Simmons stated that if the runs were made with the three additional loops it would take about 1 1/2 years to complete.
- 8.8 Mr. Dwyer stated that the program is an important one and stressed that it was particularly important that the correlation of data must have a solid foundation. Important variables should be selected and studied in all ranges. Mr. Simmons was of the opinion that the primary need was to have an understanding of the problem which could best be obtained by bringing the present project to a logical conclusion; to be followed by resolving other problems. He was of the opinion that the program should proceed now with higher temperature loops.

Special Task Force on New Sodium Mass Transfer Loops

- 9.1 Mr. Pursel reported on the recommendations of the Task Force which was set up to study problems associated with the two new mass transfer loops which are proposed by the General Electric Company, and to make recommendations concerning the loops. O. E. Dwyer, H. W. Savage, W. R. Simmons, and W. R. Wykoff were members along with Mr. C. Pursel, who chaired the task force. The fundamental premise on which the committee performed its function was that the purpose of the work on Mass Transfer is to develop a mathematical expression relating selected key measurable variables, which could be used by reactor

designers to predict point to point corrosion rates in those portions of the system external to the reactor core.

- 9.2 Mr. Pursel stated that the Task Force was of the opinion that adding a variable, such as, L/D or S/V would improve results from present loops. However, loops designed as engineering mockups or models would provide information of more confidence for design use. The task force recommends that the two new loops be designed with that in mind.
- 9.3 Mr. Savage commented that he agrees that a useful mathematical expression for corrosion will result from the work done by GE, but that there has not been enough work done on the theoretical aspect of mass transfer for the long range program.

ACTION - Mr. Simmons will submit a statement for inclusion in the task force report with regard to additional 304 SS studies.

Mr. Holliday will develop a work scope from a theoretical standpoint for mass transfer that may be funded from a different group in AEC. This will be due within three months time.

Mr. Pursel will reinstitute his committee to develop the scope of work and time schedule, loops, etc., directed to developing the engineering data necessary for prototype system design in 1967. Due in 2 months.

Standing Committee for Mechanical Properties

- 10.1 Mr. Purcell discussed the committee report on MSAR work which he said was available for review by the group and he would welcome comments on the recommendation of the committee as contained in the report. He stated that tests involving nitrogen cover gas have been discontinued. The standing committee was of the opinion that the results of Mass Transfer work on SS 304 versus 316 would resolve the question of any need for further work. The standing committee has directed MSA to proceed along the recommendations of the report. The present schedule provides for continuing work for another 6 months. Another committee meeting planned in 5 months will determine the time of close-out.
- 10.2 Mr. Pursel commended the quality of work done by MSA. He recommended that the standing committee expand the scope of work being done by MSA on SS 316 and include more work on SS 304. Mr. Jones recommended that sodium samples taken in various runs be saved for future reference when analytical procedures are better developed.
- 10.3 Mr. Savage suggested that the MSA work should include work on 5 Croloy material.
- 10.4 The working group agreed with Mr. Pursel's recommendation that the standing committee develop a scope of work for the continuance of the MSA work specifically directed to carburization in sodium problem, noting that there may be some duplication but concluding that would probably be useful as verification.

ACTION - Mr. J. Purcell will arrange for the committee to develop that scope of work and will circulate it to group for comments, then proceed as soon as possible with the work.

Standing Committee on Steam Generator Test Program

- 11.1 Mr. Mravca circulated to the group the standing committee report Nos. 4 and 5 and discussed them generally, including the new schedules for the tests and the SCTI construction.
- 11.2 Steam Generators - It was reported that three tubes in the BLH generator had fused through and would most likely be plugged. Mr. Simmons suggested that there should be no hydro-testing of the BLH steam generators and Mr. Savage recommended keeping water out of the shell.
- 11.3 SCTI - The test program for the BLH steam generators was discussed. Mr. Mravca discussed informally the selection of AI as the contractor selected to do the test evaluation work on the BLH steam generator. It was noted that an updated schedule for module fabrication was needed.
- 11.4 B&W - The advanced procurement of long lead items requested by B&W were discussed. A visit to B&W is planned for next month by the Ad Hoc Committee.
- 11.5 AI Modules - The status of module fabrication, test program, and instrumentation were discussed. For details see the fifth report by the committee.

ACTION - Mr. Mravca will distribute copies of the module updating schedule to group members.

Standing Committee on Analytical Techniques

- 12.1 Mr. Wise distributed copies of the report prepared by GE entitled, "Review Draft of the Results of the USAEC Round-Robin Analysis for Carbon in Sodium," dated March 1964, number GEAP-4602. The Standing Committee recommended that the report be distributed to the participants in the Round-Robin Analyses.
- 12.2 Changes in membership of his committee had deferred action on this item. Mr. Eggen and Mr. Lockhart had left the committee and Mr. Fred Smith (ANL) had joined the committee. He still is in need of other members and will welcome recommendations. The names of Switzer (BNL), Anderson (HA), and De Kany of Indianapolis (AEC) were suggested.
- 12.3 Mr. Simmons stressed the need for development of analytical techniques for analyzing sodium prior to establishing a firm sodium specification.
- 12.4 The group discussed chart C-3 of the report which showed variance increase with increasing mean. - ppm Carbon Individual Analysis vs. Average ppm Carbon. It was recommended that the data be plotted on a log-scale.
- 12.5 Mr. Wise discussed UNC's proposal for developing a continuous carbon meter, including UNC's unwillingness to contribute any of their own

funds to establish a proof of principle. The consensus of the group members, except Mr. Wise, was to reject the proposal unless UNC would be willing to finance the work to a point demonstrating feasibility of development or prove out their theories prior to asking AEC support.

ACTION - Mr. Wise will send each working group member a copy of GEAP-4602 for comment. He will also have the Standing Committee submit a copy of the report to G. W. Wensch with its comments and recommendations, including a proposed distribution. The report will be corrected and modified after receipt of comments from the Working Group Members, then reissued.

Miscellaneous Items

- 13.0 Mr. Pursel recommended that the group take on shipping casks and fuel handling machines as items needing attention in the SCDP. Mr. Simmons stated there would be other things that need attention, such as, radiation damages.
- 13.1 Mr. Dwyer said the problem of hot spots must be considered when discussing extending loop test temperatures to 1400° at the fuel element.

Minutes of the Sodium Components Working Group

Meeting No. 35

(Review Group No. 5)

June 11-12, 1964

New York Operations Office

New York City, New York

Present: O. E. Dwyer, BNL, Consultant
 G. C. Gower (Acting for A. E. Mravca), CH
 R. Gariboldi (Acting for J. J. Purcell), CH
 J. P. Holliday, SAN
 R. H. Jones, HQ, Secretary
 C. A. Pursel, CH
 C. W. Richards, CPAO
 H. W. Savage, ORNL, Consultant
 W. R. Simmons, ANL, Consultant
 G. W. Wensch, HQ, Chairman
 J. Wise, NY

Absent: A. E. Mravca, CH
 J. J. Purcell, CH
 W. R. Wykoff, LASL, Consultant

Guests: S. Hittman (Assisting with arrangements), NY

Introduction:

- 1.1 Dr. Wensch called the meeting to order at 9:15; due to the number of members not yet present due to travel and accommodation difficulties, it was necessary to wait until 9:30 for officially convening the meeting.
- 1.2 Dr. Wensch, Jules Wise, and Deputy Manager Smith made introductory and welcoming remarks.
- 1.3 Due to the continuing difficulties arising with AEC contractors, it was necessary for Dr. Wensch to again reiterate that the main committee and the ad hoc committees are advisory in nature and, therefore, do not direct the work of the SCDP contractors.

Review of Minutes of the Fourth Executive Session in Los Angeles

- 2.1 The minutes of the Executive Sessions of the fourth meeting of the SCDP Review Group were accepted unanimously as corrected; revised minutes will be sent to Working Group.

Review of Action Items from Fourth Meeting

- 3.1 Resumes of ad hoc committees are not as yet complete (see minutes of the fourth meeting, para. 4.8).
- 3.2 Mr. Simmons' statement regarding the additional studies needed on 304 SS (see fourth, para. 9.3) is satisfactorily covered by the ANL report on the use of 304 SS for FARET.

ACTION: Mr. Simmons will send copies of this report to the Working Group.

- 3.3 The development of a mass transfer program (see fourth, para. 9.3) for theoretical mass transfer studies is believed to be too big a task for the ad hoc committee to undertake. Mr. Holliday recommends that the AEC contract for a literature survey and program definition on the theoretical aspects of mass transfer in liquid metals.

ACTION: Mr. Holliday will prepare a memorandum from SAN to HQ requesting this to be funded.

- 3.4 Development of engineering mass transfer program, to yield data for prototype system design by 1967, has not yet been initiated (see fourth, para. 9.3).

ACTION: Mr. C. A. Pursel stated that he would organize a task force right away to get started on this work. The objective will be based on 1200°F bulk outlet temperature.

- 3.5 The ad hoc committee on mechanical properties expects to meet soon and at that time will develop the scope of work for continuing the MSA work, specifically in the area of the effects of carburization in sodium on properties.
- 3.6 The updated modular steam generator schedule will be sent out by Mr. Mravca to the Working Group by the end of June (see fourth, para. 11.5).
- 3.7 The GEAP 4602 draft on Round Robin Carbon Analysis is ready for distribution (see fourth, para. 12.5). The final printing on this has not been done (Ref: Memorandum J. Wise to G. W. Wensch).

Euratom Exchange Agreement

- 4.1 Dr. Wensch, reporting on his recent visit to Europe, explained the new US-Euratom agreement for developing fast breeder reactors. There will be liberal exchanges of both information and personnel for the next 10 years. Instructions for implementation of this exchange program is forthcoming.
- 4.2 Highlights of his visit to Cadarache to review the sodium facilities were illustrated by photographs he had received during the tour.

SCDP Review Committee Charter

5.1 Mr. C. Pursel had received and consolidated the numerous comments from the Committee on the SCDP Charter revision dated April 6, 1964; the consolidated comments and the April 6 document were studied in detail by the Group for about 4-1/2 hours. Mr. Gariboldi made detailed notes of the accepted revisions.

5.2 Mr. C. Pursel will assume the task of rewriting and reissuing the Charter showing these revisions.

ACTION: Mr. C. Pursel will transmit the rewritten Charter to the Group.

ACTION: Mr. C. Pursel will enlist the aid of past members to extend the list of projects in Appendix "B".

ACTION: Mr. W. Savage will write the history of the Committee, possibly with the assistance of past members. He will transmit this to Mr. C. Pursel for inclusion in Appendix "B".

5.3 It was decided that the Charters of the ad hoc committee would be included as appendices.

ACTION: Ad Hoc Chairman will transmit copies of their Charters to C. Pursel (R. Gariboldi) and Dr. Wensch; they should review their Charters to be sure they are consistent with the principles of the main document before sending them out.

Mass Transfer and Corrosion in Sodium

6.1 At the 5th meeting the task force recommendations concerning the design of the two new loops requested that the process parameters or design criteria be specified by G. E. Mr. Holliday passed out the answer that he had just received from G. E. He explained that the original program was initiated on the basis of isolation (or inertness) of one process variable from all others; in designing the new loops G. E. had attempted to also isolate the new parameter, "downstream effect", from all others. The task force recommendations may obscure this isolation. Considerable discussion of these points were ensued.

6.2 In reviewing G. E.'s design criteria for the new loops, the consensus of opinion of the Working Group was that the criteria were poorly prepared, easily misinterpreted, and unacceptable. Mr. Holliday is to direct G. E. to make a satisfactory presentation of the design criteria for the new loops or we will be forced to reconsider the continuation of this program.

ACTION: Mr. Holliday is to obtain a complete and understandable set of design criteria from G. E.

- 6.3 In connection with the above specification of test conditions, the Group came to the conclusion that:
- a. The effects of cladding hot-spots up to 1400°F, under high Na velocity conditions of 20 to 30 feet per second must be considered if sodium bulk outlet temperatures of 1200°F are considered for our prototype plants. Hot-spot effect should be studied at 1200, 1300 and 1400°F.
 - b. The high velocity at the IHK heat exchange surface is important to model in the all-stainless system.
 - c. The heat exchange surface conditions in the secondary sodium mixed-materials should be modelled realistically.

The extreme importance of these conclusions is that we may find that we have to back away from our objective of 1200°F bulk outlet sodium temperatures due to high solution and deposition rates.

- 6.4 No satisfactory conclusion could be reached by the Group to Mr. Jones' question of whether the hot-spot, high-velocity, study could be carried out in simplified and more economical loops; Mr. Savage believed that this might be a possibility.
- 6.5 Actions still pending from the 4th meeting concerning the Mass Transfer and Corrosion program are covered in paragraphs 3.3 and 3.4 of these minutes.

Steam Generators and SCTI

- 7.1 Mr. G. Gower presented summary reports of:
- a. The SCTI construction work.
 - b. The fabrication of the Alco steam generator by BLH. The Group was concerned about the change from G. E. high temperature strain gages, which were to have been installed by AI, to low temperature gages which BLH will install themselves; Mr. C. Richards is obtaining a written statement from AI as why this happened.
 - c. The AI modular steam generator fabrication, noting that the use of type 321 SS is causing them some difficulty particularly in the tubing not passing inspection.
- 7.2 AI has requested that the AI modules be tested in the SCTI before the Alco/BLH unit due to the impending possibility of selling an SGR reactor plant. The Alco test operations are scheduled to start about December 15, 1964. Testing of the modules could not start until about one month later. The consensus of opinion of the Working Group is that AI should go out for bids on both installations at the same time; then DRD can decide at a later

date which steam generator should be tested in view of schedules. If the modular schedule slips very much in the next few months, the Alco unit should be installed and its testing carried out as soon as possible.

- 7.3 In discussing the hydrostatic testing of the shell side of the Alco steam generator at BLH, Mr. Simmons recommended pneumatic testing rather than hydrostatic testing. However, if straining of the nozzles is to be done concurrently with the pressure test, he believes pneumatic pressurizing is too dangerous. It was the general conclusion of the Group that hydrostatic testing would be performed but that the greatest of care must be exercised in assuring that the demineralized water used is of high quality and is chloride free.

ACTION: Mr. Gower is to arrange with BLH to obtain assurance on water quality during hydrostatic testing.

- 7.4 Mr. Gower presented the B&W prototype unit cost estimate. The step increase in cost of this unit is being investigated by the Chicago Operations Office.

Mechanical Properties of Materials in Sodium

- 8.1 Mr. Gariboldi reported on progress of the MSA program. The most unusual operation to be reported is that MSA is now noting a "double break" in their plugging runs.
- 8.2 The Group discussed the availability of high temperature materials which are compatible for sodium service. Mr. Savage expressed his interest in seeing a program initiated for developing an alloy which is specifically conditioned for high temperature sodium service.

Reports Distribution

- 9.1 Mr. Gariboldi passed out a chart showing a survey on report distribution entitled "SCDP Reports Requested by Contractors", dated April 13, 1964; in general, contractors have requested copies of monthly, topical and summary reports in nearly equal numbers. In studying the reporting situation Chicago Operations made the following recommendations:
- a. Monthly Reports should be eliminated.
 - b. Monthly News Letters would be issued by CH.
 - c. Quarterly Reports would replace Monthly Reports.
 - d. Topical Reports would continue as at present.

- 9.2 The recommendations resulted in considerable discussion by the Group. The need for further consideration caused this subject to be tabled until the next meeting.

ACTION: Mr. Purcell (and Gariboldi) will consider comments received from the discussion in preparing the next SCDF meeting.

Impurities in Sodium

- 10.1 The three UNC Continuous Oxide Meter field units will be made available to interested laboratories and contractors for operational tests. Mr. Wise is dispatching the inquiries for expressions of interest in these tests.
- 10.2 Mr. Wise reported on the Westinghouse work on removing samples from the Fermi Cold Trap.
- 10.3 The UNC Carbon Meter proposal was turned down because proof of principle had not been attempted. Mr. Wise reports that UNC will make a bench test to provide this proof with their own funds.
- 10.4 Mr. Wise reported on UNC work for the Air Force on electro-chemical purification of sodium; this appears to be based on the UNC continuous oxide meter used in reverse, e.i. with voltage applied to the electrodes.

Sodium Pump Test Facility

- 11.1 Mr. Wise passed out NY-prepared implementation document for the Pump Facility.
- 11.2 Mr. Holliday commented that as far as he knows all of the pumps in operating sodium reactor systems have been produced by one manufacturer and with satisfactory performance.
- 11.3 Mr. C. Pursel notes that this same manufacturer's report in the document indicates that no R&D is necessary for producing large sodium pumps; he feels this is refreshing for a change.
- 11.4 Mr. Simmons reported on the EBR-II secondary system linear induction pump failure after about 1000 hours of operation. The pumping tube had developed two cracks about 3" long at the internal spacer supports. Consideration was given to replacing this pump with the 5000 gpm ANL test pump which had been tested for 15,000 hours; upon inspection of the pumping tube, however, it was found to have a 1/2" crack at the same location.

Long Range Program

- 12.1 Mr. Wise now has the revised program prepared. He reviewed it briefly and will send copies of it to the membership for comment.

ACTION: Mr. Wise will send revisions to Group.

Standards for Presentation Material

- 13.1 Mr. Richards has studied ASME and AI standards for projection material. He passed out copies of "Art Standards" for consideration by the Group. It is recommended that in future meetings only 3-1/4" x 4" and 2" x 2" (35 mm) slides should be used and that projectors will be provided at each meeting for these sizes.

ACTION: Mr. Richards will prepare a letter for Dr. Wensch to the Field Offices on slide material standardization. The Field Offices will in turn notify their respective contractors of these standards for SCDP meetings.

Arrangements for Next Meeting

- 14.1 The Group agreed that the next meeting should include contractor reviews by the Committee.
- 14.2 The next meeting will be in October at Chicago.

ACTION: Mr. C. Pursel will choose data and make necessary arrangements.

Miscellaneous Reports

- 15.1 Mr. Savage, on an unofficial trip to B&W in Barberton, talked to them concerning the 1,000 MW steam generator design. He likes the over-all design but has reservations on the following items:
- a. They have not made stress analysis of sharp bends.
 - b. There is a possibility of flow striations through the tube bank on the shell side.
 - c. With sodium heating the circumferential variation in heat flux, which B&W found in their DNB testing, will not exist.
- 15.2 Dr. Wensch reported on the U.S. visit of a Euratom exchange candidate. Anyone desiring to have him at thier installation for one year should plan to interview him during his visit.

Conclusions

- 16.1 The meeting on June 11 started at 9:30 a.m. and adjourned at 6:30 p.m. On July 12 the meeting came to order at 9:15 a.m. and adjourned at 2:05 p.m. for lunch.
- 16.2 The membership expresses their appreciation to Mr. Wise for the arrangements he made in their behalf.

Minutes of the Sodium Components Working Group

Meeting No. 36

(Review Group No. 6)

Minutes of the last meeting were reviewed and approved as written. C. W. Richards discussed the status of the sodium components test installation and the Atomics International modular heat exchangers. He reported that the Alco unit had been delivered and that 40 thermocouples had been installed on the shell by AI. Strain gages are to be installed just before transient tests are run. This is being done because of the expected short lifetime of the strain gages. The hot air preheat system for the primary sodium system has required much balancing to permit satisfactory operation. The electrical heaters on the sodium inlet line to the gas furnace burned out during preheating of the system. Failure was due to compaction of insulation around the Calrod heaters. The header box to the furnace has been opened, and the heaters are being repaired. An inadvertent interconnection between the primary and secondary sodium systems was discovered during vacuum pump down and has been corrected. The 5,000 gallon sodium tank from the Hallam pump test facility will be added to the SCTI tied into both the primary and secondary systems to provide required sodium dump capacity. Ralph Jones asked if an improper dump of the sodium inventory could cause the tank to overflow. C. W. Richards indicated that administrative control would be required over the dump procedure to avoid this possibility. Concern was expressed by all as to the complexity of the dump process. The subcommittee on the operation of the SCTI is to review the proposed dumping scheme and make necessary recommendations as soon as possible. March 15, 1965, is the current earliest date for completion of preoperational testing. Seven additional engineers have been added to the SCTI staff to expedite operating procedure preparation. A total of 32 engineers are currently available on a six-day week.

In discussing the modules, Richards indicated that a superheater tube was to be replaced due to porosity in a weld. The same repair techniques which were applied successfully to evaporator tube weld repairs are to be used. AI plans to plug the tube if repair procedures are unsuccessful.

John Pursell reviewed the progress at MSA on physical properties of material. The type 304 stainless steel on which tests have been recommended is not type 304-L but has chrome-nickel specifications which are narrower than for normal type 304 stainless steel. Interest in Incaloy-800 has led to recent recommendations for testing. These will probably be carried out in a type 316 stainless steel system initially. The use of simple thermal convection loops rather than static pot tests to determine the relative carburization of type 304 stainless and type 316 stainless steel was suggested by O. E. Dwyer. The loops would permit a closer prediction of carbon potentials.

Due to the difficulty with moderator cans at Hallam, a request was made to MSA for fatigue data to assist in required stress analysis. The

present program at MSA should indirectly produce the required information. It is currently planned to do this work.

The present committee covering the work at MSA has been set up to study the physical properties of materials in sodium. It is suggested that the name of the committee be changed to Mechanical Properties of Materials for Sodium-Cooled Reactors to permit a broader scope. Wensch said that such title might be too broad and that other work which would lead to an extension of the present program should be considered on its own merit at the time it is suggested.

Jules Wise reported on the sodium impurity program. Metz has dropped off the committee and has been replaced by Waterbury. The report of the June 30 subcommittee meeting contains a tabulation of the Committee's plan for the sodium impurity program. There was some discussion as to whether this work should be channeled towards one of the national laboratories or should be parceled out to industry. John Purcell felt that the program at APDA was a good foundation for an expanded program. Wensch indicated that the Committee should continue to work on a well-founded program and that their presentation should discuss the problems and the scope of the work required using both the laboratories and industry.

Babcock & Wilcox then reported on the status of their steam generator program. The first item discussed was the B&W-APDA sodium-steam reaction program. John Morabito and Wayne Chase indicated that a literature search is underway, preliminary design recommendations have been made, and a mathematical model is being developed. Paul Probert mentioned that modifications to the tube supports to provide greater flow areas for reaction product release has caused some problems concerned with shipping the unit. Probert then mentioned modifications which are being made to the steam generator design. The internal valve is being removed, the downcomer annuli are being opened up, and the downcomer tube support spacing is being changed. The possibility of the bundles being lifted by reaction force is being examined. The B&W steam generator contains 3800 gallons of sodium with the center pipe filled. Probert also reported on the materials program in progress at B&W.

John Holliday reported on the mass transfer program at General Electric. The design of the new GE mass transfer loop has been authorized and long-term procurement which would not affect design has been approved.

Jules Wise reported on the sodium pump test facility. A four-part program has been proposed by New York Operations Office. This would include additional design studies, a facility design, site survey, and facility operation. It is intended to provide a design package to an architect-engineer to permit facility design based on the Westinghouse criteria. The FY-1966 budget contains money for this work. In addition, work is planned on bearings and seals and on pump design, dovetailing with facility design. Sites available include CANEL, Oak Ridge, ANL, Idaho, Savannah River, AI, and Hanford.

Wise reported on the status of the UNC oxide meter. Housings are made and sensors are being tested in thermal convection loops. Testing indicates the meter is useful, although improvements are still possible. Calibration shows the slope of voltage versus oxide concentration is theoretically correct but the signal level is low by a constant factor. At 10°F temperature fluctuation gives approximately a 10% change in output reading, with a response time in the order of minutes. Field tests are planned at APDA, ORNL, and a third site not yet chosen. This could be MSA, LASL, or AI. LASL is currently building a loop for testing sites of this type and plans to offer to test these meters. Work on a carbon meter is in the very preliminary stage but appears promising.

Wise also reported on the cold trap work at Westinghouse. Coring techniques have been developed for removing samples from the cold trap. Major problems have been encountered in sample analysis. These problems have been reviewed with APDA and ORNL. Until Westinghouse has resolved their difficulty, APDA will provide analytical services.

Wensch gave the schedule of future meetings, as itemized below:

February, 1965	Executive Session, San Francisco
May, 1965	Information Meeting, Chicago
June, 1965	Executive Session
October, 1965	Contract Review
January, 1966	Executive Session

The theme for the June, 1965 Information Meeting will probably be "Materials", and there may be invited papers on advanced reactor materials from NASA and EURATOM.

Minutes of the Sodium Components Working Group

Meeting No. 37

(Review Group No. 7)

March 3-4, 1965

San Berkely, California

Attendees:

G. W. Wensch, Chairman, LMCRB, USAEC, Headquarters
R. H. Jones, LMCRB, USAEC, Headquarters
J. Dissler, USAEC, New York Operations Office
C. W. Richards, USAEC, Canoga Park Area Office
G. Gower, USAEC, Chicago Operations Office
R. J. Gariboldi, USAEC, Chicago Operations Office
J. J. Purcell, USAEC, Chicago Operations Office
O. E. Dwyer, Brookhaven National Laboratory, Upton, New York
H. W. Savage, Oak Ridge National Laboratory, Oak Ridge, Tennessee
W. R. Wykoff, Los Alamos Scientific Laboratory, Los Alamos, New Mexico
T. A. Nemzek, USAEC, San Francisco Operations Office
J. B. Radcliffe, USAEC, San Francisco Operations Office
C. V. Backlund, USAEC, San Francisco Operations Office
J. A. Bailey, USAEC, San Francisco Operations Office
J. P. Duffy, USAEC, San Francisco Operations Office

1.0 Introduction

T. A. Nemzek, Deputy Manager, SAN, welcomed meeting attendees and announced that there would be a dinner that evening at the Castaway in Jack London Square.

2.0 Introductory Remarks

G. W. Wensch, USAEC, Headquarters, opened the meeting formally and appointed secretaries for the four sessions as follows: Monday morning - J. A. Bailey, USAEC, SAN; Monday afternoon - R. J. Gariboldi, USAEC, CH; Tuesday morning - J. Dissler, USAEC, NY; Tuesday afternoon - C. W. Richards, USAEC, CPAO.

3.0 Review of Facilities

Dr. G. W. Wensch

3.1 SRE-PEP

There are at present no plans to operate SRE with the PEP modifications but consideration is being given to using it as a fast fuel irradiation facility. The decision as whether to modify or decommission the facility will be made within two months. The SGR program is terminated and work not related to the fast breeder program at Atomics International is being reoriented or terminated.

3.2 EBR-I

Decommissioned.

3.3 EBR-II

At present, EBR-II is shut down for the repair of a pile oscillator rod which is jammed. This malfunction is a result of a faulty bearing. It is suspected that the bearing failed because carbon steel rather than stainless steel was used in the manufacture of the bearings. This incident points to the need for greater quality control in the manufacture of reactor components.

3.4 FARET

Construction has not yet started but the cost estimate has increased from 17 million to 21.25 million (3 million contingency included). The purpose for FARET is being reviewed in the light of current information on Doppler coefficients from critical experiments. It is probable that the FARET program will be reoriented away from physics and toward fuel irradiation. If the facility is used for fuel irradiation, the size of the heat dissipating equipment may prove to be inadequate. A decision is expected within two months.

3.5 FFTR

Hanford has been authorized to undertake a design study of the Fast Fuel Test Reactor.

3.6 ATR

There are no current plans for the use of ATR in the fast breeder program.

3.7 SEFOR

Generally, the plant construction and R&D program of SEFOR are in good shape. The construction schedule has been delayed several months by difficulties in getting a construction permit. It is still anticipated that the reactor can be constructed within the cost estimate. The principal problem in the SEFOR R&D program is procurement of the critical assembly fuel for ZPR-III. The pre-production prototype plates recently sent to ANL from NUMEC were totally unsatisfactory.

3.8 Hallam Nuclear Power Facility

There have been 8 or 9 moderator can failures. The consequent swelling has made it impossible to remove some of the moderator cans and 18 of the fuel assemblies even with forces of 11,000 pounds. Present efforts are directed entirely toward removing the fuel. It is estimated that 37 months would be required to redesign, fabricate and test new moderator cans. Most of the moderator can failures have been in the region of a large flux gradient.

3.9 ZPR-III

ZPR-III is currently being used for FARET and will be used later this year for SEFOR. It is expected to be phased out in 1968.

3.10 ZPPR

ZPPR will be used to simulate fast flux cores for 1000 MWe FBR plants.

3.11 ZPR-VI

ZPR-VI is to be modified to accommodate an all plutonium loading.

4.0 Minutes from Meeting No. 6

No minutes from Meeting No. 6 were available for review.

5.0 Pending Action Items

5.1 SCTI Storage Tanks

The Steam Generator Committee was assigned the job of getting details on the sodium storage tank and valves for SCTI and making recommendations to the Chicago Operations Manager. C. W. Richards, USAEC, CPAO, reported that the larger tanks had been installed and that Canoga Park had reviewed and approved Atomics International's plans. A complete safety review of SCTI by Chicago Operations will be conducted upon completion by Atomics International of the operating manuals (due March 31, 1965).

5.2 Hydrostatic Testing of Modular Steam Generator

The Standing Committee on Steam Generators (A. E. Mravca, USAEC, CH) was assigned the task of reviewing water treatment for hydrostatic testing of the modular steam generator. No action has been taken.

5.3 Sodium Mass Transfer Committee Charter

J. P. Holliday, USAEC, SAN, was to rewrite the charter for the Standing Committee on Sodium Mass Transfer. This was completed.

5.4 Bibliography on Strain Carburization

MSA is to publish a survey of foreign literature on strain carburization. This has not been completed and J. J. Purcell, USAEC, CH, will follow up on it.

5.5 Repair of Steam Generator Tube

C. W. Richards, USAEC, CPAO, was to have notified Headquarters formally if Atomics International could not repair a particular steam generator tube. It was later repaired and so reported in one of the weekly reports.

6.0 Working Group Charter and History

6.1 Charter

All charters for the Standing Committee have now been submitted. G. W. Wensch indicated that he would review these charters with RDT management.

6.2 History

H. W. Savage, ORNL, reported no progress in the writing of the history. He estimated he would complete a draft of from 5-10 pages by July 1, 1965.

7.0 Other Old Business

7.1 Distribution of Trip Reports

H. W. Savage proposed that he would send copies of future trip reports to all consultants and AEC members of the working group. The Chairman agreed with this proposal.

7.2 SCDP Long Range Program

This was to be completed by J. Wise and discussed in the afternoon session. It has not as yet been completed; G. W. Wensch relieved New York Operations of the responsibility for this work and transferred it to Headquarters. O. E. Dwyer, BNL, pointed out the need for feed back of current problems into the long range plan. G. W. Wensch indicated the need to include substantial proof testing and improved quality control in the development of sodium components. The 10 year plan originally prepared in October 1964 needs to be discussed and updated. Fuel development particularly needs emphasis.

7.3 ZPR-III Fuel and SEFOR

Using the experience on this fuel program as an example, G. W. Wensch emphasized the need to document the responsibility for the cause of and the steps being taken to correct unsatisfactory performance on the part of the contractor. If necessary he said, the contract should be terminated.

7.4 Eighth SCDP Information Meeting

This meeting will be held at the Pick Congress Hotel, Chicago, on June 16, 17, 1965. The emphasis will be on materials for fast breeder reactors. The agenda has been sent to G. W. Wensch by J. J. Purcell for approval.

7.5 UK-USAEC Information Exchange on Fast Reactors

The AEC has signed and the United Kingdom is expected to sign an information exchange agreement under which both long and short term personnel assignments may be made in the United Kingdom. Five or six long term (18 months) and a number of short term (2-4 weeks) assignments are contemplated. Contractor personnel are encouraged to send the names of qualified specialists to G. W. Wensch.

7.6 Monthly Coordination Report

H. W. Savage asked if the monthly coordination report included all related projects. J. J. Purcell answered that it included all of those things under the cognizance of the Liquid Metal Cooled Reactors Branch. The question was raised as to how Chicago Operations would know promptly about the initiation of new projects. It was suggested that Chicago Operations monitor the financial plans to keep abreast of the new projects. J. J. Purcell reported that some of the monthly reports from which he makes up the monthly coordination report have been delinquent and he encouraged the appropriate field offices to expedite contractor preparation.

7.7 Discussion of Future Plans

H. W. Savage requested that the AEC inform the consultants periodically of the future plans for development of sodium components and fast breeder reactors. G. W. Wensch agreed. H. W. Savage further stated that we need not only a long range plan but also a short range plan (2-3 years).

7.8 SNAP-8 Corrosion Program

H. W. Savage reported that work under the current work statement for this program is coming to an end and there are a number of significant conclusions which he would like to review both with the Working Group and with General Electric.

7.9 Standing Committee on Steam Generators

R. H. Jones, HQ, expressed concern with the lack of activity of this Committee.

7.10 USSR Visit - Dr. Wensch

G. W. Wensch discussed briefly the recent trip of American reactor experts to the USSR.

7.11 Status of European Sodium Technology - H. W. Savage

The highlights of Mr. Savage's trip to Europe were presented and discussed. The vapor distillation techniques developed by the British warrant examination. Dounreay FBR is a very successful experiment. Culcheth loops are being used to test Niobium and ferritic steels. Risley is a growing laboratory and will test a 7000 gpm pump shortly. The eddy diffusivity probes are of interest. Steam generator designs lean toward modular types. Na-H₂O reaction work has started at Karlsruhe. European R&D is "State Government" oriented. ISPRA-FBR program is ambitious as they plan a 100-300 MWe prototype within five years.

8.0 Mechanical Properties of Materials - J. J. Purcell

8.1 Mr. Purcell presented a discussion of the noteworthy advanced data made available by MSA. This recent data indicates that:

- (1) 304 SS may carbonize faster than 316.
- (2) Creep rates appear to drift and are significantly affected by factors not presently understood. Carbonization case hardening appears to be a prominent factor.
- (3) Aging appears to reduce impact absorption capability.

9.0 Sodium Analytical Techniques- J. Dissler

9.1 Mr. Dissler presented an invitational proposal formulated by the Committee for Sodium Analysis. This would concentrate the analytical effort under one contractor. The program, estimated to cost \$500,000, provides for:

- (1) A survey of problem areas and any organizations of the "state of the art",
- (2) Examination of sampling techniques and handling procedures,
- (3) Development of analytical procedures, and
- (4) An intra-laboratory demonstration.

9.2 He also discussed F. Smith's proposal to establish monthly reports of sodium impurity measurements made at all facilities and reactor sites; this would allow a statistical analysis to be made.

9.3 Mr. Jones objected to the invitational package because it failed to recognize work which is presently in progress in support of our base programs. Objection was also made to concentrating the entire effort with one contractor. Relative to the statistical reporting of all measurements being made, this could not be expected to be enlightening due to the present state of scatter in analytical results.

9.4 Since this proposed invitation had not been available to the Working Group prior to the meeting, Dr. Wensch tabled it for further consideration at the next meeting in June.

10.0 Steam Generators and SCTI - G. Gower

10.1 Mr. Gower presented the status of the Alco-BLH, B&W and AI steam generator work in conjunction with the program to develop and test these units in SCTI.

10.2 Work at SCTI is progressing with only minor difficulties being incurred. The Alco-BLH unit is 75% installed. The drain tank modification to SCTI is virtually complete.

10.3 The B&W prototype fabrication was deferred six months to analyze the redesign for sodium water reaction effects.

11.0 New Program Items, NY - J. Dissler

11.1 Sodium Pump Test Facility

The Conceptual Design Study Document (WCAP 2526, November 1963) gives design and cost estimate \$6,000,000 of facility for prooftesting large pumps for future fast breeder reactors using

and 1 loop for 60,000 gpm pump tests
 2 loops for 120,000 gpm pump tests or two 60,000 gpm
 pump-paralleling tests.

NY has broken down the remaining work into:

Title I Preliminary Design and Scoping Studies -
 \$100,000 and nine months to perform.
Title II Final design and specifications.
Title III Actual construction.

The Title I solicitation package is prepared but not sent out. This design study will lead to optimization for a minimum capital cost facility and will incorporate flexibility in facility for proof testing of other components such as valves, instrumentation, and mechanisms which require large flow rates to establish their performance.

The next step is to survey government owned or leased sites and utilize the characteristics of the site selected in this finalized Title I design study. NY has solicited industry for expressions of interest in building the facility; the response was not satisfactory (for example, 5-year write off of the facility was wanted in one response). Dr. Wensch indicated that, since there would be future use of the facility for other types of tests after the pump test, it does not seem advisable to build the facility at other than a government site.

11.2 Large Sodium Pump Design Study - J. Dissler

In the Na Pump Development and Facility Design evaluation (WCAP 2347), it was recommended that a mechanical centrifugal pump, vertically mounted, appeared most suitable for development. The 1000 MWe design studies all proposed this type pump. Shaft seals and totally enclosed motors were both considered. A \$150,000 ten-month design study will be solicited for this type of pump.

The specified pump capacity of 50-60,000 gpm has been selected. Possibly 6 pumps of 50,000 gpm and 4 pumps of 80,000 gpm or more will be tested. Solicited design studies will ask for evaluation of pump location in the primary system. Design temperatures for pump location will be 900°F for cold leg and 1200°F for hot leg.

11.3 Bearings and Seals Test Program - J. Dissler

A bearing and seal test program, in support of the pump development, will be initiated this year. Candidate bearings and seals will be tested to establish engineering design data and proof test reliability. Feed-back from the pump design study will guide the bearing and seal development.

New Program Items, CH - R. Gariboldi

11.4 Steam Generator Evaluations

CH reported that bids had been sent out and responses received for performance evaluation of steam generators which are to be tested in SCTI.

11.5 Large Valve Design Study

CH is readying request for proposal for an evaluation of designs for large (42") valves. It will encompass selections of valve types best suited to high temperature sodium service for stop, throttling, and check valves.

11.6 Piping Flexibility

CH is readying requests for proposal for development of flexibility analysis for thin-walled piping for high-temperature close-coupled sodium systems.

11.7 Under-Sodium Scanner

APDA is developing the ultrasonic transducer for an under-sodium scanning system. Presently, a determination of the attenuation and scattering properties of ultrasonic waves in sodium is being determined to evaluate the basic feasibility of such a device.

11.8 Other New Work Items

H. W. Savage asked what the statement of work was for the MSA programs in FY 1966. As stated in yesterday's meeting, the work should be directed toward getting data which is useful to designers.

11.9 G. W. Wensch questioned whether there are any further uses for the GE Task I mass transfer loops Nos. 1 to 6. The Mass Transfer Committee will investigate the future use of these facilities.

11.10 J. Dissler reported on the TiV alloy compatibility test with fuel and sodium which Westinghouse is funding. Data will be made available to the AEC. Bob Allio at Westinghouse is the responsible scientist. The question of whether the GE loop could be used for further evaluation of the TiV alloy resulted in a discussion of the work which ANL has done on TiV alloys.

Westinghouse used ANL data in developing their alloy which is supposed to have increased corrosion resistance in high temperature strength.

- 11.11 CH is to look into the TiV alloy development work and advise the Committee and consultants of the status of the work.

12.0 Sodium Mass Transfer Project - Presented by the General Electric Company

The General Electric representatives were:

R. W. Lockhart
D. R. Riley
R. S. Young
M. C. Rowland
D. Dutina
E. G. Brush
E. L. Zebroski
G. D. Collins
K. Cohen

The presentation and comments are summarized as follows:

- 12.1 As an introduction to their presentation, Mr. Riley reviewed their four year FBR Program. It is GE's estimate that the country will be on a fast reactor basis by 1990-1995. In 1972-73 there will be sufficient Pu available for operation of a couple of prototype plants. In 1980 we will be fully utilizing Pu from thermal reactor systems.

Technical program elements needed for a prototype commitment on a 300 MWe reactor plant are:

SEFOR Operation
Fuel Technology
Fuel Processing
Core Analyses and Design
Sodium Technology
Sodium Components

GE is presently engaged in all of these activities except Sodium Components; they rely on AEC programs to develop these. G. W. Wensch stated that for GE to rely on the AEC to provide the technology on sodium components is not enough; GE must prepare preliminary guidance on their requirements for such development. K. Cohen, GE, said that this information would be supplied to the AEC before the ANL meeting in August after updating their 1000 MWe fast reactor study.

12.2 Sodium Technology Development should:

- a. Establish character of sodium compatibility with cladding material under typical FBR conditions.

b. Result in understanding of basic sodium technology in order to establish operating limits.

c. Provide criteria for selection of critical materials.

12.3 The GE Mass Transfer Program, Task I, was summarized by Mr. Young. The six mass transfer loops have been operated for the past four years to obtain information on candidate materials behavior in sodium. Five replicate runs, with delta T and oxide content varied, have resulted in development of an empirical corrosion equation. The candidate materials tested were 316 SS, 2-1/4 Cr and 5 Cr steels in single alloy loops. The significant results were:

- a. Metal loss rates 1/2-2 mils/year at 1200°F, 12 ppm oxide, and 21 feet/sec. Materials are marginal for use at these loss rates. Loss rates beyond initial operation are linear with oxide concentration.
- b. Carbon stabilization is effective in controlling carbon loss in ferritic steel. Ferritic steel carbon loss to stainless steel is serious at high temperatures. Conversely, 1/2% Titanium - stabilized ferritic steel is not affected.
- c. Selective leaching and deposition of alloying elements from the austenitic steels was observed.
- d. Observation of intergranular penetration in the loop piping when the loops were taken apart, showed:

Ferritic - few mils in 20,000 hours
 316 SS - 1 mil in 28,000 hours at low O₂.
 316 SS - 7 mils in 20,000 hours

12.4 Material Exposure Effects were reported by M. C. Rowland as follows:

- a. The information reported was obtained from loop 2 (316/2-1/4 Cr) samples at 20,000 hours and after 25,000 hours the loop was cut up and examined.
- b. Measurements taken at the hot leg of run 2-5 showed a weight loss. Steady state corrosion was linear from about 1,000 to 20,000 hours. Data taken at the cold leg C-1 position showed a large weight gain reaching a maximum at 5600 hours and then falling off at longer exposures. Here the short term samples had a surface accumulation while the long term samples were clean; this is interpreted as showing that surface buildup is eventually sloughed off.
- c. The surface chromium concentration versus time in run 2-5 was reported as:

Hot leg - Concentration drops and then levels off.
 Cold leg - Due to Cr deposition there is a gain which levels off at about 6,000 hours.

d. Carbon movement in run 2-5 was reported as:

Hot leg - Carbon pickup in hot leg is linear throughout entire test.

Cold leg - Carbon loss which levels off after 4,000 hours.

e. The effect of exposure of 316 SS to both high and low oxygen sodium indicated that surface Cr and Ni content remains close to "as received", whereas continuous exposure to low oxide sodium results in appreciable loss of surface Cr and Ni. Intergranular attack in hot to cold leg piping (between H-3R and C-1 where temperature is supposedly isothermal) is severe contrary to what was expected.

Loop 3 - 316 SS - 5-1/2 mils in 20,000 hours

Loop 1 - 316 SS - 2 mils in 20,000 hours

Loop 3 - 2-1/4 Cr - 2 mils in 20,000 hours

12.5 The program on Sodium Analysis in support of the Mass Transfer work was presented by D. Dutina as follows:

- a. Sodium samples were taken at the start of each run and whenever a specimen was removed from the loop. Analyzed for Cr, Fe, Ca, Ni, and recently H. No chemical analyses for oxygen were performed; oxide concentration was determined as that shown by the plugging meter.
- b. The water-acid method was used in analyzing for carbon. Results reported as:
 - (1) Loops having low carbon transfer
 - #1 - 60 ppm total carbon
 - #4 - 34 ppm total carbon
 - #6 - 41 ppm total carbon
 - (2) Loops having high carbon transfer
 - #2 - 40 ppm total carbon
 - #3 - 40 ppm total carbon
 - #5 - 41 ppm total carbon
 - (3) Loop 7 - 304 SS - 33 ppm total carbon
Carbon was added as carburized steel
- c. Analysis of metal impurities in sodium did not show any pattern to go along with the corrosion data. Impurities of Fe, Cr, and Ni were typical of most operating loops. When samples are dissolved there is some residue of metal which must be dissolved by other chemicals indicating that other than simple metallic compounds exist.
- d. Analytical techniques were developed to measure Ca and H, and results seem to indicate that these elements are not responsible for the double breaks seen in plugging runs. Cover gas analyses have never shown carbon, but high (1/2%) concentration of hydrogen has been found.

e. The improved analytical techniques program will investigate methods for impurity separation:

- (1) Liquid ammonia
- (2) Mercury amalgamation
- (3) Distillation

These methods will be used simultaneously for making separations from large sodium samples (10 L). For impurity identification the following techniques will be used:

- (1) X-ray and electron diffractions for compounds
- (2) Microscope for homogeneity
- (3) X-ray fluorescence for elements
- (4) Wet chemistry for metals and interstitials
- (5) Off gases for decomposition products

GE feels there is a need to determine the species leading to differences in carburization. The British speculate that carbonyl or methanyl compounds may have an effect on carburization. GE suggested that it might be desirable to synthetically formulate compounds for corrosion study.

12.6 The Corrosion Mechanism Empirical Model was explained by Mr. E. G. Brush as follows:

The initial step in corrosion of 316 SS in sodium is one of diffusion and oxidation, and the product may be totally or partially removed subsequently. This mechanism is represented by a model in which backward and forward diffusion of elements in the alloy and the driving forces causing composition changes are mathematically described.

In applying the model to observed corrosion data the following observations were made:

a. In Unsaturated Positions

Fe - noble
Cr, Ni, Mn -- Active
Mo -- neutral

b. In Saturated Positions

Cr -- noble
Fe, Mn -- Active
Ni, Mo -- Neutral

- c. There has been good agreement between calculated and observed corrosion rates.
- d. The activation energies are:

For Alloy Diffusion ~ 52 kcal

For Local Rate Constant ~ 10 kcal

12.7 Discussion

Dr. Wensch inquired about the wide spread in the magnitude of these energies of the heat of activation; the 10 to 50 kilocalories per mole appeared reasonable from solid state diffusion theory but the spread appeared rather large. Dr. Wensch suggested that the surface condition of the stainless steel and ferritic layer, and possibly the degree of cold working, could affect the diffusion interface and consequently, in this postulated case, the heat of activation value. Dr. Brush expressed agreement with this avenue of approach.

- 12.8 The Task II Loop Design and Test Plan was described by Mr. R. W. Lockhart: The design criteria for the two new loops recognizes hot-spot fuel clad temperatures and models a typical reactor (based on the four 1,000 MWe sodium cooled reactor systems) were presented as follows:

- a. Test Loop Flow and Capacity:

Calculated flow < 8 gpm; heat capacity ~ 100 kw.

- b. Material

Heat transfer surface 316 SS

Isothermal section 304 SS

- c. Temperature and Temperature Distribution:

1300-800°F

- d. Film Temperature Drop:

High flux heater 60-80°F

Low flux heater 20-30°F

- e. Flow Velocity:

2-25 feet per second

- f. Component Configuration:

Unit cell section or mockup

(annular or tubular cross-section)

- g. Corrosion Rate Determination - Ring Samples Predominate

h. Material Exposure Effects

i. Sample Removal Apparatus - Access to ends and hot and cold legs.

The changes in amounts of corrosion products (ΔS) in each unit volume of sodium flowing through a reactor mockup section will be the same. The dimension of the test sections will be determined from the ΔS in terms of section length, wetted perimeter, and configuration for a given loop flow rate. The scale of the mockup compared to the reactor system will be 1/30,000. To change from one reactor system to another, the walls of the test sections will be changed.

GE will send their corrosion predictions (based on Para. 12.6) to G. W. Wensch before the two new loops are operated. This will establish the validity of the mathematical model as an engineering tool.

The operating conditions of the loops were given as:

Loop 8 - T max 1300°F
T min 800°F
T_S 305°F

Loop 9 - T max < 1300°F (hot channel)
 > 1100°F (ave. rod)
T min 800°F
T_S 250°F

Operating high q/A runs of 2 and 4 months are believed satisfactory to obtain necessary data.

Program will run from July 1965 to December 1966.

The rebuilt loop test program will be complimentary to the new program. The variables were listed as follows:

Loop 1 - 316 SS - High heat flux test from May-June
 $t_s \sim 275^\circ\text{F}$; $t_s = 305^\circ\text{F}$

Loop 6R - 304 SS - Material comparison (effect of cold work; differences between 304 and 316 SS)

Loop 5R - 304 SS - Stressed samples (internal pressure and mechanical stress)

Loop 4R - 304 SS - Chemistry (Add C, Ca, H, N, or X)

12.9 Discussions:

H. W. Savage asked if there was any correlation in corrosion of the horizontal pipe sections between the hot and cold legs with the H3 position. The answer was "no". Losses from H3 are believed to be due to the composition effect (downstream effect). Area where oxygen corrosion was observed is where none was predicted. and no samples were present there.

O. E. Dwyer asked if ionizing radiation had been considered as having an effect on carbon transport. Lockhart felt that this should be investigated and suggested that one way would be to precarburize a sample in a corrosion loop and then irradiate the sample in a reactor loop. Reactor temperatures are too low to do the total job in a reactor. GE might also do some studies prior to reactor mockup on radiation changes in diffusion, thermodynamics, chemical equilibrium, and flux dependency.

In answer to a question, Lockhart stated that in Loops 2 and 3 the 2-1/4 Cr decarburizes to 0.02%, grain growth is observed, and surface recarburization is observed.

13.0 Sodium Components Test Installation - Presentation by Atomics International - Dr. Eggen

13.1 SCTI Status

During the last year the Sodium Components Test Installation (SCTI) has undergone preoperational tests, system shakedown operation, and system modifications. Currently it is scheduled to start initial operations on June 1, 1965 and the official testing of the Alco IHX and Alco/BLH steam generator will start on July 1, 1965.

The work on the sodium storage tanks is about two weeks behind schedule. Instrumentation tests are ahead of schedule. Steam and feedwater system tests are behind by several days. Preparation of the preoperational test procedures manual and plant descriptions are approximately 90% complete. Standard operating procedures are presently being prepared.

13.2 SCTI Modifications and Maintenance Items

A number of system modifications and maintenance items have been necessary in the last year:

- a. In September 1964, after purging the primary system and filling with sodium, it was found that the primary storage tank was undersized. On checking, the secondary storage tank was also found to be too small. A new primary tank was purchased and the old primary tank was used to replace the undersized secondary tank in the steam generator pit.
- b. The water leakage problem in the steam generator pit was rectified by the installation of a sump pump.
- c. The instrument air compressors, which have been in place for several years, had to be reworked to remove the pitting in the cylinders and valve parts which resulted from moisture condensing in them.
- d. The header heaters on the Gas Fired Sodium Heater had to be replaced due to failures which resulted from improper installation.

- e. The pressure reducing steam flow nozzles were interchanged during construction; these have now been unscrambled and installed in their proper locations.
- f. Auxilliary connections to the primary and secondary piping systems were interchanged during construction resulting in the two systems being tied together; these connections have now been properly transposed.
- g. A number of instrument-line valves were installed backwards; these have now been installed correctly.
- h. Miscellaneous safety valves, check valve and traps required modifications.

13.3 SCTI Potential Problem Areas

Dr. Eggen listed the following as being potential problems in the operation of SCTI:

- a. Primary pump flooding. This is a free-surface pump located at the lower end of the system.
- b. Sodium heater burnout. The probability of burnout is remote and does not warrant a replacement unit (~\$100,000).
- c. Tube plugging in sodium heater. Possibility of oxide plugging of several tubes during startup.
- d. Two-pass condenser tube failures. This is an old navy single pass condenser which was rebuilt as a two-pass unit; therefore the water re-entry is at the packed-end with no flare.
- e. Low-load control of system. Although the control system has been analog analyzed, there is still concern about control stability at low-loads.
- f. Rupture disc replacement. There is very little known about the life characteristics of the rupture discs under normal pressures.

13.4 Organization for SCTI Operations

The trade union negotiations have resulted in it being necessary to use one Stationary Engineer on each operating crew. The remaining crew members may be drawn from regular AI test engineers and technicians.

13.5 Discussions of SCTI Presentation

- a. Mr. Jones asked whether design-basis information was being furnished to the operators in the plant description (para. 13.1) and pointed out that this must be made available to SCTI operators if they are to function efficiently and safely. Dr. Eggen stated that descriptions are being written by the plant designers.

- b. Mr. Jones asked what happens when primary pump (Para. 13.3a) trips out, what Δp loss occurs between surge tank and pump, and how pump tank gas supply and gas exhaust are controlled. Dr. Eggen explained that Δp is possibly a few feet of sodium, that this is sensed by level probes which admit inert gas, and that malfunction may result in flooding the pump. Should this occur, there may be a shutdown of several days. The alternates are to install a canned rotor pump or relocate the present pump to a high elevation.
- c. Dr. Wensch asked how we ended up with this design. Dr. Eggen said it was an economy move to use an existing pump but it should not have been installed at the low elevation.
- d. Mr. Jones noted that inert gas costs are going to be high in trying to control pump tank sodium level by gas admission and venting. Has AI looked at a gas accumulator? Dr. Eggen said they would.
- e. Dr. Wensch asked that AI give some assurance that the inert gas line vapor traps will work. Dr. Eggen said AI was confident they would since they are a proven design used at Hallam.
- f. Dr. Wensch asked what AI is doing to prevent errors, such as the sodium storage tanks (Para. 13.2a), in the future. Dr. Eggen explained that the SCTI is a very complex system -- more complicated than a reactor system--and is subject to design, construction, and operating errors. Mr. Dickinson, Assistant to the Executive Vice President, entered the discussion at this point to explain that AI is setting up a Configuration Review Group to guard against such errors.
- g. Dr. Wensch asked for an order of importance to the problem areas (Para. 13.3). Dr. Eggen expects that the No. 1 problem is pump flooding and No. 2 problem is tube plugging. The No. 3 problem is possibly low-load operations troubles.
- h. In the general discussions which followed this AI presentation, a number of points were made by the committee members. Mr. Jones recommended that condenser tube manufacturers be consulted to correct the possible tube erosion problem now; Dr. Wensch asked that AI give a definite indication that this would be done. Mr. Gariboldi expressed the opinion that some of the anticipated problem areas showed up as a result of the system hazards analysis. Mr. Savage noted that in his experience the instrument and control systems are a source of much trouble. Mr. Savage expressed his concern about the pump flooding problem and commented that a means of trapping the gas to minimize the gas volume in the pump might be considered. Mr. Jones questioned whether the possibility of plugging the sodium heater tubes with oxide should be listed as a possible problem area since, with proper operation, this could not occur.

14.0 Modular Steam Generators - Presentation by Atomics International, Dr. Eggen

14.1 Status of Fabrication

The two evaporators, which are now in inert gas storage, have received their ASME code stamps. Lower-end welding is still in progress on the two superheater units. These 37-tube modules are prototypical of larger units, which may have as many as 121 tubes. The experience gained by AI in fabricating these units would result in more efficient manufacturing methods for a large plant order. For one thing, they should not use 5-1/4 Cr steel again; they would accept increased material thickness of 2-1/4 Cr to compensate for decarburization effects.

14.2 Fabrication Problems

The use of 5-1/4 Cr steel for the evaporator units required vacuum cast material. A large billet was obtained and cut into 6" thick slabs. Using ultrasonic inspection, the various slabs were sorted for ultimate forging into tube sheets and nozzles. During the assembly process, requiring 300 internal tube welds, five cases of human error occurred; the main reason for error involved the use of steel wool plugs in the tubes to control the inert cover gas. One superheater tube suffered four repairs, three of which involved errors in the use of the wool plugs.

All welds of the units were x-rayed and dye penetrant checked.

The design report on the modular steam generators has been issued. An AI internal report on manufacturing methods, problems, and costs will be sent to the Standing Committee on Steam Generators.

14.3 Discussions of Steam Generator Presentation

- a. Dr. Wensch asked whether the reference to "efficient" manufacturing (Para. 14.1) indicated that AI would have more confidence in reliability of the units. Dr. Eggen answered affirmatively adding that the evaporator material for future reactor plants would not be 5-1/4 Cr steel.
- b. Dr. Wensch asked what has happened to change their minds on the use of 5-1/4 Cr steel after so thoroughly contending its use during the design stage.

Dr. Eggen explained that the fabrication cost increment of 5-1/4 Cr over 2-1/4 Cr cannot be justified. The evaporator modules built of 2-1/4 Cr would only cost about \$40,000 each (~25% of cost with 5-1/4 Cr).

- c. Dr. Wensch asked what AI had done to assure manufacturing success in changing from 2-1/4 Cr (on which they had based their methods) to 5-1/4 Cr steel.

Dr. Eggen said they had run 5-1/4 Cr steel tabs and found no difficulties which would indicate their welding methods were not applicable. However, in actual fabrication of the units the methods had to be revised -- the tab checks just did not give a true indication.

- d. Mr. Jones asked why we are again in the position of proof-testing a prototype unit (at a cost of about \$1 million) which is not a prototype by the time it is manufactured; why not build two evaporators of 2-1/4 Cr steel at \$40,000 each?

Dr. Eggen commented that the change in material does not change the operation as a prototype.

- e. Mr. Savage asked why AI had picked 5-1/4 Cr steel anyway.

Dr. Eggen said it was necessary for SCTI operating conditions; 2-1/4 Cr would decarburize at the hot-end temperature of > 900 F.

- f. Dr. Wensch asked if AI had moved too fast on materials selection and recommended less building and more thinking might be in order. Dr. Eggen stated that they would use 2-1/4 Cr for a reactor plant and 5-1/4 Cr for SCTI.

This concluded the AI presentation by Dr. Eggen.

15.0 Sodium-Water Reactions - Small Leak Test - R. Gariboldi

Construction and procurement of the APDA small-leak test equipment is proceeding close to schedule. About a two-week delay was caused by inaccessibility to the site after a recent snow storm.

The small-leak test is designed to investigate the erosive effects of an initial small leak on adjacent tubes. This type of erosion, from a leak which is below the limits of detection, may result in deterioration of adjacent tubes to such an extent that major multiple tube failures occur. The configuration of the tube helix simulates the B&W steam generator design and is being performed as part of the test program recommended by B&W.

Mr. Savage commented that he was not aware of this test. He cannot evaluate how good the test arrangement is without knowing the details of the tests and program details. Mr. Jones explained that this program was initially part of the B&W contract but was later funded by CH directly to APDA. Mr. Wykoff and Dr. Dwyer indicated that they had reviewed the proposal for this test (they had included a description of the test program in their joint presentation on "Sodium-Water Reactions", Meeting No. 3, January 16-17, 1964).

Mr. Savage commented that not being fully informed on the programs is a recurring problem; it not only applies to this APDA work but also to SCTI and the work at MSAR. Mr. Richards recommended that there be a complete review of all programs before the next Committee meeting.

16.0 Fermi Cold Trap Analysis - J. Dissler

- 16.1 The cold trap analysis work at Westinghouse is approaching completion and the final report is being prepared.

17.0 Future Meeting Plans

- 17.1 The next meeting will be an Information Meeting on June 16 and 17, 1965 at Chicago; the theme of this meeting will be "Materials for Sodium Cooled Reactors". It will be followed by an Executive Session of the Committee on June 18. It was established that the dates shown for this meeting do not conflict with the ANS meeting.

18.0 ORNL and SNAP-8 Mass Transfer - H. W. Savage

- 18.1 Mr. Savage made a slide presentation of views of Oak Ridge National Laboratories and of the work that his group has been doing on Mass Transfer for the primary NaK system for SNAP-8. Mr. Savage stressed the importance of exact modeling of the scale-down (in this case 50:1) in carrying out this work; in this connection he expressed satisfaction with the GE Mass Transfer plans for the two new loops. One of the interesting points in the presentation was the high corrosion rates, noted in three of the tests, which were typical of higher oxide conditions than the operating history of the loops would indicate; these were probably the result of inadvertent short periods of oxygen admission to the system (such as during repairs).
- 18.2 Mr. Savage and his staff have made significant contributions to the understanding of hydrogen migration in high temperature liquid metal systems. This work may go uncompleted because of termination of the SNAP-8 work at ORNL.

19.0 Conclusion of Meeting

- 19.1 It was suggested that the Standing Committee on Mass Transfer (Mr. Holliday, Chairman) should review the new work scope for the two loops at GE prior to the startup date of July 1, 1965. Dr. Wensch concurred.
- 19.2 Dr. Wensch expressed his thanks to the Committee Members and Consultants and to the SAN Office for their participation in this meeting.
- 19.3 The meeting was adjourned at 5:20 p.m.

Minutes of the Sodium Components Working Group

Meeting No. 38

(Review Group No. 8)

June 16-18, 1965

Chicago, Illinois

Minutes of the Sodium Components Working Group Meeting with Babcock and Wilcox (B&W) and Atomic Power Development Associates (APDA) representatives and the executive meetings which preceded and followed the B&W presentation are as follows:

Attendees:

Working Group

R. H. Jones, HQ., Chairman
J. J. Dissler, NY
J. P. Holiday, SAN
C. A. Pursel, CH
C. W. Richards, CP

Consultants

O. E. Dwyer, BNL
H. W. Savage, ORNL
W. R. Simmons, ANL
W. R. Wykoff, LASL

B&W

P. B. Probert, Project Manager
J. G. Clark
T. P. Farrell
J. E. Hocking
F. A. Perrera
G. L. Skinkle

Standing Committee, Steam Generator

G. C. Gower, CH., Actg. Chairman
K. C. Hoffman, BNL
K. D. Kuczor, ANL
R. E. MacPherson, ORNL
L. Whinery, LASA

Other AEC Representatives

J. J. Purcell, CH
J. E. Weinberg, CH

APDA

W. L. Chase
J. A. Ford

In the executive meeting attended by the AEC and National Laboratories personnel, the broad objectives of the meeting with the B&W and APDA representatives were described as:

1. Determine if an initial tube failure will make the steam generator designed by B&W unsafe.
2. Determine if the prototype steam generator can be safely operated in the Sodium Component Test Installation (SCTI).

3. Consider whether there are any obvious safety problems in the full size steam generator.

Mr. Savage mentioned the May 21, 1965, letter from Mr. Pursel to the Working Group which had outlined the APDA sodium-water reaction test program supporting the B&W design and which had been written in response to a request by Mr. Savage at the Working Group meeting in Berkeley, California, in March 1965. Mr. Savage asked whether the criteria presented therein had been satisfied by B&W, and Mr. Gower replied that some, but not all, had been satisfied and referred to the June 4, 1965, Standing Committee Report No. 8 - Steam Generator Testing.

The B&W and APDA representatives were then requested to enter the meeting room, and Mr. Probert presented a tentative agenda for consideration. Mr. Jones requested that the discussion be limited to (1) the Sodium-Water Reaction Study and (2) a Review of Quality Control Procedures for Prototype Fabrication.

Mr. Probert stated that the presentation would include APDA's work on mathematical analysis of sodium-water reactions and corrosion, while B&W would review (1) their work on stress analysis of the steam generator based on the APDA input and (2) manufacturing quality control procedures. Mr. Probert stated that the conclusions of their stress studies were:

1. The prototype steam generator can survive with simultaneous complete tube failures (25 total). This postulated accident is worse than a series (one after the other) tube failures which would result in lower pressures.
2. For the full size steam generator the existing shell thickness can survive 20 simultaneous tube failures, which is considered to be the worst case. The analysis indicated that shell stresses were greatest for tube ruptures in the boiler downcomer location.

Mr. Ford listed the assumptions they made in their mathematical analysis of sodium-water reactions in the steam generator as:

1. Leak rate of water and steam is instantaneous (step change from zero leak rate).
2. Peak reaction temperature of 1800°F was taken from APDA tests run in 1958.
3. Hydrogen released by the sodium-water reaction expands isothermally.
4. The hydrogen bubble instantaneously assumes the shape of the container.
5. There are two flow paths (up or down the center channel and up the downcomer annulus) for reaction relief.

6. The pressure drop of each region of the steam generator was smeared over the whole region and has negligible effect on bubble pressure.
7. There is sodium above the leak location but the static head above the leak is negligible.

APDA chose as the worst set of conditions for their analysis the startup of the steam generator with the sodium and water isothermal at 350°F and water pressure of 2625 psig. During operation with steam in the tubes instead of water the reaction pressures would be less.

Mr. Ford showed charts plotting bubble pressure as ordinate and time as abscissa for simultaneous ruptures of 1, 5, 100, and 676 tubes in the full size steam generators. There was a chart for each of four locations in the boiler section (A. bottom of downcomer annulus, B. top of downcomer annulus, C. bottom of tube bundle near center channel, D. top of tube bundle near center channel). The highest bubble pressures were obtained at locations A and C and were similar in magnitude. For a one-tube rupture the pressure at 10^{-4} seconds was about 5×10^3 psi at 0.1 seconds. For a 5 tube rupture the pressure at 10^{-4} seconds was about 9×10^3 psi and decreased to about 500 psi at 0.5 seconds. For 100 tubes the pressure at 10^{-4} seconds was about 5×10^4 psi decreasing to 10^3 psi at 0.1 seconds. For 676 tubes the pressure at 10^{-4} seconds was 8×10^4 psi decreasing to 10^4 psi at 0.08 seconds. In the discussions on these pressure-time tube rupture charts it was noted that the pressures for a 5-tube failure in the full size unit were the same as for a 25-tube rupture in the prototype. Mr. Ford said that the fact the pressures were the same was simply fortuitous and not the result of design. In response to a question of why the shell stresses had not been calculated at a higher temperature, say 900°F, Mr. Ford replied that temperature increase was not significant in view of the short reaction time.

Mr. Ford listed three mechanisms for propagation of tube failure:

1. High temperature softening of surrounding tubes. (Ford indicated there is a lack of experimental data for this mechanism but stated it is not of concern below 3000°F).
2. Corrosion from reaction products.
3. Mechanical damage from reaction pressure.

Mr. Chase reported on the results to date from the sodium-water reaction tests. The first test had a small orifice (0.016") behind the rupture disc, and it was supposed to put in 0.03 pounds of water per second at 350°F and 2650 psig. There was difficulty in initiating the reaction because, as later examination showed, crud built up in the rupture crack and sealed it against further leakage. (It was suggested that APDA consider use of a rupture disc that would rupture all around rather than open only a crack). Examination of three tubes adjacent to the rupture

showed oval type wastage of 4-6 mils. Conclusion was that it is probable that wastage can propagate to more than the immediate row.

In the second test a 3/32" orifice was used behind the rupture disc, and it was sized to admit 3 pounds of water per second at 350°F, 2650 psig. Visual examination of adjacent tubes looked like a ball-peen hammer blow had been struck against the tubes.

Observations from these tests are that wastage takes place in seconds and at the most in a matter of minutes. The fact that a reaction has taken place is determined by a temperature increase in the system.

Mr. Perrera based his discussion on a paper entitled "Dynamic Bursting Strength of the Babcock and Wilcox Co. 1000 MWT Sodium Heated Steam Generator During a Major Sodium-Water Reaction", copies of which he gave to all in attendance. After his presentation questions were raised on whether his stress calculations based on a shell temperature of 650°F should not be performed assuming a shell temperature of 900°F in order to assure greater conservatism. There was also a question of whether temperature had an effect on yield strength and strain hardening constant, whether an analysis of the shell using yield strength instead of ultimate strength would result in a different conclusion, and whether this made the analysis more or less conservative. In response to a question if there were any circumstances which could produce a bulge in the shell, Mr. Perrera answered that statistically there were none. Only by increasing the temperature of shell locally by having a leak in the liner in conjunction with the reaction was this conceivable. A question was raised that since there were several methods of analyzing the shell stresses which would result from a sodium-water reaction, would it not be reasonable for B&W to check their analysis by using one of the other methods such as the work-energy equation, $pV = \sigma \epsilon t l$, where pV is the reaction energy and is equated to the energy absorbed by the vessel.

Mr. Farrell gave out a few copies of a folder in which he showed how quality control was applied to fabrication jobs at B&W. The Quality Control group is in the Boiler Division where the steam generator fabrication would be done and reports directly to the Manufacturing Department. Quality Control Process Engineers prepare the detailed process sheets which guide a job through the shop. They also review procurement material orders before they are placed and inspect the material when it is received in the plant. Mr. Farrell showed examples of process sheets for a forming operation and welding specifications to show the thoroughness of quality control procedures and checks. He stated that fabrication of components is given the same quality control review as naval projects in the shop.

At the completion of the formal B&W presentation Mr. Savage commented that the specified helium leak detection rate of 0.01 micron per cubic foot per hour for checking welds appeared too high. B&W stated that the leak rate for individual tubes would be 0.001 microns/ft³/hr and that the total leak rate after the tubes were all welded would be 0.01 microns/ft³/hr. Any leak above background would be repaired but B&W

did not want to put a zero leak rate requirement in the specification because interpretation would cause problems during inspection. Mr. Savage stated that it was important to know and specify the leak detection capability of the mass spectrometer.

It was noted that the only transients specified in Volume I of the Design Report were 5°/second while the AEC-B&W contract required the unit to be designed for transients of 25°/second. Mr. Probert stated that the unit would meet the transient conditions specified in the contract.

After the B&W and APDA people had left the room, the AEC and National Laboratory personnel commented on the presentation as follows:

1. B&W is using a conservative approach in analyzing and designing the unit since it did not seem credible that a large number of tubes would instantaneously fail. The accident analysis assumption that there would be no decrease in water flow with time was conservative. The fact that there is a protective device (rupture disc) in the unit which would relieve the pressure from a sodium-water reaction makes the analysis and design conservative.
2. From the APDA tests it appears that a small tube leak could cause damage to the whole unit due to tube wastage.
3. Quality control is important to assure the integrity of the unit and it appears that the B&W procedures will be satisfactory. It was suggested that a further review of the quality control procedures should be made to insure that nothing was overlooked. Although the philosophy used by B&W in setting leak detection rates for checking tube welds sounds okay, a leak rate or leak detection procedure should be specified.
4. The Steam Generator Standing Committee has recommended that a larger continuous drain line be installed on the unit because the one presently designed is small enough that it could plug causing the annulus to be flooded with sodium.
5. A strain-energy calculation should be made in between baffles to assure that vertical support structure will not fail in an accident.
6. Accident analysis should include a bulge analysis.
7. B&W should make their analysis more workmanlike by taking out errors which appear therein.
8. It would be nice to know what Probert had in mind when he said that design changes could be made in the unit which would result in a 20-30% reduction in costs. CH indicated that a cost reduction study was included in B&W's project proposals for next year.

9. B&W should be authorized to go ahead with the fabrication of the prototype. RDT will initiate action to accomplish this.

Mr. Probert was recalled to the meeting and told that:

1. The Working Group recommendation to RDT will be to go ahead with the unit fabrication.
2. B&W should sharpen up their analysis and design report. A tube weld leak rate should be specified and might be in the form of a leak detection procedure rather than a leak rate specification.
3. B&W should check their dynamic stress analysis of the shell by another method such as the work-energy relationship. The analysis should be made with the strain hardening value at operating conditions.
4. B&W should perform a set of calculations on the adequacy of the baffle support.
5. B&W should consider putting a larger (2") annulus drain line between the baffle and the shell.
6. B&W should make an analysis of localized shell bulges with a one tube failure and the jet impinging on the shell.
7. B&W should make a central channel implosion analysis to assure that the central channel will not collapse after a tube failure and thus seal off one of the avenues for reaction relief.

The Chicago Operations Office will notify B&W of these recommendations as soon as headquarters has approved them.