December 11, 1990

Docket No. 50-029

MEMORANDUM FOR: Richard H. Wessman, Director
Project Directorate I-3
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

FROM: Patrick M. Sears, Project Manager
Project Directorate I-3
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

SUBJECT: SUMMARY OF PUBLIC MEETING CONCERNING ANNEALING OF REACTOR VESSELS IN THE SOVIET UNION

On December 3, 1990, Mr. A. Taboada of the Office of Nuclear Regulatory Research made a presentation to interested members of the public concerning annealing operations of reactor vessels in the Soviet Union. The slides Mr. Taboada used are enclosed. The presentation was in preparation to witnessing the annealing of a reactor vessel in the Soviet Union by various NRC & utility employees as well as industry engineers.

A short discussion of the logistics concerned with the trip to the Soviet Union was made by Mr. E. Shoemaker of International Programs.

A list of attendees is enclosed.

Original signed by
Patrick M. Sears, Project Manager
Project Directorate I-3
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Enclosures:
As stated

cc w/enclosures:
See next page

LA:PDI-3	PM:PDI-3	MEB	DET	D:PDI-3
MRushbrook	PMSears:mes	CSerpan	JRichardson	RWessman
12/6/90	12/6/90	12/10/90	12/12/90	12/11/90

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000027

ENCLOSURE

Dec 3, 1990

REACTOR VESSEL ANNEALING

NAME	ORGANIZATION/POSITION	PHONE
PATRICK SEARS	NRC/NRR YANKEE PROJ. MGR	301-492-14[illegible]
SAM LEE	NRR/LRPD	492-0771
B. D. LIAW	NRR/DET / Dep. Director	492-3298
A. TABOADA	RES/NRC	301-492-3838
R. JENKINS	CONSUMERS POWER	517-788-1505
W. Hopkins	Bechtel	301-417-3091
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Lynn Connor	SAIC	703-827-4957
Eve Fotopoulos	SERCH Licensing, Bechtel	301-417-3094
C. J. Cheng	NRC/NRR/DET/EMCB	301 492-0796
J.L. Caldwell	NRC/OEDO	301 492-1726
R. Wessman	NRC/NRR/PDI-3	301 492-1433
J.E. Richardson	NRC/NRR/DET	301-492-0722
K R WICHMAN	NRR/DET/EMCB	301 492 0757

ENCLOSURE

MPR ASSOCIATES, INC.

November 20, 1990

Mr. Chuck Serpan
Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
5650 Nicholson Lane
Rockville, MD 20852

Subject: Report of Meeting Concerning Annealing of Reactor Vessels in the Soviet Union

Dear Mr. Serpan:

Attached per our agreement is the MPR report of a meeting with various Soviet groups concerning the operational aspects of annealing reactor vessels in the USSR. The agreements and discussions between the Kurchakov Institute and the NRC concerning arrangements for possibly witnessing a reactor vessel annealing operation at Novovoronezh Unit 3 were covered in the NRC report of the meeting and are not duplicated in the attached report.

If you have any questions concerning the attached report, please do not hesitate to call.

Sincerely yours,

Noman M. Cole

cc: A. Taboada, NRC

MPR ASSOCIATES, INC.

November 20, 1990

MEETING REPORT

REPORT OF MEETING AMONG VARIOUS USSR GROUPS INVOLVED WITH REACTOR VESSEL ANNEALING OPERATION, THE U.S. NRC, AND MPR ASSOCIATES

Subject: Reactor Vessel Annealing

Place: Kurchatov Institute, Moscow, USSR

Date: November 5 through 10, 1990

Persons Participating:

USSR Participants:

(a) Kurchatov Institute

Amaev, Amir D.
Shtrombakh, Yaroslav I.
Kryukov, Alexander M.
Gurovitch, Boris A.
Sokolov, Michael A.
Victorov, Victor F.
Perevezentsev, Vladimir N.
Dobromyslov, Konstantin V.
Gorskyi, Konstantin V.
Proshina, Olga A.
Khudoyarov, Alexander V.
Levit, Vladimir I.

(b) Novovoronezh Nuclear Plant

Zaiyotnykh, Boris A.

(c) "Hydropress" Design Bureau

Rogov, Michael F.
Dragunov, Yuryi G.

(d) All-Union Research Institute for Nuclear Power Plant Operation

Fedorovskyi, Yuryi A.
Bakirov, Murat B.

U.S. Participants:

(a) Nuclear Regulatory Commission

Charles Z. Serpan, Jr.
Alfred Taboada

(b) MPR Associates, (NRC Contractor)

Noman M. Cole, Jr.
Alexander Zarechnak

1050 CONNECTICUT AVENUE N.W. WASHINGTON, D.C. 20036 202-659-2320

PURPOSE:

The purposes of this meeting were: (1) discuss USSR's experience in removal of radiation damage from reactor vessel by means of annealing; and (2) make arrangements and plans for the NRC, MPR, and utility personnel to actually witness such annealing operations at Novovoronezh during the upcoming outage.

SUMMARY:

The summary of the meeting discussions and the information containing USSR annealing experience is documented in Attachment 1.

Attachment 1 only covers the technical information provided by the USSR concerning the operational aspects of their reactor vessel annealing efforts. Detailed drawings and procedures were not provided, but information was given orally. Accordingly, detailed dimensions and figures provided in the attachment should be taken as approximate. The procedural steps are provided as an overall sequence and not step by step procedures. Also, this report does not attempt to cover the metallurgical, stress, irradiation damage, etc. information previously supplied by the Soviets.

The signed memorandum between Kurchatov Institute and the NRC which summarizes the meeting agreements and discussion of the arrangements for possibly witnessing the annealing of the reactor vessel at Novovoronezh Unit 3 are covered in the NRC report of this meeting and are not duplicated herein.

CONCLUSIONS

Based on the information provided at this meeting, it would appear that the USSR annealing technique is readily applicable to the bulk of the U.S. PWRs from a physical standpoint, provided arrangements are made to:

- Allow draining of a reactor vessel in which the reactor internals have been removed and at the same time retain the necessary water level for shielding around the removed reactor internals.
- Ensure that the radiation levels are not too high when a stainless steel clad reactor vessel is being drained and that their radiation levels do not interfere with installing or removing the annealing heater assembly from the reactor vessel.

The Soviet plants have different physical and arrangement characteristics that allow them to accommodate the above operations more readily than the bulk of the U.S. PWRs. Conceptual approaches to accommodate these operations in U.S. plants are discussed in Attachment 1, Section X. The detailed witnessing of an annealing operation in a Soviet plant will confirm that we have not misunderstood what we have been told and that there are no other subtleties in the operation that were missed due to the language barrier.

Obviously, in addition to making changes for physical compatibility, a detailed stress analysis will have to be performed on the U.S. vessels (with their larger diameters, different vessel support schemes, and shorter distances between the active core zone and piping nozzles) to confirm that the stresses resulting from the annealing operation are within satisfactory limits.

Noman M Cole Jr

NOMAN M. COLE, JR.
MPR

ATTACHMENT 1

MEETING ON REACTOR ANNEALING

TABLE OF CONTENTS

I Preface

This report only covers the technical information provided by the USSR concerning the operational aspects of their reactor vessel annealing efforts. Detailed drawings and procedures were not provided, but information was given orally. Accordingly, detailed dimensions and figures provided in this report should be taken as approximate. The procedural steps are provided as an overall sequence and not step by step procedures. Also, this report does not attempt to cover the metallurgical, stresses, irradiation damage, etc. information previously supplied by the Soviets.

The signed memorandum between the Kurchatov Institute and the NRC which summarizes the meeting agreements and discussion of the arrangements for possibly witnessing the annealing of the reactor vessel at Novovoronezh Unit 3 are covered in the NRC report of this meeting and are not duplicated herein.

The agenda for the meeting proposed by Dr. Amaev is provided as Enclosure 1.

II Organizational Structure

An association of seven Soviet agencies has been formed to develop, implement and market the annealing of reactor vessels in the USSR and Eastern Europe. This association is called a MOKHT, an abbreviation for Interbranch Economic Association. The agencies involved in the MOKHT for annealing and their respective responsibilities are described below:

OKB "Hydropress" (or "Gidropress")

This is the main designer of the heating rig and lead organization for the annealing application. Their representative is in charge of the annealing at the site.

Kurchatov Institute of Atomic Energy

The Kurchatov Institute developed the knowledge and data for the annealing (time, temperature) and the requirements for sampling, hardness, checks, etc. They performed the detailed stress analysis and heat transfer, metallurgical examinations, etc. (Kurchatov provides the science, Hydropress provides the engineers, and Tzniitmash provides the technical implementation.)

NPO "Tzniitmash" (Central Institute of Heavy Construction)

This is the manufacturer and operator of the heating rig and associated equipment; they also record and process the data (temperature, power, etc.) during the annealing.

VNIIAES - All Union Research Institute for Nuclear Power Plant Operation

VNIIAES developed the technique for hardness measurements and produced the equipment for this measurement.

TZNII KM "Prometei"

Apparently, this is a metallurgical lab in Leningrad. Its role in the upcoming annealing operation was not discussed.

PO "Izhorskyi Zavod"

Reactor vessel manufacturer.

VVO "Atomenergoexport"

The official USSR export organization.

The personnel from the Kurchatov Institute were quite open and frank, and most helpful in providing detailed technical information supportive of the U.S. request to witness the annealing of the Novovoronezh Unit 3 reactor vessel. The representatives from Hydropress (the designers of the VVER 440 annealing equipment) were far less forthcoming in providing detailed technical information and facts. The Hydropress personnel made clear that if a contract was provided, they would be happy to provide detailed technical information.

The manufacturer and operator of the annealing rig, Tzniitmash, was not invited to our meeting. Dr. Amaev felt that their participation would be premature at this point.

III <u>Background On Plant Features for Handling Reactor Internals and a Dry Reactor Vessel</u>

The VVER-440 and VVER-1000 reactors have refueling cavity arrangements that are quite different from the bulk of the U.S. PWRs. This difference affects the way the reactor vessels can be drained when the reactor core barrel is removed. The differences are discussed below:

<u>(A) VVER-440 Reactor</u>

The refueling cavity in VVER-440 is slightly larger in diameter than the reactor vessel flange and on one side has a <u>narrow canal</u> so that individual spent fuel assemblies can be moved to the spent fuel storage pit area. The refueling cavity around the reactor vessel cannot accommodate the storage of either the upper internals package or the core barrel. In the VVER 440s the internals are removed in a shield-cask type device and stored in pits that are separated from the refueling cavity and spent fuel pits. In this arrangement, after the fuel has been removed from the reactor vessel, the gate in the narrow fuel transfer canal is closed and then the refueling cavity and reactor vessel can be drained (for discussions on radiation level in a dry reactor vessel, see VI). For the basic refueling cavity arrangement of a VVER-440, see Figure 1.

(B) VVER-1000 Reactor

The VVER-1000 refueling cavity arrangement is quite similar to that used in the bulk of the U.S. PWRs, but with one major exception. Specifically, they have provisions to install a large gate in the refueling cavity. This gate allows separation of the reactor vessel from the deep end of the refueling cavity where the removed internals are stored (See Figure 1). Thus in this arrangement, once the reactor internals are moved into the deep end of the refueling cavity, the gate is installed and the area around the reactor vessel can then be drained. Water in the deep end of the cavity is maintained for shielding of the stored reactor internals.

(C) U.S. PWRs

The bulk of the U.S. PWRs do not currently have provisions for draining the reactor vessel area when the reactor vessel internals are stored in the refueling cavity. The only recent vintage (1970 to present) U.S. PWR with provisions for a large gate across the refueling cavity to allow the area directly around the reactor vessel to be drained while still retaining water over the stored reactor internals was TMI-2. (See Section X for discussion of the concept of the equipment which would allow U.S. plants to have the reactor vessel area drained and still retain the water shielding around the stored reactor internals.)

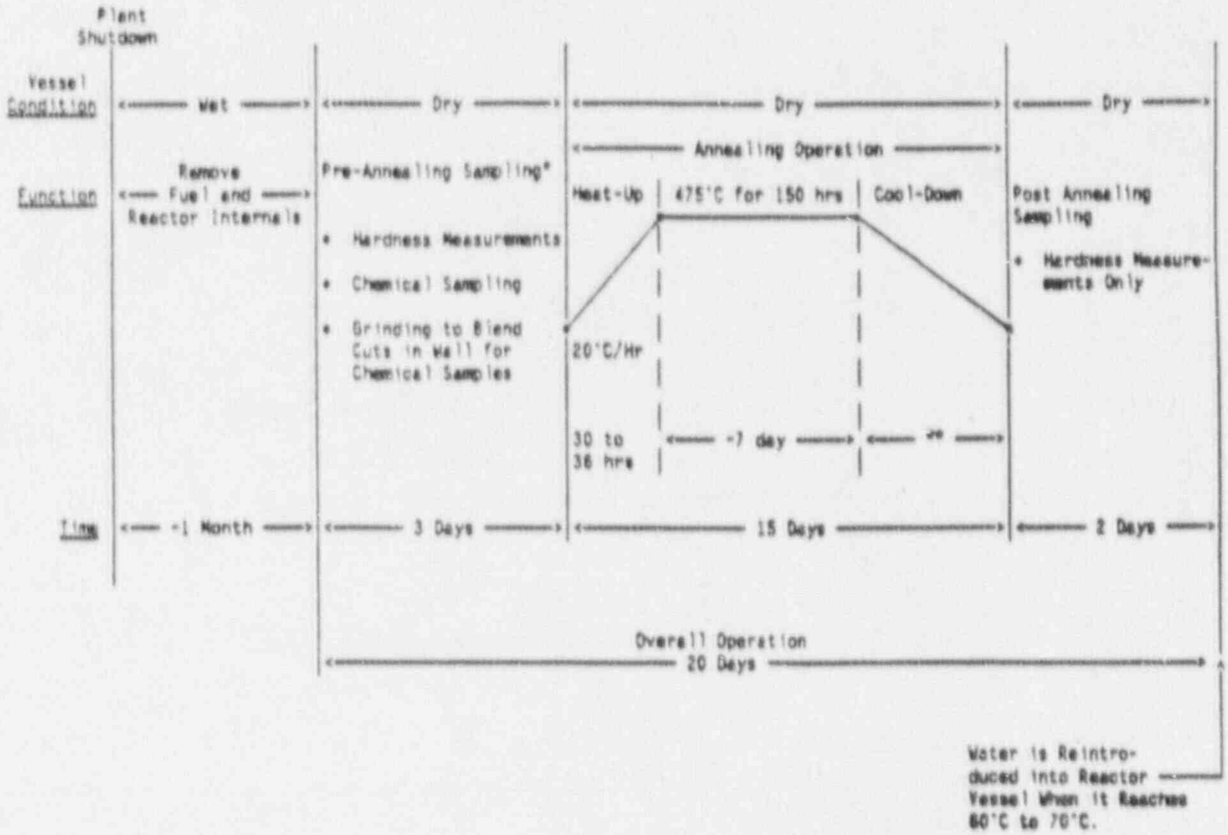
IV Overall Sequence for Annealing Operations in VVER-440 Reactors

A. Unclad VVER 440 Reactor Vessel

Several different sequences have been followed for annealing unclad VVER-440 reactor vessels. The major difference in the sequences is the different number and kinds of vessel inspections made before and after annealing. As time has gone on, a greater number and more sophisticated inspections have been developed. The different sequences for unclad vessels are as follows:

1. UNCLAD VESSEL WHERE NO METALLURGICAL SAMPLES ARE TAKEN FROM THE REACTOR VESSEL

The basic schedule for this type of annealing operation is shown below:



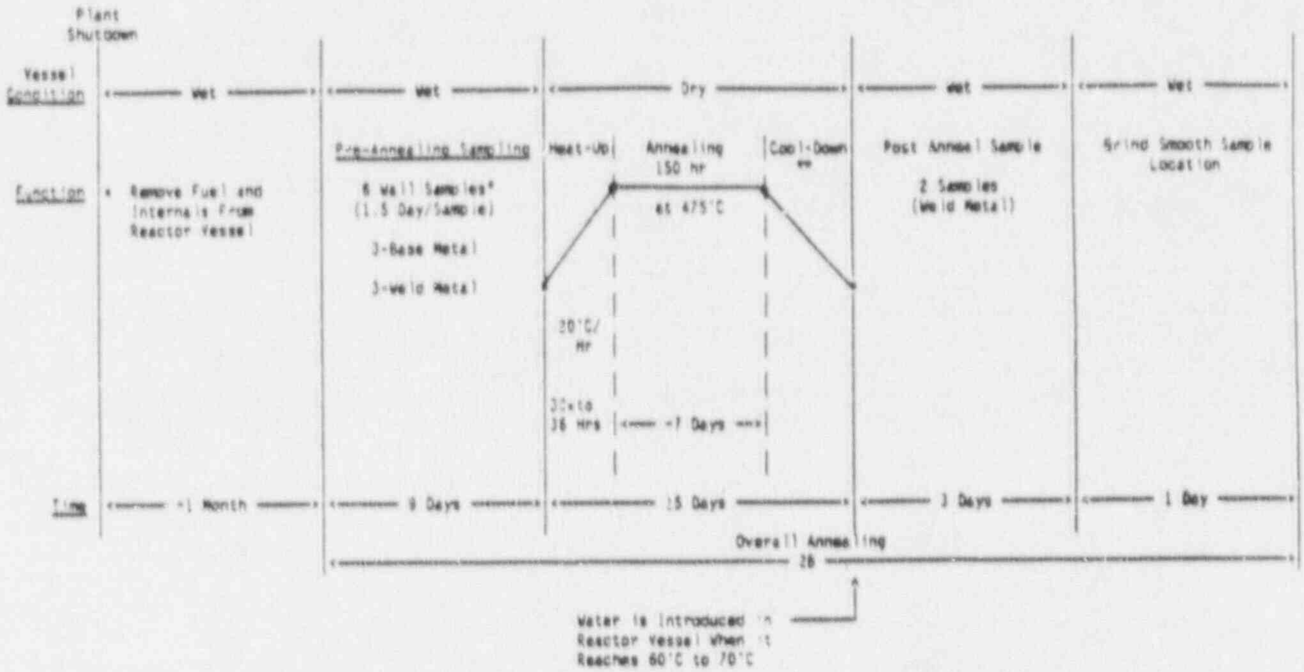
Notes

* At times, the reactor vessels are given a periodic UT examination as required by the USSR regulatory authority.

** While the limit for cool-down is 30°C/Hr, presently they have not been able to cool the reactor vessel down at anywhere near this rate, particularly after the vessel gets below the 450°F to 350°F range. They are working to develop techniques to greatly improve this portion of the operation.

2. UNCLAD VESSEL WHERE METALLURGICAL SAMPLES ARE TAKEN FROM THE WALL OF THE REACTOR VESSEL

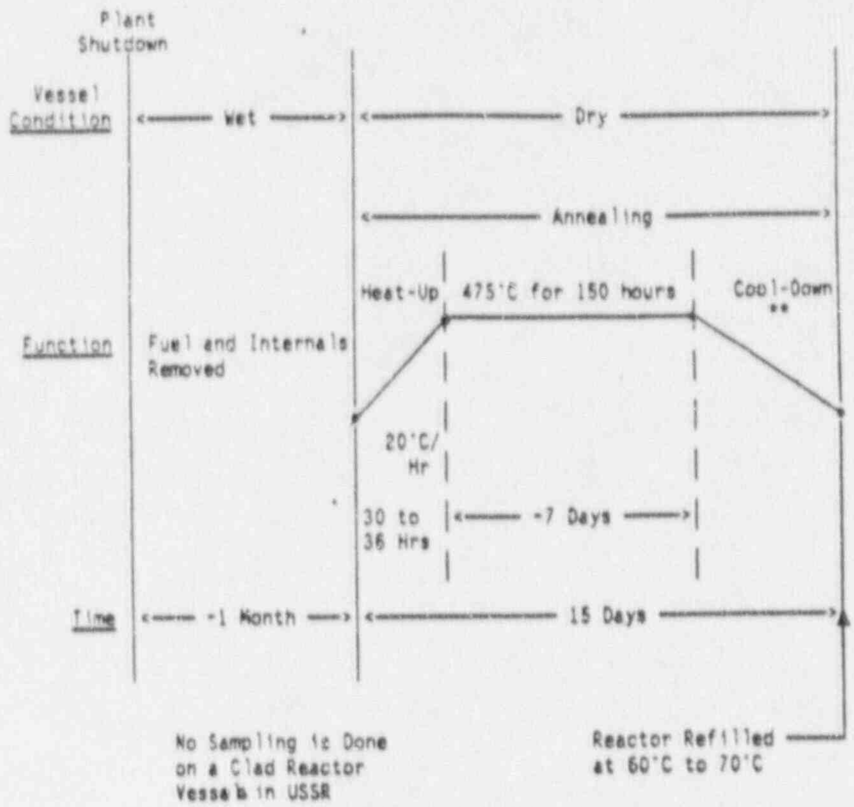
The basic schedule for this type of annealing operation is shown below:



Note
* The Novovoronezh Unit 3 annealing in December 1990/January 1991 will be the first time the Soviets have used one of their own devices to remove metallurgical samples. They hope to convince their Regulatory Authority that the metallurgical samples can also be used for the hardness and chemical samples. If not, they may have to take additional measurements which could add up to three more days to the schedule. (Note: In the East European reactors, metallurgical samples were taken from the reactor vessel by a German-developed machine, an EDM type of device.)
** Cool down is quite slow due to inability to cool off the vessel; see note in Section IV A.1 above.

B. Clad Reactor Vessel

The basic schedule for this type of annealing operation is shown below:



**See note in Section IV A.1 above.

V Annealing Experience to Date and Details of the Annealing Operation

A. The Soviets have annealed a total of nine reactor vessels. Seven of these reactor vessels have been unclad.

B. During the annealing of the nine vessels to date, they have had no problems with airborne activity due to the heating and drying of the reactor vessel. They do not clean the vessel wall before annealing. The cleaning that they do is more of a gross cleaning of the very bottom of the reactor vessel to remove any debris or loose crud that may be located there. They appear to have a nominal seal between the reactor vessel flange and the top cover of the heater assembly unit, with filters to allow expansion of heated air in the reactor vessel.

C. The Soviets indicated that they are proposing to reduce the annealing time from 150 hours to 100 hours. The original data showed that most of the annealing operation was accomplished in 30 hours and was sufficient for annealing at 460°C, and they originally suggested 100 hours for conservatism. When the annealing was first tried, their regulators changed the time to 150 hours for additional conservatism. Based on their experience with the completed nine annealings, they hope to get the regulator to reduce the time from 150 to 100 hours as they had originally proposed. The annealing temperature is 475°C± 15(887°F±27).

D. All stress information provided on the annealing operation is analytically backed out from the temperature readings; strain gauges were not used.

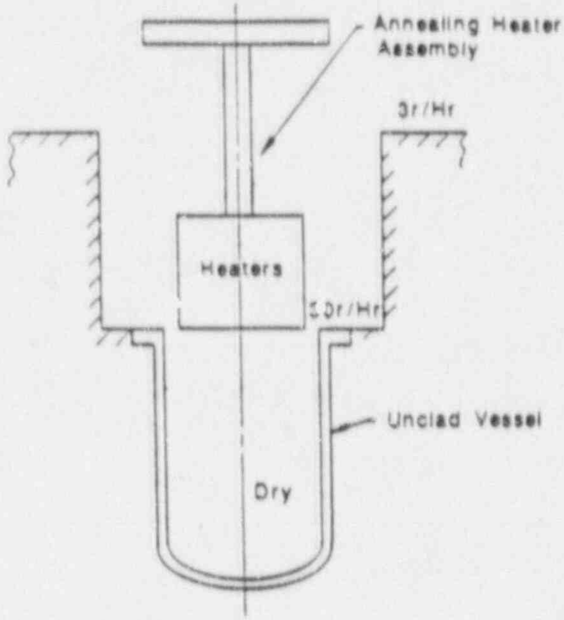
VI Removal of Water from Reactor Vessel

The overall sequence of the annealing operation starts after the reactor fuel, head and internals are removed and the water level in the reactor vessel area is drained down to the elevation of the reactor vessel flange.

A. After these initial steps a shielded inspection cabin (approx. 9'2" in diameter) is lowered over the vessel and visually positioned. The shielded inspection cabin has a pump and hoses attached to its bottom so that as the cabin is lowered into the vessel, the water in the reactor vessel can be pumped dry. The hardness measurements, chemical sampling and the grinding/blending of the areas around locations where the chemical samples are removed are done with the reactor vessel dry, using the shielded inspection cabin.

B. The "switch-over" from the shielded inspection cabin to inserting the annealing heater assembly unit into the reactor vessel is done next and is also done dry. They indicated that the "switchover" operation is basically done remotely with only a small number of personnel allowed in containment and only to monitor alignment of the heater assembly unit as it is being lowered into the reactor vessel. They indicated that the reactor building crane can be operated remotely from outside the reactor building and its movements monitored by T.V.

C. They provided the following information on radiation levels in an unclad reactor vessel. We were not given radiation levels for clad vessels. They indicated it was available at the plant but they just didn't have that specific data.



We roughly estimate, based on Nickel content, that the radiation levels could be up to 10 times higher with a clad reactor vessel.

D. The Soviets indicated that they have also used just a sump-pump and hoses to dewater the vessel. (I have the impression that this approach was used during clad vessel annealing where the shielding inspection cabin is not used.)

E. The Soviets indicated they have never had an over exposure of personnel during any of their annealing operations to date.

VII <u>Shielded Inspection Cabin for Sampling Reactor Vessel Wall</u>:

A. The Soviets indicated that shielded cabin walls were about 10 inches thick and made of a combination of steel and lead. The cabin is approximately 9'2" in diameter.

B. While they provided no specific radiation level, they indicated the levels were very low in the cabin. I talked with the engineer who had been in the cabin, and he indicated the radiation readings were almost nothing. (NOTE: If they have 10 inches of shielding as indicated above, the level should be quite low. We have used such a shielded cabin for reactor vessel work for a non-commercial application.)

VIII <u>Annealing Heater Assembly Details</u>

A. There was considerable reluctance to provide detailed drawings of equipment and its dimensions (mainly on the part of people from <u>Hydropress</u>), and this reluctance to provide information appeared to somewhat upset the people from the Kurchatov Institute. However, the best dimensional information that we obtained is shown on Figure 2.

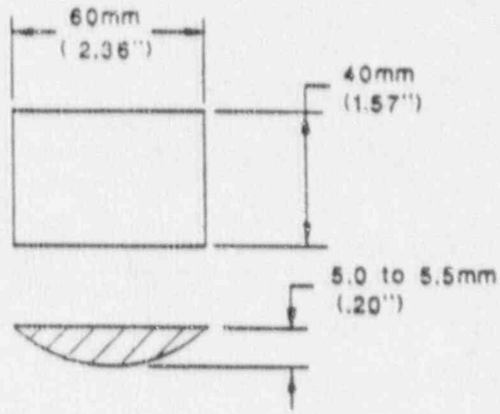
B. The annealing heater assembly consists of three levels or banks of heater elements. The height of the three banks of heaters for the VVER-440 is about 6 feet and the heaters are approximately 11 feet in diameter. Each of the levels of heaters is divided electrically into three segments and each segment at each level is controlled by a pair of thermocouples. There are a total of 18 reactor vessel I.D. wall thermocouples (i.e. 3X2X3). Once the heater assembly is installed in the reactor vessel, the thermocouples are extended outward and forced contact is made with the reactor vessel wall. The reactor vessel wall thermocouples provide on-line control for the amount of energy supplied to each heat segment.

C. At the steady state temperature, the heater assembly requires about 150 KW. At steady state only the top and bottom levels of heaters provide significant power. All three levels are used during heatup, requiring a total of approximately 225 KW. The total maximum capacity of the three heater levels is 500 KW.

D. The nominal gap between the body of the heater assembly and the I.D. of the reactor vessel is about 10". A thermal blanket at the top of the heater assembly extends out to block and cover the gap between the reactor vessel and heater when the heater assembly is in position.

IX <u>Removal of Metallurgical Samples from Reactor Vessel Wall</u>

The first metallurgical samples taken from the reactor vessel wall before and after annealing were removed using a German cutting device on a German VVER-440. This cutting device operates in a wet or dry environment. From our discussions, the metallurgical sampling tool appears to be an EDM device. The size of the reactor vessel wall sample is shown below.



The USSR has now developed their own metallurgical sampling machine and plans to use it at Novovoronezh Unit 3 during the December '90/January '91 annealing operation. This is a separate machine and is not used as a part of or an attachment of the shielded inspection cabin.

X Possible Concept to Allow Drainage of Reactor Vessel Area in U.S. PWRs

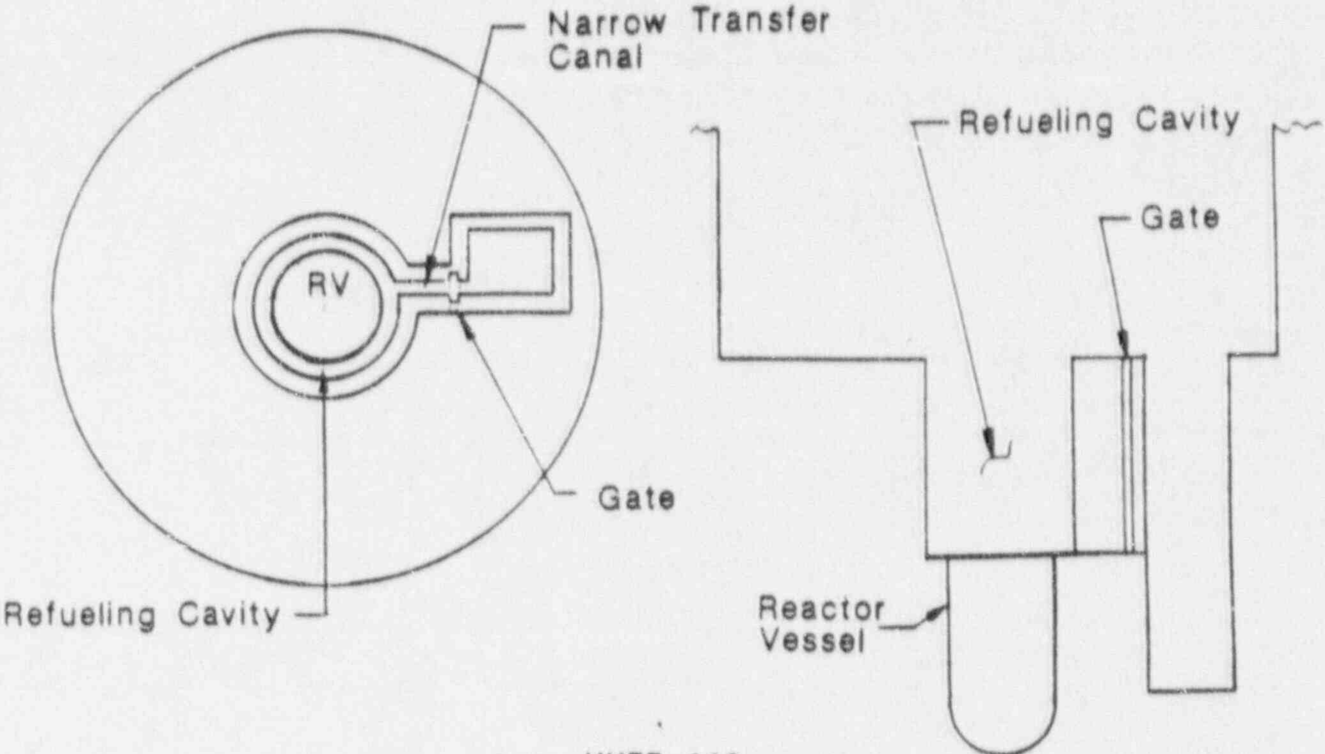
In U.S. PWRs when the reactor internals are removed and stored in the deep end of the refueling cavity, the cavity normally cannot be drained in the area immediately around the reactor vessel. Conceptually, a large diameter dutchman (14' diameter and about 25' to 27' long) could be made that bolts and seals to the reactor flange. T : dutchman should allow the refueling cavity water level to be maintained while the water in the reactor vessel area is drained first to the level of the reactor vessel flange. If radioactive levels are too high to allow complete draining of the reactor vessel, the following sequence can possibly be used. The annealing heater assembly can first be lowered to the level of the reactor vessel flange. A sump-pump can be provided just beneath the heater assembly and the vessel pumped dry as the heater is lowered. This is similar to the scheme the Soviets use when installing the shielded inspection cab'n. In the above proposed conceptual arrangement, the shielding provided by the annealing heater should reduce the radiation levels during its installation and the cover section at the top part of the annealing heater assembly unit should eliminate any concern when the heater assembly is completely installed in the reactor vessel.

Accordingly, to make implementation of the Soviet annealing system practical in the bulk of the U.S. PWR's, arrangement must be made for the following:

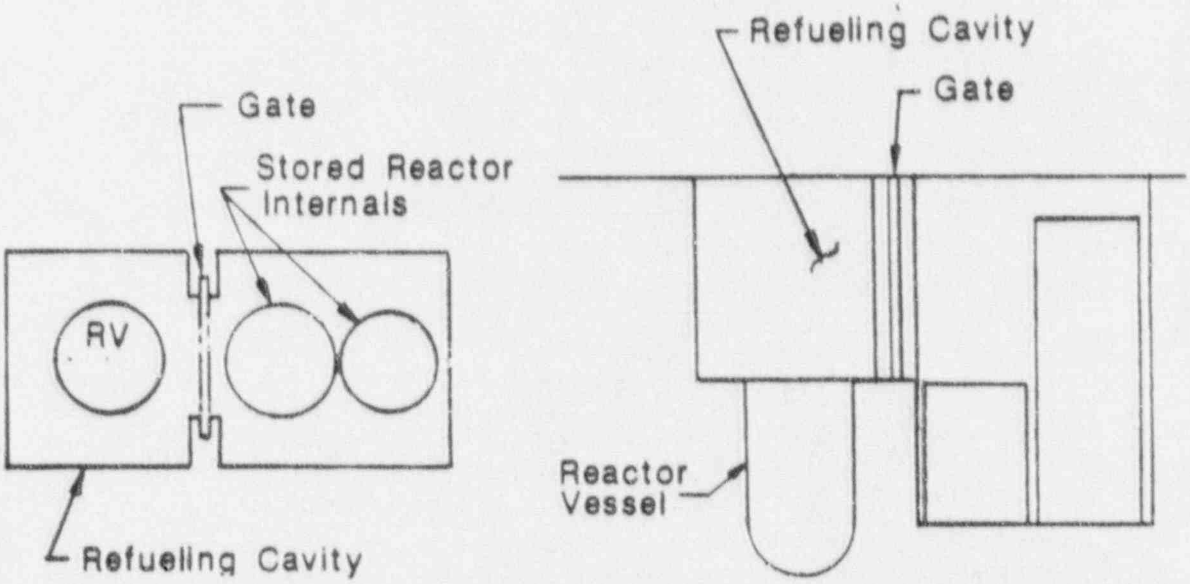
- Provisions to drain the reactor vessel while keeping the removed reactor internals covered with water.
- Provisions to insure that the radiation levels are not too high when the clad reactor vessel is being drained and when the heater assembly is being installed or removed.
- Provisions to incorporate a sump-pump system in the heater assembly to drain the reactor vessel (or prove we can live with the radiation levels from an empty clad reactor vessel)

For information on the sizes of typical U.S. PWR reactor vessels see Figure 3. For information on the Yankee Power reactor which the NRC indicates is possibly an early candidate for annealing, see Figure 4.

Also to use the Soviet system in the bulk of the U.S. PWRs, obviously the annealing heater unit must be made larger for the typical vessel in this country. Specifically, the heater section has to be made larger in diameter and the length of the heater section increased to anneal the vertical weld in some U.S. reactor vessels. The current heater diameter for the VVER-440 annealing units is about 11 feet and the diameter would need to be increased to about 13 feet for the typical U.S. vessel. The current heater length for the VVER-440 annealing unit is about 6 feet (mainly for circumferential welds), and the total vertical seam welds in some U.S. vessels that may need annealing have an overall length of ~ 12 feet. One could possibly use the short length heater and do the annealing in multiple steps; however, this could double or triple the time required for the annealing phase and thus have a major impact on plant down time.



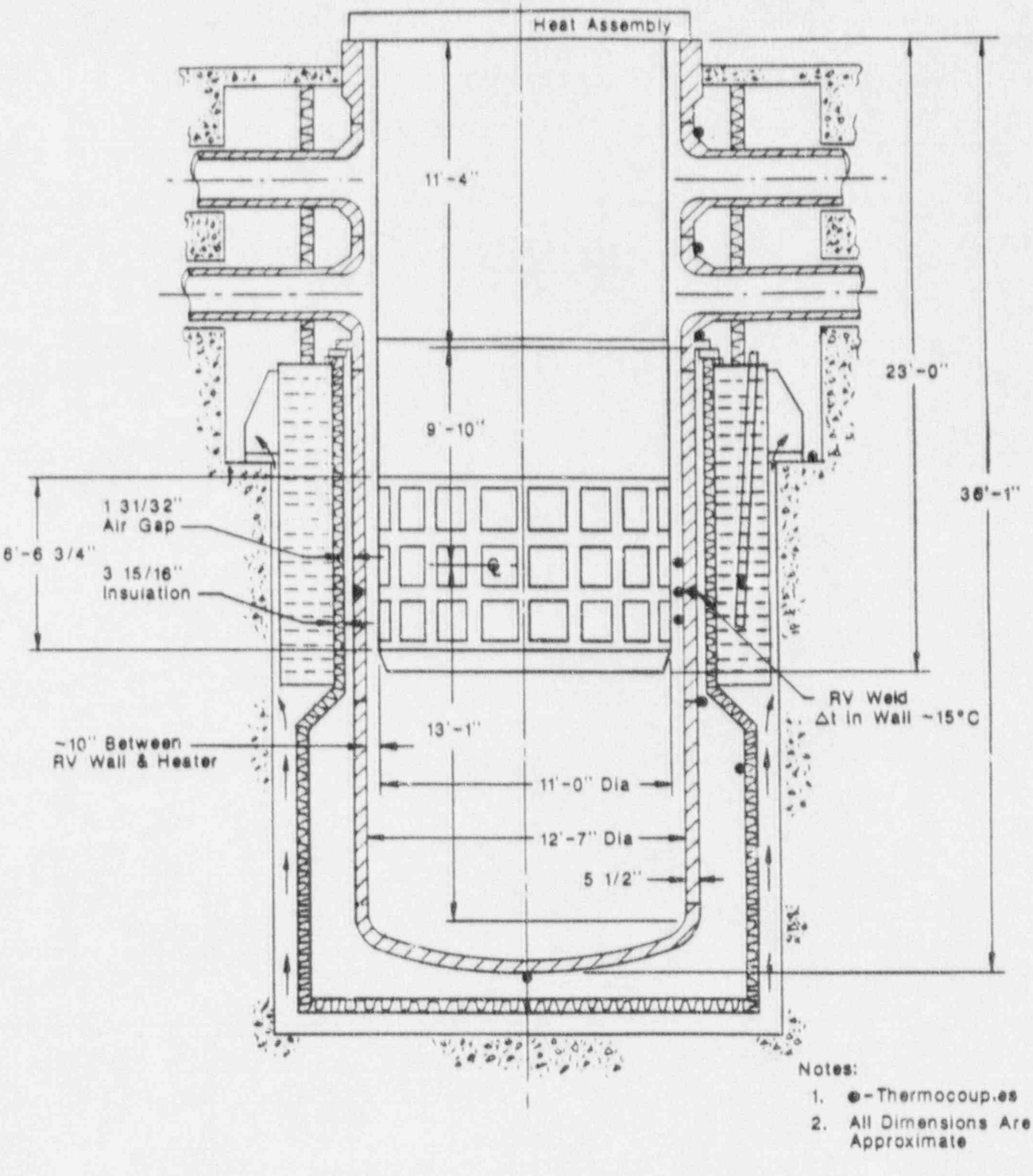
VVER-440



VVER-1000

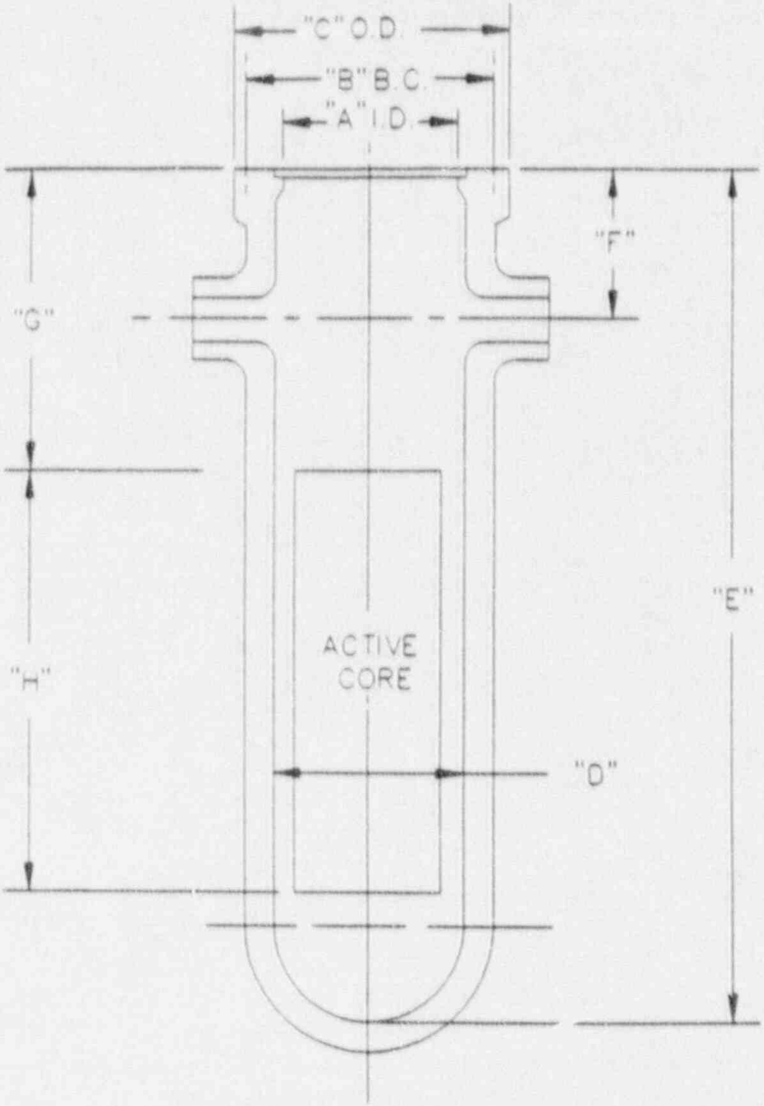
CONCEPTUAL ARRANGEMENT OF
REACTOR VESSEL AND REFUELING CAVITY
FIGURE 1

MPR ASSOCIATES
F-73-34-4
11-14-90



VVER-440 REACTOR VESSEL
AND ANNEALING HEAT ASSEMBLY
FIGURE 2

MPR ASSOCIATES
F-73-34-2
11-14-90



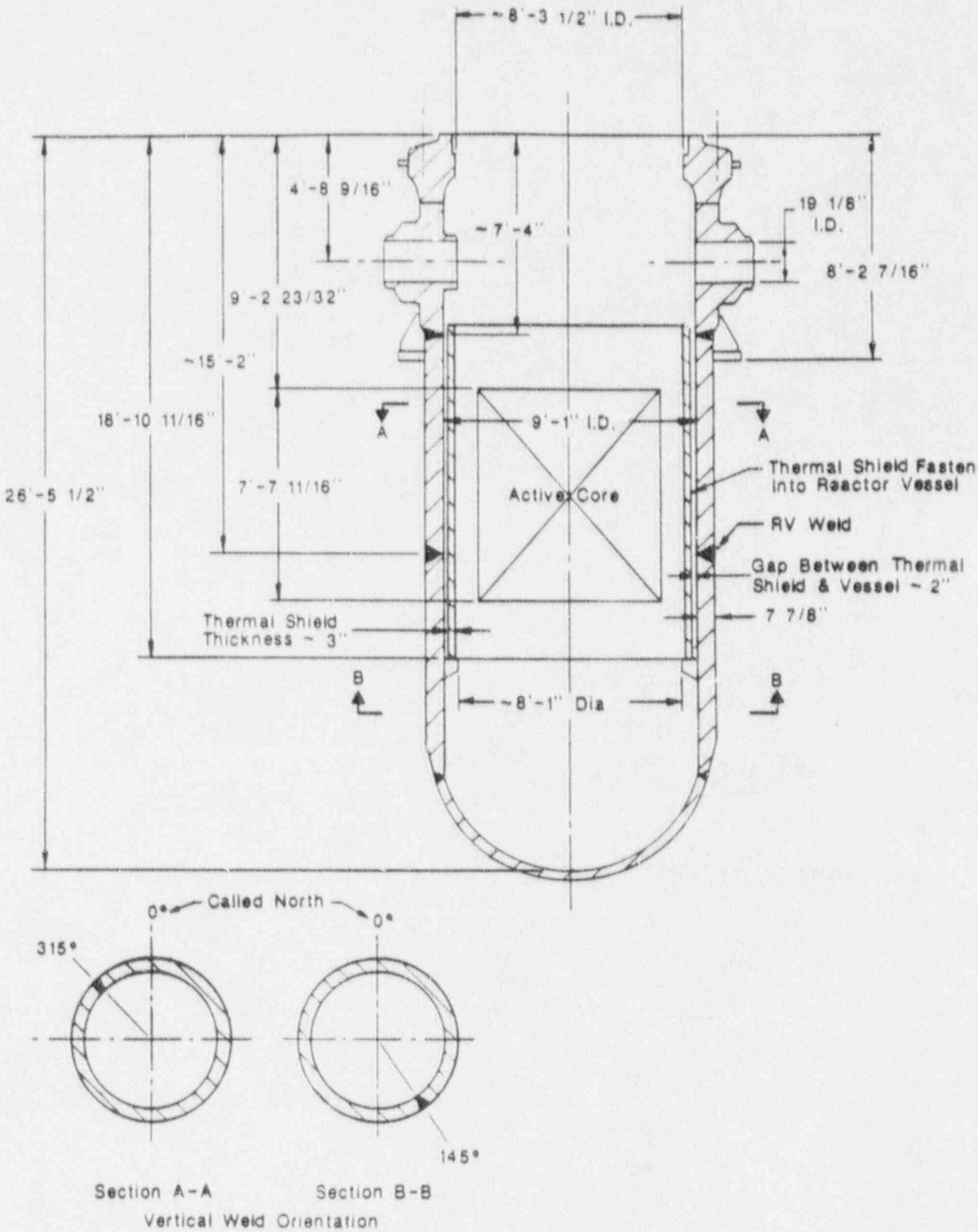
DIM	A	B	C	D	E	F	G	H
CALVERT CLIFFS	166.00	192.13	205.00	172.00	403.88	80.50		136.70
TMI-2	164.88	186.75	200.00	170.62	379.00	84.00	138.00	
BELLEFONTE	178.00		217.25	182.00	396.00	85.50	138.50	143.00
IPP	167.00	191.88	205.00	173.00	413.66	85.50	148.13	144.00

Dimensions Are In Inches

TYPICAL U.S. PWR VESSELS

FIGURE 3

MPR ASSOCIATES
F-73-34-1 B
11/14/90 (24)



Yankee Rowe - 175 MWe

FIGURE 4

MPR ASSOCIATES
I-73-34-3
11-19-90

Enclosure 1

AGENDA FOR THE MEETING OF USSR AND US SPECIALISTS AT THE KURCHATOV INSTITUTE FOR ATOMIC ENERGY TO DISCUSS THE TOPICS OF WORKING GROUP 3 OF THE JCCNRS

<u>Monday, November 5</u>

10:00 Introduction: A. D. Amaev and C. Serpan

10:30 Presentation by the Specialists of the USSR From Hydropress:

Y. G. Dragunov - 45 min
M. F. Rogov - 45 min

12:00 COFFEE BREAK

12:15 Questions, Answers, Discussions

13:30 Lunch at the Kurchatov Cafeteria

15:00 Continuation of the Working Meeting
Presentation by Y. A. Fedorovski
"Experimental Determination of the Temperature Distribution in the Reactor Vessel Wall and Supports and the Stresses and Deformation in the Reactor Vessel During Annealing of the Seam Weld (including heatup and cooldown)."

16:15 COFFEE BREAK

16:30 Presentation by M. B. Bakirov of the video on determination of the degree of restoration of the material properties of the reactor vessel using hardness measurements.

17:30 Return to the Hotel

<u>Tuesday, November 6</u>

10:00 Visit to the Hot Cell Laboratory of the Kurchatov Institute to view the equipment used to study reactor vessel materials.

12:00 Return to the Conference Room/Coffee Break

12:30 Continued Discussions on Previous Presentations

13:30 Lunch at the Kurchatov Cafeteria

15:00 Continuation of Presentations
B. A. Gurovitch - 1 hour
A. M. Kryukov - 45 min
M. A. Sokolov - 45 min

17:30 Return to the Hotel

Wednesday, November 7

Soviet National Holiday
Visit to Red Square to Watch the
Parade and Demonstration

Thursday, November 8

10:00 Documentation of the Results of the Meetings
Discussion and Comments on items 1 through 10 of the Activities of Working Group 3 of the JCCCNRS

Agreement regarding participation in the annealing of the reactor vessel of Novovoronezh - Unit 3

11:30 Coffee Break

Preparation of the Meeting Memorandum

15:00 Lunch

Friday, November 9

Discussion of Agreements
Signing of Agreements

Saturday, November 10

Departure

ENCLOSURE

ANNEALING OF SOVIET VVER-440 REACTOR VESSELS

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Presentation to NRR

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US-USSR JCCCNRS WG-3

- Agreed to exchange information on neutron embrittlement of PV steels
- USSR has developed procedures to remove PV embrittlement by thermal annealing
- USSR is applying these procedures to Soviet reactors
- As part of JCCCNRS exchange agreement a US team is planning to visit the Novovoronezh-3 VVER 440 reactor to observe the annealing operations
- In November 1990 we met with the Russians to discuss their experiences in this area and to plan this visit
- I'm going to present some of this information

US TEAM TO ATTEND NOVOVORONEZH-3 ANNEALING OPERATION

NRC

C. Z. Serpan
A. Taboada

NRC Contractors

ORNL- S. Iskander

MPR- N. Cole
A. Zarechnak
B. Lipford

Industry Representatives

PG&E- S. Chestnut
M. Sullivan

YAEC- S. Fournier

FPL- S. Collard

Consumers Power-
D. Hoffman

TENERA (EPRI) Consultant

W. Pavinich

US–USSR COOPERATION

Background on Reactors

- VVER-440 early PWR model
  440 MW(t), 6 horizontal steam generators probably patterned after naval nuclear units
- Pressure vessel small diameter; sized to fit RR tunnels
- High flux and fluence on vessel wall
- Unexpectedly high embrittlement of vessels
- No surveillance in early Soviet plants
- Initial embrittlement information from Finnish Loviisa-1
- Finns adopted flux reduction and heating of ECCS water in early 1980s to maintain acceptable RT-NDT and prevent PTS accidents
- Flux reduction too late for many Soviet plants – Annealing adopted

US-USSR COOPERATION

Background on Reactors

- Pressure Vessel Steels

VVER-440	15Cr2MFA	Cr-Mo-V
VVER-1000	15Cr2NMFA	Cr-Mo-Ni-V

P typically > 0.025; Cu nominal 0.10-0.12

US forging	A508 Cl 2	Mn-Ni-Mo
US plate	A533-B	Mn-Ni-Mo

Cu can be > 0.30, Ni > 0.5

- Inlet Temperature on Vessel

VVERs	270 C
US PWRs	288 C

Core to Vessel Water Gap		Vessel Diameter and Thickness	
VVER-440	27 cm	350 cm	14 cm
VVER-1000	39 cm	400 cm	19 cm
US PWR	50 cm	440 cm (1000 MW)	21 cm

- Forged Rings - No Axial Welds

VVER-440	Circumferential welds below core centerline
VVER-1000	Circumferential welds at top and bottom of core
US PWR	Axial welds, circumferential welds near core centerline

US–USSR COOPERATION

Soviet Annealing

- Old VVER–440s being annealed
  9 annealings complete, as of 7/90 (All model V230)
  - Novovoronezh–3
  - Armenia–1
  - Nord–1, 2, 3 (GDR)
  - Kozloduy–1, 3 (Bulg.)
  - Kola–1, 2

  Planned
  - Bohunice–1, 2 (CSSR)
  - Novovoronezh–2, 3
- Conditions
  time – about 150 hours
  temperature – 460 C
- Recovery
  Reported to be essentially 100%
- Reembrittlement
  Rate reported to be no higher than initial
- Validation
  Experimental test reactor trends
  Direct hardness measurements from manned "cabin" lowered into vessel
  Sub–size Charpy–V specimen tests of annealed material removed from the pressure vessel wall

ORGANIZATIONAL STRUCTURE

- An organization of seven Soviet agencies formed to develop, implement, and market the annealing of reactors in USSR and Eastern Europe

- Association called MOKHT, an abbreviation for Interbranch Economic Association

- Includes:

  - OKB Hydropress, the main designers and lead organization for annealing application

  - Kurchatov Inst of Atomic Energy, the developers of much of the research and data on annealing using test reactors

  - NPO Tzniimash (Central Inst. of Heavy Construction), the manufacturer and operator of the heating rig and associated equipment

  - VNIIAES (All Union Research Inst. of Nuclear Power Plants) who developed the techniques for hardness measurements

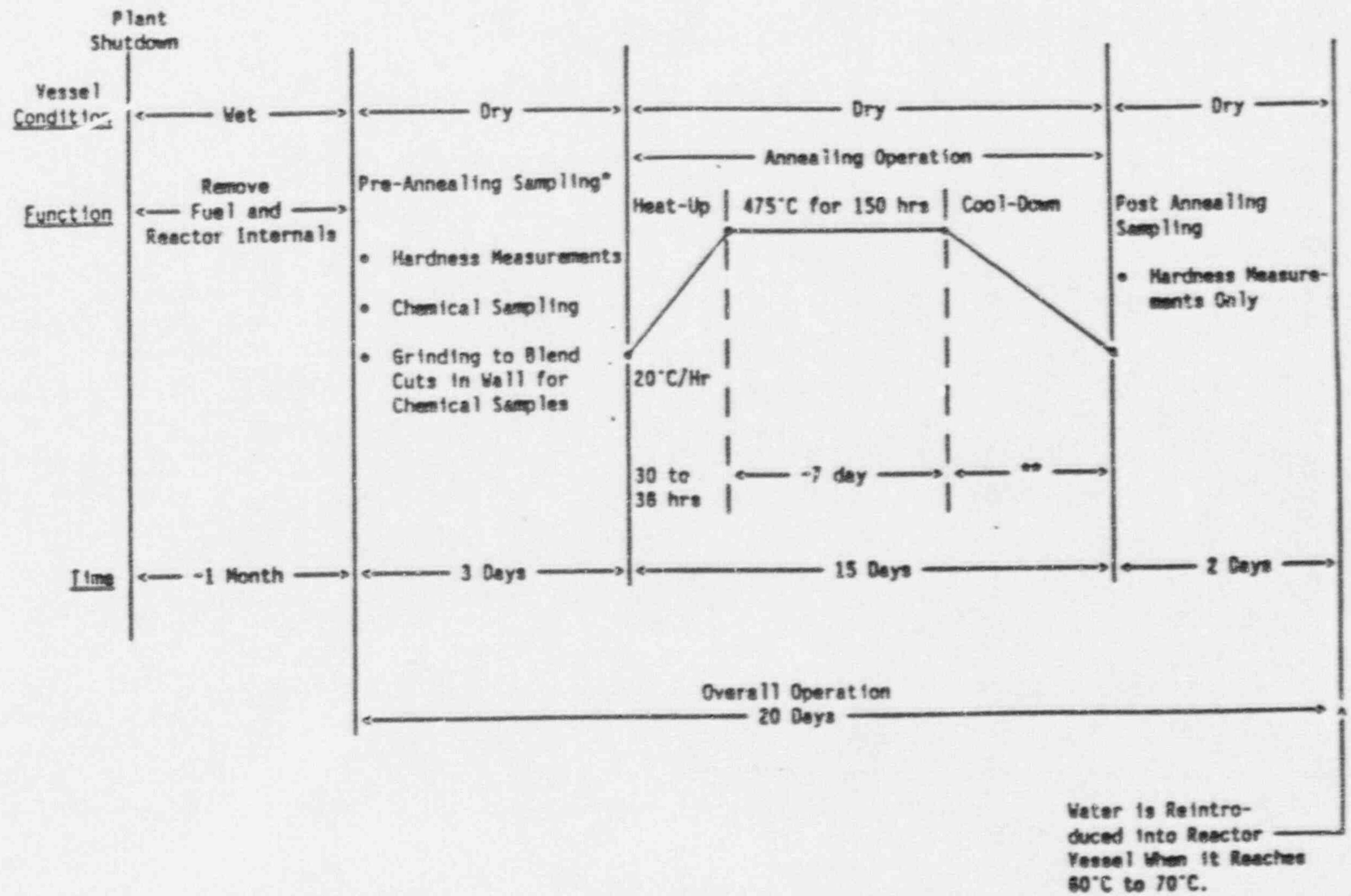
  - TZNII KM Prometei, Metallurgical organization in Leningrad

  - PO Izhorski Zavod, the reactor vessel manufacturer

  - VVO Atomenergoexport, the official USSR export organization

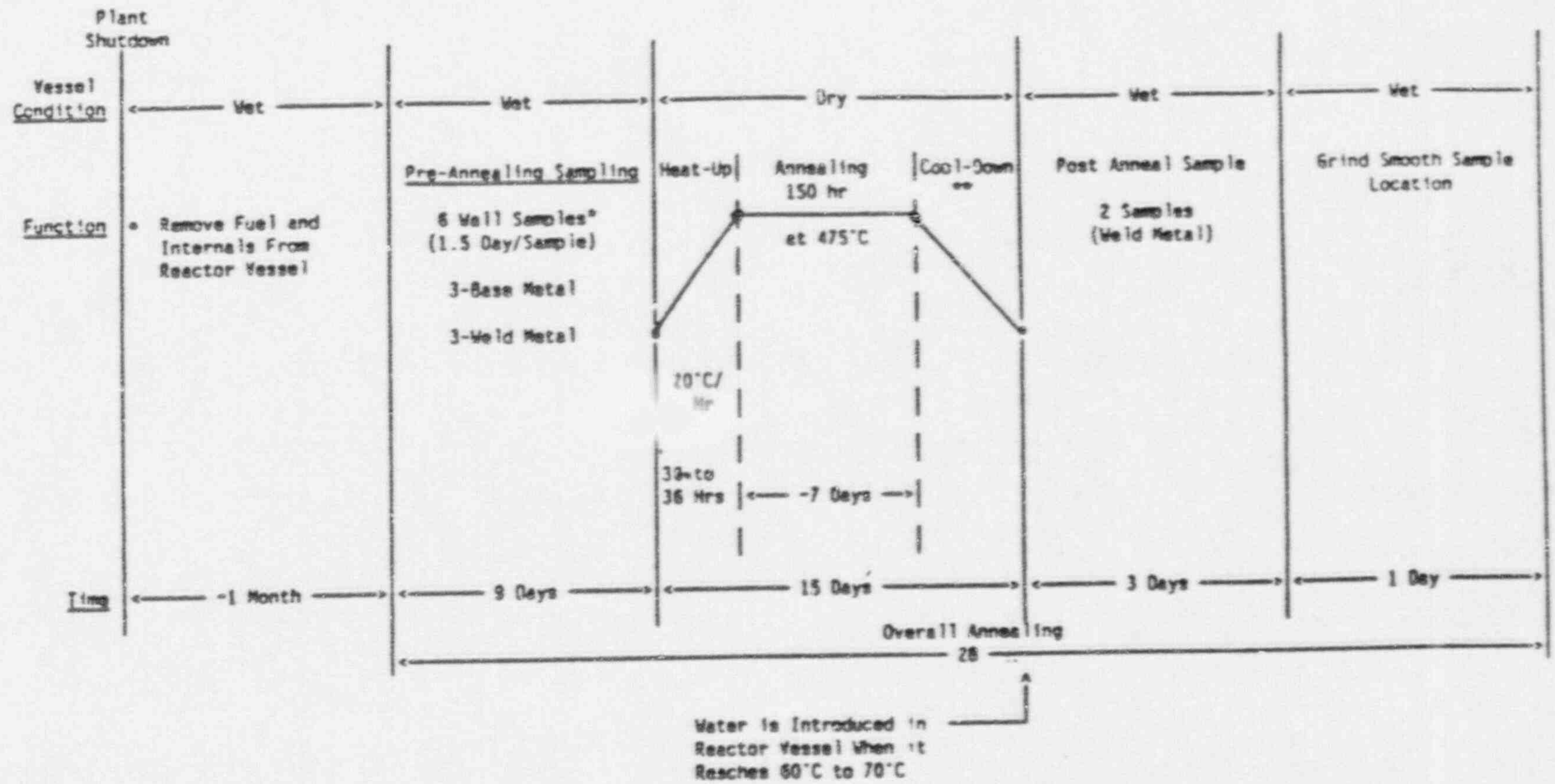
1. <u>UNCLAD VESSEL WHERE NO METALLURGICAL SAMPLES ARE TAKEN FROM THE REACTOR VESSEL</u>

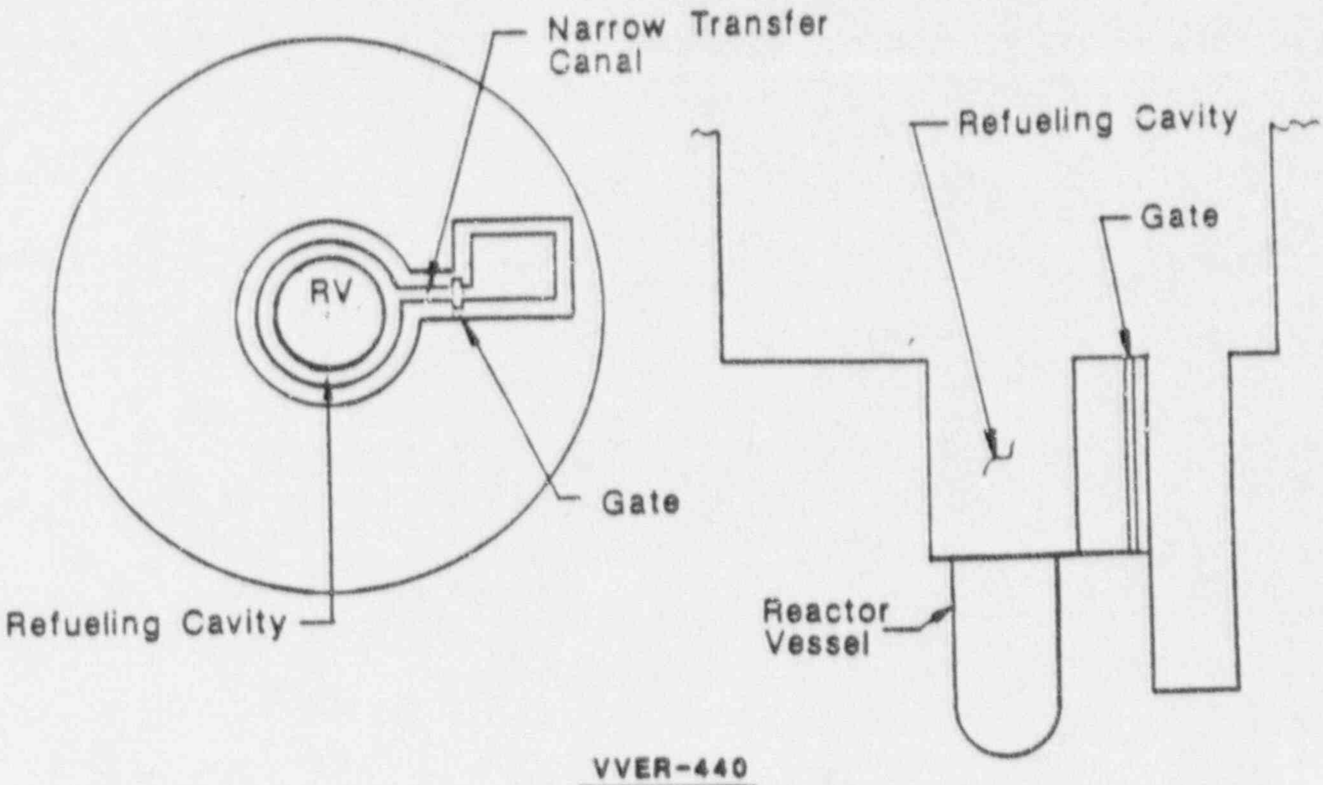
The basic schedule for this type of annealing operation is shown below:



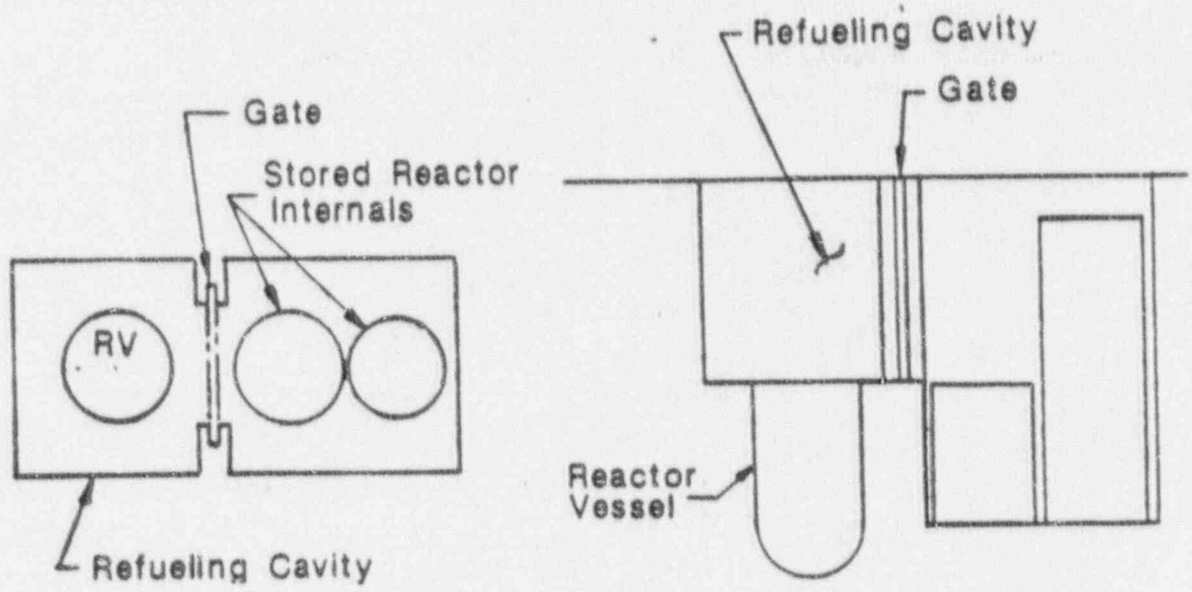
2. UNCLAD VESSEL WHERE METALLURGICAL SAMPLES ARE TAKEN FROM THE WALL OF THE REACTOR VESSEL

The basic schedule for this type of annealing operation is shown below:





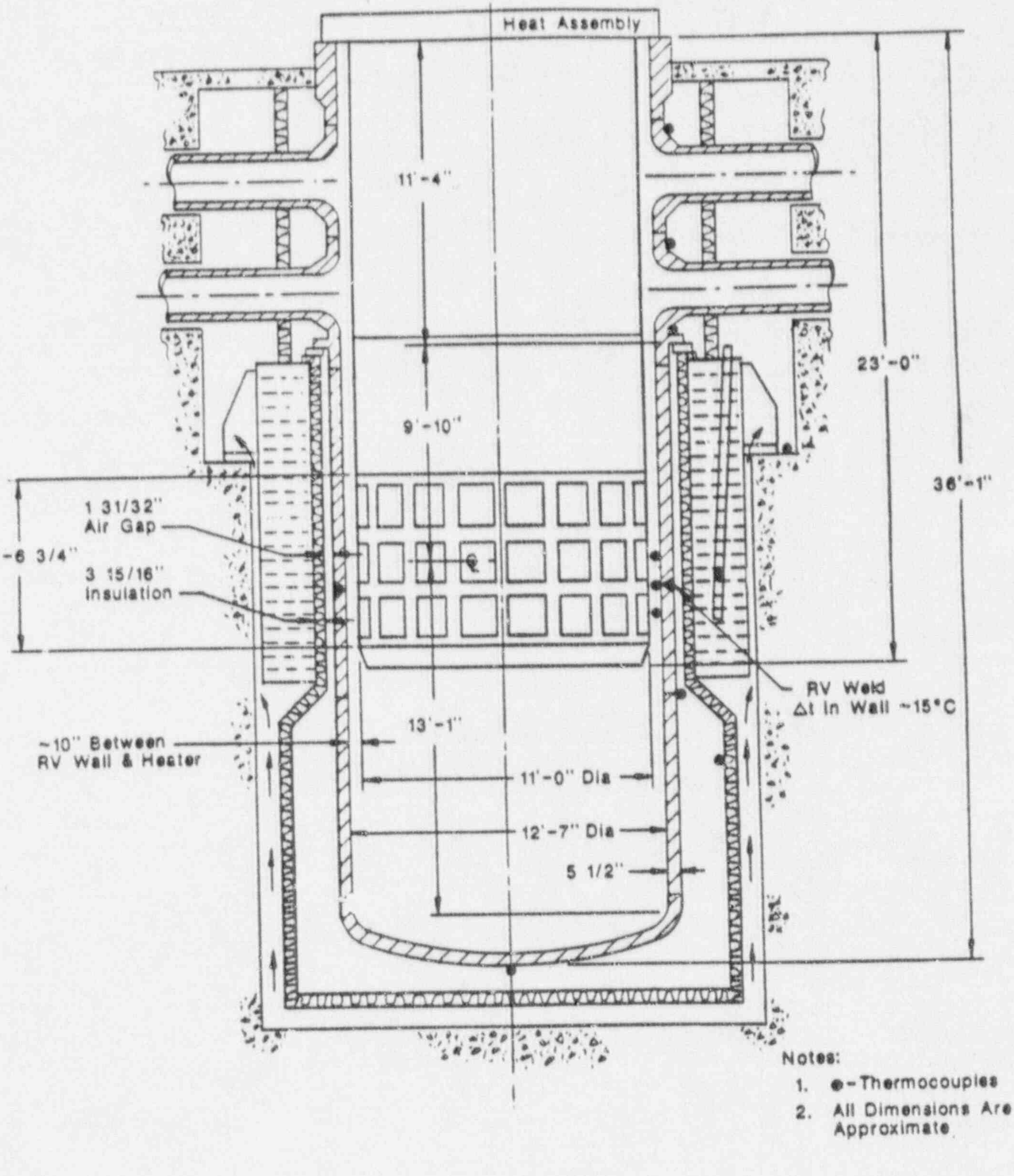
VVER-440



VVER-1000

CONCEPTUAL ARRANGEMENT OF
REACTOR VESSEL AND REFUELING CAVITY
FIGURE 1

MPR ASSOCIATES
F-73-34-4
11-14-80



VVER-440 REACTOR VESSEL
AND ANNEALING HEAT ASSEMBLY
FIGURE 2

MPR ASSOCIATES
F-73-34-2
11-14-90

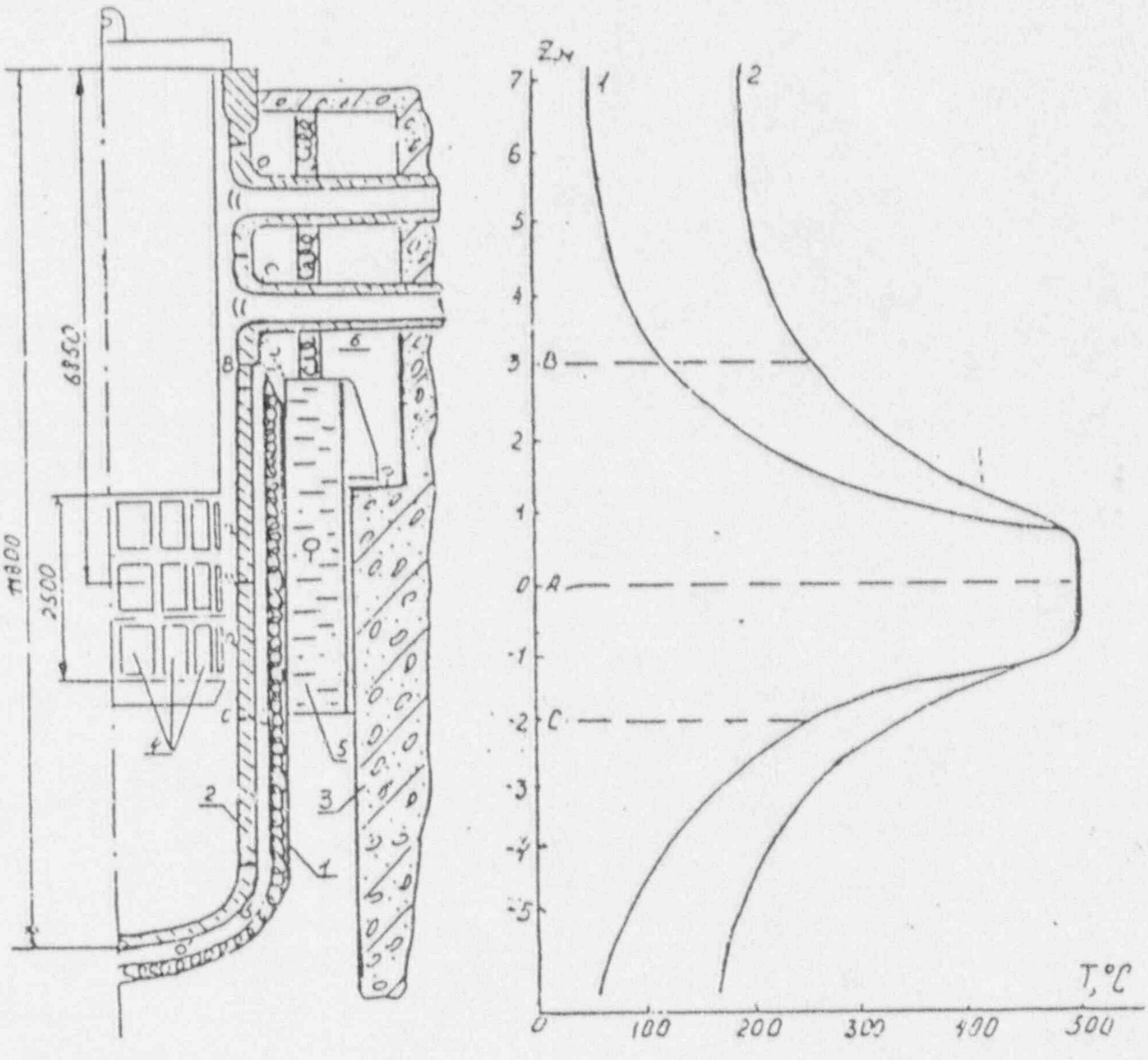
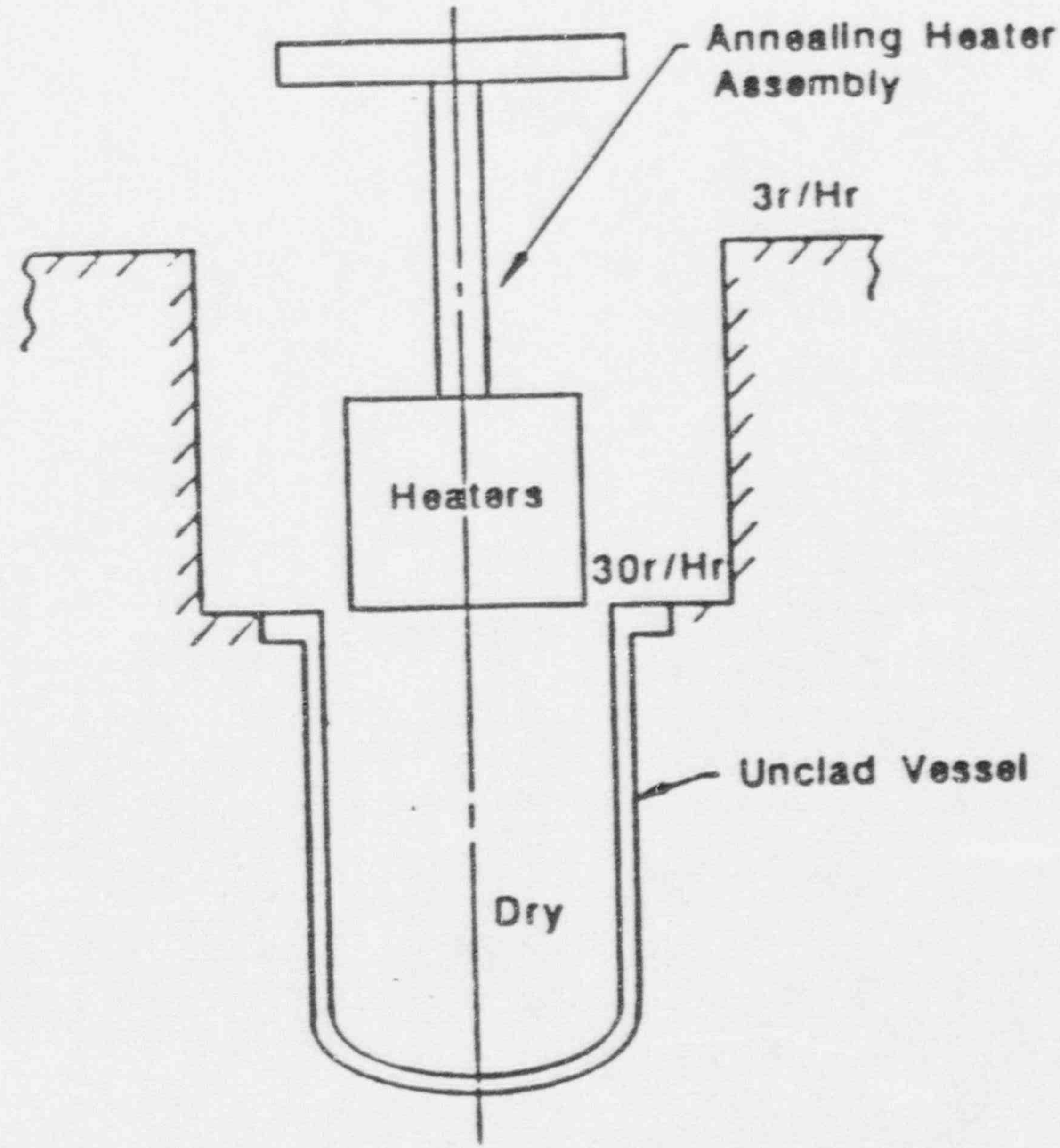
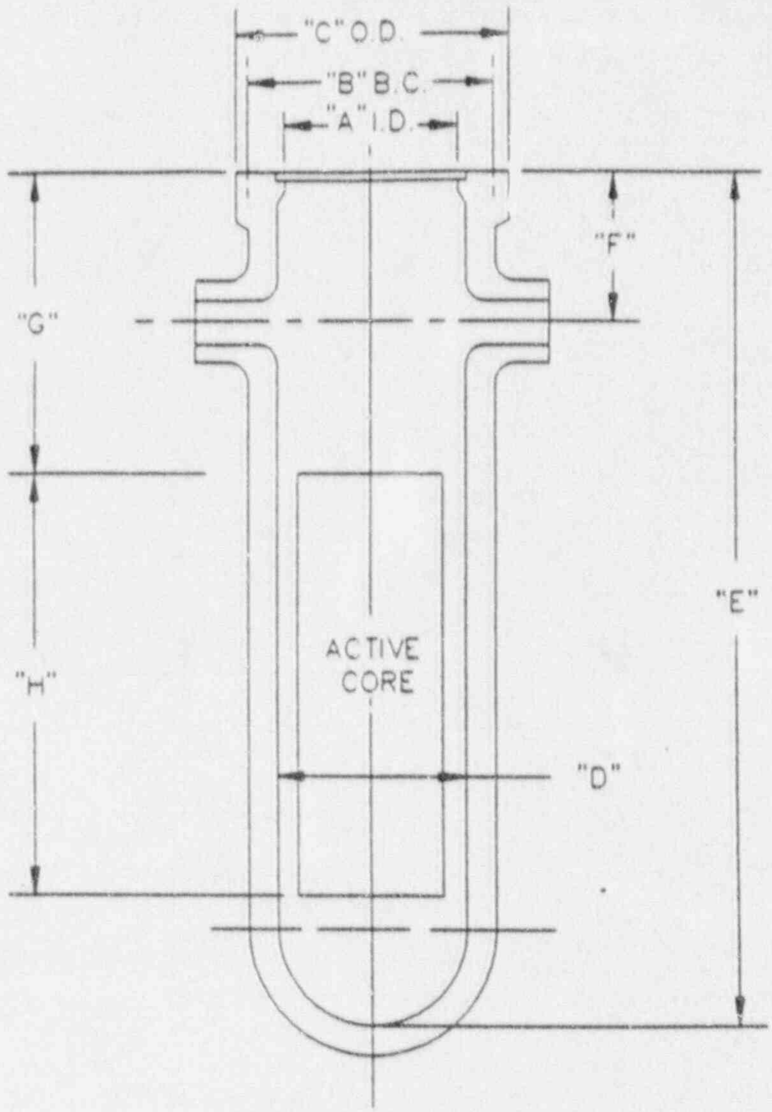


Fig. 1. Diagram of annealing of reactor vessel.
Fig. 1a. Sketch of the reactor vessel with heating arrangement and the pit volume: 1 - thermal insulation; 2 - reactor vessel; 3 - structural concrete; 4 - electric heaters; 5 - annular tank with water; 6 - supporting ring; φ - thermocouple.
Fig. 1b. Distribution of temperature along the height of the vessel: 1 - instant of establishment of holding stage; 2 - end of holding stage.


Annealing Heater
Assembly
3r/Hr
Heaters
30r/Hr
Unclad Vessel
Dry



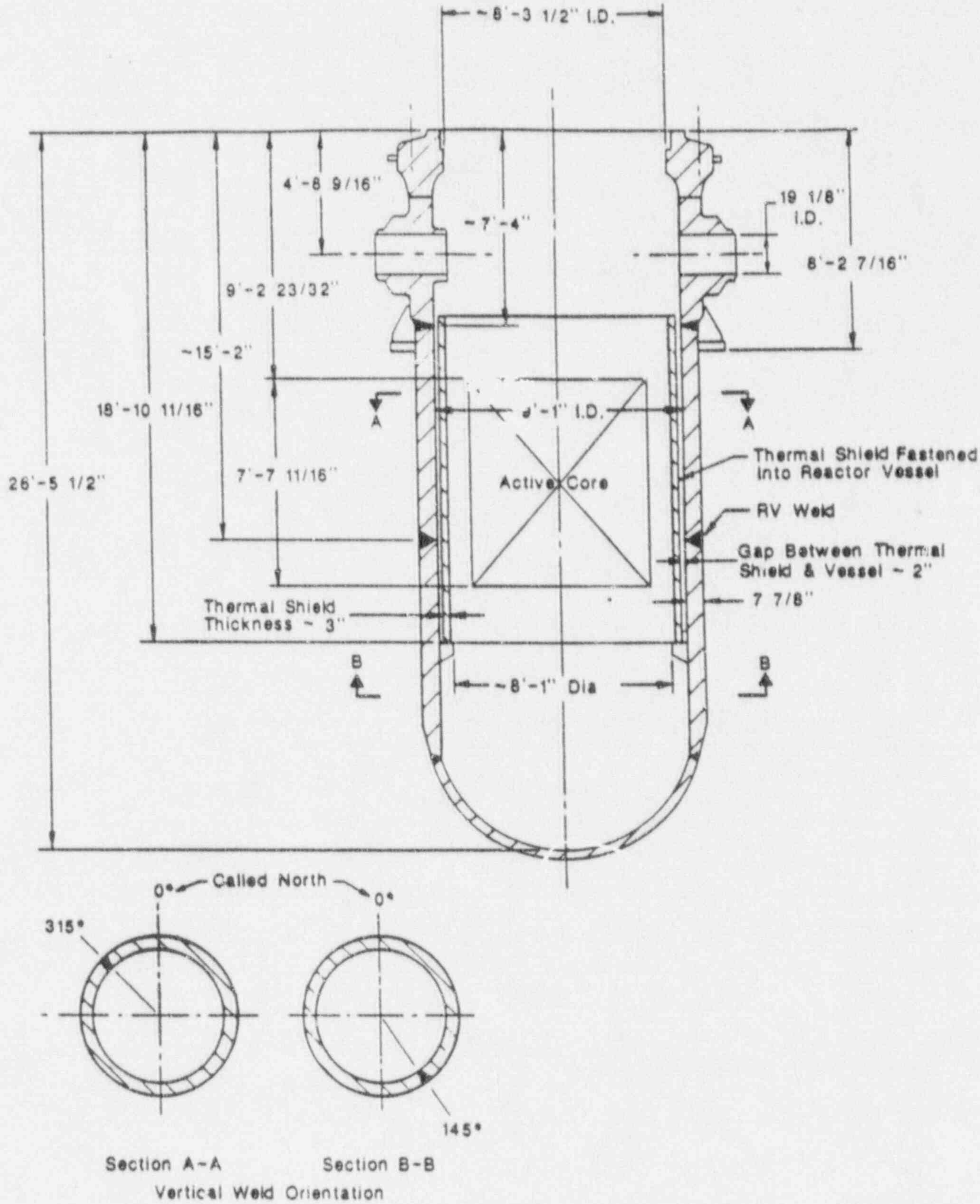
DIM	A	B	C	D	E	F	G	H
CALVERT CLIFFS	166.00	192.13	205.00	172.00	403.88	80.50		136.70
TMI-2	164.88	186.75	200.00	170.62	379.00	84.00	138.00	
BELLEFONTE	178.00		217.25	182.00	396.00	85.50	138.50	143.00
IPP	167.00	191.88	205.00	173.00	413.66	85.50	148.13	144.00

Dimensions Are In Inches

TYPICAL U.S. PWR VESSELS

FIGURE 3

MPR ASSOCIATES
F-73-34-1 B
11/14/90



Yankee Rowe - 175 MWe

FIGURE 4

MPR ASSOCIATES
F-73-34-3
11-19-90

CONCLUSIONS

- The USSR annealing techniques are generally applicable to US reactors provided arrangements can be made to:

    - drain the reactor but provide shielding around reactor internals

    - ensure that the radiation levels are not too high due to the stainless steel cladding

    - control the thermal stresses to avoid excessive distortions

    - limit the temperatures of the surrounding concrete to acceptable levels