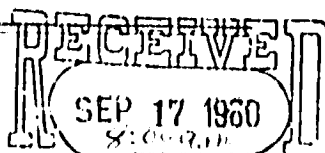


1. Considered 10-19, 1960
2. Name of Applicant Arthur J. Smith
3. Post Office Address San Juan
4. Amount of water claimed 2.5
5. Source of water supply San Juan River
6. Water to be used for irrigation
Acres to be irrigated 100
7. Water to be diverted and used in San Juan County about
15 miles up of San Juan River
8. Proof of Publication Received yes
Not Received no
9. Application Approved yes
Subject to nothing
Not Approved no
Action deferred no
10. Remarks:

No. 142-3
 Water Division No. 3 Big Sioux River District
 (Blanks to be filled by the Engineer for the W. R. C.)



STATE WATER RESOURCES COM.
 PIERRE, SOUTH DAKOTA

APPLICATION FOR PERMIT

To Appropriately Water within the State of South Dakota

(NOTE—Draw a line through items not applicable.)

1. Name of applicant W. H. Rork, Manager, Sioux Falls Division
 Postoffice address Sioux Falls, County Minnehaha, State So. Dak.

- I. If a corporation _____
- (a) Name of same Northern States Power Company
- (b) Date and place of incorporation _____
- (c) Amount of capital stock Adequate
- (d) Amount paid in Adequate
- (e) Names and addresses of directors See attached list

(NOTE—A certified copy of articles of incorporation must accompany the application.)

- II. Method of accomplishing the work and financial resources of the applicant:
- (a) Method of accomplishing work (Whether by contract, employment of others, or by direct labor)
Contract
- (b) Cash on hand, \$ Adequate
- (c) Treasury stock, \$ _____
- (d) Bonds to be issued, \$ _____
- (e) Other resources, \$ _____

2. Name of diversion work Well No. B
3. Amount of water claimed 150 gpm (max) cubic feet per second 0.33 cfs
4. Source of water supply Ground water-non flowing well, 170 ft. deep
5. Location of point of diversion 42 ft. west and 1270 ft. south of the northeast corner of Sec. 31, T102N, R48W on _____ bank Minnehaha County.
6. Annual period or periods during which water is to be used Throughout year
7. To be used for:

- I Irrigation or domestic use: Gravity, overhead sprinkling or combination system? _____
- (a) Number of acres to be irrigated _____ acres.

- (b) Legal subdivisions to be irrigated _____

(NOTE—A list of lands to be irrigated, giving each subdivision and fraction with acreage thereof, should be written here, or may be appended as a part of this application. Same must also be shown on accompanying map.)

- (c) Statement as to domestic use (giving location, etc.) _____

II. Stockwatering, mining, milling, power, fish culture, fire protection and public recreation:

- (a) Nature of use Sanitary water for power plant uses
 Name any of the above uses claimed

- (b) Amount of power to be generated 88,500 horse power.

Amount claimed for engine cooling None

- (c) Location of plant Adjacent to south line of SE 1/4 Sec. 30-102-48

- (d) Method of developing power Steam turbine

- (e) Point where water will be returned to stream SE 1/4 SE 1/4 Sec. 30-102-48

MAP No 425-3

8. Estimated cost of work:

(a) Head Gates, \$..... (b) Pumping plant, \$.....
 (c) Fluming, \$..... (d) Canal-earth, \$..... Rock, \$.....
 (e) Other structures \$..... Total, \$.....

9. Description of diversion works:

I. Nature of works: (Reservoir, dam, ditch, flume, pumping plant, etc.)

Well- see Form 2A

II. Dimensions of works:

(a) Dam: Height.....feet; length at bottom feet; length at topfeet; thickness at bottomfeet; thickness at topfeet; slope at front water face; slope at back facematerial used in construction
 (b) Reservoir: Capacity when filledacre feet. Surface area at highwater mark.....acres.

DEPTH AT OUTLET-Feet	SURFACE AREA AT EACH DEPTH AT OUTLET--ACRES	FEET	ACRE-Feet CAPACITY

(c)* Head gate: Width.....feet; heightfeet;
 Material
 (d) Canal: Total lengthmiles.

LOCATION BELOW HEADGATE	DEPTH	BOTTOM WIDTH	WIDTH AT WATER-LINE	GRADE PER MILE
At Mile	 feet	 feet	 feet	 feet
At Mile	 feet	 feet	 feet	 feet
At Mile	 feet	 feet	 feet	 feet
At Mile	 feet	 feet	 feet	 feet
At Mile	 feet	 feet	 feet	 feet
At Mile	 feet	 feet	 feet	 feet

(Give dimensions where reductions in size are made.)

10. Time required for completion of workthree.....years.
 11. Time required for complete application of water to the proposed beneficial usethree.....years.
 12. Choice of newspaper for publication of notice of intention to appropriateSioux Falls
Argus-Leader.....

STATE OF SOUTH DAKOTA }
 County ofMinnehaha.....} ss.

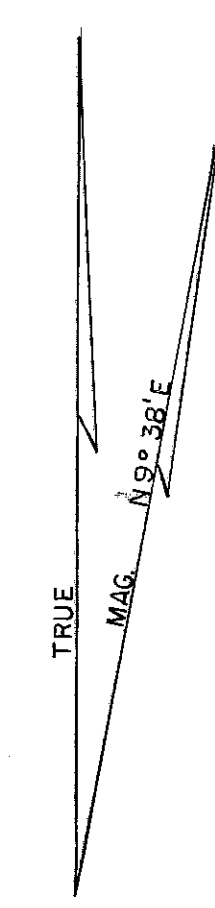
I,W. H. Rork....., being first duly sworn on my oath depose and say: That my relation to the above described undertaking is that of owner, that I have read the above foregoing statement, examined the map accompanying the same, and that I know of my own personal knowledge that the matters therein stated and shown are true.

Signed[Signature].....

Subscribed and sworn to before me this16..... day ofSept..... 19.....60

Notary Public (or other qualified officer.)

*Each diversion must have a headgate or measuring device.



SURVEYORS CERTIFICATE

I, K.E. BENSON, REGISTERED LAND SURVEYOR AND PROFESSIONAL ENGINEER OF THE STATE OF SOUTH DAKOTA DO HEREBY CERTIFY THAT I HAVE MAPPED THE AREA AS SHOWN FOR PURPOSES OF WATER APPROPRIATION FOR INDUSTRIAL USE.

K.E. Benson
K.E. BENSON

STATE OF SOUTH DAKOTA
COUNTY OF MINNEHAHA

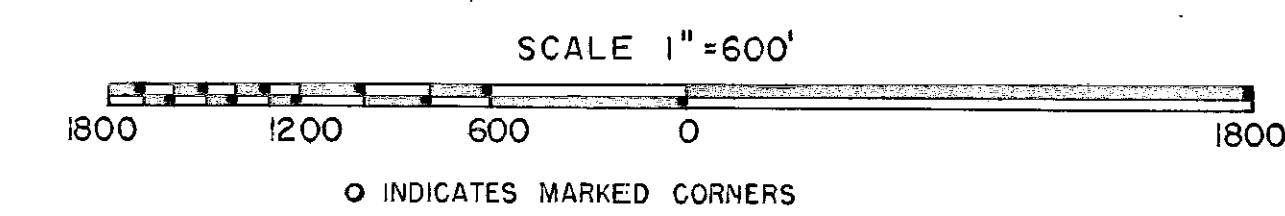
ON THIS 17 DAY OF December, 1958, BEFORE ME, THE UNDERSIGNED, A NOTARY PUBLIC APPEARED K.E. BENSON, WELL KNOWN TO ME TO BE THE PERSON DESCRIBED ABOVE AND WHO ACKNOWLEDGED TO ME THAT HE EXECUTED THE FOREGOING CERTIFICATE.

August 22, 1959
MY COMMISSION EXPIRES

Lyndel E. McCormick
NOTARY PUBLIC

N.S.P. CO.
PATHFINDER STEAM PLANT
DIVERSION NO. A
MINNEHAHA COUNTY, S. DAK.

Note: For construction details and logs of wells see Folder No. 561-3



Map No. 425-3 (Appl. No. 561-3) (Appl. No. 742-3)

Remarks by State Water Resources Commission:

STATE OF SOUTH DAKOTA
County of Black Hills ss.

Pierre, South Dakota, November 9, 1966

This is to certify that the foregoing application was received by the Commission at 8:00 o'clock
6 m. upon the 17th day of September, 1966.

State Water Resources Commission
By: [Signature]
Chief Engineer, Executive Officer

Number of permit 747-3

Date of first receipt of application September 17, 1966

Date of return to applicant for correction, amendments or changes required as follows: _____, 19____

Date of receipt of corrected application _____, 19____

Date from which applicant may claim right September 17, 1966

Approved October 19, 1966, Recorded in Book 6 Page 133

This is to certify that we have examined the foregoing application for a permit to appropriate water of the State of South Dakota, and we hereby grant the same as stated herein, subject, however, to the following limitations and conditions:

1st. The equivalent of at least one-fifth of the work above specified is to be completed on or before _____

April 19, 1967

2nd. The whole of said work is to be completed on or before October 19, 1963

3rd. The limit of time for proof of beneficial use of water appropriated in accordance herewith is

October 19, 1963

4th. The water appropriated shall be used for the purpose of providing sanitary

water for power plant

5th. The prior right of all persons who, by compliance with the laws of the State of South Dakota, have acquired a right to the use of water must not be injuriously affected by this appropriation.

6th. The amount of the appropriation herein granted shall not exceed 0.33 cubic feet per second; neither shall it exceed the capacity of the above described system of diversion works, nor the least amount of water that experience may hereafter indicate as necessary for the production of crops in the exercise of the best husbandry; and further, said appropriation must be limited to not more than one-seventieth (1/70) of one cubic foot of water per second or time for each acre of land to which water is actually and beneficially applied for irrigation on or before October 19, 1966; said water to be used during the following described annual period:

Continuously

Witness my hand this 9th day of November, 1966

State Water Resources Commission

By: [Signature]
Chief Engineer, Executive Officer

Certificate of Construction Issued AUGUST 15, 1966

Water License Issued AUGUST 15, 1966

DIRECTORS - NORTHERN STATES POWER COMPANY

<u>NAME</u>	<u>ADDRESS</u>
R. F. Pack	Minneapolis, Minnesota
Allen S. King	Minneapolis, Minnesota
H. C. Cummins	Minneapolis, Minnesota
Kenneth H. Dayton	Minneapolis, Minnesota
S. P. Duffy	Minneapolis, Minnesota
H. H. Gallagher	Waseca, Minnesota
T. G. Harrison	Minneapolis, Minnesota
A. B. Jackson	St. Paul, Minnesota
R. S. MacFarlane	St. Paul, Minnesota
B. C. Marks	Fargo, North Dakota
P. H. McDowell	Sioux Falls, South Dakota
Donald C. Minard	LaCrosse, Wisconsin

9. (Continued)

III. Well Specifications

(a) Hole and casing

Size of drill hole or excavation 17-inch diameter Depth 170 feet

Type of casing carbon steel
(wood, concrete, steel, etc.)

Size of casing 12-in outer, 8-in inner
Thickness of casing 3/8 inch, 5/16 inch

Length of casing 120 ft (12 in) If collection gallery, length, size and depth of
gallery 155 ft (8 in)

(b) Screens

Type of perforated screen Stainless-steel shutter

Size of perforated screen 8-inch 15 feet
(diameter) (length)

Thickness of gravel pack 26-inch length of gravel pack 50 feet

(c) Water Bearing Materials

Distance to water 57 ft Character of water bearing materials sand and clay

Thickness of water bearing material 50 ft, approximately

(d) Pump and Motor

Type of pump Deep-well turbine
(centrifugal, propeller, mixed flow, etc.)

Name of pump Layne Bowler size 8-in

Kind of motor Electric, vertical, hollow shaft
(gasoline, electric, diesel, etc.)

Horsepower 15 hp Name of Motor Allis-Chalmers

(e) Complete well

Capacity 150 gpm at drawdown of 30 ft Estimated cost \$16,000

(f) Owner of land upon which well is located

Name

Northern States Power Company, Sioux Falls, So. Dak.
Address

(g) Distance to nearest existing wells

On same owner's property 120± rods. On property owned by others 230± rods
See Permit No 561-3

STATE OF SOUTH DAKOTA

WATER LICENSE No. 742-3

WHEREAS, On the 17th day of September A. D. 1960
the Northern States Power Company
of Sioux Falls County of Minnehaha and State of
South Dakota duly made application (No. 742-3) to us for a permit to use .33
cubic feet per second of the waters of ground water
County of Minnehaha State of South Dakota, for industrial
purposes; and

WHEREAS, On the 9th day of November A. D. 1960
Permit No. 742-3 was issued to said applicant for the diversion of said water, and providing for the
completion of the works of diversion therein described on or before the 19th day of
October A. D. 1963 and for the application to beneficial use of said
water on or before the 19th day of October A. D. 1963
and,

WHEREAS, On the 29th day of July A. D. 1966
the holder of said permit duly made proof of the completion of adequate works for the diversion of .33
cubic feet per second of said waters, as evidenced by our Certificate No. 742-3
dated August 15, 1966 confirming the completion of works of sufficient capacity for
diverting and conveying to the place of intended use .33 cubic feet per second of water, with date of
priority of September 17, 1960 and,

WHEREAS, On the 29th day of July A. D. 1966
proof was duly made of the application to beneficial use of .33 cubic feet per second of said water;
for providing sanitation facilities at the power plant.

NOW, THEREFORE, By the virtue of the authority vested in us by the laws of the State of South Dakota,
We hereby grant and confirm to the Northern States Power Company
of Sioux Falls the holder and owner of said permit No. 742-3
a water right, dating from September 17, 1960 to the use of .33
cubic feet per second of the waters of ground water
In the County of Minnehaha and State of South Dakota or so much thereof as may be
necessary for the purposes hereinbelow mentioned, to be diverted at a point 42' W and 1270' S of the
NE corner, Section 31, T102N, R48W
and conducted ~~xxxxxxx~~ to power plant

for the purpose of sanitation facilities in the power plant

subject, however, to the laws of the State of South Dakota applicable to a license for the use of the waters of the
State, and subject, also to the local or community customs, rules and regulations which have been or may be
adopted from time to time by a majority of the users from a common source of supply, canal or lateral from
which such water may be taken, when such rules and regulations have for their object the economical use of such
water.

WITNESS, My hand and seal of our office at Pierre, South Dakota,
this 15th day of August A. D. Nineteen
Sixty-Six
Hundred and _____

State Water Resources Commission

By:

J. W. GRIMES
Chief Engineer, Executive Officer

STATE OF SOUTH DAKOTA

Water License No. _____

To _____

Source of Supply _____

County _____

Am't _____ c. f. s.

Point of Diversion _____

Place of Use _____

Purpose _____

Date of Priority _____

Recorded _____

in Book _____ of _____ Page _____

Permit No. 742-3

Water Division No. 3 Big Sioux River Water District

Certificate of Completion of Works

TO ALL WHOM IT MAY CONCERN:

This is to Certify, That the Northern States Power Company

of Sioux Falls, County of Minnehaha, and State of South Dakota

the holder of Permit No. 742-3, issued upon Application No. 742-3, bearing date of priority of September 17, 1960, authorizing the diversion of

.33 cu. ft. per second of the waters of ground water

County of Minnehaha, State of South Dakota, at a point 42'W and 1270' S of the NE corner, Section 31, T102N, R48W

for industrial

purposes, has fully complied with the provisions of the laws of the State of South Dakota relating to proof of completion of the works of diversion set out and described in said Permit; that said works are found in satisfactory condition for diverting and conveying to the place of intended use .33 cu. ft.

per second of water; and that the ~~use of said water are described as follows:~~ use of said water are described as follows, to-wit: for sanitary purposes in power plant operation.

Witness my hand this 15th day of August, A. D. 1966

State Water Resources Commission

By: J. W. GRIMES
Chief Engineer, Executive Officer

(First Publication on or before Sept. 21, 1960.)

APPROPRIATION OF WATER

Office of State Water Resources Commission,

Pierre, S. Dak., September 19, 1960

Notice is hereby given that ~~the Northern States Power Company~~ whose postoffice address is ~~Sioux Falls~~ S. Dak., has made an application in accordance with the provisions of the water laws of South Dakota for a permit to appropriate for beneficial use ~~0.33~~ cubic feet of water per second of time from ~~the~~ ~~ground water~~ through ~~xxx~~ ~~Well 180~~, the point of diversion of which is to be located ~~on the~~ ~~back of said stream~~ In the ~~NE~~ ~~1/4~~ of the ~~NE~~ ~~1/4~~ of Section ~~31~~ Twp. ~~102N~~ Range ~~18W~~ Said water to be used for the purpose of providing ~~irrigation on the following described land:~~

~~Sanitary water for power plant uses~~

~~and for~~

This application will be taken up by the State Water Resources Commission at their office at Pierre for consideration upon the ~~19th~~ day of ~~October~~, 19~~60~~, at ~~2 p.~~ M. All interested persons may appear and be heard.

Appropriate action will be taken by the Water Resources Commission after suitable time has elapsed for the consideration of any or all information presented.

State Water Resources Commission

cc: W.H. Leopard-Manager
Argus Leader
Sioux Falls, South Dakota

By:

~~Chief Engineer, Executive Officer~~
~~Burton F. Jones~~
Water Right Specialist

PROOF OF PUBLICATION

STATE OF SOUTH DAKOTA }
County Minnehaha } ss.

M. T. Haggard being duly sworn, deposes and says the annexed printed copy of Notice of Intention to Appropriate Water was taken from the _____
Sioux Falls Argus Leader a newspaper which during the whole time of publication of said notice herein after stated, has been and is printed and published in the _____
City of Sioux Falls County of Minnehaha and State of South Dakota; that the said notice was published in said newspaper on the following dates:

September 22, 1960

September 29, 1960

October 6, 1960

October 13, 1960

in each and every issue of the full number thereof, the first publication being made on the 22nd day of September 1960 and the last publication on the 13th day of October 1960, upon which days or times of publication aforesaid the newspaper was regularly published, and that during the whole time of said publication he was Comptroller ~~the printer and publisher~~ of the said newspaper.

W. J. Haggard

Subscribed and sworn to before me this 13th day of October A. D. 19 60

Charles E. Jones

Notary Public Minnehaha County, S. D.

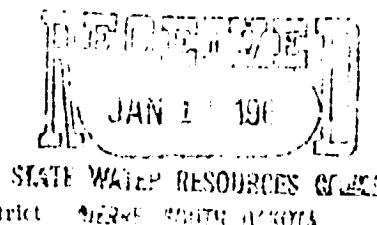
June 31, 1960

APPROPRIATION OF WATER
Office of State Water Resources
Commission

Pierre, S.D. Sept. 19, 1960
Notice is hereby given that the Northern States Power Company whose post office address is Sioux Falls, S. Dak., has made an application in accordance with the provisions of the water laws of South Dakota for a permit to appropriate for beneficial use 0.33 cubic feet of water per second of time ground water through Well "A", the point of diversion of which is to be located in the NE 1/4 of the NE 1/4 of Section 31, Township 102N, Range 48W. Said water to be used for the purpose of providing Sanitary water for power plant uses. This application will be taken up by the State Water Resources Commission at their office at Pierre for consideration upon the 15th day of October, 1960, at 2 p.m. All interested persons may appear and be heard.

Appropriate action will be taken by the Water Resources Commission after suitable time has elapsed for the consideration of any or all information presented.
State Water Resources Commission,
By: Burton F. Jones,
Water Right Specialist,
(Sept. 27, 29; Oct. 6, 13)

Permit No. _____



Water Division No. _____

Water District _____

NOTICE OF COMPLETION OF WORKS

This blank must be filled out by the holder of permit and forwarded to the Executive Officer at least 60 days before the time set for completion of works

(P. O.) Sioux Falls, South Dakota(Date) January 10, 1961

TO THE STATE WATER RESOURCES COMMISSION
OF SOUTH DAKOTA, PIERRE:

DEAR SIR: Notice is hereby given of the completion of the works for the diversion of _____
0.33 cu. ft. per second of the waters of the state from ground water
 through the Well No. B
 for Sanitary water for power plant purposes
 _____ in accordance with the terms and con-
 ditions of a certain permit heretofore issued by the Water Resources Commission of the State of South Dakota.

1. The name of the person or corporation holding said permit is Northern States
Power Company
2. The postoffice address of such person or the place of business of such corporation is Sioux Falls,
 County of Minnehaha, State of South Dakota.
3. The number of such permit is 742-3 and the date set for the completion of such work is
April 1, 1961
4. Said water to be used for Sanitary water for power plant purposes.
5. Said works of diversion will be fully completed on the date set for such completion, and the amount of
 water which said works are capable of conducting to the place of intended use, in accordance with the plans ac-
 companying the application for such permit, is 0.33 cubic feet per second.
6. The amount of land for which said water is available is _____ acres,
 particularly described as follows: _____

I hereby certify that the facts set forth in the above notice are true.

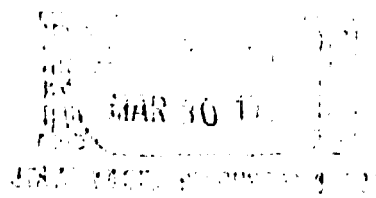
Northern States Power Company

(Signature of Owners)

Manager, Sioux Falls Division

Permit No.

Water Division No. Water District



Notice of Application of Water to Beneficial Use

(This blank must be filled out by holder of permit and forwarded to the State Water Resources Commission at least sixty days before the time set for application of water.)

(P. O.) Sioux Falls, South Dakota(Date) March 30, 1961

TO THE STATE WATER RESOURCES COMMISSION OF SOUTH DAKOTA, PIERRE:

DEAR SIR: Notice is hereby given that on the 1st day of June 1961, at Sioux Falls County of Minnehaha State of South Dakota, before _____ proof will be submitted of the application to beneficial use (Examining Engineer or Officer) of 0.33 cubic feet per second of the waters of the state from ground water in accordance with the terms and conditions of Permit No. 742-3 heretofore issued by the Water Resources Commission of South Dakota.

1. The name and postoffice address of the person or corporation holding said permit are Sioux Falls, County of Minnehaha, State of South Dakota
2. The use to which said water has been applied is Sanitary water for power plant.
3. The amount applied to beneficial use is 0.33 cubic feet per second.
4. The place where said water is used is (if for irrigation, give full and accurate description of the lands irrigated) Pathfinder Atomic Power Plant
5. The name of the canal or ditch or other works by which said water is conducted to such place of use is Well No. B.
6. The right to take the water from such works is based upon permit No. 742-3
7. The source of supply from which such water is diverted is Well No. B
8. The date of priority which said user is prepared to establish is September 17, 1960

Northern States Power Company
(Sign) /s/ J. H. J. [illegible]
Manager, Sioux Falls Division

Permit No. 742-3
BIG SIOUX
 Water Division No. 3 RIVER Water District

Certificate of Examination of Works

Report of Examining Engineer

To the State Water Resources Commission, Pierre, South Dakota:

Dear Sirs: I hereby certify that in accordance with your letter of authorization dated _____
 19____, I have this day made a thorough examination of the diversion works constructed by _____
NORTHERN STATES POWER CO of SIOUX FALLS
MINNEHAHA County, South Dakota, holder of Permit No. 742-3, issued
 upon Application No. 742-3, bearing date of priority of SEPTEMBER 17, 1960, authorizing the
 diversion of .33 cu. ft. per second of the waters of GROUND WATER for INDUSTRIAL
 purposes. I have to report on the condition of the same as follows:

The diversion works comprise: 170' - 8" WELL WITH LAYNE-BOWLER
TURBINE PUMP-TYPE B DR HC, POWERED WITH ALLIS-
CHALMERS 15 H.P. ELECTRIC MOTOR TYPE HSD-5.
WATER PUMPED THROUGH 4" LINE APPROXIMATELY
2500' TO PLANT

and the system is in the following condition: EXCELLENT

The point of diversion is located 42' W & 1270' S OF THE NE
CORNER, SECTION 31, T102N, R48W

The works are capable of diverting and conveying to the place of use .33 cu. ft. per second of water,
 which is to be used for INDUSTRIAL (SANITARY WATER FOR POWER PLANT)

The legal sub-divisions to be irrigated are: _____

_____ comprising a total of _____ acres of land.

The domestic use intended comprises _____

The utilization for power, mining, or other beneficial uses comprises: _____

Witness my hand, this 29TH day of JULY, 1966

—SEAL—

Quinton Jones
 Examining Engineer
 OFFICER

COPY NO. 81
REPORT NO. ACNP-5905

SUPPLEMENT NO. 5
to

Preliminary Safeguards Report
Pathfinder Atomic Power Plant

Prepared under AEC Contract No. AT(11-1) - 589
dated 22nd Day of November 1957
between
Northern States Power Company
and
U. S. Atomic Energy Commission

by

Northern States Power Company
15 South Fifth Street
Minneapolis 2, Minnesota

Approved: Hibbert Hill

Hibbert Hill
Chief Engineer

Approved: Earl Ewald

Earl Ewald
Vice President
in Charge of Operation

October 31, 1960

October 31, 1960

SUPPLEMENT NO. 5
to
SAFEGUARDS REPORT NO. ACPN-5905
on
PATHFINDER ATOMIC POWER PLANT

INSTRUCTIONS FOR REMOVAL OF SUPERSEDED SHEETS AND INSERTION OF NEW SHEETS	
Remove Sheets Listed Below Previously Dated	Insert Sheets Listed Below Dated October 31, 1960
i & Figs. I thru III ii ----- iv thru ix x thru xiv 1.65 & 1.66 Fig. 1.4 Tab: "SECTION 2, POWER PLANT" 2.1 thru 2.17 Fig. 2.1 thru 2.5 4.1 & 4.2 ----- Tab: "SECTION 5, CONTROL AND INSTRUMENTATION" 5.1 thru 5.16 Fig. 5.1 thru 5.4	i & Figs. I thru IV ii Fig. V (following page iii) iv thru ix x thru xvi 1.65 (dated Aug. 15, '60) & 1.66 Fig. 1.4 Tab: "SECTION 2, SYSTEMS" 2.1 thru 2.71 Fig. 2.1 thru 2.18 4.1 thru 4.8 Fig. 4.1 thru 4.4 Tab: "SECTION 5, PLANT DYNAMICS ANALYSIS" 5.1 thru 5.12 Fig. 5.1 thru 5.11

October 31, 1960

1 INTRODUCTION

This Safeguards Report describes the Pathfinder Atomic Power Plant; its site, equipment, and operation. The report is based on correlated contributions from the Northern States Power Company, Allis-Chalmers Manufacturing Company and their consultants. It is intended that this report should present the plant design philosophy and site description in detail. As design progresses, the report will be amended so as to result in a Final Safeguards Report.

Owners and operators of the Pathfinder Atomic Power Plant will be the Northern States Power Company of Minneapolis, Minnesota. Central Utilities Atomic Power Associates *(CUAPA), a group of ten private midwest utilities, and the U. S. Atomic Energy Commission, under the provisions of Contract No. AT-(11-1)-589, contribute toward the associated research and development program. The plant, including the reactor, will be designed and constructed by the Allis-Chalmers Manufacturing Company of Milwaukee, Wisconsin. The Pioneer Service and Engineering Company of Chicago, Illinois will provide the architect and engineering services for the project.

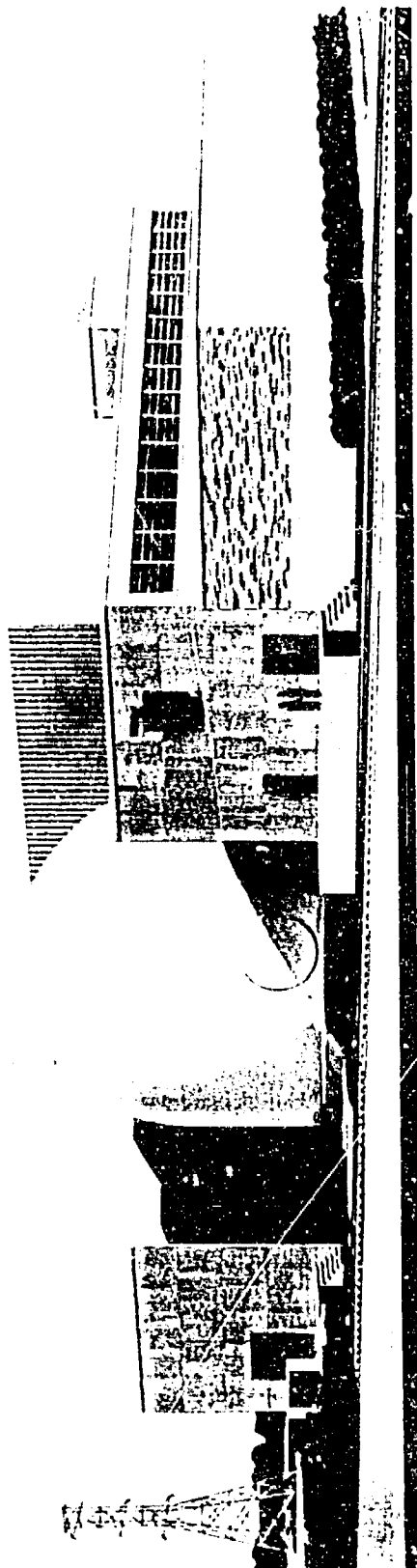
The Pathfinder Atomic Power Plant will be located on a site on the south bank of the Big Sioux River, 5.5 miles northeast from the center of Sioux Falls, South Dakota. The conceptual design of the plant is shown in Figures I, II, III, and IV. It is scheduled for operation in June, 1962.

A research and development program, as provided for in Appendix B of the AEC Contract No. AT-(11-1)-589, is in progress at the facilities of the Allis-Chalmers Manufacturing Company and its subcontractors. A critical experiment facility (see ACNP-5809) provides means for determining and checking nuclear constants in a series of experiments.

*CUAPA Member Companies

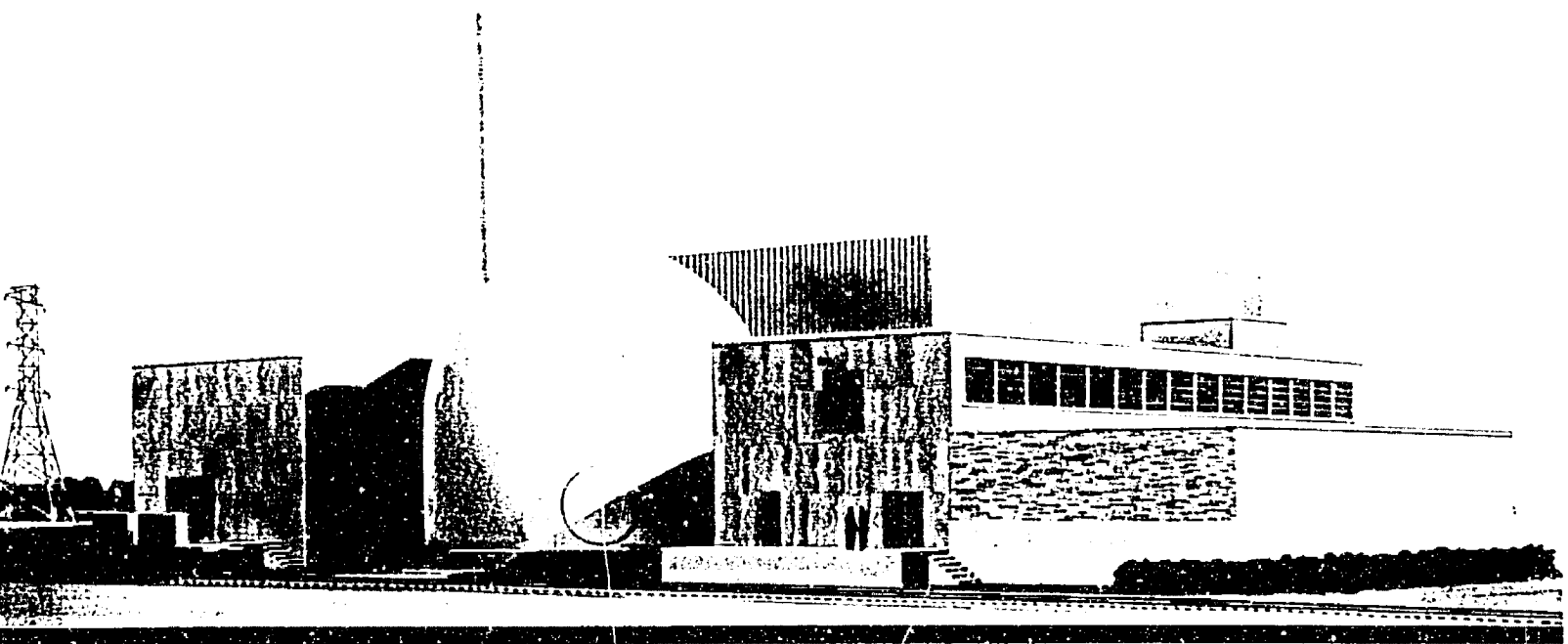
Central Electric & Gas Company
Interstate Power Company
Iowa Power & Light Company
Iowa Southern Utilities Company
Madison Gas & Electric Company

Northern States Power Company
Northwestern Public Service Co.
Otter-Tail Power Company
St. Joseph Light & Power Co.
Wisconsin Public Service Corp.

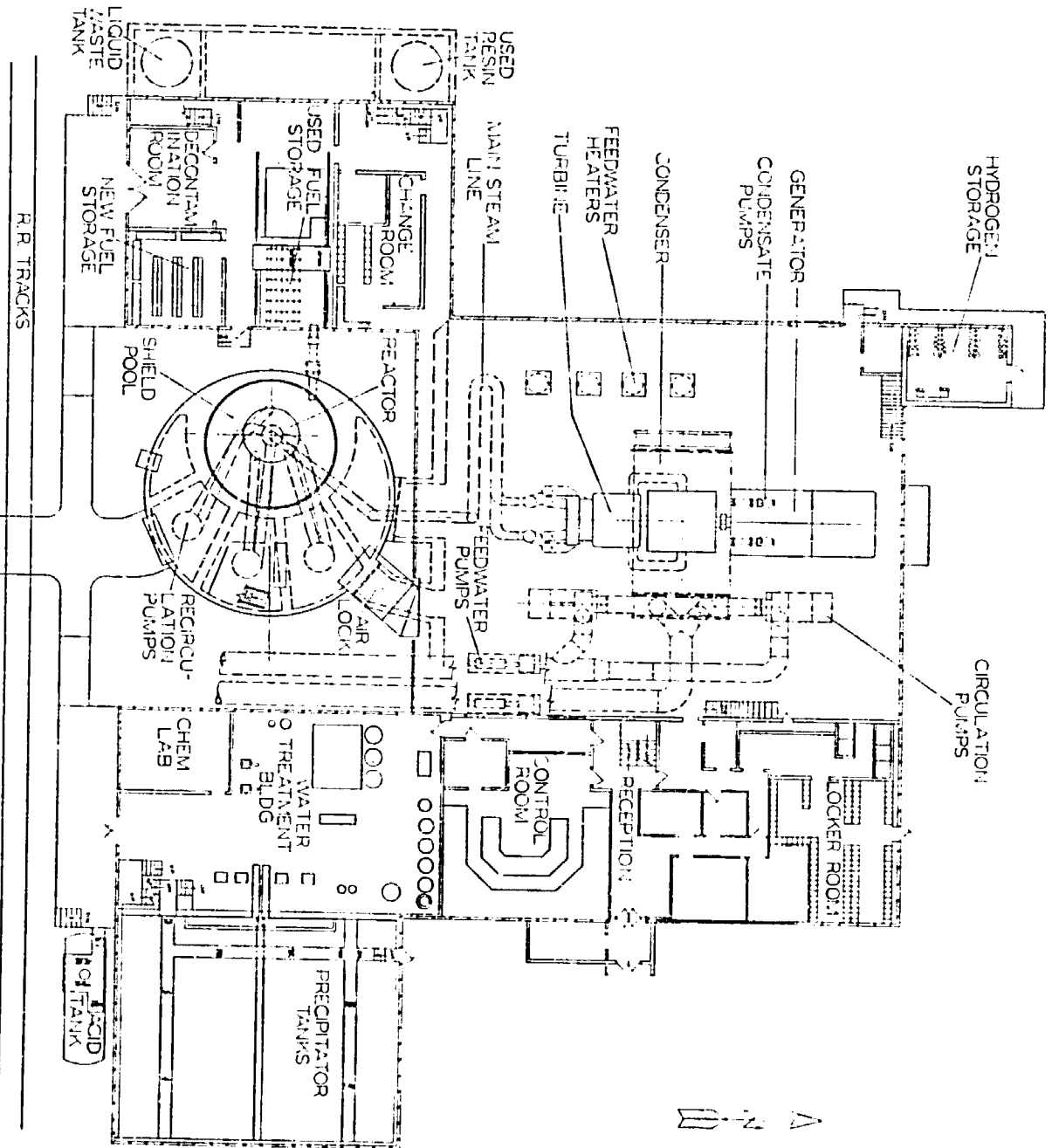


PATHFINDER ATOMIC POWER PLANT
(ARTIST'S CONCEPTION)

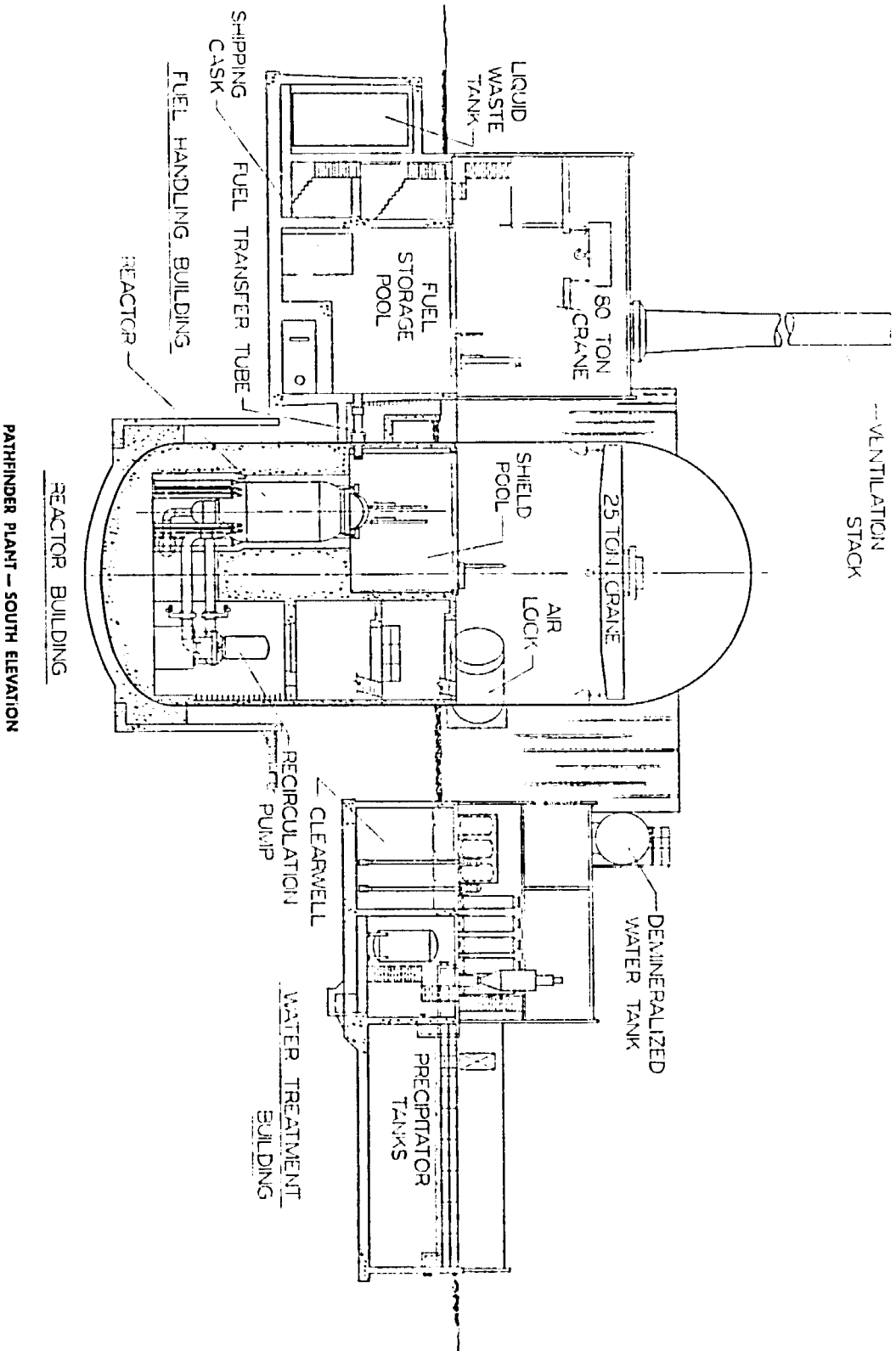
FIG. 1
October 31, 1960



PATHFINDER PLANT - PLAN VIEW



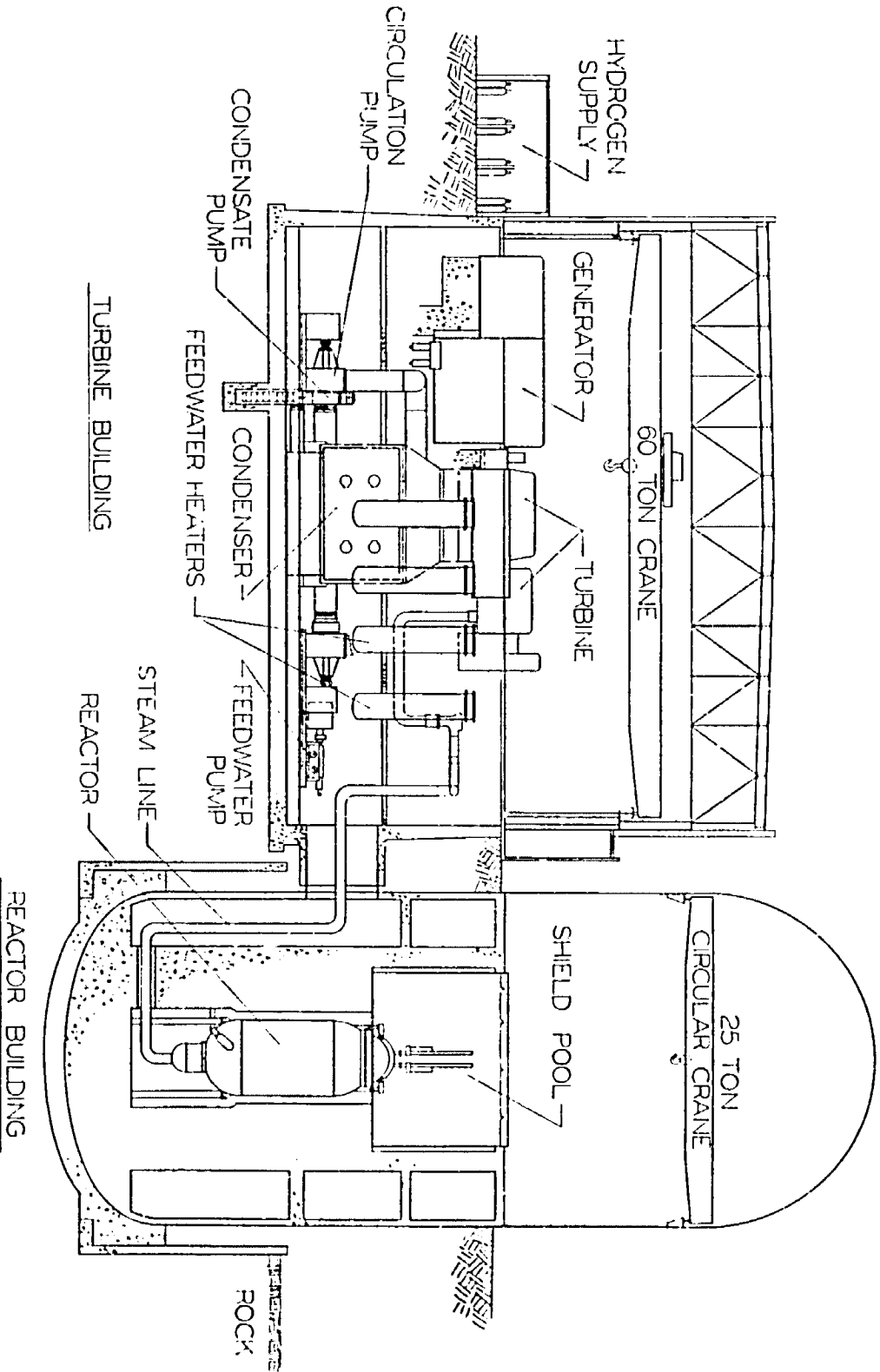
PATHFINDER PLANT - PLAN VIEW



PATHFINDER PLANT - SOUTH ELEVATION

FIG. III
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PATHFINDER PLANT - WEST ELEVATION



PATHFINDER PLANT - WEST ELEVATION

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1: SUMMARY

Presented in this report is a description of the design and operation of the Pathfinder Atomic Power Plant and its reactor with nuclear superheater. The plant site and the safeguards are reviewed in detail.

This report substantiates that the health and safety of the public and operating personnel will be protected by proper plant design and safe operating procedures. Various types of accidents are analyzed in order to verify that adequate safeguards are provided.

The reactor for the plant is of the heterogeneous boiling water type with a two-region core. A superheater region in the center is approximately a right circular cylinder surrounded by a boiler region. The fuel elements in the superheater region will contain highly enriched uranium dioxide in a stainless steel cermet clad with stainless steel. The fuel elements in the boiler region will contain slightly enriched uranium dioxide clad with Zircaloy-2. The reactor will operate at a normal pressure of 615 psia. Light water is used as the coolant and moderator and will be recirculated through the boiler region by pumps located external to the reactor vessel. Controlled recirculation will provide an additional means of controlling the output of the reactor. Steam generated at 489F in the boiler region will be passed through the superheater region raising the temperature to 825F for ultimate use in a condensing steam turbine. Present specifications for the Pathfinder reactor with nuclear superheater are listed in the table on the following page. Figure V, which follows the table, is a simplified flow diagram showing heat balance.

Various potential and hypothetical hazards and incidents have been reviewed and results of analysis are presented in this Safeguards Report. Safety is a prime consideration in the design of the Pathfinder Atomic Power Plant and its reactor and safeguards analyses will continue.

In this report, it is shown that the reactor building, which is designed to meet all applicable codes, is structurally stable and capable of withstanding internal pressures resulting from maximum release of steam or coolant. It is also shown that the reactor building is capable of containing radioactive fission products released into the building during any reasonable postulated incident. It is concluded that the Pathfinder Atomic Power Plant will not constitute a hazard to the health and safety of the public and operating personnel.

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to prevent water leakage back into the reactor vessel. The high pressure rotary face seal on the main drive pinion shaft prevents leakage of the high-pressure water from the rack housing. Any leakage past the high pressure seal goes to the monitored seal drain, the same seal drain that carries away leakage from the low pressure rotary face seal on the drive housing.

All connections to the control rod drives are made above the level of the shield pool. The connection lines are brought from the side of the shield pool to the drives by a tilt-up bridge. All connections are removed from the drives for refueling operations and the tilt-up bridge is moved out of the area required for the traveling bridge crane used to handle fuel elements (refer to Fig. 1.19).

A scram assist spring is located in the upper end of the slotted inner containment tube. The scram assist spring is twenty inches long and is compressed to a 10 inch length as the drive rack moves to its upper position. The stored energy of the scram spring is used to assist gravity in driving the control rod into the core during scram.

The control rod is attached to the rack by means of a bayonet latch. The bayonet latch is locked or unlocked by rotating the round rack 45 degrees. Rotation of the rack can be achieved only by the use of a special unlatching tool which turns the inner containment tube, and, therefore, the rack. While the reactor is operating, the inner containment tube is locked in place, thus preventing rotation of the rack.

Section 2

SYSTEMS

2.1 Power Plant

2.1.1 Steam Line

The main steam line is 16 inch schedule-60 pipe fabricated from A-335 Grade P 11 steel, and covered with 5 inches of insulation. The line is equipped with a motor operated isolation valve (Figure 2.1). This valve, located within the reactor building, will be tripped on scrams requiring isolation to maintain the integrity of the containment shell. This valve is designed to close in about 15 seconds. It will also be used as a main steam line stop valve during normal startup and shutdown operations. A 4 inch line, bypassing the isolation valve, is provided for steam flows up to 60,000 lb/hr. The main steam line divides into two 12 inch lines at the turbine. A turbine trip valve is located in each line.

A 12 inch main steam dump line is connected to the main steam line ahead of the turbine trip valves. It will be used to bypass steam around the turbine to the desuperheater pipe located in the condenser. The dump valve installed in this line will automatically control the steam line pressure when the pressure is not controlled by the turbine inlet valves. The valve will also be used during plant startup and shutdown operations.

Four bellows-sealed safety valves sized for 115% rated steam flow are installed on a common 10 inch header which is connected to the main steam line between the reactor and the main steam line isolation valve.

The safety valves discharge through flexible connections to a common 14 inch discharge line, which discharges the steam to the condenser desuperheater pipe. The safety valves are capable of relieving 115% rated reactor steam flow.

2.1.2 Turbine

The turbine is a tandem-compound, double-flow 3600 rpm unit utilizing conventional design standards and materials of construction that have, through many years of use and development, attained a high degree of reliability. Necessary modifications to the conventional turbine shaft seals were made to eliminate the possibility of reactor steam escaping into the turbine building. The modified seals are supplied with non-radioactive sealing steam from a special gland steam evaporator, which utilizes reactor steam to evaporate demineralized water. An auxiliary gland steam generator, fired with oil or gas, is provided for use during startup and shutdown, and as a standby for the evaporator. This generator is designed to operate at pressures up to 575 psig, thus it can supply steam to heat the reactor water during startup operations. The steam conditions at the turbine inlet valves are 525 psig and 825 F with a flow of 613,000 lb/hr at 66 MWe. The turbine supplies steam to four regenerative feedwater heaters from extraction points in the turbine casing (Figure 2.2).

2.1.3 Condenser

The two pass surface condenser is designed for a heat load of 435,000,000 Btu/hr at a vacuum of 28-1/2 inches Hg. With admiralty tubes and a deaerating hotwell, it is of standard design with the following exceptions:

(2.2)

to prevent water leakage back into the reactor vessel. The high pressure rotary face seal on the main drive pinion shaft prevents leakage of the high-pressure water from the rack housing. Any leakage past the high pressure seal goes to the monitored seal drain, the same seal drain that carries away leakage from the low pressure rotary face seal on the drive housing.

All connections to the control rod drives are made above the level of the shield pool. The connection lines are brought from the side of the shield pool to the drives by a tilt-up bridge. All connections are removed from the drives for refueling operations and the tilt-up bridge is moved out of the area required for the traveling bridge crane used to handle fuel elements (refer to Fig. 1.19).

A scram assist spring is located in the upper end of the slotted inner containment tube. The scram assist spring is twenty inches long and is compressed to a 10 inch length as the drive rack moves to its upper position. The stored energy of the scram spring is used to assist gravity in driving the control rod into the core during scram.

The control rod is attached to the rack by means of a bayonet latch. The bayonet latch is locked or unlocked by rotating the round rack 45 degrees. Rotation of the rack can be achieved only by the use of a special unlatching tool which turns the inner containment tube, and, therefore, the rack. While the reactor is operating, the inner containment tube is locked in place, thus preventing rotation of the rack.

The gearmotor is controlled selectively by either a manual pushbutton or an automatic servo control. The low inertia rotor of the motor stops very rapidly because of an integral mechanical brake. Coast is less than 1/3 inch.

Because of the speed limiting characteristics of the A-C motor, a dangerous withdrawal rate for the control rods can never be reached. (Refer to subsection 2.9.1 for rod speeds.)

Whenever it is required to remove the vessel cover the control rods are disconnected and remain in the core. The procedure is as follows:

1. A special tool is used from the drive bridge to engage the square top of the rack turning mechanism. By pushing down the ball lock is released and the rack may be turned 45° to disengage the control rod from the latch.
2. The rack is then raised a few inches to disengage it completely from the rods.
3. The rack is then rotated back to its original position and driven up until its bottom end is above the plane of the lowest edge of the pressure vessel cover. The rack is then rotated 45° to lock it in position so that the power leads can be disconnected without dropping the rack.
4. The cover is removed and placed in the storage space provided for it in the shield pool. Support bosses are provided on the cover in order to protect its seal surfaces during storage in the pool.

Section 2

SYSTEMS

2.1 Power Plant

2.1.1 Steam Line

The main steam line is 16 inch schedule-60 pipe fabricated from A-335 Grade P 11 steel, and covered with 5 inches of insulation. The line is equipped with a motor operated isolation valve (Figure 2.1). This valve, located within the reactor building, will be tripped on scrams requiring isolation to maintain the integrity of the containment shell. This valve is designed to close in about 15 seconds. It will also be used as a main steam line stop valve during normal startup and shutdown operations. A 4 inch line, bypassing the isolation valve, is provided for steam flows up to 60,000 lb/hr. The main steam line divides into two 12 inch lines at the turbine. A turbine trip valve is located in each line.

A 12 inch main steam dump line is connected to the main steam line ahead of the turbine trip valves. It will be used to bypass steam around the turbine to the desuperheater pipe located in the condenser. The dump valve installed in this line will automatically control the steam line pressure when the pressure is not controlled by the turbine inlet valves. The valve will also be used during plant startup and shutdown operations.

Four bellows-sealed safety valves sized for 115% rated steam flow are installed on a common 10 inch header which is connected to the main steam line between the reactor and the main steam line isolation valve.

The safety valves discharge through flexible connections to a common 14 inch discharge line, which discharges the steam to the condenser desuperheater pipe. The safety valves are capable of relieving 115% rated reactor steam flow.

2.1.2 Turbine

The turbine is a tandem-compound, double-flow 3600 rpm unit utilizing conventional design standards and materials of construction that have, through many years of use and development, attained a high degree of reliability. Necessary modifications to the conventional turbine shaft seals were made to eliminate the possibility of reactor steam escaping into the turbine building. The modified seals are supplied with non-radioactive sealing steam from a special gland steam evaporator, which utilizes reactor steam to evaporate demineralized water. An auxiliary gland steam generator, fired with oil or gas, is provided for use during startup and shutdown, and as a standby for the evaporator. This generator is designed to operate at pressures up to 575 psig, thus it can supply steam to heat the reactor water during startup operations. The steam conditions at the turbine inlet valves are 525 psig and 825 F with a flow of 613,000 lb/hr at 66 MWe. The turbine supplies steam to four regenerative feedwater heaters from extraction points in the turbine casing (Figure 2.2).

2.1.3 Condenser

The two pass surface condenser is designed for a heat load of 435,000,000 Btu/hr at a vacuum of 28-1/2 inches Hg. With admiralty tubes and a deaerating hotwell, it is of standard design with the following exceptions:

1. The hotwell is oversized to provide storage for the water used to flood the reactor steam dome and superheater during shutdown.
 2. When steam is bypassed around the turbine or relieved through the reactor safety valves, it enters the condenser through the large diameter desuperheater pipe (Figure 2.1). The desuperheater pipe, located just above the hotwell, contains spray nozzles which are supplied with condensate to reduce the steam temperature.
 3. During refueling, the reactor and shield pool are cooled by passing shield pool water over the condenser tubes.
- Noncondensable gases are removed from the condenser by a triple element, two stage steam jet air ejector. A rotary vacuum pump is also provided for use during startup and shutdown.
- The condenser is cooled by circulating water which flows to the condenser by gravity from the basin of a conventional double-flow, induced draft cooling tower (Figure 2.3). The water is returned to the cooling tower by the two circulating water pumps which take suction from the condenser outlet waterbox. Both the inlet and outlet waterboxes are divided. To provide for operation of the entire condenser with one circulating pump, a 30 inch butterfly valve is installed in the dividing wall of the outlet waterbox and a discharge valve is provided for each pump.
- A cross-connect line is provided between the outlet waterbox and the hotwell so that the large volume of water in the cooling tower basin can be used to keep the reactor core flooded following a major rupture in the

primary system. This line is equipped with two stop valves in series, with a leak-off between the valves, to insure isolation of the condensate and circulating water.

The cooling tower water make-up treatment system treats water pumped from the Big Sioux River. The system consists of two river pumps, two traveling screens, two precipitators, a clearwell and two cooling tower water make-up pumps.

2.1.4 Feedwater System

The feedwater system contains two condensate pumps, two condensate filters, four regenerative feedwater heaters, a drain cooler, two feed pumps and a feedwater control valve (Figure 2.5). Three low pressure heaters are located between the condensate pump and the feedwater pump. One high pressure heater is located between the feedwater pump and the reactor. Each of the above pumps and filters is sized for full normal capacity flow, thus one set is available for standby service. Bypass lines are provided for each feedwater heater.

The final feedwater temperature will be controlled at partial loads by bleeding reactor steam to the high pressure feedwater heater. A steam control valve will establish the final feedwater temperature by controlling the flow of steam to the heater. The conventional spray-type desuperheater is supplied with feedwater. When reactor steam is bled to the heater, an air-operated check valve will close in the high pressure extraction line.

The feedwater control valve is located between the feedwater pump and the high pressure heater. The three element control system for this valve will automatically position the feedwater valve to control the reactor water level. Manual control of the feedwater control valve is also provided.

Make-up water is supplied from the 20,000 gallon demineralized water storage tank to the condenser hotwell.

2.1.5 Emergency Shutdown Cooling System

The emergency shutdown cooler will use shield pool water to condense reactor steam following a scram requiring isolation. The cooler has sufficient cooling capacity to: (1) prevent popping of the reactor safety valves, and (2) provide sufficient steam flow through the superheater to prevent overheating of the fuel elements.

Reactor steam will flow to the tube side of the cooler through a 6 inch line which is connected to the main steam line at a point located between the reactor and the main steam line isolation valve (Figure 2.1). The air-operated valve in this line is interlocked with the main steam line isolation valve, and will open on scram requiring isolation. A 3 inch line, equipped with a check valve, connects the cooler tube-side outlet to the reactor feedwater line. Since the cooler is located above the reactor, condensate will return to the reactor by natural circulation.

The cooler shell-side 3 inch supply line and 20 inch return line are connected directly to the shield pool below the normal water level. To promote natural circulation, the return line is 4 feet above the supply line.

2.2 Reactor Water Purification System (Figure 2.6)

In order to maintain high purity reactor coolant, a side stream low pressure purification system is used. It is designed with the philosophy of incorporating as many secondary functions as practical. The system will fulfill four functions:

1. The primary function of the purification system is to remove activated corrosion products normally found in the reactor water. This is necessary to keep system radioactivity levels low, minimize the possibility of plateout on heat transfer surfaces and the accumulation of activated crud in parts of the system where it could make direct maintenance difficult or impossible.

The system is designed to maintain a total solids concentration in reactor water of less than 1 part per million (ppm). During normal operation up to 100 gpm of reactor water is fed to the purification system. The major cation impurities expected during normal operation are Zr, Fe, Cr, Ni, Mn, Co and Cu.

2. A second function is performed by the system in case of fuel element rupture, when the system will be used to remove fission products and other activated crud during a reasonable shutdown period prior to removing the reactor cover.

3. A third function is performed during the reactor startup procedure, when the superheater and a section of the main steam line is drained through the purification system.

4. A fourth function is accomplished while the reactor is being shut down, prior to removing the vessel cover. Once the reactor is flooded, its temperature is reduced further by circulating reactor coolant through the purification system - to the main condenser - and back to the reactor. Heat is removed from the stream in the purification system shutdown cooler and in the main condenser. Flow to the condenser is maintained initially by the pressure difference between reactor and condenser; and toward the end of this operation by pressurizing the reactor with the condensate pump.

The system after the flash tank will operate at low pressure, approximately 50 psia. The low pressure concept was chosen after studies showed it to be desirable from the operational, economic and safety standpoints and to facilitate its use for the secondary functions described above.

Most of the components of the purification system, coming in contact with reactor water, are made of stainless steel. The piping system is of welded construction. All high pressure piping welds are radiographically inspected. Although most valves are conventional in design, refinements in valve packing and stem leakoffs will keep system leakage to a minimum.

During normal plant operation, reactor water is bled from the discharge nozzles of the three reactor water recirculation pumps. The water flows to a common header where the combined flow is up to 100 gpm. It then flows through a high pressure line which penetrates the reactor building

after passing through an isolation valve. The water flows to the fuel handling building where all of the purification system components are located.

At this point, the high pressure reactor water is throttled into a flash tank maintained at approximately 35 psig. Steam from the flash tank flows directly to the #12 feedwater heater, located in the turbine building, where it is condensed and returned to the feedwater system. This steam can be bypassed to the main condenser when necessary. This is shown in Figure 2.2.

Approximately 62 gpm of the original 100 gpm leaves the flash tank as saturated water at flash tank pressure. After leaving the flash tank, the water is cooled to 140 F or less in a cooler, which uses condensate as the normal coolant. From there, it flows through a system of pre-filters, ion exchangers, and after-strainers to the main condenser.

When the reactor is shutdown for re-fueling or maintenance, it is possible to maintain a continuous purification system flow rate of 250 gpm. The "shutdown" pump maintains this flow rate. Both ion exchangers will be put into service, operating in parallel when it is desired to exceed 125 gpm. Each filter is capable of handling a flow up to 250 gpm with a resulting shorter filter-cycle.

The shutdown pump is installed on a bypass in the high pressure section of the purification system. It is mounted vertically at recirculation pump floor level in the reactor building main steam line chase. The conventional single stage centrifugal pump is designed to

withstand full reactor pressure. Specifications for the pump casing require dye penetrant inspection of the casing and radiographic inspection of all welds. The conventional stuffing box seal is provided with condensate from the reactor recirculation pump seal water system. Approximately half of this feed passes into the pump, the other half drained to the reactor building sump. Remote operated stop valves are provided at pump suction and discharge. This pump is used continuously when the reactor is shutdown, and during phases of reactor startup and shutdown.

The flash tank is located in the fuel handling building. It is housed in a separate concrete vault. The tank, mounted vertically on the mezzanine floor, measures 34 inches I.D. and 7 feet 6 inches high. Made entirely of 304 stainless steel, the flash tank is designed for 100 psig, and meets the requirements of Section VIII of the ASME Code for Unfired Pressure Vessels as modified by case 1273N. Normal operating pressure is 35 psig.

Four nozzles enter the tank tangentially at an elevation above the normal water level. One is used for normal operation, the remaining three nozzles will be opened to maintain required flow when the reactor pressure is low during shutdown or startup. A flow control valve (P-10) precedes the nozzles. This valve is designed to permit 120 gpm flow to the flash tank when the reactor is at full pressure, the control valve is open full, and one nozzle is open. Hence, when maintaining the 100 gpm design flow during normal plant operation, most of the pressure drop occurs through the nozzle, thus insuring long life of the valve.

Moisture carryover in steam from the flash tank is maintained at less than 1% by a dry pipe, similar to that in a conventional boiler drum.

A pressure relief system is provided on the flash tank. This system will limit tank pressure to 110% of maximum allowable working pressure while relieving the maximum possible blow-down flow rate. Maximum possible flow rate can be achieved only if the following conditions occur coincidentally:

1. Failure of flash tank high pressure interlock to close blow-down control valve.
2. Reactor at normal operating pressure and temperature.
3. All valves between reactor and flash tank fully open including four nozzle valves.

A rupture disk is located in a pipe leading from the bottom water outlet pipe directly to the main condenser. A steam safety valve is attached to the steam outlet pipe, and discharges directly to the main steam bypass line, which in turn enters the main condenser. The rupture disk is designed to blow at a higher pressure than the safety valve. The dual system enables the steam and water phases to be separated; thus minimizing severe two-phase flow conditions through a single safety valve and discharge pipe.

There are two shell-and-tube coolers located in a shielded area in the fuel handling building. One is used as the "normal cooler", and the other as a "standby and shutdown cooler". Each is designed for 150 psi pressure.

Water from the flash tank flows through the shell side of the normal cooler. Purification water temperature is reduced to 140 F or less by condensate. From the discharge of the main condensate pump, a side stream flows through the tube side of the normal cooler and is returned to the feedwater system after the second feedwater heater. The condensate passing through the tube side of the cooler is at a pressure higher than the purification water. Consequently, any leakage would introduce condensate into the purification system. Reactor water cannot enter the condensate system without first being filtered and demineralized.

The shutdown cooler is used during phases of reactor startup and shutdown. In addition, it will act as a standby to be used in place of the normal cooler if necessary. Its capacity is greater than that of the normal cooler, enabling it to be used for reactor shutdown cooling. Water from the cooling tower system will be used as coolant. Any leakage in this unit will also be into the purification system, thereby preventing leakage of radioactive water into the cooling water system.

Two, 100 square foot, element type precoat filters precede the ion exchangers. During normal operation one filter is in use with the other on standby. This type of filter is remotely precoat and backwashed, thereby minimizing exposure of personnel by activated filter crud.

The mixed bed ion exchangers remove the soluble corrosion products from the reactor water as well as stop any suspended particles which may have passed through the pre-filters. Each unit is designed for a 125 gpm maximum flow. For limited periods the ion exchangers can be operated in

parallel at a combined flow of 250 gpm. Underdrains for resin retention consist of metal edge type strainers. Resins will be charged and removed from the vessels by hydraulic sluicing.

An additional small strainer is used following each ion exchanger. This strainer will prevent resin from entering the condenser in the event of an ion exchanger underdrain failure.

Additional safety is provided in the system through the use of alarms and interlocks. Of major importance are those used in connection with flash tank operation. High and low water levels in the tank will cause an alarm to sound in the control room. The high level alarm set point is close to the inlet nozzle elevation. If water level should rise to within a few inches of the steam outlet pipe, separate interlocks will first cause the blow-down control (P-10) and then the steam outlet stop (P-46) valves to quickly close, thus shutting down the system. A high pressure interlock is also provided to close the blow-down control valve on high flash tank pressure.

Should a leak develop in the flash tank or surrounding piping, an increase in activity level in ventilation air drawn from the flash tank vault will be quickly detected by a ventilation duct monitor. At a pre-set high level the radiation monitor will automatically cause the purification system isolation valve (P-7) to close.

2.3 Solid Waste Disposal System

2.3.1 Solid Wastes

Solid wastes are composed of combustible wastes, non-combustible wastes, filter cartridges, spent resins, chemical wastes, spent fuel-elements, fuel-element ends and control rods. Table 2.1 gives the expected quantities of such wastes.

Combustible wastes, such as rags, paper, clothing, mops and rubber goods, and non-combustible wastes such as nuts, bolts, gaskets, glass and small pieces of equipment will be collected and packaged in sealed, shielded containers. These containers will be shipped off-site for ultimate disposal. The use of an incinerator for disposing of radioactive combustibles is not contemplated.

Filter cartridges will be transferred from the filter body into a container by semi-remote methods. These sealed containers will be shipped off-site for ultimate disposal.

Resins will be transferred from the ion exchangers by sluicing to a shielded resin-storage tank located in the fuel-handling building. The storage tank is provided with a pump to remove the resin after the decay of short-lived activity. The resin will be pumped to the shielded shipping container. These resins will be shipped off-site for ultimate disposal.

Chemical wastes such as back-wash filter crud and neutralized liquid wastes will be stored in a concentrated-waste storage tank to allow the activity to decay. From the concentrated-waste tank, a portion of the chemical wastes will be pumped to a concentrated-waste measuring-dump tank, which has approximately the same volume as the shipping container. The chemical wastes will be dumped into the shielded shipping container. These containers will be shipped off-site for ultimate disposal.

Spent fuel-elements, fuel-element ends and control rods will be transferred to and stored in the fuel-storage pool for a decay period. After the decay period these wastes will be remotely transferred to a shielded shipping coffin. The coffin will be shipped off-site to the fuel-processing plant.

TABLE 2.1

ESTIMATED QUANTITIES OF SOLID WASTES

<u>Type</u>	<u>Quantity</u>
1. Combustible Wastes	1000 lbs per month
2. Non-combustible wastes	200 lbs per month
3. Filter cartridges	85 lbs per month
4. Spent resins	1250 lbs per month
5. Chemical wastes	150 lbs per month
6. Spent fuel-elements, fuel-element ends and control rods	1/3 of boiler core changed every 5.6 months Superheater core changed every 9 months

2.4 Liquid Waste Disposal System

2.4.1 General Concept of the Liquid Waste Disposal System

In the Pathfinder Plant liquid wastes of varying quantities, radio-activities and chemical concentrations will be produced. The liquid waste disposal system is designed to process any type of liquid which can be expected to enter it. The basic criterion for operation of the radioactive liquid waste system is that the radioactive content at the point of disposal to the river shall be less than the recommended limits. From National Bureau

of Standards Handbook 69, this limit $(MPCU)_w$ is 10^{-7} microcuries per cubic centimeter ($\mu\text{c/cc}$). (If Ra-226 and Ra-228 are not present, the maximum permissible concentration of unidentified radionuclides in water, $(MPCU)_w$, is $10^{-7}\mu\text{c/cc}$ for interim application in the neighborhood of an atomic energy plant.) The system is designed with sufficient flexibility so that it may be readily adapted to reasonable changes in State or Federal limits on concentrations and to variations of in-plant quantities of wastes.

Equipment is provided to treat radioactive liquid wastes by holdup and decay, filtration, neutralization, demineralization and dilution.

Generally, low activity wastes will be treated by filtration and demineralization to reduce the activity to a level where the treated water can be returned for plant use or discharged to the Big Sioux River via a drainage ditch. High-activity wastes will be neutralized, if necessary, and fed to a concentrated-waste storage tank for decay prior to shipment off-site. Provision is made for installation of an evaporator to treat high-activity wastes in the event such an installation proves desirable after the initial periods of operation of Pathfinder.

The Big Sioux River will not be relied upon for dilution purposes. Batch control will be used for radioactive wastes so that the required treatment can be designated in advance and thus insure that the processed wastes discharged to the river will be below the limits recommended. Liquid wastes will be reprocessed if acceptable discharge levels have not been reached by one-cycle processing.

2.4.2 Sources and Activities

Liquid wastes are expected from the following sources: primary system (reactor water), condensate, equipment drains, building service drains, resin sluicing water, decontamination operations, laboratory drains and backwash filter wastes. Wastes entering the liquid waste disposal system are divided into two categories: low-activity wastes and high-activity wastes. Low-activity wastes are arbitrarily defined as those with an activity concentration of less than $10^{-3} \mu\text{c/cc}$ and high-activity wastes are those wastes with an activity concentration of $10^{-3} \mu\text{c/cc}$ or greater. Table 2.2 gives estimated quantities and activities of such wastes.

TABLE 2.2 - ESTIMATED QUANTITIES AND ACTIVITIES OF LIQUID WASTES

TYPE	Normal Monthly Flow (Gallons)	Normal Activity (Microcuries/ Cubic Centimeter)
<u>Low-Level Activity</u>		
Turbine Bldg. Equip. Drains	1000	10^{-4}
Turbine Bldg. Serv. Drains	4200	10^{-6}
Reactor Bldg. Serv. Drains	700	10^{-5}
Fuel Handling Bldg. Serv. Drains	<u>7500</u>	<u>10^{-5}</u>
Total Low-Level Activity Wastes and Average Radioactive Conc.	13,400	1.4×10^{-5}
<u>High-Level Activity</u>		
Laboratory Drains	6000	10^{-4}
Decontamination Drains	2000	10^{-2}
Filter Wastes (Pre-Coat type)	1500	1
Demineralizers Sluice Water	<u>200</u>	<u>10^{-3}</u>
Total High-Level Activity Wastes and Average Radioactive Conc.	9,700	1.5×10^{-1}

Even though the liquids from the laboratory drains are expected to be of low-activity level as previously defined, they are added to the high-level wastes because of the type of treatment required. The liquid waste quantities given in Table 2.2 are considered to be conservative in that the estimated quantities are generous. It is conceivable that when the plant is placed into operation, actual quantities may be less.

Table 2.3 gives the reactor water activity.

TABLE 2.3 - REACTOR-WATER ACTIVITY RESULTING FROM MAJOR NUCLIDES

Corrosion Products	$\mu\text{c/cc}$	*Fission Products	$\mu\text{c/cc}$
P-32	4.6×10^{-3}	SR-89	8.5×10^{-3}
CR-51	3.9×10^{-2}	SR-90	3.5×10^{-4}
FE-55	5.1×10^{-3}	I-131	5.0×10^{-5}
MN-56	8.3×10^{-2}	I-135	1.8
CO-58	1.0×10^{-2}	CS-137	3.3×10^{-4}
CO-60	2.3×10^{-3}	TOTAL	$1.809 \mu\text{c/cc}$
CU-64	3.6×10^{-4}		
NI-65	8.7×10^{-2}		
ZR-95	5.1×10^{-5}		
TOTAL	$.231 \mu\text{c/cc}$		
Reactor Water Activity (Fission and Corrosion Product)			$2.04 \mu\text{c/cc}$
Tritium Activity (after 1 year full power operation)			$.15 \mu\text{c/cc}$
Total Reactor Water Activity			$2.19 \mu\text{c/cc}$

*Based on 50 mg U-235 exposed.

The fission product activity results from a postulated maximum of 50 milligrams of exposed U-235 from surface contamination of fuel pins. The actual contamination is specified to be less than this. However, fuel pin

leaks may raise the activity to as high as 500 milligrams of exposed U-235 equivalent. It is anticipated that reactor-water activity will normally be the maximum concentration in wastes encountered by the liquid-waste disposal system. However, backwash filter wastes and decontamination solutions may, at times, contain a higher activity because of the concentration of corrosion products in these wastes. It is expected that the major portion of the liquid wastes entering the liquid-waste disposal system will contain on the average, 10^{-7} to 10^{-4} μ c/cc. The liquid waste disposal system is capable of treating any of the above activities.

One of the objectives in the design of the liquid waste disposal system is to reclaim as much water for plant use as is practical. Reclaimed water will be returned to the system.

Those radioactive wastes discharged to the drainage ditch will be neutral in nature and will contain approximately 300 parts per million total solids made-up principally of calcium and magnesium sulfates and bicarbonates and normal plant corrosion products such as Fe, Cr, Ni, Cu and Zn compounds. It is estimated that 10,000 gallons per month will be discharged to the river.

2.4.3 Operating Procedures

Figure 2.7 shows the basic flow diagram of the liquid-waste disposal system. Wastes will be accumulated in sumps located in the fuel handling, turbine and reactor buildings. A high waste level alarm will be indicated on a waste-disposal control panel. The waste-disposal operator may then pump wastes from any sump to the 1000 gallon divided surge tank. The surge tank

is divided so that wastes can be processed in 500 gallon batches. A monitor in the line to this surge tank will indicate the level of activity of these wastes.

If the activity of the wastes at the surge tank is low, less than $10^{-3} \mu\text{c/cc}$, the wastes will be pumped through a filter to the waste disposal demineralizer. From the waste disposal demineralizer, the wastes monitored at the discharge side, will travel to the reclaimed water tank. The reclaimed water storage tank will be the discharge point for the liquid waste disposal system. Its effluent will be monitored and manually discharged to the drainage ditch or reused within the plant depending upon need.

If the activity of the wastes at the surge tank is high, $10^{-3} \mu\text{c/cc}$ or greater, or the waste-disposal demineralizer effluent activity is $10^{-5} \mu\text{c/cc}$ or greater, such wastes will be sent to the high-level, decay storage tank. This tank is a four-compartment 12,000 gallon tank which serves as a decay tank but also may serve as an additional surge tank. When a compartment is filled with high-activity wastes, it will be closed off and the radioactive wastes will be allowed to decay for approximately two days. At the end of the decay time, the liquid will be monitored to determine its activity level. If safe discharge levels are not reached by such one-cycle processing, the wastes can be recycled through the system to further reduce the activity levels.

High activity wastes will flow to a 300 gallon surge tank. From this tank, wastes will flow to a neutralizing tank where the pH can be adjusted, if necessary. From the neutralizing tank, wastes will be pumped to an

evaporator feed tank and then to a concentrated waste storage tank. The concentrated wastes can be sent to the 12,000 gallon resin storage tank for decay purposes or can be drummed and shipped off-site for ultimate disposal. The 12,000 gallon resin storage tank is a two compartment tank which provides for decay of resins until they are shipped off-site.

Provision is made for pumping low-activity wastes to the high-activity disposal system. This procedure may be desirable if the low-activity wastes contained high solids. Provision is also made for pumping neutralizing tank effluent to the divided surge tank. This procedure may be desirable if the high-activity wastes contained low solids.

In the event that unexpected large volumes of low-activity wastes are generated, these wastes may be discharged to the fuel-storage pool where the pool demineralizers can process such wastes at 300 gpm. The water from the fuel-storage-pool demineralizers can be discharged to the 12,000 gallon decay storage tank or to the pipe leading to the drainage ditch.

The liquid waste disposal system has been designed with sufficient flexibility so that flows can be redirected in the event of equipment malfunction.

Liquid wastes after proper treatment by the liquid waste disposal system are discharged to the drainage ditch and diluted with cooling-tower blowdown prior to entry to the river. The cooling-tower blowdown provides a normal, minimum dilution factor of 40. The average dilution factor is approximately 100. A continuously recording monitor will monitor all wastes being discharged

from the liquid-waste disposal system to the drainage ditch. If the activity level of the wastes being discharged exceeds $10^{-6} \mu\text{c/cc}$, the monitor will actuate an alarm on the waste disposal control panel and the valve in the discharge line to the drainage ditch will be closed automatically and wastes will then be diverted to the 12,000 gallon high-level decay tank. Analyses during plant operation will determine the radionuclides present on the wastes discharged.

In considering the radionuclides discharged to the river, special consideration will be given to tritium. The amounts of tritium discharged to the river are relatively large compared to the radioactive fission and corrosion products discharged. Tritium, however, emits only low-energy beta particles, has a short biological half life and does not concentrate in small organs. For these reasons, the maximum permissible concentration in water $(\text{MPC})_w$ for tritium are relatively large. The waste-disposal effluent will be sampled periodically and analyzed for tritium to insure that the tritium concentration discharged to the river is less than the $(\text{MPC})_w$ for tritium in an unrestricted area (Handbook 69 states $3 \times 10^{-5} \mu\text{c/cc}$).

Under abnormal conditions, should the average concentration of radionuclides, tritium excepted, exceed the $(\text{MPC})_w$ value for a mixture of unidentified nuclides not containing Ra-226 and Ra-228, analyses will be made for specific nuclides. These analyses will insure that the discharge is within recommended limits.

The total tritium activity discharged to the river is expected to be less than 60 curies per year which amounts to less than 1% of the total tritium activity permitted in the expected cooling tower blowdown. The total corrosion and fission product activity discharged to the river is expected to be less than 1.5 curies per year.

2.4.4 Control and Monitoring

Figure 2.8 shows the detailed flow diagram of the liquid waste disposal system.

During the initial stages of operation, it is planned to handle all wastes as batches to insure safe discharge levels. During this period of time, the re-claimed water tank will serve as a discharge tank. Low-activity and treated wastes will be sent to this tank prior to their release to the drainage ditch. The wastes can be sampled and monitored in this tank.

It is expected that operating data will show that the major portion of wastes collected in the sump will have a low-activity level such that they may be discharged, after monitoring, directly to the drainage ditch for dilution with cooling tower blowdown. Since this blowdown may be used for dilution purposes, the waste disposal operator will be informed of any change in the amount of cooling-tower blowdown flow. Cooling-tower blowdown valve position, which can be directly correlated with blowdown flow, will be recorded on a strip-chart recorder in the control room. An alarm contact is provided on the blowdown valve position recorder to annunciate at the waste treatment panel when and if cooling-tower blowdown drops below 500 gpm.

This would warn the operator that he must not expect benefit from additional dilution in the cooling-tower blowdown channel before the activity reaches the river. He will then make any necessary adjustments to insure that waste activity discharged from the fuel-handling building will be below discharge levels ($10^{-6} \mu\text{c/cc}$).

Figure 2.7 shows the major control monitoring points. Monitor 1 is a continuously recording monitor to serve two purposes: Insure discharge of wastes below $10^{-6} \mu\text{c/cc}$ and provide a permanent record of all radioactivity discharged from the liquid-waste system to the river.

Monitor 2 indicates the activity of water that may be returned for plant use. Monitor 3 indicates the activity of the waste-disposal-demineralizer effluent. It will show whether this effluent will require further treatment or can be discharged to the reclaimed water storage tank. Monitor 4 will indicate the activity of the decay storage tank water and will show whether this effluent will require further treatment. Monitor 5 indicates the activity of the wastes entering the waste disposal system. The activity of these wastes will dictate the treatment required.

Monitor 1 will initially be set at or near $10^{-6} \mu\text{c/cc}$. In the event the wastes being discharged exceed this level, an alarm will be set off on the waste-disposal control panel. Simultaneously, a valve located downstream of the monitor will be closed automatically and wastes will be diverted to the 12,000 gallon high-level decay tank.

Sampling valves are provided on tanks in the liquid-waste disposal system so that samples can be drawn, analyzed and monitored. Continuous

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monitoring will be done at the point in the drainage ditch where the liquid-waste system discharges to the ditch and will serve as a final check on the activity discharged. Samples of river water will be collected from above and below the plant site periodically to determine any change in river water activity.

2.4.5 Decontamination Provisions and Procedures

Floors, walls and other surfaces of the buildings will be decontaminated if radioactive spills occur. Areas where radioactive materials are constantly being handled, such as the decontamination room, laboratories, etc., will be protected with an easily scrubbed protective coating. Protective clothing that has been contaminated will be packaged and shipped off-site as commercial radioactive waste.

Equipment in the reactor water system, where internal contamination from "crud" deposition can be expected, will be provided with decontamination nozzles which project through the surrounding shield wall so that portable decontamination equipment can be attached for flushing purposes. This will allow decontamination before personnel enter the shielded enclosure around the equipment.

A decontamination room is provided for removing contamination from small equipment which can be disassembled and moved. This room is located in the fuel handling building and its drain goes to the liquid waste system. The room is provided with acid resistant sinks.

Drains from the decontamination room flow by gravity into a neutralizing hold-up tank. Drains from equipment in the reactor water system which may require decontamination are also connected to this tank. The neutralizing hold-up tank feeds the neutralizing tank which has provision for adding neutralizing agents, agitating equipment, sampling and monitoring facilities. The treatment of decontamination room wastes is discussed in the section on liquid waste disposal.

2.5 Gaseous Waste Disposal System

2.5.1 General Concept of Gaseous Waste Disposal

During normal operation of the Pathfinder Atomic Power Plant, there will be three sources of potentially radioactive contamination in the stack effluent. These are (1) gaseous radioisotopes produced by neutron activation of water, (2) gaseous radioisotopes produced by fissioning uranium-235 and (3) gaseous radioisotopes produced by activation of shield cooling air. Argon 41 and Nitrogen 16 are the most prevalent radioisotopes from activation, whereas, Xenon and Krypton are the principal gaseous fission products. It is expected that N-16 will be present at the air ejector vent to the extent of 5.1×10^6 microcuries per second. Three (3) microcuries per second of A-41 will be produced in the shield cooling air. With perfect fuel elements there would be no Xenon and Krypton in the stack effluent, since they would be contained within the fuel element cladding. However, it is recognized that: (1) small amounts of U-235 can become impregnated into the external surfaces of the cladding which cannot be removed by any practical or economical method, (2) there is some small diffusion of the fission gases through the cladding material, and (3) cladding failures occur which permit leakage of fission gases from the fuel material.

A full core loading fabricated in accordance with specifications provides no more than 22 mg of exposed U-235 on the fuel element cladding. However, for the purposes of the design of the waste disposal system, it was assumed that U-235 can be present on Pathfinder fuel element cladding

in amounts as high as 50 mg. An estimate of this activity together with other sources of activity originating within the reactor is shown in Table 2.4. At full power operation, this 50 mg of U-235 would result in a fission gas production of 3×10^5 microcuries per second. Small cladding failures could produce greater concentrations. (See discussion in Subsection 7.3.7)

TABLE 2.4

ESTIMATED PRODUCTION RATES OF RADIOACTIVE OFF-GASES

(Fission gasses based upon an assumed fuel surface contamination of 50 mg of exposed U-235)

Isotope	Half-Life	Production Rate
N-15	7 sec.	5.1×10^6 microcuries/sec.
N-17	4.14 sec.	1.8×10^3
H-3	12.46 yrs.	2.4×10^{-5}
A-37	35 days	2.0×10^{-5}
A-41	109 min.	7.8×10^{-2}
O-19	20.4 sec.	1.7×10^4
Kr-83M	114 min.	3.8×10^1
85M	4.36 hrs.	5.2×10^1
85	10.27 yrs.	4.8×10^{-2}
87	78 min.	3.2×10^2
88	2.77 hrs.	2.0×10^2
89	3.18 min.	1.3×10^4
90	33 sec.	8.7×10^4
Xe-131M2	12 days	1.7×10^{-2}
133M	2.3 days	4.4×10^{-1}
133	5.27 days	7.9
135	9.13 hrs.	1.0×10^2
137	3.9 min.	1.4×10^4
138	17 min.	2.9×10^3
139	41 sec.	6.3×10^4
140	16 sec.	1.3×10^5

The National Committee on Radiation Protection (NCRP) has recommended in NBS Handbook 69 a set of maximum permissible values for the concentration of radioisotopes in air to which the public has unrestricted access. For N-16 this is specified as 7×10^{-9} microcuries per cubic centimeter ($\mu\text{c/cc}$); for A-41 it is $4 \times 10^{-8} \mu\text{c/cc}$; and for Xe-138, which is the controlling fission gas, it is approximately $3 \times 10^{-8} \mu\text{c/cc}$. Recognizing that these are essentially maximum limits, it is planned that Pathfinder activity be a factor of ten below them.

In order to reduce the activity levels of the radioactive gases produced in the Pathfinder Plant, decay, filtration, dilution and atmospheric dispersion are used.

All gases originating within the reactor are ejected at the main condenser through the gaseous waste disposal system. This system can either pass the gases directly through with a transit time of about 15 minutes or delay them as long as 12 hours to permit additional decay. The system can be closed off entirely and receive the radioactive gases for as long as 24 full power hours in case of emergency. Under a circumstance requiring isolation of the waste disposal system, however, the operator will probably prefer to shut the plant down in a normal manner after about 18 hours to avoid the necessity of an emergency shutdown after 24 hours.

The design of the gaseous waste disposal system is based on the assumption that 50 mg of U-235 is exposed in the reactor and that N-16 and other gases pass through the system with the minimum transit time (15 min). Using delay tanks, the system will handle the equivalent of about 100 times this activity in a 24 hour period.

2.5.2 System Description and Operation

The 50 mg of exposed U-235 surface contamination is assumed to occur from the boiler and superheater cores. The non-volatile fission products and halogens from the boiler core will remain to a large extent in the water and will be removed by the reactor water purification system (See subsection 2.4.2). The noble fission gases from the boiler core and all fission products from the superheater core will appear in the main steam. It is expected, that the remainder of the halogens and non-volatiles carried by the main steam will be stripped out in the condenser and will remain in the condensate. The noble fission gases will be ejected from the main condenser by the air ejector system.

The ventilation air discharged to the stack will contain A-41 resulting from irradiation of ventilation air in the reactor biological shield. This activity will be diluted with other building ventilation air in the stack and dispersed to the atmosphere. This will insure that the concentration of A-41 in unrestricted areas will be below the specified maximum permissible concentration in air $(MPC)_a$.

Equipment and tank vent gases will be fed to a common header which enters the plenum at the stack where they are diluted with ventilation air in the stack and dispersed to the atmosphere. Calculations indicate the activity in these gases will be less than $10^{-9} \mu\text{c/cc}$ after dilution.

Figure 2.9 shows the basic flow diagram for the Pathfinder gaseous waste disposal system.

During normal operation, the off-gases will flow from the condenser through a two-stage air-ejector system. Located between the 2nd stage ejector and its condenser is a metallic catalyst type recombiner. In the recombiner, hydrogen and oxygen, from dissociated reactor water, will be recombined to form water. The water, formed as steam, and the air ejector motive steam will be condensed in the air ejector after-condenser and returned to the main condenser. The non-condensable radioactive gases will flow to the radioactive gaseous waste disposal system.

Immediately following the air-ejector-condenser is a 3-minute holdup pipe to decay the short-lived nuclide such as N-16, N-17, O-19, Kr-90, Xe-139, and Xe-140. Calculations show the activity at the discharge of the holdup pipe to be $4.7 \times 10^4 \mu\text{c/sec}$. A high-activity alarm monitor will be located at this point. The gases will flow through one baffled holdup tank and through an "absolute" type filter to the base of the stack. The gases will decay for an additional 12 minutes in this flow path and will reach the base of the stack with an expected activity of $4 \times 10^3 \mu\text{c/sec}$. The 80 foot stack is mounted on the fuel handling building and the top of the stack is 106 feet above ground level. Internal draft fans will provide dilution of the off-gases with ventilation air prior to discharge from the stack. Near the base of the stack is a continuously recording monitor to provide operating data to insure the gas and particulate discharge is below the specified limits. The activity at the stack discharge is estimated to be $4 \times 10^3 \mu\text{c/sec}$, or $3.4 \times 10^{-4} \mu\text{c/cc}$. This

activity is noble fission gas activity. Detailed studies of the site topography and meteorology indicate that atmospheric dispersion from the stack will reduce activity to $1/10$ (MPC)_a or less at any ground point off-site. (See subsection 2.5.4)

In the event of a major fuel-element rupture, the main steam line area detector will indicate unusually high activity and permit proper action to be taken (Refer to subsection 7.3.7).

The air-ejector-exhaust monitor will indicate what levels of activity are present in the off-gases. This monitor will serve as the control point for the gaseous waste disposal system. When high-activity is detected, the monitor will automatically cause the valve in the discharge line of the gaseous waste disposal system to be closed and use of the holdup tanks will be initiated. The compressor will be started manually and the gases compressed and fed to one tank for about 12 hours, after which time, the compressed gases will be directed to the second tank. The contents of the first tank can then be manually released to the stack, and the empty tank again used as a receiver for the compressed gases. The use of this compressed gas system provides an additional activity reduction factor of approximately 100 due to decay.

2.5.3 Monitoring

The following radiation-detection instruments will be used in the gaseous waste disposal system control.

The ventilation ducting will be monitored by a G.M. tube at its discharge point to the stack plenum for gross gaseous activity in the

ventilation air. The ventilation system and off-gas effluents will be shut down manually if ventilation monitors alarm.

The main steam line area monitor will indicate the presence of a large burst of activity in the steam.

Figure 2.9 shows the two monitors in the gaseous waste disposal system. Monitor 1 is the condenser air ejector exhaust monitor, capable of detecting gross gamma activity. It will be located after the 3-minute holdup pipe. An alarm located on the waste disposal control panel will indicate the presence of high activity at this point. Monitor 2 is a continuously recording monitor, located 1/3 of the distance up the stack, which measures gaseous and particulate activity. A moving filter paper assembly checks particulate activity. Either monitor can sound an alarm on the waste disposal control panel.

A pre-operational site monitoring program was begun in April, 1959. This program is continuing and will become part of the Pathfinder environmental survey program. (See Section 8)

2.5.4 Atmospheric Dispersion of Radioactive Gases

The activity discharged from the stack will be distributed in the atmosphere and to the ground depending upon the atmospheric conditions and the plume behavior that the stack effluent assumes after leaving the stack. This plume behavior will be determined by the wind conditions and temperature profile present at the time of discharge. The five major

types of plume behavior and vertical temperature gradient which are likely to occur at the Pathfinder site are:¹

1. Lofting (Inversion below, lapse above) - The inversion prevents the gases from reaching the ground and at the same time the effluent may be rapidly diluted in the lapse layer above the inversion.
2. Looping (Strong lapse) - Gases diffuse rapidly but sporadic puffs having strong concentrations are occasionally brought to the ground near the stack for a few seconds during light winds.
3. Coning (Weak lapse) - Gases diffuse in a cone shape with the axis horizontal.
4. Fumigation (Lapse below, inversion above) - Large concentrations are brought to the ground along the entire effluent stream by thermal eddies in the lapse layer.
5. Fanning (Inversion) - Minimum vertical diffusion of gases.

A. Equations for Calculation of Ground Concentrations

1. Lofting

In the case of lofting, the plume, and therefore the activity in the plume, will never reach the ground and is the most favorable condition for dispersion. Since there are conditions

1. United States Department of Commerce Weather Bureau, Meteorology and Atomic Energy AECU 3066, U.S. Government Printing Office, July 1955, Page 60.

which are more unfavorable to dispersion and which give higher ground concentrations, the case of lofting will not be given further consideration.

2. Coning and Looping

For coning and looping conditions, the following equation of C. G. Sutton² fairly accurately describes the plume behavior and the diffusion of the effluent:

$$\chi = \frac{(2) (10^{-5}) Q}{\pi C^2 u x^{2-n}} \exp\left(-\frac{h^2}{C^2 x^{2-n}}\right) \quad (1)$$

Where χ = ground concentration ($\mu\text{c/cc}$)
 Q = activity leaving stack ($\mu\text{c/sec}$)
 C = diffusion parameter (m^n/sec)
 n = dimensionless parameter associated with stability
 u = wind speed (m/sec)
 h = height of plume above the ground (m)
 $= \Delta h + h_s - h_g$ where
 Δh = height of plume rise above the stack (m)
 h_s = height of stack (m)
 h_g = height of ground (m)
 x = distance from base of stack to ground point (m)

The factor 2 appears in the numerator to account for "reflection" of the diffusing particles by the ground plane.

The factor 10^{-6} appears in the numerator to convert the units of the righthand side of equation (1) from $\frac{\mu\text{c}}{\text{m}^3}$ to $\frac{\mu\text{c}}{\text{cc}}$.

2. Ibid., P. 47, (Equation 4.50)

3. Fumigation

Fumigation represents the most unfavorable dispersion conditions with regard to instantaneous ground concentrations because portions of the plume can be brought to the ground along the entire effluent stream.

An expression has been developed for ground concentration during fumigation conditions:

Based on experimental work at Brookhaven, it was found that, over a period of 15 minutes, fumigation concentrations averaged 20 times the concentration computed by Sutton's equation. This factor appears to be sufficiently applicable to other stacks. Upon substitution of this factor of 20, (1) becomes:

$$\chi = \frac{(4) (10^{-5}) Q}{\pi C^2 u x^{2-n}} \exp \left(- \frac{h^2}{C^2 x^{2-n}} \right) \quad (2)$$

4. Fanning (inversion)

For the theoretical treatment of cloud diffusion during coning, looping and fumigation, equation (1) is a good approximation.

It is also a good approximation for the diffusion of a cloud during inversion conditions when the cloud has its origin on the ground.

However, when the cloud has its origin at some height above the ground, the assumption of isotropic diffusion of the cloud during inversion conditions is usually in error. The horizontal diffusion, although much less than for unstable regimes, is

larger than the vertical spread.³ Under these circumstances, equation (1) is altered to make a better estimate of the cloud diffusion:⁴

$$\chi = \frac{(2) (10^{-6}) Q}{\pi C_y C_z u x^{2-n}} \exp \left(-\frac{h^2}{C_z^2 x^{2-n}} \right) \quad (3)$$

Where,

C_y = diffusion coefficient for cloud spread in the horizontal direction, $(m^n/2)$

C_z = diffusion coefficient for cloud spread in the vertical direction, $(m^n/2)$

B. Calculation of Atmospheric Dispersion

To obtain quantitative estimates, equations (1), (2) and (3) for atmospheric dispersion were used. Wind speeds and temperature profiles for the Pathfinder Atomic Power Plant site were developed from the meteorological data of Miss E. M. Frisby (reference footnote 6). Ground profiles were determined from the U. S. Army Map Service topographic map. Additional information was taken from the report, Meteorology and Atomic Energy (AECU 3066).

The following assumptions and basic data were used:

1. In applying the equations of O. G. Sutton, the values of the meteorological parameters were assumed to be:

3. Ibid., P. 60.

4. Ibid., P. 47 (Equation 4.51).

	<u>Fanning</u> (Strong Inversion)	<u>Coning</u> (Weak Lapse)	<u>Looping</u> (Strong Lapse)
n	0.50	0.25	0.20
C	Cy=0.12 Cz=0.05	0.12	0.24
u (m/sec)	1.0	5	1.0

2. Only the maximum concentrations of radioactivity in the plume are considered, therefore, plume spread in the y-plane is not evaluated.
3. The fission products are released to the stack at a constant rate over a long period of time resulting in a continuous point source emanating from the stack.
4. The meteorological conditions are constant for long periods of time and over large distances from the stack.
5. In the calculation of the atmospheric dispersion the "worst direction" will be considered. The "worst direction" is defined as that direction from the Pathfinder plant which has the steepest, rising slope of ground. That is, it is the direction from the plant which has the highest ground elevation, closest to the plant. In this direction, the average ground concentration will be highest.

Effective Stack Height

In equations (1), (2) and (3) the height of the plume above the ground (h) appears as an important factor. The height of the plume above the ground (h) is determined by three factors:

1. height of stack (h_s)
2. height of plume rise (Δh) above the stack
3. height of ground (h_g)

These factors are related by:

$$h = h_s + \Delta h - h_g \quad (4)$$

Pathfinder's stack outlet will be at an elevation of 1432 ft. Two factors which affect plume rise are buoyancy of plume due to temperature difference between the effluent and atmosphere, and stack exit velocity. In this analysis credit will be taken only for the rise of the plume due to stack exit velocity. Since the stack exit gas temperature will in most cases be more than 25 F higher than the ambient temperature, the effective stack height determination will be conservative.

The effect of stack exit velocity on plume rise is expressed by a relationship developed by Bonsanquet et al:⁵

$$\Delta h_{\max} = \frac{4.77}{1 + 0.43 \left(\frac{u}{V_s} \right)} \left(\frac{\sqrt{CV_s}}{u} \right) \quad (4)$$

Where, $\Delta h_{\max}$ = maximum height of plume rise, m, a function of
(for the distances considered here, $\Delta h_{\max} = \Delta h$
for equation (4).

u = wind velocity, m/sec.

V_s = stack gas velocity, m/sec.

c = flow rate in stack, m^3/sec .

5. Ibid., P. 71 (Equation 5.1)

Height of the ground is taken from the topographic map of the Pathfinder site.

Height of Plume Rise

$$h_{\max} = \frac{4.77}{1 + .43 \left(\frac{u}{v_s} \right)} \left(\frac{\sqrt{CV_s}}{u} \right) \quad (4)$$

Inserting the Pathfinder stack constants and the most pessimistic wind speed for coning yields:

$$\Delta h = 31 \text{ meters.}$$

Atmospheric Dispersion Factors

The relative atmospheric dispersion for different meteorological conditions may be determined by defining an atmospheric dispersion factor, $\frac{\chi}{Q}$. The atmospheric dispersion factor is defined as the ratio of the ground concentration (χ) downwind to the activity leaving the stack (Q).

1. Atmospheric Dispersion Factor for Coning

Using equation (1),

$$\frac{\chi}{Q} = \frac{(2) (10^{-6})}{C^2 u x^{2-n}} \exp \left(- \frac{h^2}{C^2 x^{2-n}} \right)$$

Inserting the proper values of the parameters for the coning condition,

$$\frac{\chi}{Q} = \frac{(8.8) (10^{-6})}{x^{1.75}} \exp \left(- \frac{(69.5) h^2}{x^{1.75}} \right)$$

"Figure 2.10 shows the plot of $\frac{\chi}{Q}$, the atmospheric dispersion factor, versus x , the distance from the plant in the worst direction."

2. Atmospheric Dispersion Factor for Looping

Again using equation (1) and inserting the proper values of the parameters for the looping conditions,

$$\frac{\chi}{Q} = \frac{(1.11) (10^{-5})}{x^{1.8}} \exp \left(- \frac{(17.3) h^2}{x^{1.8}} \right)$$

"Figure 2.10 shows the plot of $\frac{\chi}{Q}$, the atmospheric dispersion factor, versus x , the distance from the plant in the worst direction."

3. Atmospheric Dispersion Factor for Fumigation

Using equation (2),

$$\frac{\chi}{Q} = \frac{(4) (10^{-5})}{C^2 u x^{2-n}} \exp \left(- \frac{h^2}{C^2 x^{2-n}} \right)$$

Inserting the parameters for looping,

$$\frac{\chi}{Q} = \frac{(2.22) (10^{-4})}{x^{1.8}} \exp \left(- \frac{(17.3) h^2}{x^{1.8}} \right)$$

"Figure 2.10 shows the plot of $\frac{\chi}{Q}$, the atmospheric dispersion factor, versus x , the distance from the plant in the worst direction."

4. Atmospheric Dispersion Factor for Fanning

Using equation (3),

$$\frac{\chi}{Q} = \frac{(2) (10^{-6})}{C_y C_z u x^{2-n}} \exp \left(- \frac{h^2}{C_z^2 x^{2-n}} \right)$$

Inserting the parameters for fanning,

$$\frac{\chi}{Q} = \frac{(1.06) (10^{-4})}{x^{1.5}} \exp \left(- \frac{(400) h^2}{x^{1.5}} \right)$$

"Figure 2.10 shows the plot of $\frac{\chi}{Q}$, the atmospheric dispersion factor, versus x , the distance from the plant in the worst direction."

C. Concentration of Activity Off-Site

The calculations in the preceding paragraphs under 2.5.4 B. only determine the magnitude of the dispersion factor due to atmospheric diffusion. To realistically estimate the average concentrations of gaseous activity off-site, a number of processes which reduce these concentrations must also be considered. Radioactive decay, predilution and averaging are the processes which contribute the most to the reduction of average concentrations of gaseous activity off-site.

Reduction Factors

1. Radioactive Decay

The gaseous waste disposal system operates normally with a 15 minute holdup time. Under abnormal conditions, the hold-up tanks come into operation and result in an average 12 hour hold-up time. Because of short half-lives, the amounts of N-16 and the fission gases (Kr and Xe) will be reduced significantly before they reach the stack exit. In fact, N-16 will essentially decay completely away after a 15 minute hold-up. (A-41 is not affected by this hold-up because it has its origin chiefly in the shield cooling air and does not pass through the gaseous waste disposal system)

2. Predilution in the Stack

Predilution with ventilating air substantially affects the expected atmospheric concentration within the first thousand meters from the stack. Beyond this distance, the predilution with 25,000 cfm of ventilating air in winter and 85,000 cfm in summer has little

effect. No credit for predilution with ventilation air is taken in the calculations of atmospheric dispersion. Nearer the stack, however, where fumigation and looping conditions are important, the predilution has substantial effect. The effect is sufficient to make Fanning (inversion) conditions the limiting criterion rather than the more local effects of fumigation and looping.

The predilution of the A-41 with 25,000 cfm of ventilation air brings its concentration to about $(MPC)_a$ for unrestricted areas. For example, the concentration of A-41 at the stack exit is $2.54 \times 10^{-7} \mu\text{c/cc}$. The $(MPC)_a$ for unrestricted areas for A-41 is $4 \times 10^{-8} \mu\text{c/cc}$. A reduction factor of 0.64 is all that is needed to reduce the concentration of A-41 to $(MPC)_a$ for unrestricted areas.

3. Yearly and Daily Averaging

Meteorological data (6) from the plant site indicates the frequency of the various plume conditions and the frequency of the wind direction. The drift in any of the 16 cardinal directions during the year does not occur over 4 to 5% of the time.

Four cardinal directions, east, southwest, west and north and the worst point case were selected for the atmospheric dispersion calculations. The results of these calculations are presented in Tables 2.6, 2.7, 2.8, 2.9, and 2.10.

When considering fumigation, another averaging effect must be used to make a realistic appraisal of the various concentrations.

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6. Frisby, E. M., Review of Climatological Observations at the Pathfinder Site near Sioux Falls, South Dakota, May 1, 1958 to April 30, 1959.

Fumigation conditions exist only during the break up of an inversion and only for about 15 minutes per inversion. Therefore, for one inversion per day, a reduction factor of $\frac{1/4 \text{ hr}}{24 \text{ hr}}$ or about 10^{-2} may be used to reduce the instantaneous concentrations of fission gases.

4. Averaging Concentrations Over Arc Width

For the purposes of the climatological study cited in footnote 6, the wind was designated as coming from sixteen cardinal directions. Each direction therefore includes $22\frac{1}{2}^{\circ}$ of arc. At 1000 meters the arc length subtended by $22\frac{1}{2}^{\circ}$ is 393 meters. However, under inversion conditions, at 1000 meters, 99.7% of the activity of the cloud will be within an arc length of about 90 meters. Meteorological information obtained at the Pathfinder site, and other data in general, indicates that for light winds and inversion conditions, the wind direction changes frequently, often through large angles. To account for this meandering over the $22\frac{1}{2}^{\circ}$ arc, the equations developed in subsection 7.8.1 were used to calculate the average dose reduction.

Specifically, the equation,

$$\frac{\bar{X}}{X} = \frac{360^{\circ}}{22\frac{1}{2}^{\circ}} \frac{Cy}{2\sqrt{\pi XH}}$$

was used to calculate the ratio of average plume concentration over $22\frac{1}{2}^{\circ}$ arc length to the peak plume concentration. Table 2.5 lists the ratio for various meteorological conditions, at various distances from the stack.

Table 2.5

Table of Reduction Factors to Account for Cloud Meander and Arc Length for Various Meteorological Conditions

Downwind Distance, X(Meters)	Reduction Factor X/X ₀	
	<u>Fanning, Coning</u>	<u>Fumigation, Looping</u>
700	1.06×10^{-1}	0.56
1,000	9.6×10^{-2}	0.54
2,000	8.0×10^{-2}	0.50
4,000	6.8×10^{-2}	0.47
10,000	5.4×10^{-2}	0.43

Concentration of Activity Off-Site

In the calculation of the concentrations of fission gas activity at the site boundary and off-site in the "worst direction", the following procedure was used: (The "worst direction" is toward a rise in ground elevation south of the plant)

The assumed fission gas stack release rate was first multiplied by the atmospheric dispersion factor from Figure 2.9. These concentrations were then multiplied by the appropriate reduction factors due to frequency of plume direction, frequency of wind direction and cloud meander. Tables 2.6, 2.7, 2.8, 2.9 and 2.10 show the reduction factors which were used and Table 2.11 shows a summary of this analysis.

October 31, 1960

Table 2.6 - ATMOSPHERIC DISPERSION

Direction East - Site Boundary

Plume Condition	$\frac{\chi_c}{Q}$	Frequency of Plume Condition	Frequency of Wind Direction	Cloud Meander	Q ($\mu\text{c/sec}$) Released	Contribution To dose ($\mu\text{c/cc}$)
Lofting	0	-	-	-	-	0
Looping	2.36×10^{-11}	.0101	0	.54	4×10^3	neg.
Coning	1.22×10^{-11}	.3785	.0047	.096	4×10^3	$.835 \times 10^{-11}$
Fumigation	7.03×10^{-11}	.0348	.02	.54	4×10^3	10.5×10^{-11}
Fanning (Inversion)	8.97×10^{-11}	.459	.0186	.096	4×10^3	29.4×10^{-11}
					TOTAL	4.07×10^{-10}

Table 2.7 - ATMOSPHERIC DISPERSION

Direction Southwest - Site Boundary

Plume Condition	$\frac{\chi_c}{Q}$	Frequency of Plume Condition	Frequency of Wind Direction	Cloud Meander	Q ($\mu\text{c/sec}$) Released	Contribution To dose ($\mu\text{c/cc}$)
Lofting	0	-	-	-	-	0
Looping	9.22×10^{-12}	.0101	.0070	.50	4×10^3	$.131 \times 10^{-11}$
Coning	8.46×10^{-12}	.3785	.0093	.08	4×10^3	$.952 \times 10^{-11}$
Fumigation	1.84×10^{-10}	.0348	.02	.50	4×10^3	25.6×10^{-11}
Fanning (Inversion)	$\ll 10^{-10}$	.459	.0139	.08	4×10^3	neg.
					TOTAL	2.67×10^{-10}

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Table 2.6 - ATMOSPHERIC DISPERSION

Direction East - Site Boundary

Plume Condition	$\frac{\chi_c}{0}$	Frequency of Plume Condition	Frequency of Wind Direction	Cloud Meander	Q ($\mu\text{c/sec}$) Released	Contribution To dose ($\mu\text{c/cc}$)
Lofting	0	-	-	-	-	0
Looping	2.36×10^{-11}	.0101	0	.54	4×10^3	neg.
Coning	1.22×10^{-11}	.3785	.0047	.096	4×10^3	$.835 \times 10^{-11}$
Fumigation	7.03×10^{-11}	.0348	.02	.54	4×10^3	10.5×10^{-11}
Fanning (Inversion)	8.97×10^{-11}	.459	.0185	.096	4×10^3	29.4×10^{-11}
TOTAL						4.07×10^{-10}

(2.45)

Table 2.7 - ATMOSPHERIC DISPERSION

Direction Southwest - Site Boundary

Plume Condition	$\frac{\chi_c}{0}$	Frequency of Plume Condition	Frequency of Wind Direction	Cloud Meander	Q ($\mu\text{c/sec}$) Released	Contribution To dose ($\mu\text{c/cc}$)
Lofting	0	-	-	-	-	0
Looping	9.22×10^{-12}	.0101	.0070	.50	4×10^3	$.131 \times 10^{-11}$
Coning	8.46×10^{-12}	.3785	.0093	.08	4×10^3	$.952 \times 10^{-11}$
Fumigation	1.84×10^{-10}	.0348	.02	.50	4×10^3	25.6×10^{-11}
Fanning (Inversion)	$\ll 10^{-10}$	.459	.0139	.08	4×10^3	neg.
TOTAL						2.67×10^{-10}

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Table 2.8 - ATMOSPHERIC DISPERSION

Direction West - Site Boundary

Plume Condition	$\frac{\chi}{0}$	Frequency of Plume Condition	Frequency of Wind Direction	Cloud Meander	Q ($\mu\text{c/sec}$) Released	Contribution To dose ($\mu\text{c/cc}$)
Lofting	0	-	-	-	-	0
Looping	3.16×10^{-11}	.0101	.0116	.54	4×10^3	7.98×10^{-12}
Coning	7.25×10^{-12}	.3795	.0047	.096	4×10^3	4.96×10^{-12}
Fumigation	6.33×10^{-10}	.0348	.02	.54	4×10^3	9.52×10^{-10}
Fanning (Inversion)	$\ll 10^{-10}$	.4590	.0465	.096	4×10^3	neg.
TOTAL						9.65×10^{-10}

(2.46)

Table 2.9 - ATMOSPHERIC DISPERSION

Direction North - Site Boundary

Plume Condition	$\frac{\chi}{0}$	Frequency of Plume Condition	Frequency of Wind Direction	Cloud Meander	Q ($\mu\text{c/sec}$) Released	Contribution To dose ($\mu\text{c/cc}$)
Lofting	0	-	-	-	-	0
Looping	4.35×10^{-11}	.0101	.0187	.56	4×10^3	1.82×10^{-11}
Coning	2.51×10^{-12}	.3795	.0186	.106	4×10^3	$.752 \times 10^{-11}$
Fumigation	8.69×10^{-10}	.0348	.02	.56	4×10^3	$.136 \times 10^{-11}$
Fanning (Inversion)	$\ll 10^{-10}$	.459	.0116	.106	4×10^3	neg.

TOTAL 1.39×10^{-9}

October 31, 1960

Table 2.10 - ATMOSPHERIC DISPERSION

Direction South - Worst Point

Plume Condition	$\frac{X_c}{Q}$	Frequency of Plume Condition	Frequency of Wind Direction	Cloud Weader	Q (μ c/sec) Released	Contribution To Dose (μ c/cc)
Lofting	0	-	-	-	-	0
Looping	1.3×10^{-11}	.0101	.0140	.5	4×10^3	$.568 \times 10^{-11}$
Coning	1.6×10^{-11}	.3785	.0186	.03	4×10^3	3.60×10^{-11}
Fumigation	2.8×10^{-10}	.0348	.02	.50	4×10^3	58.4×10^{-11}
Fanning (Inversion)	7.5×10^{-10}	.459	.0209	.08	4×10^3	2.30×10^{-11}
TOTAL						2.73×10^{-9}

(2.47)

Table 2.11 - SUMMARY OF DOSE ANALYSIS

Direction	Distance	Total Dose μ c/cc
East	Site Boundary	4.07×10^{-10}
South-West	Site Boundary	2.67×10^{-10}
West	Site Boundary	9.65×10^{-10}
North	Site Boundary	1.39×10^{-9}
South (worst point)	2000 meters (off-site)	2.73×10^{-9}

Figures 2.10 and 2.11 show the variation of average concentrations with distance from the stack for the various meteorological conditions for the "worst point" case.

D. Summary

With 50 mg U-235 fuel element contamination and without the use of the holdup tanks the yearly averaged concentration at the "worst point" off-site is conservatively calculated as $2.73 \times 10^{-9} \mu\text{c/cc}$. Therefore, since is a factor of 10 below $(\text{MPC})_a$, the Pathfinder gaseous waste system is considered to be adequate.

2.6 Plant Ventilation Systems

The design of the plant ventilation system is based on (1) removing heat given off by equipment at a rate which will allow efficient and safe operation of the equipment, and (2) a sufficient number of air changes for the safety and comfort of personnel in occupied areas of the plant.

Provisions are made so that the breakdown of any one piece of ventilation equipment will not require plant shutdown. Plant shutdown will be required, however, if one of the following occurs:

1. Failure of both induced draft fans.
2. Failure of two of the following fans:
 - a. Turbine building heating and ventilation unit.
 - b. Turbine building spot ventilation fan.
 - c. Reactor building ventilation fan.

The reactor building ventilation system is described in Section 3.

2.6.1 Stack and Induced Draft Fan System

The stack and induced draft fan system is provided to dispose of the exhaust air from zones where direct contamination with radioactive gases is possible (Figure 2.12). The exhaust air from the reactor building, turbine building, and fuel handling building flows through ducts to the induced draft fan inlet plenum in the fuel handling building. Two induced draft fans draw air from the plenum and discharge it to the stack.

Radioactivity detectors are installed in all ducts discharging air into the plenum. These detectors will sound an alarm in the control room on a rise in radioactivity, and on further rise, will automatically close

the isolation air valve or damper in the affected duct.

Radioactivity detectors in the stack will provide continuous indication in the control room, and will sound an alarm on a rise in radioactivity. When required, the exhaust air will be diluted by admitting outside air to the plenum through two air valves.

2.6.2 Turbine Building Ventilation System

The turbine building is divided into two zones:

- 1) Shielded zone - This is the space below the operating floor enclosing the steam lines and valves, feedwater heaters, and related equipment. Except for the condenser, this zone is physically isolated by concrete shielding from the rest of the turbine building.
- 2) Non-shielded zone - This includes all the space in the turbine building except the shielded zone. It also includes the equipment rooms and shops under the administration building.

All of the ventilating air will be delivered into the non-shielded zone, and all of the exhaust air will be removed from the shielded zone (Figure 2.13). This arrangement insures that air will always flow from the non-shielded zone to the shielded zone through the spaces around the condenser.

The air delivered by the turbine building heating and ventilation unit can be 100% outside air, or a mixture of outside air and recirculated air from the non-shielded zone. Dampers in the outside air supply duct and the recirculated air duct will be positioned to maintain the non-shielded zone pressure slightly above atmospheric pressure.

The turbine building spot ventilation fan is provided to supplement, and as a standby for, the turbine building heating and ventilation unit (Figure 2.14). It is also a standby for the reactor building ventilation fan.

The turbine building exhaust system consists of two ducts connecting the shielded zone to the plenum of the induced draft fans (Figure 2.13). Each duct is equipped with a motor-operated damper, a temperature detector, and a radioactivity detector.

2.6.3 Fuel Handling Building Ventilation System

The fuel handling building heating and ventilation unit will distribute air to all sections of the building, except the decontamination room and the purification system flash tank vault. Since radioactive contamination is a possibility throughout the building, no air will be recirculated. The stack induced draft fans will draw air through exhaust ducts from all sections of the building. A special exhaust duct is provided to remove the air which has passed over the fuel storage pool.

A second heating and ventilation unit will supply air to the decontamination room. Air will be removed from this room by an exhaust fan and passed through an absolute filter before it is delivered to the induced draft fan plenum.

The flash tank vault has a supply duct from the shielded zone of the turbine building, and an exhaust duct to the induced draft fan plenum. Thus, the induced draft fans will induce an air flow from the turbine building to the flash tank vault.

2.6.4 Water Treatment Building Ventilation System

The water treatment building heating and ventilation unit will deliver air to all sections of the building, except the precipitator room. At least one-third of the air will be outside air.

A wall mounted exhaust fan will remove air from the precipitator room, thus, inducing air flow from other sections of the building. The turbine building spot ventilation fan can supply air to the precipitator room. This air will be exhausted through wall louvers.

2.6.5 Other Ventilation Systems

The administration building, control room, and oil storage room have conventional ventilation systems. These are separate from the plant ventilation systems.

2.7 Fire Protection System

The Pathfinder Plant fire protection system will have hose stations located throughout the plant, so that all areas of the plant can be covered by at least one, and in most instances two, stations. The hose stations are all connected to a fire protection system header, which is constantly pressurized from the plant cooling water system. This arrangement permits one or both of the plant's two 1500 gpm cooling water pumps to be used for fire fighting. These pumps take water from the cooling tower basin, thus providing approximately a 200,000 gallon reservoir for fire fighting. A 500 gpm deep well pump is also interconnected with the fire protection header to provide back-up for the cooling water pumps.

Fire protection for the cooling tower is provided by two hose houses and hydrants, which are connected to the 500 gpm deep well pump. The

station's main and auxiliary transformers are protected by fog spray system served by the plant fire protection header.

Supplementing the above water system will be chemical extinguishers or CO₂ extinguishers, as the case may require, for any areas where electrical or chemical fires can occur and water cannot be used.

2.8 Electrical System

The output from the 66 eMW three phase main generator will be stepped up from 13.8 kv to 115 kv and connected into the existing Sioux Falls Division System by means of two 115 kv transmission lines. One line ties into the bus of the Sioux Falls Lawrence Generating Plant where interconnections are made with the Bureau of Reclamation System and the Interstate Power Company System. The other line connects with the Minnesota Valley Generating Plant at Granite Falls, Minnesota, where interconnections are made with the Bureau of Reclamation, Otter Tail Power Company and Northern States Power Company's Main Twin Cities System.

For continuity of electrical service within the plant, four independent sources of power, as indicated in Figure 2.15 will be available:

- (1) The 13.8 kv generator with voltage stepped down for station service,
- (2) the 115 kv system available through a second stepdown transformer,
- (3) an automatic starting standby 125 kw diesel-generator and (4) an emergency 500 kva manually switched interconnection outdoor with a local 12.5 kv distribution line. The station a-c service system will be divided into three voltage classes: 2400 volt, 480 volt and 120/208 volt.

The 2400 volt system load will be divided between two independent busses which may be manually transferred (without interruption) from the 13.8 kv stepdown transformer to the 115 kv stepdown transformer or vice

versa. As these busses will normally be fed from the 13.8 kv transformer when the plant is operating, provision will be made to automatically transfer these 2400 volt busses to the 115 kv stepdown transformer in case of failure of the normal supply.

The 480 volt system load will also be divided between two busses normally independent and fed from separate 2400/480 volt stepdown transformers. One of these transformers will be fed from one of the 2400 volt busses, the other transformer will be fed from the other 2400 volt bus. In case of loss of either of these two sources to the 480 volt system, a 480 volt bus tie breaker will automatically close to feed both 480 volt busses from the remaining source. In case both sources to the 480 volt system are lost the diesel-generator will be automatically started to carry certain essential 480 volt and 208/120 volt loads.

The station 208/120 volt system load (consisting primarily of lighting and fractional horsepower motors) will connect to a single bus normally fed from one of the 2400 volt busses via a 2400 - 120/208 volt stepdown transformer with provision for automatic transfer to a second stepdown transformer fed from the other 2400 volt bus. Upon complete loss of all feed to the 208/120 volt system, the plant emergency lights will be automatically transferred to the 125 volt station storage battery. After the diesel-generator has started, these emergency lights, some additional (standby) lighting and the plant telephone system will be fed via the "standby" bus from a 15 kva transformer energized by the diesel-generator.

During the loss of all plant a-c power sources, the nuclear instrumentation, the reactor steam pressure controls, certain a-c powered instruments and the main steam isolation valve will be powered, without

Interruption, by a 5.6 kva inverter operated by the station battery. This inverter will serve only until the diesel-generator (or other a-c sources) can take over this load.

The manually switched connection to the 12.5 kv distribution line will be used to augment or back-up the diesel-generator in case of prolonged outage of normal power sources, also as a standby source of supply to the deep well pumps in case of fire.

2.9 Instrumentation and Control System

2.9.1 Reactor Control

General

The Pathfinder Plant will normally be controlled manually for reactivity (or power level) and automatically for pressure. The basic design and operational procedure for the reactivity and pressure control systems have been established, and important operating conditions, control settings and limits have been checked analytically on the Pathfinder Simulator.*

The feedwater - reactor water level and turbine control systems have also been established and will be conventional except for minor modifications. Both of these systems will normally operate automatically.

The above systems have been chosen on the basis of (1) proven reliability with operational experience, (2) stability and fast response of components, (3) simplicity of design and operation, (4) inclusion of fail-safe features and (5) ease of adjustment, replacement, and servicing of components. Details of the control system operation are given below for normal and abnormal system conditions.

* Report No. ACNP-6005

Reactivity Control

1. Control Rods

The control rods will be operated manually to provide reactivity changes necessary for large power changes and to make adjustments for fuel burnup. In addition, they will provide safety protection against nuclear incidents. The automatic shutdown system can interrupt magnet current in the control rod clutches as outlined in Sub-section 1.4. The important features of the control rod operation circuits (from a control standpoint) are listed here.

Control rods will be operated as follows:

- (1) One rod at a time may be raised at the rate of about 61 inches/minute. This is a reactivity insertion rate of less than $5\frac{1}{2}$ /second for any control rod.
- (2) All rods may be simultaneously or individually lowered at the rate of about 72 inches/minute.
- (3) Each rod position is transmitted to the control room continuously with special indications of fully in and fully out positions.
- (4) Rod withdrawal is prohibited for the following reasons:
 - a. Recirculation line valves being operated.
 - b. Low source level.
 - c. Micromicroammeters below 5% of scale range. This prohibit will be bypassed in the most sensitive current range of the micromicroammeters.

2. Recirculation Rate

Reactor power can also be manually controlled by varying the

positions of the butterfly valves in the three recirculation lines. This is done remotely from the control room where the positions of each valve will be shown. The butterfly valve - recirculation control can be used conveniently to vary power output from 75 to 100% full power. An advantage of recirculation control is that a nearly constant axial void distribution will be maintained in the core. The butterfly valve operators have been carefully selected so that recirculation rate changes will not cause reactivity insertion rates greater than that obtained by withdrawing the most valuable rod (5¢/sec.). This criterion was established by comparing plots of excess reactivity for (1) control rod removal at 5¢/sec. and (2) various linear rates of recirculation increase. It was found that increasing recirculation at the rate of 455 gpm/sec (50%/sec²) resulted in an excess reactivity plot with a maximum amplitude and maximum rate of change equal to that for rod removal at 5¢/sec.

The above results show why interlocks will be provided to prevent a pump startup at any time with its discharge valve wide open. Present operational procedure* for the pumps and butterfly valves will permit:

- (1) Any pump to be started only after its discharge butterfly valve is at 50° or slightly less (near closed).

* See Sec. 6 for recirculation pump and valve operating procedure.

- (2) The maximum rate of flow change during ganged operation to be 455 gpm/sec.

Pressure Control System

The Pathfinder pressure control system and the reactor water level control system are described below and include all the hardware and equipment necessary to automatically position the turbine inlet valves and/or the regulating dump (bypass) valve for maintaining constant steam line pressure. Steam line pressure (P_2) is used as the control signal.

Reference will be made to the associated Reactor Pressure Control drawing, Figure 2.16; and a Pathfinder Pressure Control Schematic, Figure 2.17. As implied before, the control system will adjust steam flow in balance with the reactor steam generation rate in the process of maintaining steam line pressure at its set point. This pressure setpoint is readily adjustable over a range of 400 psi.

The power supply for the pressure control system (and the feedwater control system) is from the same bus that furnishes the reactor instrumentation power. In the event of a plant power outage, the D.C. battery block through a 5.6 KVa Inverter then provides A.C. voltage to the bus. Thus, the control systems are safe from plant auxiliary system power failure.

Normal Reactor-Turbine Operation

Two pressure transmitters, 935 and 936 (Figure 2.16), are located downstream from the superheater exit inside the reactor building and furnish an electrical signal proportional to pressure. Means are provided

to instantaneously switch from one to the other upon a failure or erratic pressure signal. This signal is matched against a manually adjustable set point, RP-11a, and the resultant voltage error is applied to the remainder of the control system through a proportional plus reset controller, RP-10a. When automatic pressure control (normal) is used, the Instantaneous Transfer Stations (30, 128 and 129) are on auto. The signal output of RP-10a is a valve position demand signal and has a standard signal range of -25 volts to +25 volt D.C. for 0 to maximum output. A bias of -12.5 volts is applied by RP-11d and amplified by a gain of 2 by RP-10b to provide the signal in proper voltage range to the Electric-Pneumatic Converter (RP-16). The resultant pneumatic signal, covering a range of 3-27 psi, is the actual control signal applied to the pneumatically driven turbine inlet valve positioner, (1203). This component utilizes the pneumatic control signal to provide a linear motion of 2 inches applied to the turbine reach rod. A 2 inch reach rod motion will full stroke the inlet valves. Thus, a +25 V to 0 voltage output range of the controller, RP-10a, corresponds to a 3-27 psi range of the pneumatic signal, which in turn corresponds to 0 to full open position demand of the turbine inlet valves.

In the unlikely event that steam is being generated in excess of the turbine capacity (about 112% over rated flow) or the turbine load limit setting, the excess steam will be throttled by the regulating dump (bypass) valve. The inlet valve position feedback signal is thus at its "open" limit (110 VAC) and any increased output of RP-10a becomes the demand signal to the bypass valve actuator (1031). The signal output

of RP-11c will then be limited to 25 volts D.C. and the signal output of the 3 point summer (RP-10a) will stay constant at -25V.

It should be noted that when automatic pressure control is being utilized, the turbine governor does not control the inlet valves (below 102% rated speed). Biasing out the turbine governor is accomplished by adjusting the speed changer to 2% above its normal position. In this range, the turbine speed is controlled by the frequency of the power system.

Normal Reactor Operation - Turbine Speed Controlled

This condition exists when the Pathfinder Plant is disconnected from the electrical system and is furnishing power only for the station load. Thus, the instantaneous selector station, 128, is automatically switched to manual, and the turbine load limit is adjusted to handle the house load. The speed changer is then set to govern turbine speed at 100% rated speed. During this operation, the pressure is automatically regulated by the regulating dump valve. Thus, the signal output of RP-11a does not change the inlet valve position since 128 is then on manual. Instead its output is compared to the feedback inlet valve position signal from RP-10f and the resultant error becomes the position demand signal for the regulating dump valve. In the event that manual pressure control is desired during this condition, instantaneous selector station (30) can be placed on manual and the operator can manually position the dump valve from the control room by watching the pressure indicator.

Turbine Overspeed

In the event that the generator becomes electrically disconnected from the system, turbine speed will increase due to the excess steam entering the turbine. When the speed reaches 102%, the turbine valve mechanism has the protective feature of automatically closing the inlet valves to prevent a serious overspeed ($> 110\%$ rated). During this rollback period (which is a minimum of 0.6 sec.), the variable auto-transformer will continuously transmit the inlet valve position in the feedback path and will furnish a decreasing signal corresponding to the decreasing inlet valve position. Thus, the feedback signal is responsible for opening the regulating dump valve to the necessary position to handle the existing steam flow. In case there is any slight mismatch between inlet valve and regulating dump valve positions, the resultant pressure error will send an additional signal to the regulating dump valve to maintain the set pressure. In the event of an excessive pressure increase (> 65 psi), the safety-relief valve system will operate. The four valves are set to open at approximately 608, 615, 620 and 625 psia respectively, to protect the reactor and steam line against high pressure. They do not affect the operation of the control system. At the instant 102% speed is reached, the instantaneous selector station, 128, is automatically switched to manual by an electrical signal transduced from the turbine governor. This action allows the turbine governor to have control of inlet valve position to maintain rated speed for the remaining station load on the generator. The same turbine overspeed signal is applied to the solenoid valve in the pneumatic (3-27 psi) line at 102% speed to position the reach rod at its

minimum set position. The turbine speed will then settle out to slightly above rated speed in 2-3 seconds.

Turbine Tripout

Turbine tripout can be caused by serious overspeed ($> 110\%$), turbine faults, and generator faults. These conditions cause the turbine stop valves to trip closed in about 0.35 second cutting off all steam to the turbine, thus protecting the turbine-generator from serious damage. When this stop valve action is initiated, a signal with turbine tripout intelligence will be sent to the auxiliary relay module, RP-12, thus opening the inlet valve position feedback circuit. When this action takes place, the valve position demand output signal of RP-10a will instantaneously be felt at the bypass valve with a magnitude corresponding to the previous inlet valve position. Again, any pressure error developed during this tripout period will result in an additional signal to 1031 to return steam line pressure to the set point. The bypass valve will be positioned by a high capacity actuator with a 3000 psi oil supply which can open the dump valve in a minimum of approximately 0.35 sec. The bypass valve will have a linear characteristic (i.e., valve capacity vs. valve stroke is a straight line). This decision was made after extensive analog computer simulation studies of turbine rollback and tripout with bypass valves having various characteristics. While a bypass valve characteristic matching the turbine stop valve capacity curve (in reverse) is desirable for limiting the pressure decrease upon a turbine tripout not caused by overspeed, it would definitely be undesirable for all other modes of operation because:

(1) A linear characteristic is better from a control and stability standpoint for normal bypass valve operation.

(2) A linear characteristic is a better match for the closing inlet valves during a turbine rollback.

In addition, turbine trips not caused by overspeed (i.e., turbine or generator faults) should be extremely rare in occurrence. Provision has been made to accompany all turbine trips with an automatic reactor shutdown.

Turbine Startup - Shutdown

During turbine startup when the reactor is being brought up to rated pressure, warming steam will be sent to the turbine with the dump valve instantaneous selector station set for automatic pressure control. (See Section 6.9 Normal Startup.) Thus at all times during startup or shutdown, the dump valve is on automatic pressure control. The controlled pressure can then be raised (or lowered) by manually changing the pressure set point. When the turbine is manually loaded to 10 MW and the speed changer set to the 102% speed position, station 128 is switched to auto. Thus, pressure is automatically controlled while turbine steam flow is increasing and the bypass (station 30) valve is automatically closed. The turbine can then be loaded to full power under automatic pressure control.

For turbine shutdown, the above procedures will occur approximately in reverse order to the point where the inlet valves are placed under governor control. With 30 still set on auto and practically all the steam flow passing through the bypass valve, the turbine stop valves will be

manually tripped. All steam will then flow through the bypass valve and pressure will be automatically controlled at set point until the reactor is shut down.

Feedwater-Reactor Level Control System

The feedwater-reactor level control system (hereafter called the feedwater control system) uses both pneumatic and electrical components to automatically position the feedwater control valve. This system is protected from major power failures similar to the pressure control system by receiving its power supply from the bus common to the reactor instrumentation power.

The feedwater control system uses three control elements; steam flow (compensated for pressure and temperature), feedwater flow (compensated by temperature and biased by a constant purification system flow) and reactor water level.

The flow error and reactor water level error are summed and both proportional and reset action is applied to yield a pneumatic valve position demand signal. By selecting proper proportional band and reset rate, the steam flow-feedwater flow difference signal will be the primary control signal and level error will be the secondary control signal.

In the event that either the steam flow or feedwater flow signals are accidentally lost from the control system, a "wipe-out" circuit will remove the remaining signal thus converting the system to a single-element type consisting of the level error signal only. If all control signals are lost, the feedwater control valve will stay in position.

In addition to balancing steam flow changes to feedwater flow changes, this control system has been designed to maintain reactor water level:

- (1) Within $\pm 1"$ of the set point under stable conditions over the load range of 20% to 100% of 616,000 #/hr.
- (2) Within $\pm 6"$ of the set point during level variations produced by normal load changes.
- (3) Within $\pm 10"$ during abnormal load rejection and/or turbine tripout.

A low capacity feedwater flow bypass control valve will be used during reactor startup, shutdown, and other non-operating conditions. This valve is manually controlled.

The feedwater control valve actuator has been designed to limit the rate of feedwater flow change to 40 gpm/sec. Interlocks will also prevent automatic valve motion while either recirculation rate is being changed or control rods are being withdrawn.

2.9.2 Nuclear Instrumentation

The nuclear instrumentation system designed for Pathfinder has two functions. First, it will provide information for the reactor operator about the neutron population in the reactor core. The eight measurement channels give this information from the source level to operating power levels. Second, the nuclear instrumentation system will protect Pathfinder against serious nuclear excursions by means of its "Automatic Shutdown System".

The system is made up of solid state or transistorized components with the exception of the micromicroammeters in the operating channels. Ex-

perience with this equipment indicates it to be very reliable and give excellent service. The nuclear instrumentation power supply is designed so that in the event of a plant power outage, a D.C. battery block, through a 5.6 Kva inverter, provides A.C. voltage to the instrumentation bus.

The eight neutron detecting channels will be arranged as follows to fulfill the two functions:

1. Three startup range channels give data on count rate and reactor period in the source range.
2. One log N channel gives data on reactor period and power in the intermediate range.
3. Two operating channels provide data on power level and give safety protection from startup range to power operation.
4. Two safety channels give high power level protection during power operation.

The Automatic Shutdown System will receive data from the nuclear and process instrumentation and will protect the reactor by one of three methods. These methods are:

1. Scram Shutdown, which will be initiated by an interruption of power to the magnetic clutches on the boiler control rods. This will allow the rods to drop into the core and stop the neutron chain reaction.
2. Controlled Shutdown, which will result from driving the boiler control rods in a ganged fashion into the core, at the rate of 72 inches/minute. This method will also stop the chain reaction.

3. Runback, which will result from insertion of boiler control rods in a ganged fashion into the core at the rate of 72 inches/minute until the initiating condition is corrected.

Conditions that will cause these protective actions are listed below.

1. Scram Shutdown will be caused by:

- (1) Neutron flux in the safety channels greater than 115% of range setting.
- (2) Neutron flux in the operating channels greater than 115% of range setting.
- (3) Reactor dome pressure higher than 650 psig.
- (4) Reactor dome pressure lower than 520 psig.
- (5) Reactor building pressure higher than 5 psig.
- (6) Main steam isolation valve closure.
- (7) Loss of condenser cooling.
- (8) Loss of all power to nuclear instrumentation.
- (9) Manual "Scram" button in control room.
- (10) Turbine trip.

2. Controlled Shutdown, will be caused by the following conditions:

- (1) Plant auxiliary power failure.
- (2) Recirculating pump power failure (two or three pumps).

3. Runback, will be caused by the following conditions:

- (1) Main steam line temperature high.
- (2) Reactor water level high.
- (3) Reactor water level low.
- (4) Loss of feedwater pressure.

- (5) Loss of instrument power in electric, pneumatic, or hydraulic system.
- (6) A two out of three coincidence signal from the BF_3 startup channels when the period is less than 5 seconds.
- (7) A signal from the Log N channel when the period is less than 5 seconds.
- (8) A two out of four coincidence when power level exceeds 110% of range setting.

Data is sent from the sensing instruments into logic circuits in the Automatic Shutdown System. The signals from the two safety and the two operating channels are sent to a two-out-of-four coincidence unit in the Automatic Shutdown System. Any two coincident trip signals from the linear flux and safety channels will cause an Automatic Scram Shutdown by interruption of power to the magnetic clutches on the boiler control rods. Also, any one of the signals from the process instrumentation mentioned above can cause an interruption of magnet power and thus a scram shutdown.

Controlled Shutdown is started by any one of the causes listed under its heading.

Runback is initiated by any one of the signals listed under its heading.

Instrument Channels

The individual channels are discussed in this section.

Channels 1, 2 and 3. -- Startup Channels.

The purpose of these three channels is to provide information about the neutron population from source level to four decades above this level. An extension of two decades is made possible by withdrawal of the chambers

a short distance. These signals are sent to log count rate meters, period meters, alarms and to a two-out-of-three coincidence circuit. When the period is less than 5 seconds, Runback will be initiated from the two-out-of-three coincidence circuit. The detectors are all high-sensitivity BF_3 chambers that have the withdrawal provisions mentioned above.

Channel 4 - Log N Channel.

This channel will give information over the wide intermediate range of seven decades below full power up to full power. It contains a log flux meter and a period meter. The signal is sent to an alarm and is used to initiate Runback when the period is less than 5 seconds. The neutron sensor is a compensated ion chamber.

Channels 5 and 6 - Operating channels.

These two channels are each equipped with a micromicroammeter having a range of seven decades (from seven decades below full power to full power) so that a linear flux reading may be observed over the very wide intermediate power range. These signals are sent to linear flux meters, a recorder and to the Automatic Shutdown System coincidence circuit. The operating channel signals are two of the four signals sent to the coincidence circuit. The neutron sensors are compensated ion chambers.

Channels 7 and 8 - Safety Channels.

These two channels provide information about the neutron population in the reactor core in the power range. (Three decades below full power to full power). The signals are sent to linear neutron flux meters and recorders and to the coincidence circuit in the Automatic Shutdown System. These signals

form the other pair of signals to the 4-input coincidence circuit. The neutron sensors are uncompensated ion chambers.

A block diagram of the eight channels and their function is shown in Figure 2.18.

It should be noted that the micromicroammeters in the operating channels are always connected to "trip circuits" so that whenever the power level exceeds 115% of the scale at which the meter is set, a reactor scram will occur. This effectively provides high flux level protection from seven decades below full power to full power.

There is also provision to change the two-out-of-four coincidence circuit to a one-out-of-four coincidence if the Log N channel should fail during startup. A two-out-of-four coincidence schema, however, will always be used during power operation.

Provisions have been made to place in-core neutron flux monitors in several superheater fuel locations. These in-core ion chambers are proposed in order to detect flux shape oscillations within the first core. This step has been taken even though calculations have indicated that no flux shape oscillations will occur in Pathfinder. These are described again in Section 6 and are installed to obtain experimental information and are not a part of the regular reactor instrumentation. It is planned to omit them from other than the first core.

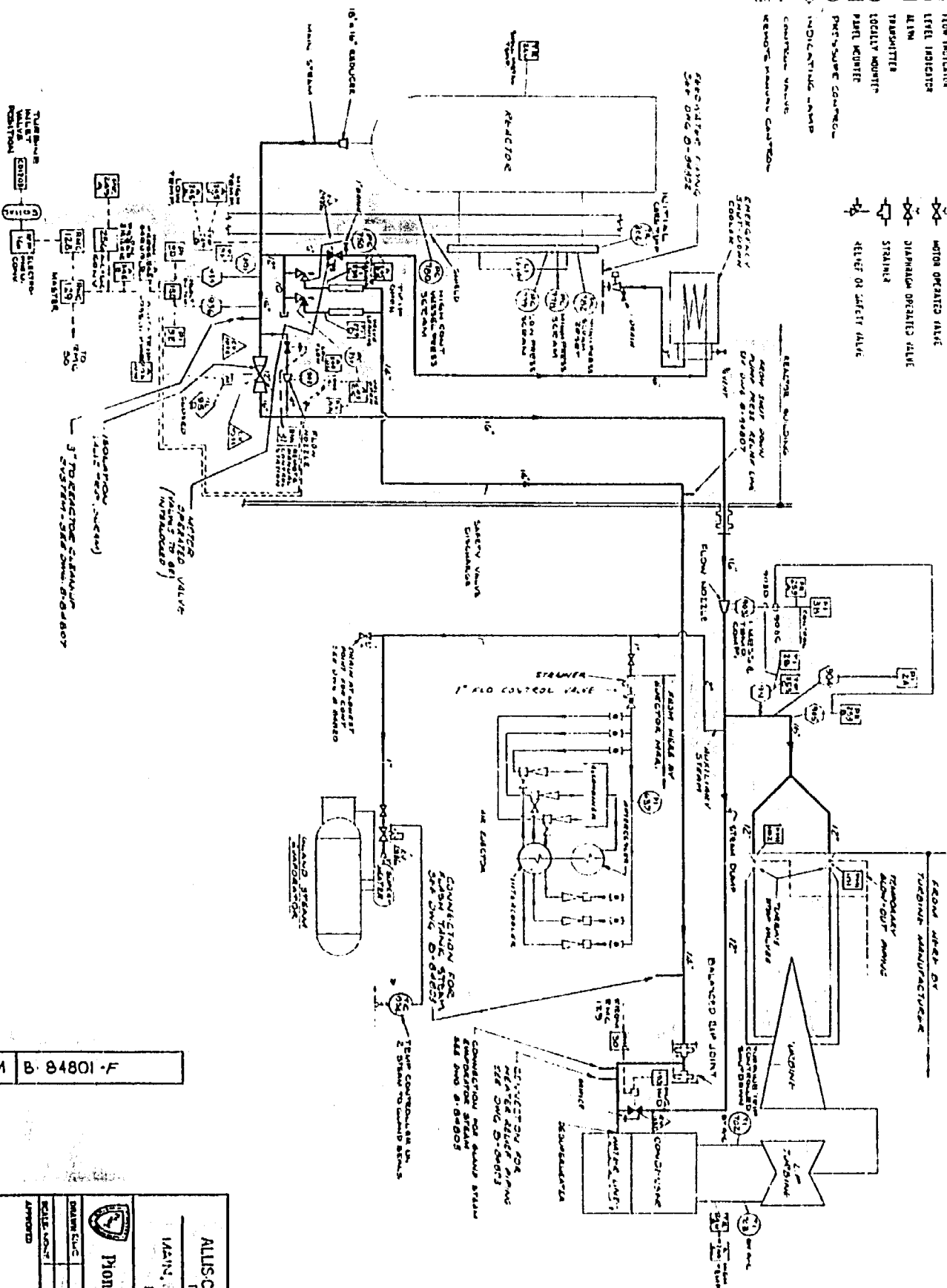
Instrumentation and Control Air System

Instrument air and compressed air for valve operators is specially filtered and is supplied by the station air system. The station air system,

which includes aftercoolers, oil separators, filters and pressure control is supplied by two compressors. Each compressor has more than 20 times the capacity required by the instrument and valve operators. Electrical power for the compressors is supplied by the auxiliary power system which is highly reliable due to 4 independent sources as described in Section 2.8. Low air pressure is indicated by an alarm in the control room. There is sufficient compressed air storage in the receivers to permit a controlled shutdown of the plant following a low pressure alarm. Upon loss of air pressure the air operated controls and valves fall in a position which assures safe operation or shutdown of the plant.

VALVE SYMBOLS:

- | | |
|---|---|
| VALVES SHOWN SOLID ARE NORMALLY CLOSED | VALVES SHOWN DASHED ARE NORMALLY OPEN |
|  |  |
| CATE VALVE | DIAPHRAGM OPERATED VALVE |
|  |  |
| GLIDE VALVE | STRAINER |
|  |  |
| CHUCK VALVE | RELIEF OR SAFETY VALVE |
|  | |
| MOTOR OPERATED VALVE | |
|  | |

[illegible][illegible]

— PUMP, TANK — STORAGE OF
ALLSCHLITZES NEG. CO. NEWARK, N.J.
PUMP AND STORAGE TANK
MAIN, AUXILIARY & STEAM DUMP
FLOW DIAGRAM



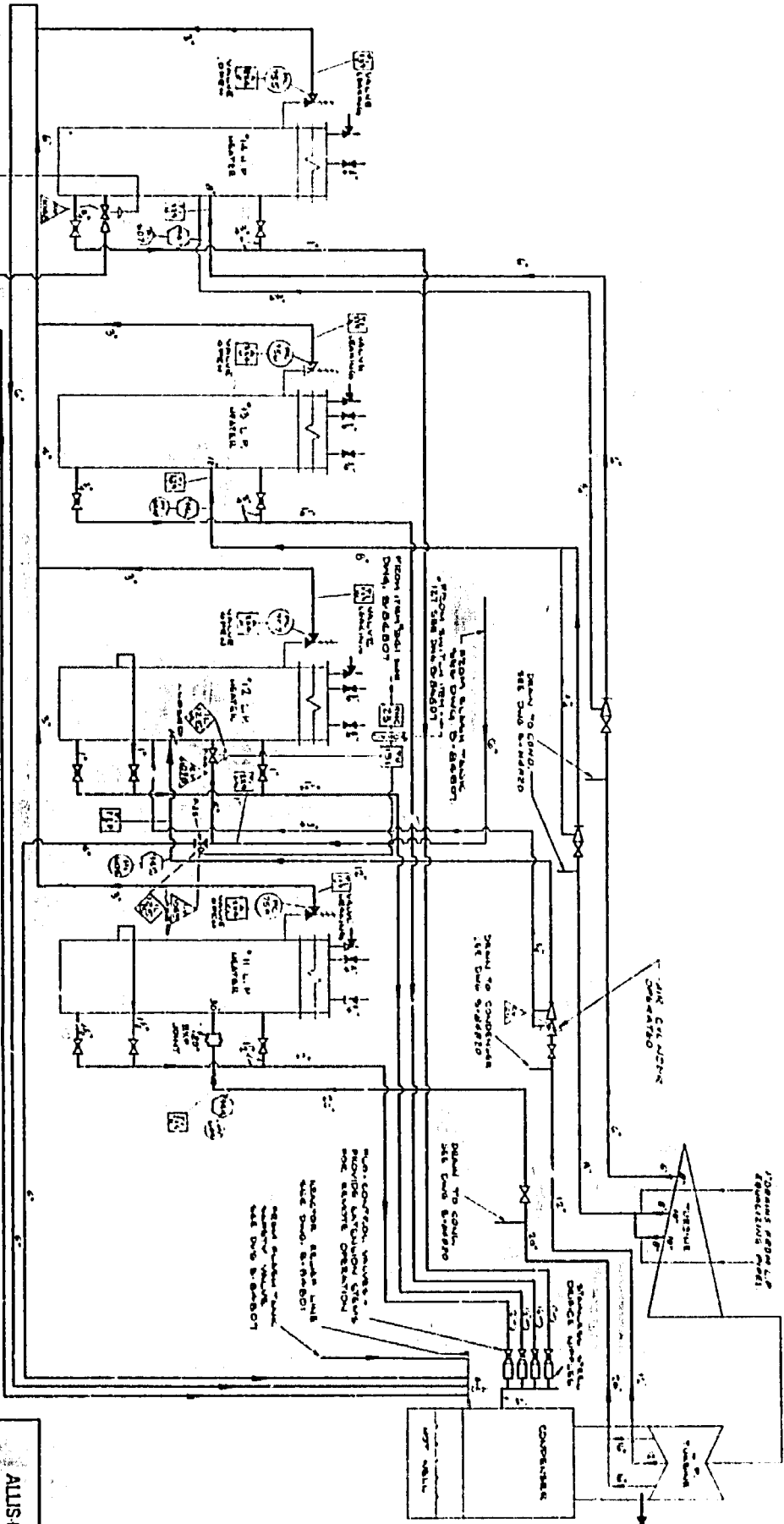
Pioneer Service & Engineering Co.

DATE REC'D	CHECKED	QUANT. LISTED	
	LED	<i>1/1/68</i>	10-58
DATE SENT			
APPROVED			PROJECT NO. 12-070-4

No. **B-84801-F**

REVISION NO.	DATE	BY	CHKD	APP'D	DESCRIPTION

- REVISIONS:**
1. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 2. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 3. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 4. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 5. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 6. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 7. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 8. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 9. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.
 10. REVISIONS MADE TO DRAWING TO CORRECT ERROR IN VALVE SYMBOLS AND TO ADD VALVE SYMBOLS TO DRAWING.



VALVE SYMBOLS:
 VALVES SHOWN SHADOW ARE NORMALLY CLOSED
 VALVES SHOWN UNSHADOW ARE NORMALLY OPEN

SYMBOLS LEGEND:
 (P) PRESSURE INDICATOR
 (C) CONTROL VALVE
 (V) VALVE
 (S) SAFETY VALVE
 (T) THERMISTOR
 (R) RELIEF VALVE
 (D) DIAPHRAGM OPERATED VALVE
 (E) EMERGENCY VALVE
 (F) FLOW INDICATOR
 (G) GATE VALVE
 (H) HATCH VALVE
 (I) ISOLATION VALVE
 (J) JUNCTION VALVE
 (K) KICK VALVE
 (L) LOCK VALVE
 (M) MOUNTED VALVE
 (N) NORMALLY OPEN VALVE
 (O) NORMALLY CLOSED VALVE
 (P) PRESSURE INDICATOR
 (Q) QUANTITY VALVE
 (R) RELIEF VALVE
 (S) SAFETY VALVE
 (T) THERMISTOR
 (U) UNIFORM VALVE
 (V) VALVE
 (W) WINDUP VALVE
 (X) X-VALVE
 (Y) Y-VALVE
 (Z) Z-VALVE

INDICATING LIGHTS
 (C) CIRCULAR LIGHT
 (S) SQUARE LIGHT
 (T) TRIANGULAR LIGHT
 (D) DIAMOND LIGHT
 (E) ELLIPTICAL LIGHT
 (F) FIVE POINTED STAR LIGHT
 (G) GEAR LIGHT
 (H) HEART LIGHT
 (I) ISLAND LIGHT
 (J) JEWEL LIGHT
 (K) KITE LIGHT
 (L) LION LIGHT
 (M) MOUNTAIN LIGHT
 (N) NINE POINTED STAR LIGHT
 (O) OCTAGON LIGHT
 (P) PENTAGON LIGHT
 (Q) QUADRANT LIGHT
 (R) RECTANGLE LIGHT
 (S) SEMICIRCLE LIGHT
 (T) TRIANGLE LIGHT
 (U) UNIFORM LIGHT
 (V) VALVE LIGHT
 (W) WINDUP LIGHT
 (X) X-LIGHT
 (Y) Y-LIGHT
 (Z) Z-LIGHT

M B-84803-G

— CO. FIDELITY — PROPERTY OF

ALLS CHARTERS INC. CO. SAVANNAH, GA.

BLEED, HEATER VENT & SAFETY VALVE RELIEF FLOW DIAGRAM

Pioneer Service & Engineering Co.

DESIGNED BY: [Signature]

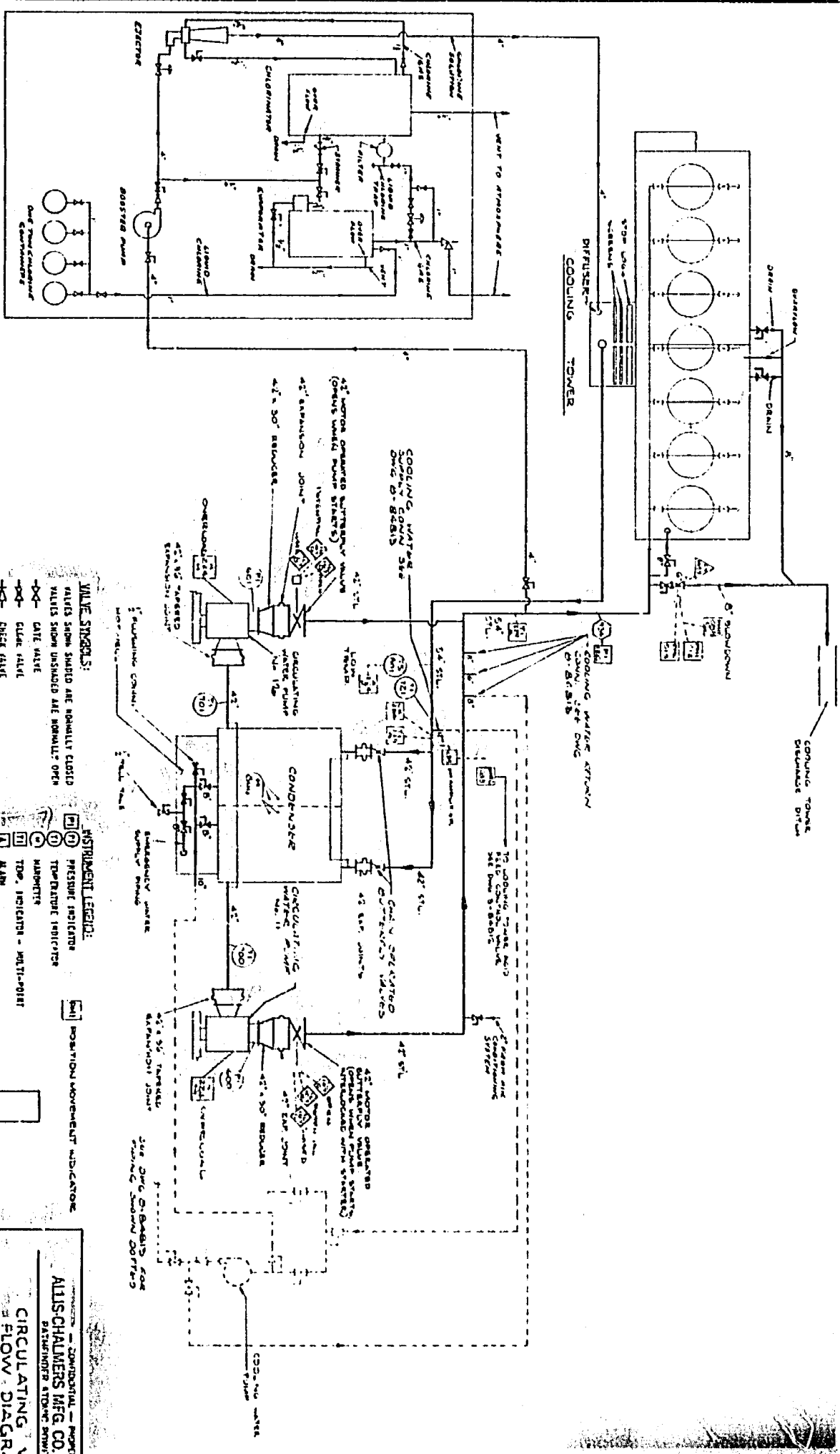
CHECKED BY: [Signature]

DATE: 10-10-64

PROJECT NO. B-84803-G

APPROVED

No. B-84803-G



CHLORINE HOUSE

- VALVE SYMBOLS:**
- Valves shown shaded are normally closed
 - Valves shown unshaded are normally open
 - Gate Valve
 - Globe Valve
 - Check Valve
 - Butterfly Valve
 - Motor Operated Valve
 - Eccentric Plug Valve (Down)
- INSTRUMENT LEGEND:**
- Pressure Indicator
 - Temperature Indicator
 - Flow Indicator
 - Multi-Point
 - Alarm
 - Recorder Controller
 - Conductivity Recorder
 - Locality Indicator
 - Field Monitor
 - Indicating Lamp
 - Transmitter
- POSITION MOVEMENT INDICATOR**

M B-84800-E

PROPERTY OF
ALLIS-CHALMERS MFG. CO. MILWAUKEE WIS.
PATENTED BY ALLIS-CHALMERS MFG. CO.

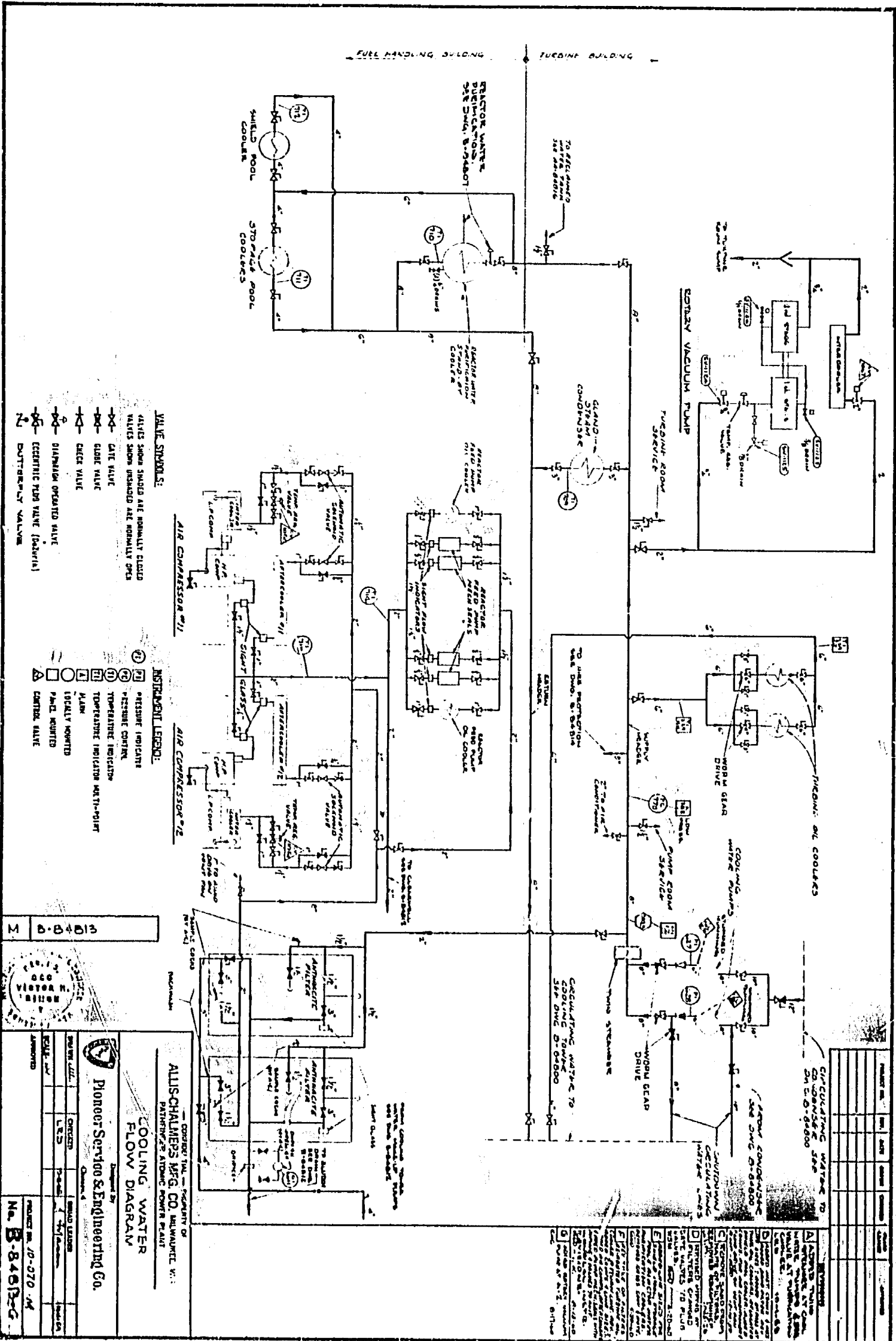
**CIRCULATING WATER
FLOW DIAGRAM**

Designed by
Monroe Service & Engineering Co.

DATE	CHANGED	REASON
1-1-57	1-1-57	1-1-57
1-1-57	1-1-57	1-1-57
1-1-57	1-1-57	1-1-57

PROJECT NO. 10-070-14
No. B-84800-E

REVISIONS	DATE	BY	CHKD	APP'D
1	1-1-57			
2	1-1-57			
3	1-1-57			
4	1-1-57			
5	1-1-57			
6	1-1-57			
7	1-1-57			
8	1-1-57			
9	1-1-57			
10	1-1-57			



ALLIS-CHALMERS MFG. CO. BILWAPPEL, W.I.
PATERSON, N.J. 07640

COOLING WATER FLOW DIAGRAM

Pioneer Service & Engineering Co.
1000 N. 10th St.
P.O. Box 1000
P.O. Box 1000
P.O. Box 1000

REVISIONS

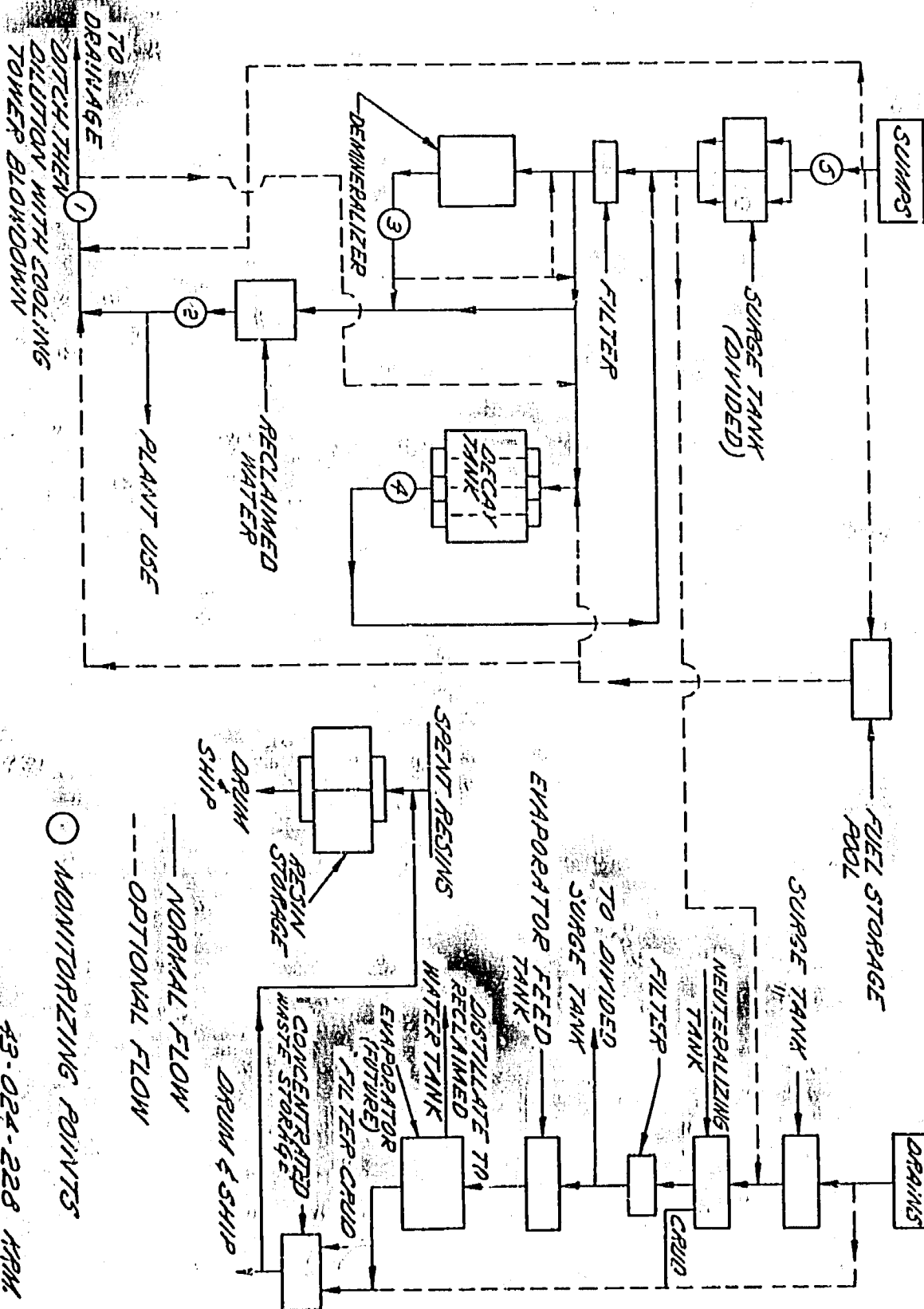
NO.	DATE	DESCRIPTION
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2	10-10-64	REVISED
3	10-10-64	REVISED
4	10-10-64	REVISED
5	10-10-64	REVISED
6	10-10-64	REVISED
7	10-10-64	REVISED
8	10-10-64	REVISED
9	10-10-64	REVISED
10	10-10-64	REVISED

8-84813

LIQUID WASTE DISPOSAL SYSTEM

(LOW ACTIVITY)

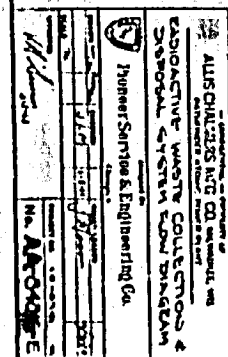
(HIGH ACTIVITY)



○ MONITORING POINTS

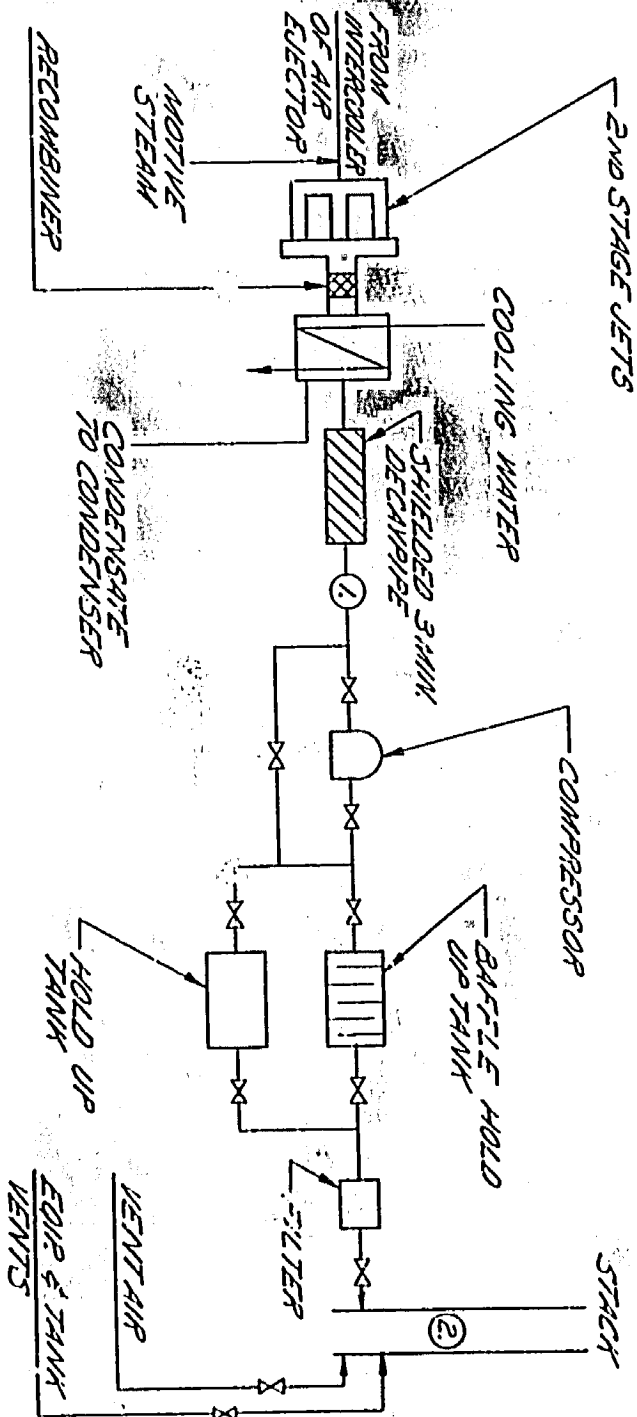
— NORMAL FLOW
 --- OPTIONAL FLOW

43-024-228 APR 64



October 31, 1964

GASEOUS WASTE DISPOSAL SYSTEM



- ① HIGH ACTIVITY ALARM MONITOR
- ② CONTINUOUSLY RECORDING MONITOR

43-024-227 NPM.

FIG. 2.9 GASEOUS WASTE DISPOSAL SYSTEM
October 31, 1960

ATMOSPHERIC DISPERSION FACTOR
VS.
DISTANCE FROM THE STACK FOR
VARIOUS METEOROLOGICAL CONDITIONS
IN THE WORST DIRECTION

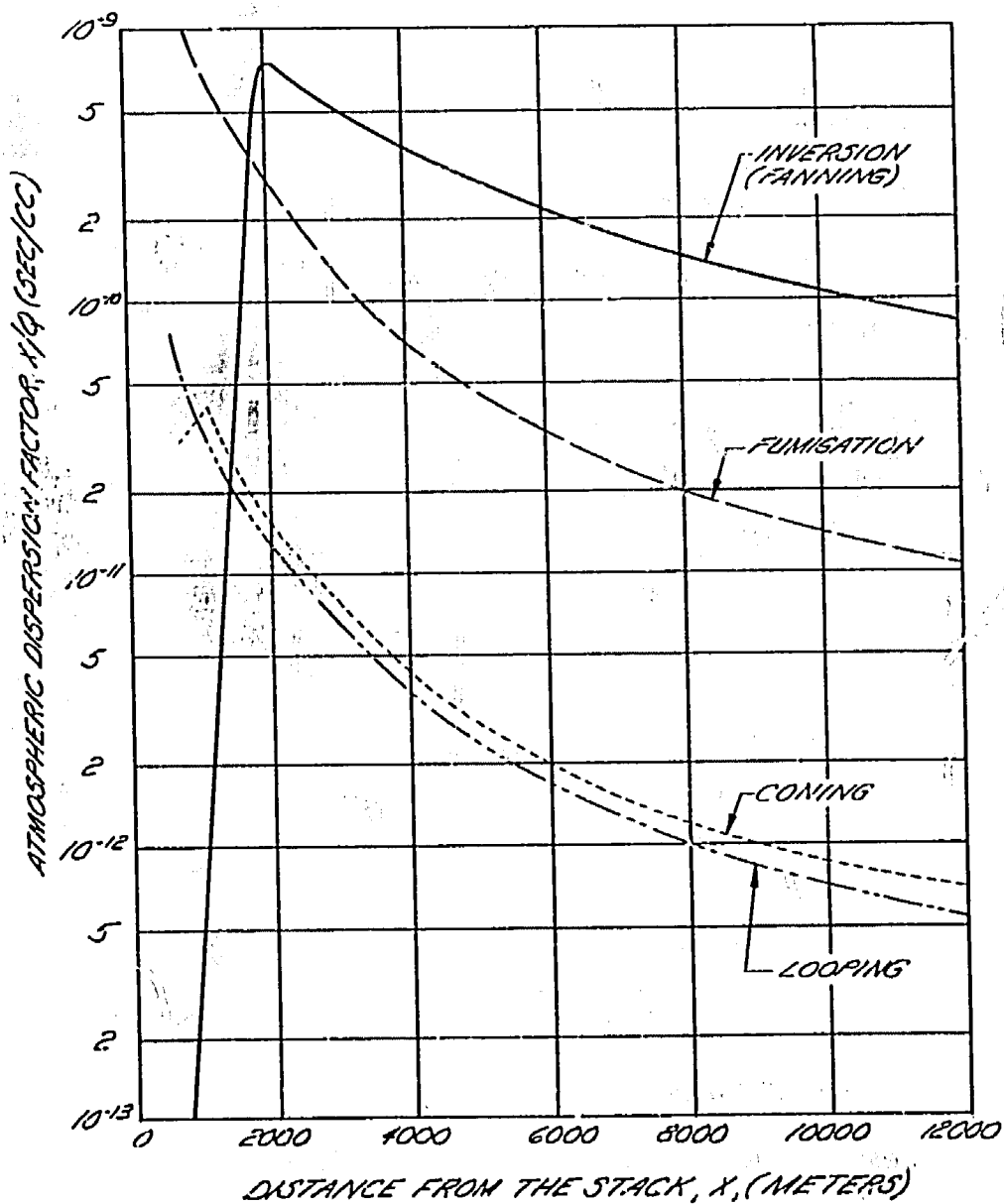


FIG. 2.10

83-024-310 17M.

ATMOSPHERIC DISPERSION FACTOR VS. DISTANCE FROM STACK

FIG. 2.10
October 31, 1960

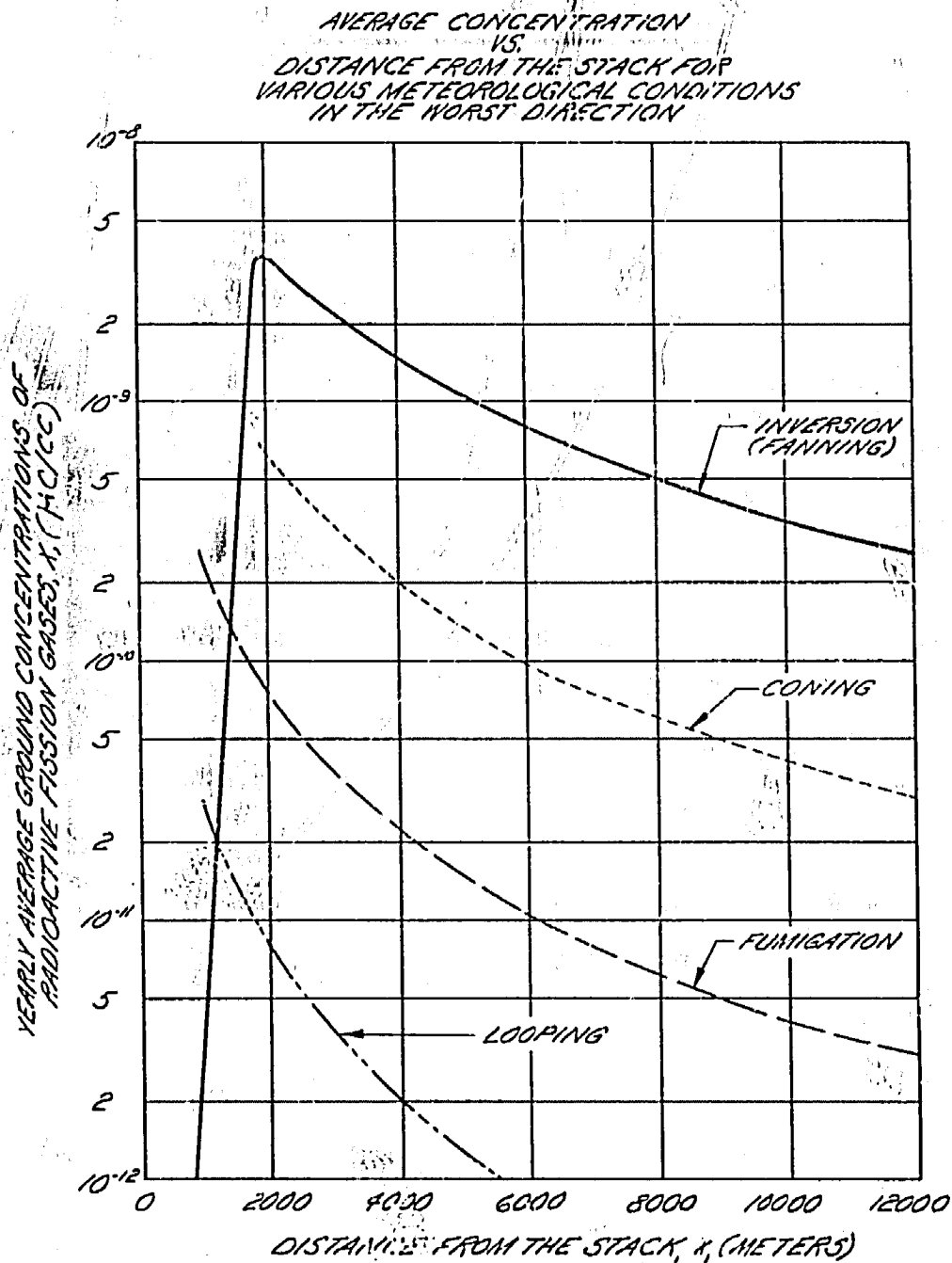
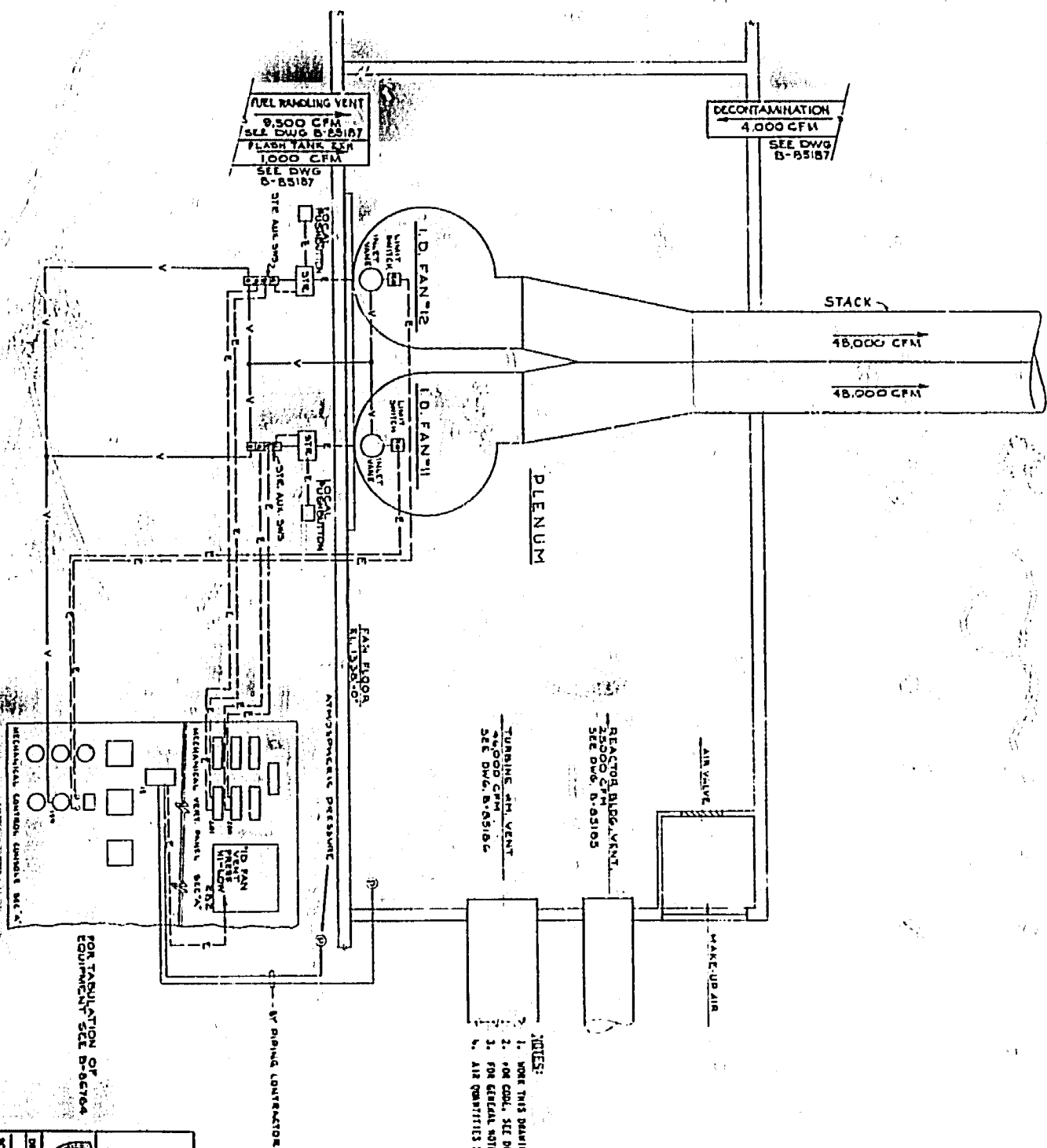


FIG. 2.11

43-024-311 AFM.

AVERAGE CONCENTRATION VS. DISTANCE FROM STACK

FIG. 2.11
October 31, 1960

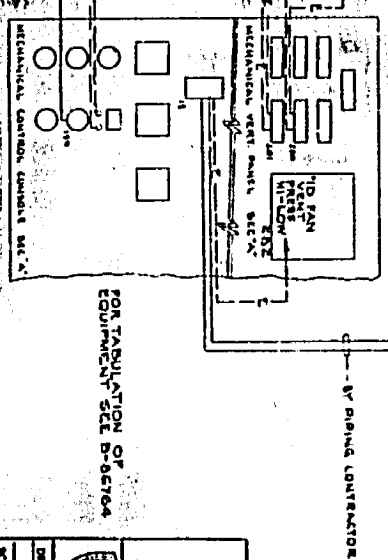


REACTOR BLDG. VENT.
2,500 CFM
SEE DWG. B-85105

TURBINE AFT VENT
4,000 CFM
SEE DWG. B-85106

- NOTES:
1. WORK THIS DRAWING WITH DRAWING B-87403
 2. FOR COOL, SEE DRAWING B-85106
 3. FOR GENERAL NOTES, SEE DRAWING B-87402
 4. AIR QUANTITIES SHOWN ARE MAXIMUM QUANTITIES.

WIRING OR PNEUMATIC CONNECTIONS
BY VENTILATION CONTRACTOR
BY ELECTRICAL CONTRACTOR

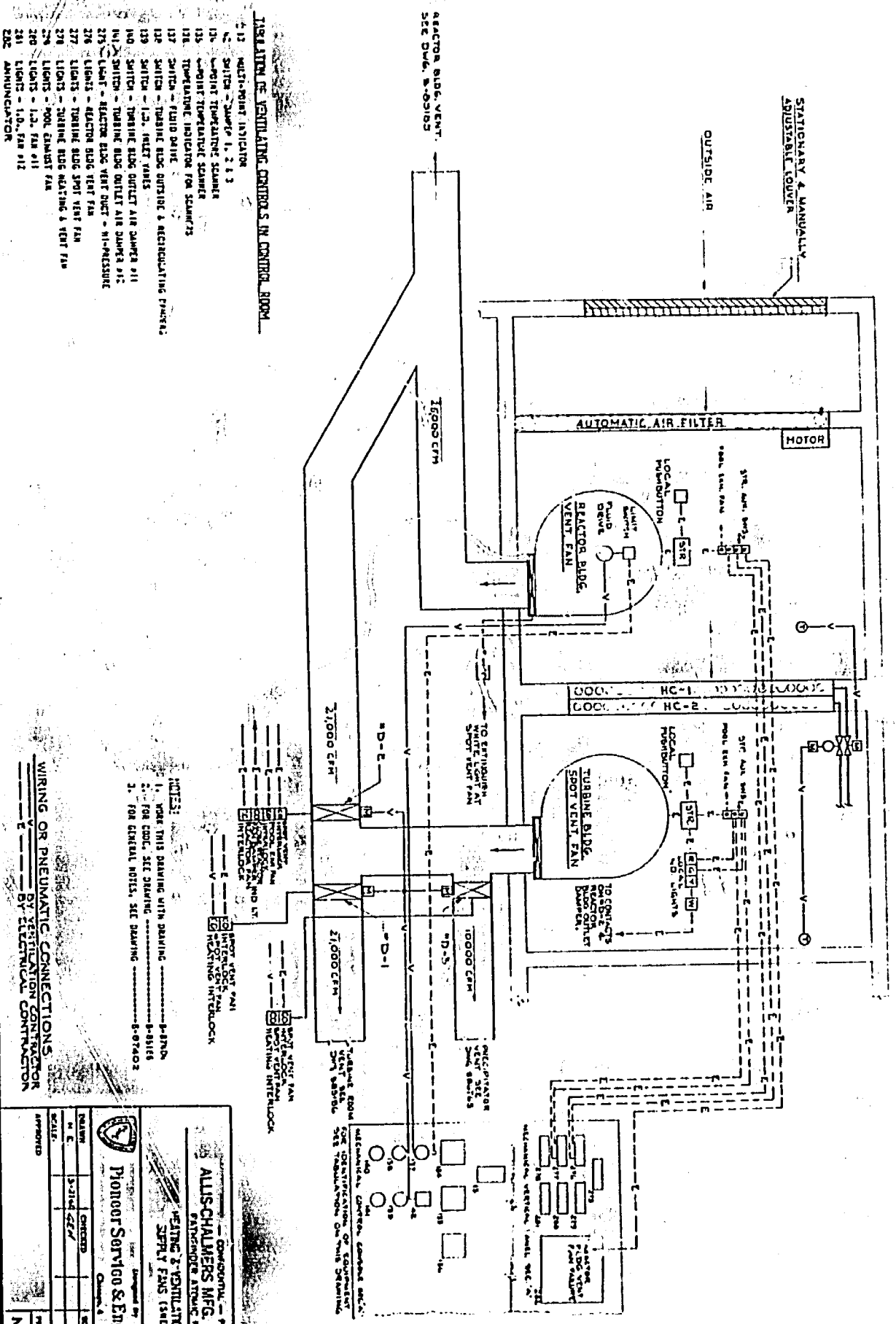


CONSULTANT - PROPERTY OF ALLIS-CHALMERS MFG. CO. MILWAUKEE, WIS. ADVANCED ATOMIC POWER PLANT HEATING & VENTILATION CONTROLS INDUCED DRAFT FANS			
Prepared by Pioneer Service & Engineering Co. Chicago, Ill.			
DATE	DESIGNED	CHECKED	REVIEWED
11-1-60	11-1-60		
SCALE			
AS SHOWN			
PROJECT NO. 10-070	DRAWN BY No. B-86767-B		

REVISIONS
1. GENERAL REVISIONS
DATE: 11-1-60
2. GENERAL REVISIONS

HEATING AND VENTILATION CONTROLS - INDUCED DRAFT FANS FIG. 212
October 31, 1960

REVISIONS
 A GENERAL TYPING
 B GENERAL REMOVAL
 C TYPING OUT Dwg
 DWN. R.J.V. 9-1-60



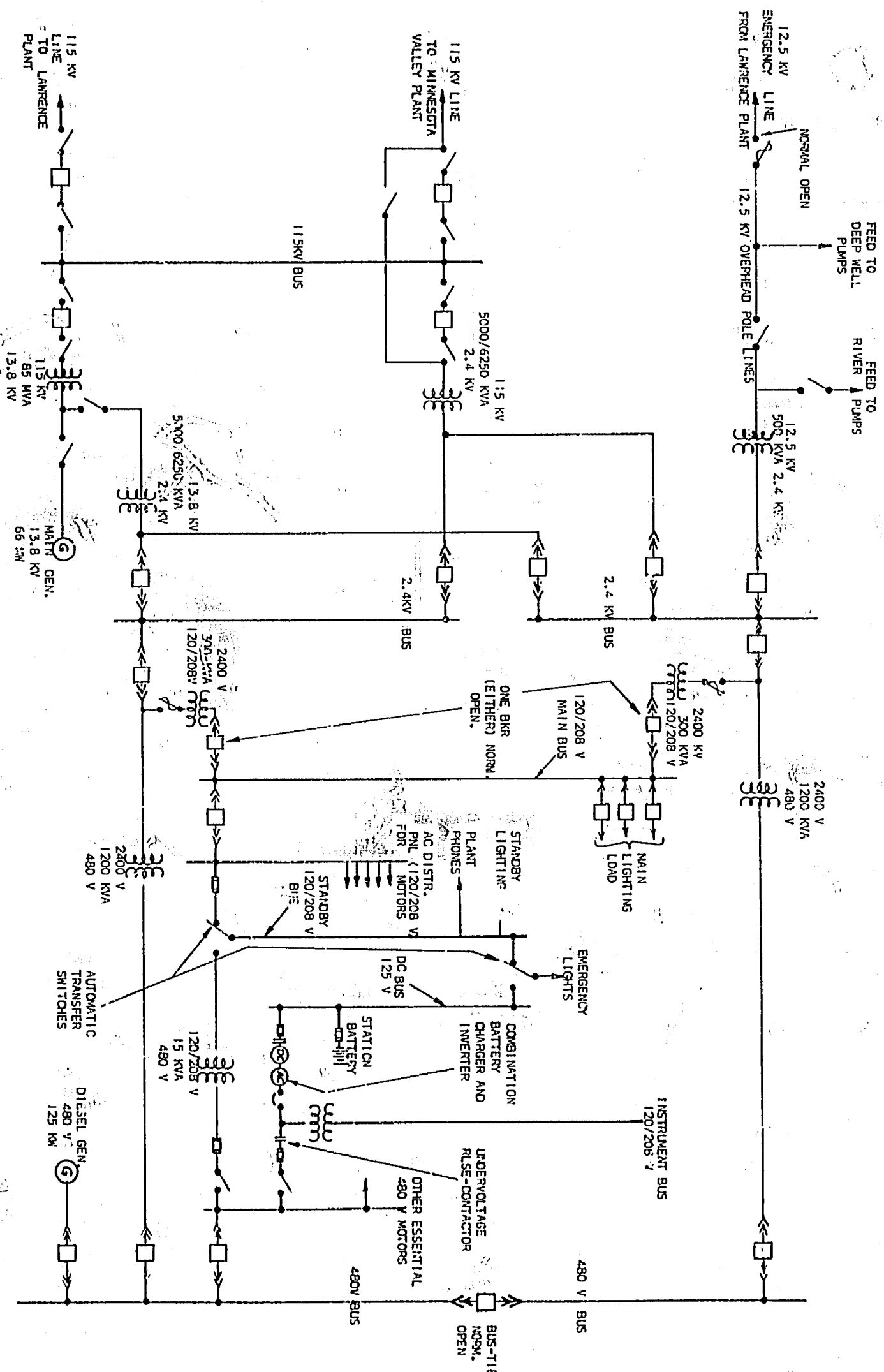
ISOLATION OF VENTILATING CONTROLS IN CONTROL ROOM

- 1. Multi-point indicator
- 2. Switch - Reactor 1, 2 & 3
- 3. Switch - Reactor 4
- 4. Switch - Reactor 5
- 5. Switch - Reactor 6
- 6. Switch - Reactor 7
- 7. Switch - Reactor 8
- 8. Switch - Reactor 9
- 9. Switch - Reactor 10
- 10. Switch - Reactor 11
- 11. Switch - Reactor 12
- 12. Switch - Reactor 13
- 13. Switch - Reactor 14
- 14. Switch - Reactor 15
- 15. Switch - Reactor 16
- 16. Switch - Reactor 17
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- 41. Switch - Reactor 42
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- 79. Switch - Reactor 80
- 80. Switch - Reactor 81
- 81. Switch - Reactor 82
- 82. Switch - Reactor 83
- 83. Switch - Reactor 84
- 84. Switch - Reactor 85
- 85. Switch - Reactor 86
- 86. Switch - Reactor 87
- 87. Switch - Reactor 88
- 88. Switch - Reactor 89
- 89. Switch - Reactor 90
- 90. Switch - Reactor 91
- 91. Switch - Reactor 92
- 92. Switch - Reactor 93
- 93. Switch - Reactor 94
- 94. Switch - Reactor 95
- 95. Switch - Reactor 96
- 96. Switch - Reactor 97
- 97. Switch - Reactor 98
- 98. Switch - Reactor 99
- 99. Switch - Reactor 100

- NOTES:
1. FOR THIS DRAWING WITH DRAWING - P-8116
 2. FOR COOL. SEE DRAWING - P-8116
 3. FOR CRITICAL NOTES, SEE DRAWING - P-8116

WIRING OR PNEUMATIC CONNECTIONS
 BY ELECTRICAL CONTRACTOR

CONFIDENTIAL - PROPERTY OF ALLIS-CHAMBERS MFG. CO. MILWAUKEE, WIS. EXCLUSIVE ATOMIC POWER PLANT HEATING & VENTILATION CONTROLS SUPPLY FANS (SHEET 1 OF 3)	
Designed by Checked by Drawn by Approved by	
PROJECT NO. 10-571 No. B-86764-B	



ELECTRIC POWER DIAGRAM

FIG. 2.15

October 31, 1960

43-202-067



FIG. 215



43-401-128

3

FIG. 2.16
October 31, 1960

PATHFINDER PRESSURE CONTROL SCHEMATIC

43-202-065 MAY

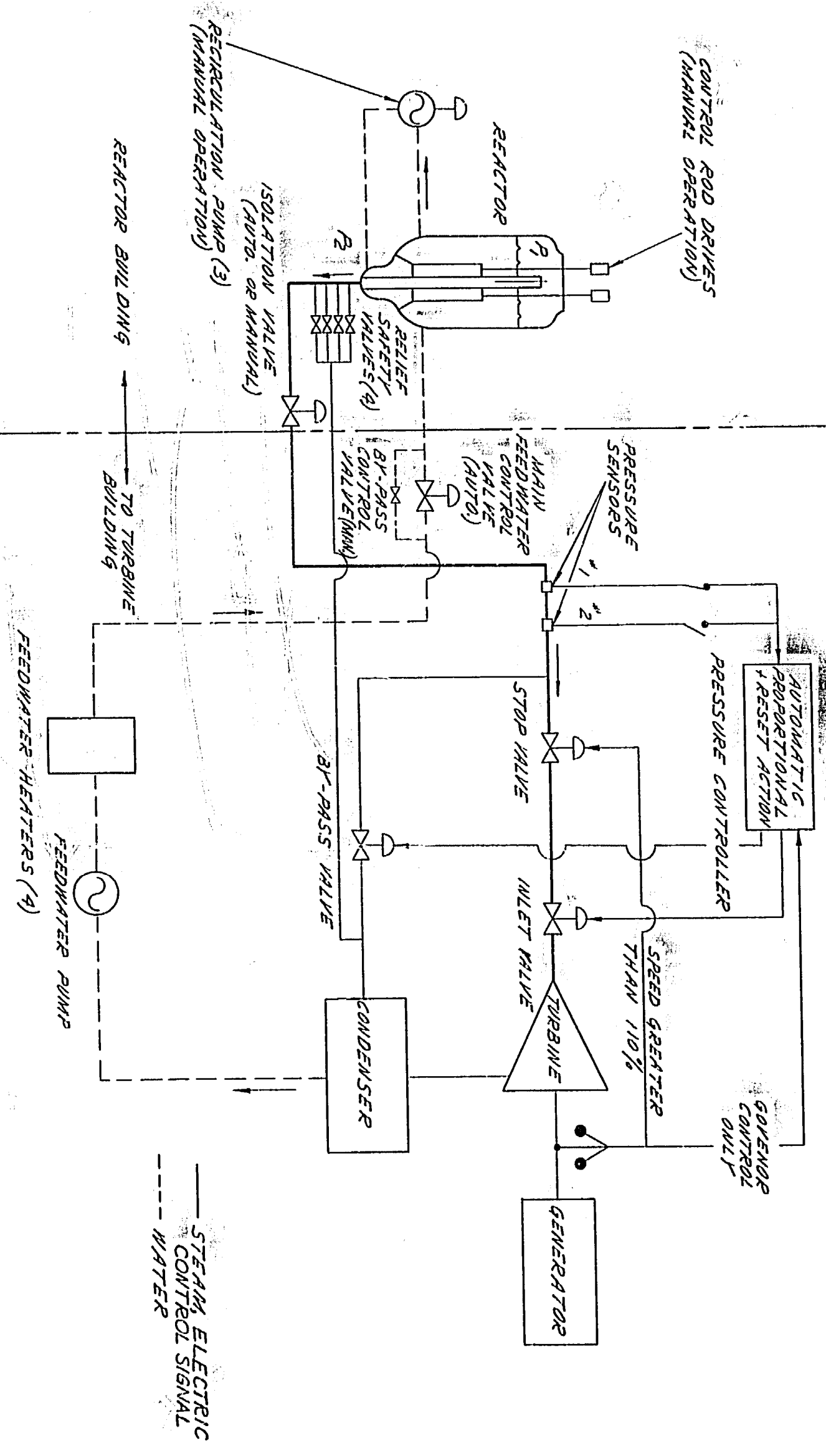
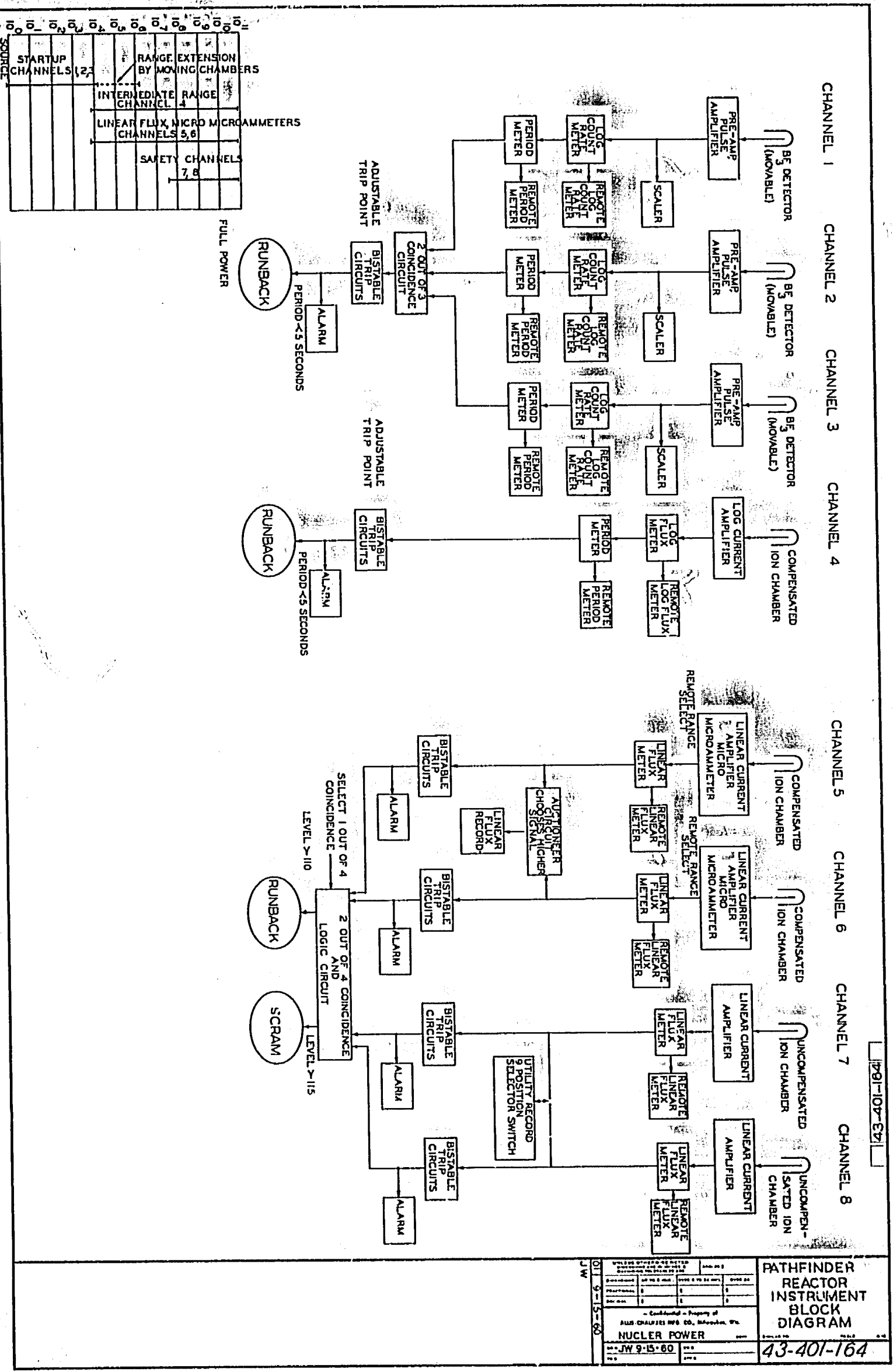


FIG. 2.17
October 31, 1960



PATHFINDER REACTOR INSTRUMENT BLOCK DIAGRAM

Section 4

SHIELDING

4.1 General Considerations

The criteria used in designing the shielding for the Pathfinder Plant conforms to accepted practices and standards for permissible radiation levels to which personnel can be exposed. Radiation levels meet the requirements of 10 CFR Part 20 including amendments as published in the Federal Register for September 7, 1960 (F.R. Doc. 60-8211). In the design of the plant, provisions are made for adding supplemental shielding if this should become necessary after the plant has been placed in operation.

The majority of the shielding calculations for Pathfinder were done with computer programs for the IBM 704. The program most often used employs cylindrical source geometry. The code requires an IBM 704 having 8,192 words of magnetic core memory. It has the following capabilities: It can handle up to 120 different regions, up to ten different materials, up to 10 gamma ray energy groups, and various combinations of materials in each region. The point to point gamma attenuation function in the program is,

$$D_s = \sum_{j=1}^J \frac{CK(E_j)\Gamma(E_j)}{4\pi} \int_{z_1}^{z_u} S(z_s) dz_s \int_{R_1}^{R_u} S(R_s) R_s dR_s \int_{\phi_1}^{\phi_u} \frac{\Psi[\Sigma_m(E_j)\theta_m, E_j, \rho]}{\rho^2} d\phi_s$$

$$S(z_s) = \gamma_1 \exp^{\gamma(z_s - \gamma_3)} + \gamma_4 = E_1 \cos E_2 (z_s - E_3) + E_4$$

(4.1)

$S(R_s)$ has the same forms as the axial distributions

$$\gamma[\Sigma_m(E_j), \theta_m, E_j, \rho] = B[\Sigma_m(E_j), \theta_m, \rho] \exp\left[-\rho \sum_{m=1}^M \theta_m \Sigma_m(E_j)\right]$$

$C(E_j)$ - conversion factor from flux to dose

$\Gamma(E_j)$ - gamma source term

$S(z_s)$ - axial source distribution

$S(R_s)$ - radial source distribution

$B[\Sigma_m(E_j), \theta_m, \rho]$ - linear buildup factor

The point to point fast neutron attenuation function in the program is, $D_n = \frac{C}{4\pi} \int_{z_1}^{z_u} S(z_s) dz_s \int_{R_1}^{R_u} S(R_s) R_s dR_s \int_{\phi_1}^{\phi_u} \frac{\gamma(\Sigma_m, \theta_m, \rho) d\phi_s}{\rho^2}$

$$\gamma_n(\Sigma_m, \theta_m, \rho) = \exp\left[-\rho \sum_{m=1}^M \theta_m \Sigma_m\right]$$

C - conversion factor from flux to dose.

The source is divided into many smaller volumes and each is assumed to be a point source to which the above equations are applied. The other shielding program uses the same attenuation calculations as described above. However it can handle more materials and regions. Also it provides for a rectangular source, a cylindrical source, or a series of point sources. This code requires an IBM 704 having 32,768 words of magnetic core memory and so was only used when required. In addition to the above computer codes some calculations were done by hand.

Some of the constants used in the shielding calculations are tabulated below.

Table 4.1 Fast Neutron Removal Cross-Sections

Material	Σ_R CM ⁻¹
H ₂ O	.103
Fe	.17
Pb	.117
Concrete	.09
Al	.08
UO ₂	.17
Zr	.16

Table 4.2

Total Gamma Absorptions Coefficients in CM⁻¹ for Various Materials

E(MEV)	$\mu_o(UO_2)$	$\mu_o(iron)$	$\mu_o(Lead)$	$\mu_o(Al)$	$\mu_o(Water)$	$\mu_o(Air)$	$\mu_o(Concrete)$
.1		3.06	---	.46	.165		
.3		.86	6.02	.28	.115		.254
.6		.59	1.48	.21	.09		.180
.8		.52	1.02	.19	.079		.165
1	.789	.46	.82	.17	.07	8.26×10^{-5}	.15
2	.466	.32	.51	.12	.05		.105
3		.28	.48	.096	.04		.086
4	.423	.26	.48	.084	.034		.076
6	.444	.24	.50	.073	.027		.065
7.3	.441	.24	.52	.068	.025		.062
8		.24	.53	.066	.024		.060
10		.24	.57	.062	.021		

Table 4.3

Gamma Energy Absorption Coefficients in CM⁻¹ for Various Materials

<u>E (MEV)</u>	<u>μ_a (Iron)</u>	<u>μ_a (Lead)</u>	<u>μ_a (Al)</u>	<u>μ_a (Water)</u>
.1	2.2	---	.12	.025
.3	.29	5.22	.078	.032
.6	.22	.96	.078	.033
.8	.21	.66	.076	.032
1	.20	.51	.073	.031
2	.165	.33	.059	.026
4	.175	.36	.054	.021
6	.18	.42	.051	.0185
7.3	.185			
8	.19	.48	.050	.017
10	.20	.52	.049	.016

Table 4.4

Linear Buildup $Bd = 1 + k\mu_0 r$

Used in Shielding Codes

Where $k = \frac{\mu_0 - \mu_a}{\mu_a}$

<u>E (MEV)</u>	<u>K (Iron)</u>	<u>K (Lead)</u>	<u>K (Al)</u>	<u>K (Water)</u>
.1	.39	---	2.8	5.6
.3	1.97	.15	2.6	2.6
.6	1.68	.54	1.7	1.64
.8	1.48	.55	1.5	1.41
1	1.30	.61	1.33	1.26
2	.94	.55	1.03	.92

Table 4.4 (Cont.)

E(MEV)	K(Iron)	K(Lead)	K(Al)	K(Water)
3	.61	.38	.67	.70
4	.49	.31	.56	.62
6	.33	.17	.43	.46
7.3	.30	.167	.28	.43

4.2 Reactor Building

The reactor vessel is located in a concrete cavity formed by the biological shield. This shield is about 10 feet thick. Between the shield and the vessel is a clearance of about one foot. The shield will be cooled by circulated air. Penetrations in the shield are provided for reactor instrumentation, the recirculation loops and steam and feedwater lines in the lower part of the cavity.

Above the reactor a pool of water 18 feet deep, with its bottom insulated from the reactor cover, will provide necessary shielding at the top of the reactor.

External to the biological shield, the lowest level of the reactor building is divided into five shielded compartments. Three of the compartments each contain a recirculation pump. One compartment will contain sump pumps and the remaining one the steam line and reactor shutdown pump. The top of each compartment is covered by a 2 foot concrete floor, thereby shielding the rest of the building from radiation. The recirculation pumps will be shielded from each other by

2 foot concrete walls facilitating limited maintenance of a pump without shutting down the plant

The main sources of radiation in the reactor building are the primary and secondary gammas in the core, and the capture gammas produced by the (n,γ) reaction in the various shielding materials surrounding the core. Near the recirculation pumps, plateout of crud on the pumps and pipes, the N^{16} in the water itself and the N^{16} in the main steam line were also considered as sources of activity. The active isotopes in the crud are as follows:

Table 4.5

Isotope	Energy of γ	T _{1/2}
Fe ⁵⁹	1.0	45d
Co ⁶⁰	1.0	5.28Y
Mn ⁵⁶	1.0 and 2.0	2.59H
Cr ⁵¹	0.3	26d
Zr ⁹⁵	0.75	65d
Zr ⁹⁷	0.7 and 1.40	17H
Ni ⁶⁵	1.5	2.56H

All active isotopes were assumed to reach maximum activity before eroding from the core and plating out on the recirculation pump surfaces. Other crud originating out-of-core was not considered, as it was assumed to make only one pass through the core before being removed by the purification system, and therefore was much less active than in-core crud.

4.3 Turbine Building

The primary source of radiation in the turbine building is the

N^{16} carried by the steam. Radioactive equipment in this building is grouped together, where possible, and shielded as a unit. Access to these areas during reactor operation is prohibited. All doorways to these areas are protected by shadow shielding. Wherever possible, structural members of the building such as walls and floors are used as shielding. In addition to the above mentioned areas, access to the area above the feedwater heaters and main steam line on the operating floor is also restricted during plant operation.

Due to the short half life of N^{16} all areas in the turbine building are accessible shortly after shutdown.

4.4 Fuel Handling Building

The purification and waste disposal systems are located in this building. The primary source of radiation here is the crud carried by the water. The active isotopes in the crud are the same as those given for the reactor building. Also the same assumptions apply here as to the origin of the crud as in the reactor building. The fuel storage pool is centrally located in the building. Most of the other components in the building are grouped around the pool to take advantage of the partial shielding the pool affords. Each of the components grouped around the pool walls are shielded separately, permitting maintenance of one component without shutting down the others.

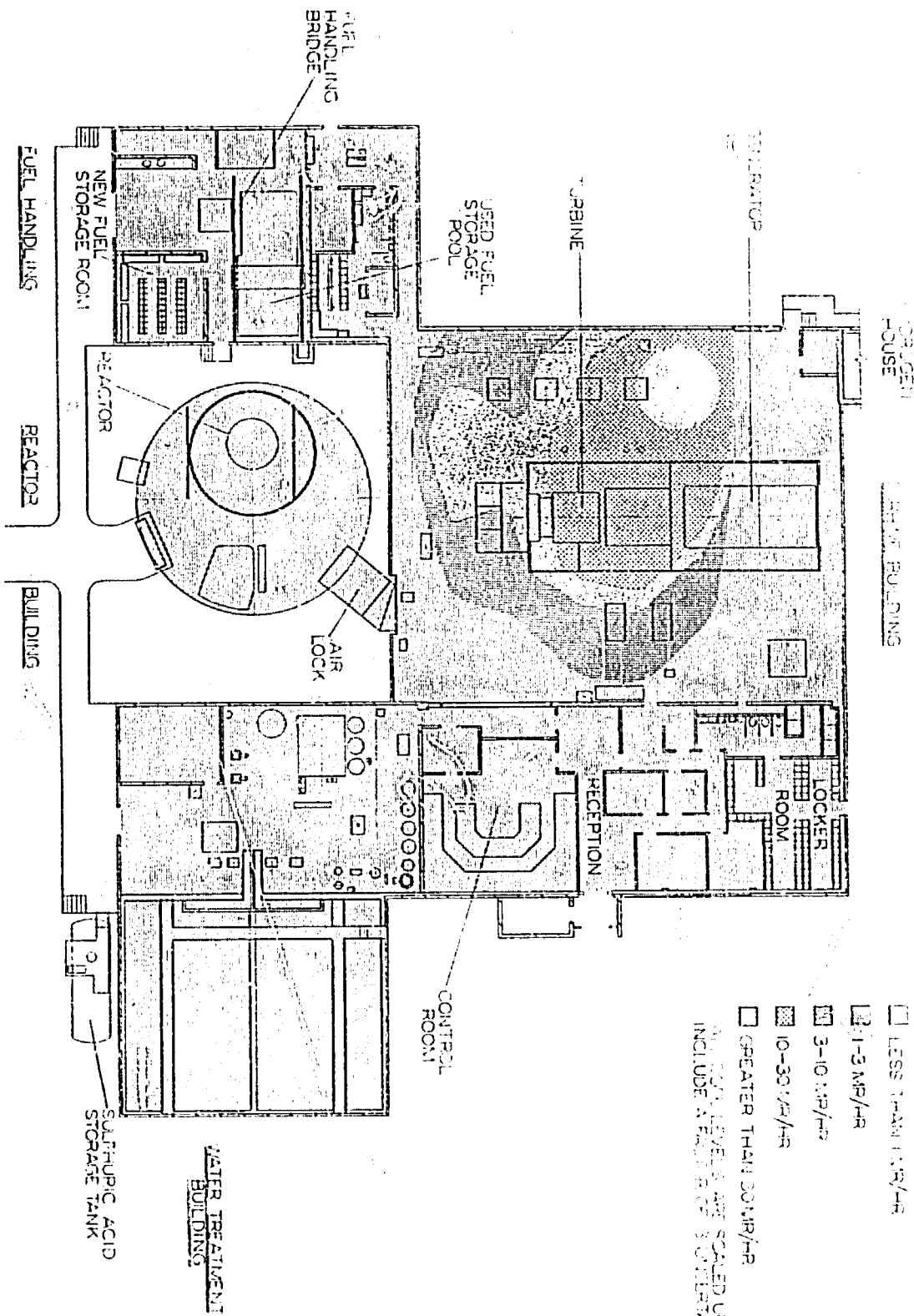
4.5 Dose Levels, Pathfinder

In figures 4.1, 4.2 and 4.3 the radiation levels are given for Pathfinder buildings. Figure 4.4 gives the gamma dose rate in R/HR and

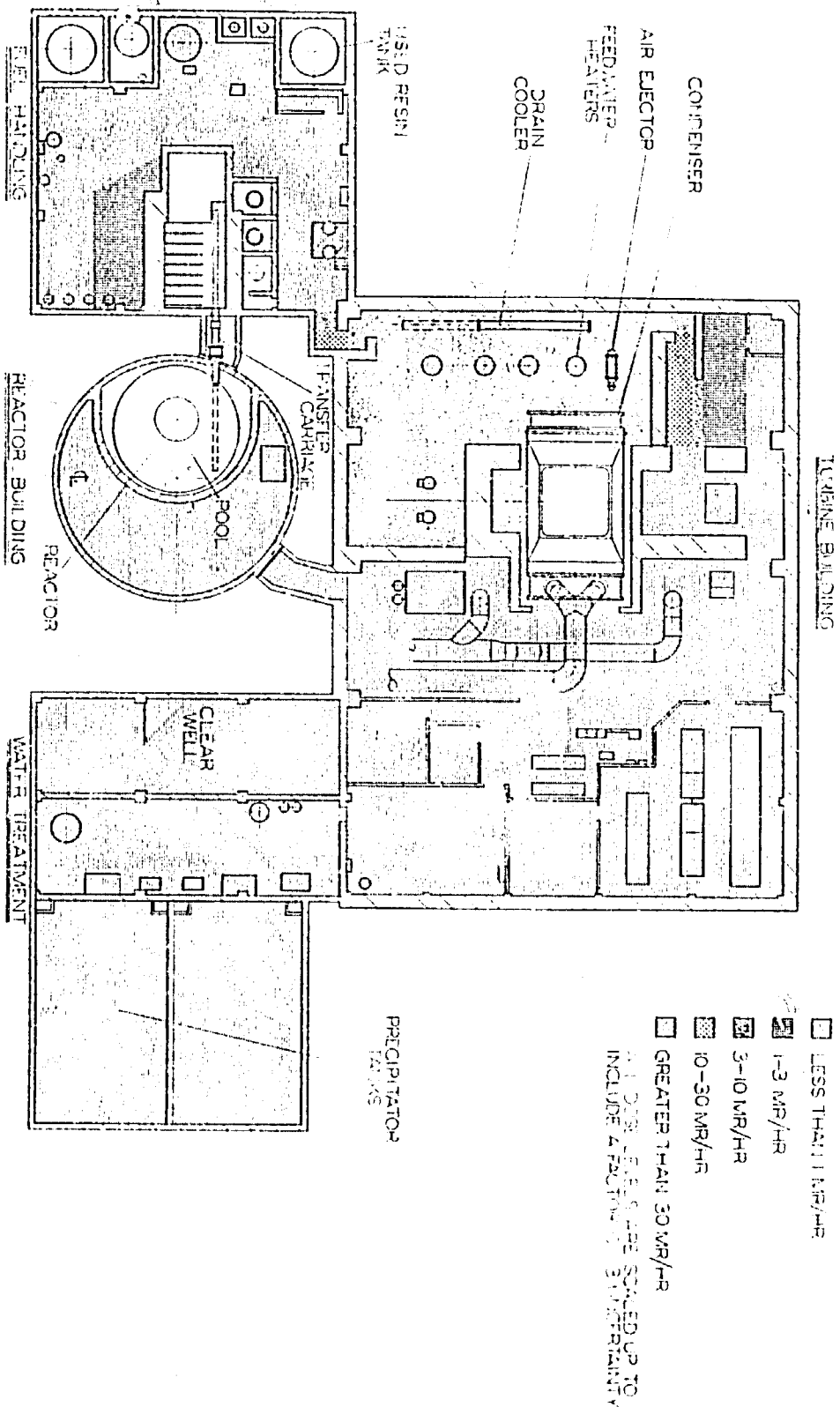
the fast and thermal neutron flux in n/cm^2 -sec radially from the core along the horizontal centerline.

The dose levels in the area around the circulation pumps (not shown in the figures) is 0.5 - 30 R/hr. All areas having dose levels greater than 30 mR/hr are restricted during reactor operation. The dose levels given above and those shown in the figures 4.1, 4.2 and 4.3 are totals from all sources of activity increased by a factor of 3 to account for uncertainties in the calculation of activities. The gamma dose rate and the fast and thermal fluxes are increased by a factor of 2 to account for uncertainties.

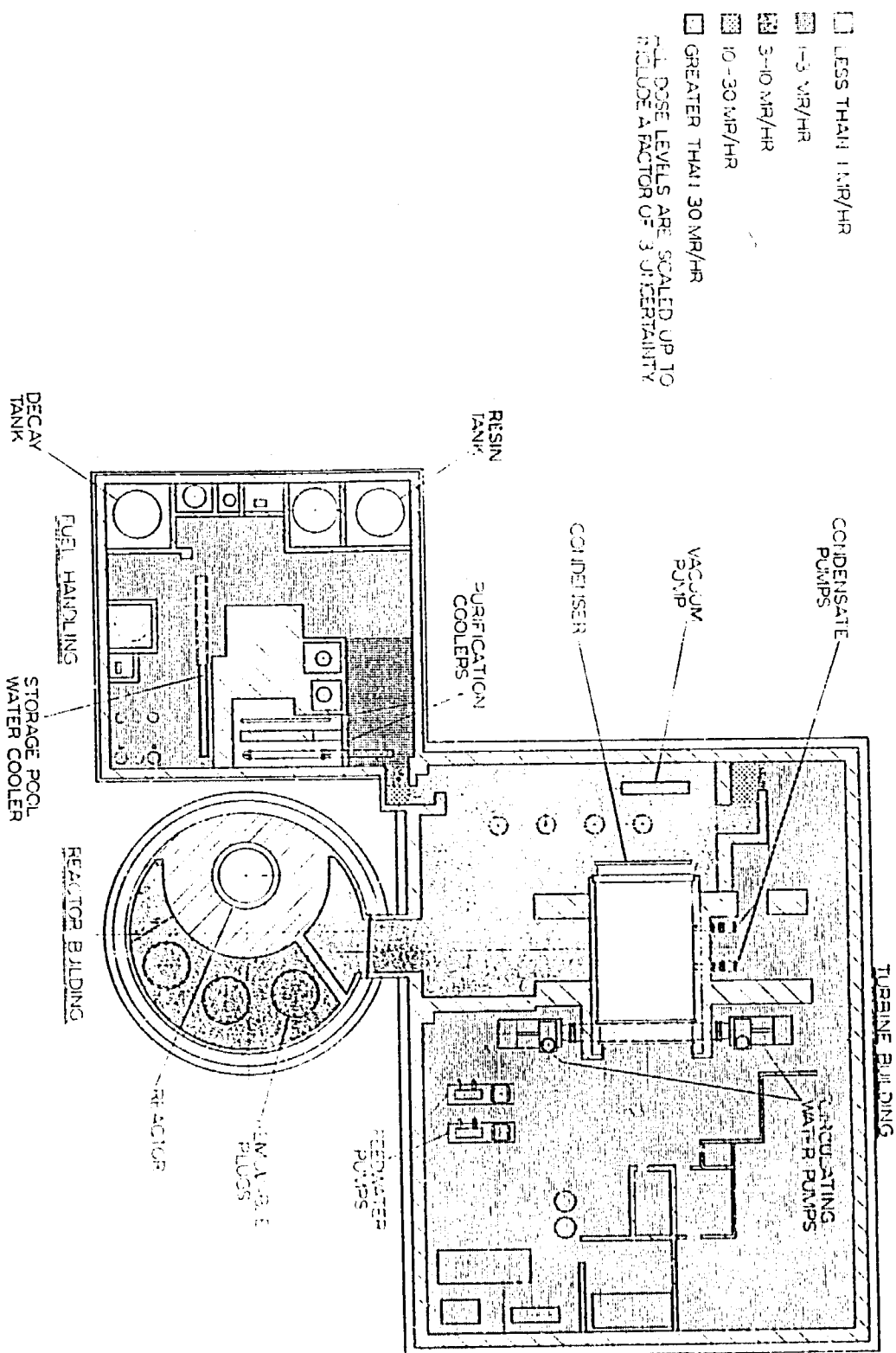
PATHFINDER PLANT DOSE RATES (OPERATING FLOOR)



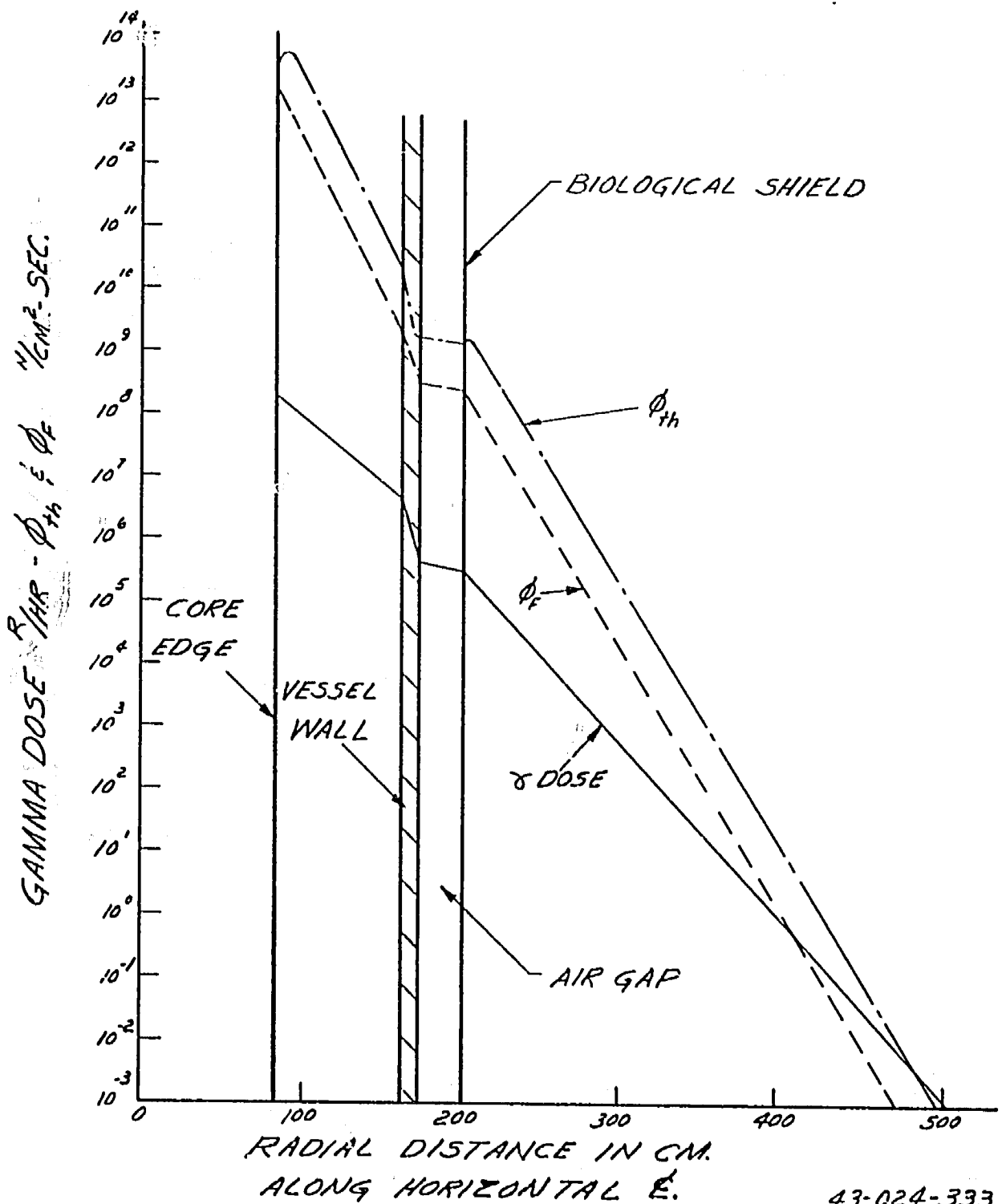
PATHFINDER PLANT DOSE RATES (MEZZANINE FLOOR)



PATHFINDER PLANT DOSE RATES (BASEMENT FLOOR)



GAMMA DOSE AND FAST THERMAL NEUTRON FLUX RADIALLY FROM CORE



43-024-333

GAMMA DOSE RATE AND FAST AND THERMAL NEUTRON FLUX
RADIALLY FROM THE CORE

FIG. 4.4
October 31, 1960

Section 5

TRANSIENT DYNAMICS ANALYSIS

As referred to here, system dynamics includes all the time-varying characteristics of the system, either normal or abnormal, with the exception of those incidents classified as postulated accidents. Because of the complexity and non-linearity of the system, most of the calculations of the dynamic characteristics are done on an analog simulator.

The accuracy of the results presented here depends on the validity of the theoretical system model, and the accuracy of the parameters used. The model used for Pathfinder was checked with the dynamic experimental data available from the EBWR and other reactors with good agreement, hence considerable confidence is placed in it. As the design progresses, more refined values of the parameters become available, and those parameters used that are still uncertain will be changed as better information is obtained. Therefore some revisions of the results presented here can be expected, although these results are considered a good approximation of the reactor performance.

So that the reader might form his own opinion of the validity of these results, a simplified derivation of the simulator, both qualitative and quantitative, is given in Subsection 5.1. Based largely on this model, the stability and transient evaluations of the system are given in Subsections 5.2 and 5.3 respectively.

5.1 General Description of Pathfinder Transient Simulator

The integro-differential equations describing the transient performance of the Pathfinder reactor and the turbine and associated control system have been programmed on an Electronic Associates Analog

Computer (Pace 231-R). The assembly of the overall system is referred to as the Pathfinder Transient Simulator. The system model is valid if the reactor is:

- (1) Light water cooled and moderated.
- (2) Near critical.
- (3) Pressurized between 400 psia and 800 psia.
- (4) The boiling water type.
- (5) Assumed to be a point reactor, i.e. only the time variation of the neutron population is considered, not the distribution of the neutron population.

The simulator has been used to:

- (1) Help design and analyze reactor system controls.
- (2) Compute results of postulated accidents or operating errors.
- (3) Help establish operating and startup-shutdown procedures.
- (4) Predict system stability.
- (5) Show the effects of varying such parameters as power, pressure, void coefficients, and controller constants on transient response.

Reactor Kinetics:

A simplified block diagram of the simulator is shown in Figure 5.1. The "Reactor Kinetics" block represents the neutron kinetics equations with six delayed neutron groups. The average neutron population is simulated since a point reactor model is being used. It was also assumed that because of the close nuclear coupling of the Pathfinder core that the superheater section neutron kinetics are identical to the boiling section neutron kinetics.

Boiler Heat Transfer:

The "Boiler Heat Transfer" represents the thermal lag in transferring heat from the fuel element. The heat capacity of the Zircaloy cladding was neglected with respect to that of the uranium dioxide, and only its thermal resistance is considered. An overall heat transfer coefficient from the edge of the fuel pellet to the coolant channel was used, and a method of analysis similar to that of Iriarte¹ was employed. This heat transfer coefficient was approximated as 2100 Btu/sec F ft², the pellet density used is 635 lbs/ft³, the specific heat 0.073 Btu/lb F., and the thermal conductivity was assumed at 0.9 Btu/sec F ft. Using the basic equations of Iriarte, the fuel element time constants were derived as general functions of the fuel parameters and plotted in Figure 5.2. Remembering that about 3% of the power is gamma heating and appears immediately in the coolant channel, the resultant transfer function becomes:

$$\frac{\dot{Q}_B}{n} = \frac{.766}{1+6.15s} + \frac{.144}{1+1.25s} + \frac{.06}{1+.48s} + .03$$

(for definition of symbols refer to Figure 5.1)

Vessel Energy Balance:

A control volume is considered whose boundary is the interface between the water that can be considered saturated and that considered subcooled, and which contains the core and all saturated water and steam.

-
1. "An Accurate Transfer Function for the Dynamic Analysis of the Temperature and Heat Release in Cylindrical Fuel Elements", by Modesto Iriarte; "Nuclear Science & Engineering", Vol. 7, No.1, p. 26, Jan. 1960.

The assumption is made that its boundaries remain constant. The energy balance of this volume is:

$$\dot{Q}_B - \Delta h W_C - h_{fg} W_S = \frac{d}{dt} \left[M_f U_f + M_s U_s \right]$$

which is the basic equation simulated.

$\Delta h W_C$ is power required to bring the core inlet water to saturated temperature.

$h_{fg} W_S$ is power required to vaporize the escaping steam.

$M_f U_f$ is internal energy of saturated water.

$M_s U_s$ is internal energy of saturated steam.

It can be shown that the rate of change of pressure is proportional to the left side of the equation through a constant dependent on the saturated masses and operating pressure. The most arbitrary constant is the mass of water considered saturated. It has been assumed that about 40% of the total primary water can be considered saturated.

Steam System:

The "Steam System" describes the relationship of steam flow rate, pressures at reactor and turbine, (P_1 and P_2), resistance of superheater and steam line, and positions of turbine inlet valves and by-pass valve (S_C and S_B). The compressibility of steam is approximated by means of a simple lag transfer function ($\tau = 0.106$ sec.).

Superheater Heat Transfer:

The "Superheater Heat Transfer" block involves the time lag between heat generation in the annular stainless steel clad cermet fuel elements and the heat transferred to the steam coolant. The thermal transfer

function is a double lag approximation with time constants of 0.95 and 0.15 seconds, respectively. The heat transfer equations involve the relationship between steam flow rate (W_s), power developed in superheater (assumed to be 21% of total thermal reactor power) and the pressure at inlet and exit of the superheater. The heat transfer coefficient varies with steam flow and film temperature, and the specific heat of steam is simulated to vary with the steam temperature. The reactor has been designed for very little boiling of the superheater moderator; subsequently, the void reactivity coefficient has been assumed negligible. Since the temperature reactivity coefficient is also negligible, there is little reactivity feedback from the superheater. Hence this feedback path has not been included. The available output information of this block is:

- (1) Superheater hot spot cladding temperature.
- (2) Hot spot steam temperature.
- (3) Bulk average steam temperature at superheater exit.
- (4) Heat flux at hot spot.

The operating temperatures of the steam and fuel at the hot spot of the superheater (as in the boiler) are determined by applying hot spot factors to the power developed and heat transferred. The factors take account of the following effects:

- (1) Axial flux distribution.
- (2) Radial flux distribution.
- (3) Control rod flux perturbation.
- (4) Fuel uncertainty.

- (5) Flux uncertainty.
- (6) Steam flow uncertainty.
- (7) Heat transfer coefficient uncertainty.

The contributions of two separate hot spot factors comprise the total factor at a point. The bulk factors are applied to the heat absorbed by the steam up to a point (Integrating effect); while the film factors are applied to the heat flowing from fuel to steam at a point. For the present superheater configuration without an overpower factor, the bulk and film hot spot factors have been evaluated at 1.578 and 2.013, respectively, for the purpose of simulation. In the equations simulating the heat transfer in the hot channel, the average channel heat integrated to the hot spot is thus multiplied by 1.578. Similarly, the average channel heat flux is multiplied by 2.013 at the hot spot. Thus, the above hot spot factors are incorporated in the hot channel equations and are assumed to remain constant during a transient.

Control System:

The pressure control system, regulating steam line pressure, was simulated according to the schematic shown in Figure 2.17. The turbine trip, automatic run-back, dump valve control, pressure relief valves, and the isolation valve are included in the simulator. The pressure controller was set at what is considered the optimum gain and reset settings. The effect of the system is to position the turbine inlet valves, or the dump valve, according to steam line pressure error.

Doppler Effect:

The block labeled "Doppler Effect" relates negative reactivity

effects due to a rise in the boiler fuel element temperature. This is a fast acting feedback mechanism. The basic equation simulated here is:

$$\frac{d(\Delta K_D)}{dt} = \frac{1}{m_F C_F} \frac{\partial(\Delta K_D)}{\partial T_F} (P - \dot{Q}_B)$$

where P is the power generated in the boiler
 m_F is the mass of the fuel pellets
 C_F is the heat capacity of the fuel pellets.

Subcooling and Exit Steam Quality:

This part generates the subcooling at core inlet and the average weight per cent of steam at the core exit (X_E). Exit quality is a function of the following variables:

- (1) Heat appearing at surface of boiler fuel pins ($\dot{Q}_B$): An increase causes an increase in steam void volume and decreased reactivity.
- (2) Recirculation flow rate (W_R): If the coolant is forced at a higher rate through the core, steam volume will initially decrease but eventually settle out at approximately the initial value.
- (3) Subcooling (Δh): The larger the temperature difference between water entering the core and that of saturation, the shorter will be the active core boiling length, and the smaller the steam void volume. Reactor pressure, feedwater flow and temperature, and recirculation flow effect this temperature difference. The transport lag between the feedwater inlet and the core inlet was taken as about 6 seconds at rated flow.
- (4) Reactor pressure (P_I): Fluctuations in pressure cause

flashing (or condensation), and cause changes in subcooling and steam density. An increase in pressure causes a decrease in the steam volume in the core and consequently an increase in reactivity. The faster the pressure changes, the more severe the associated transient.

- (5) Steam flashing (and condensation): Formation of steam is proportional to the negative of pressure rate of change.
- (6) Steam density changes: A pressure compensation is applied to the simulated void volume.

Void Reactivity:

The "Steady-State Effects" generates the negative reactivity feedback caused by the presence of steam voids in the core. It can be described as a "steady-state" function of steam quality at the core exit (X_E), and the subcooling (Δh) at the core inlet combined with a simple transfer function. These curves are calculated from the physics and heat transfer characteristics of the core and are simulated on the analog computer by a function generator.

The output signal then feeds into the "transient effects" model involving the transient void distribution. A change in void concentration must be washed up through the core before its steady-state distribution is assumed. This complex transfer function is approximated by a simple lag with a time constant of 0.057 seconds (at rated flow).

Hydrodynamics:

The "Hydrodynamics" section generates the recirculation flow (W_W), which depends on the following:

- (1) Pump speed.
- (2) Core exit quality (X_E).
- (3) Butterfly valve positions in the three loops (0).

5.2 STABILITY

Thermal:

It can be seen from the system closed-loop transfer function in Figure 5.4 that no sharp peaks exist. In other words, the system is highly damped throughout this frequency range. The reason for this high degree of damping is the large thermal lag caused by the low thermal conductivity of the uranium dioxide fuel pellets. This makes it impossible for the heat flux at the fuel surface to change rapidly, presenting a strong "damping factor" to the system.

For the purpose of investigating core stability, the system model can be linearized and greatly simplified. The effect of the system external to the core can be approximated by a transfer function representing the effect of the heat capacity of the primary system:

$$\frac{s + \frac{1}{T} + (1-\gamma) \frac{M_f}{W}}{s + \frac{1}{T} + \frac{M_f}{W}}$$

Where W is recirculation mass flow rate.

γ is the ratio of the reactivity coefficient due to changes in subcooling to the reactivity coefficient due to changes in generated power.

T is the transport time through the portion of the recirculation loop composed of subcooled water.

The superheater can also be eliminated and the "Reactor Kinetics" approximated by a linearized, two-group transfer function. The resultant block diagram is shown in Figure 5.3. A comparison of the closed-loop function of this approximation and that of the reactor simulator is shown in Figure 5.4.

Operating:

It was found on the simulator that if the pressure control system were eliminated, or if its gain were drastically reduced, the power would have a tendency to drift due to reactor pressure variations. The rate of drift is slow enough as to be easily controlled by manual rod manipulations, but it makes it very desirable to include the automatic pressure control system.

Hydraulic:

Due to the high moderator velocities and the damping effect of the recirculating pumps, the question of hydraulic stability is not considered as limiting. Preliminary studies verify this. These studies are continuing.

Superheater:

The power coefficients of reactivity in the superheater can be considered negligible, therefore the superheater has no appreciable effect on stability.

5.3 SYSTEM TRANSIENT RESPONSE

A great many cases have been run on the reactor simulator representing both likely and unlikely operating modes and mishaps and the system has been found to be quite controllable. The response of all pertinent system variables has been recorded under these conditions. Since the simulator is always being refined, and more unusual operating conditions are being postulated, this work is still continuing. Some of the more representative and interesting cases have been selected and are presented here to demonstrate the system performance.

Control Rod Run-Out, Figure 5.5:

The most valuable control rod can add reactivity no faster than 5 cents/second. This maximum rate of reactivity addition was inserted for 10 seconds, resulting in a power increase of 10%.

Recirculation Pump Failure, Figure 5.6:

Because of isolation between power supplies, and interlocks preventing restarting of pumps after such a failure, the case in which all pumps lose power and restart in 5 seconds is purely academic, but it was run to gain an idea of the effect the pumps have on the system.

Turbine Trip, Figure 5.7:

Using the approximate turbine stop and dump valve characteristics, the turbine was tripped and the control system actuated the dump valve. The disturbance resulting from this quick change-over is shown.

Turbine Runback, Figure 5.8:

Some situations call for turbine runback rather than trip. In a turbine runback the inlet valves close, and dump valve opens in 0.6 seconds.

The valve characteristics and control system lag (.08 seconds) are included here.

Reactor Scram, Figure 5.9:

Accidental Bypass Valve Opening, Figure 5.10:

This accident occurs if the operator switches the pressure regulator system to "manual", and suddenly fully opens the dump valve, leaving the turbine inlet valves at their full-open position.

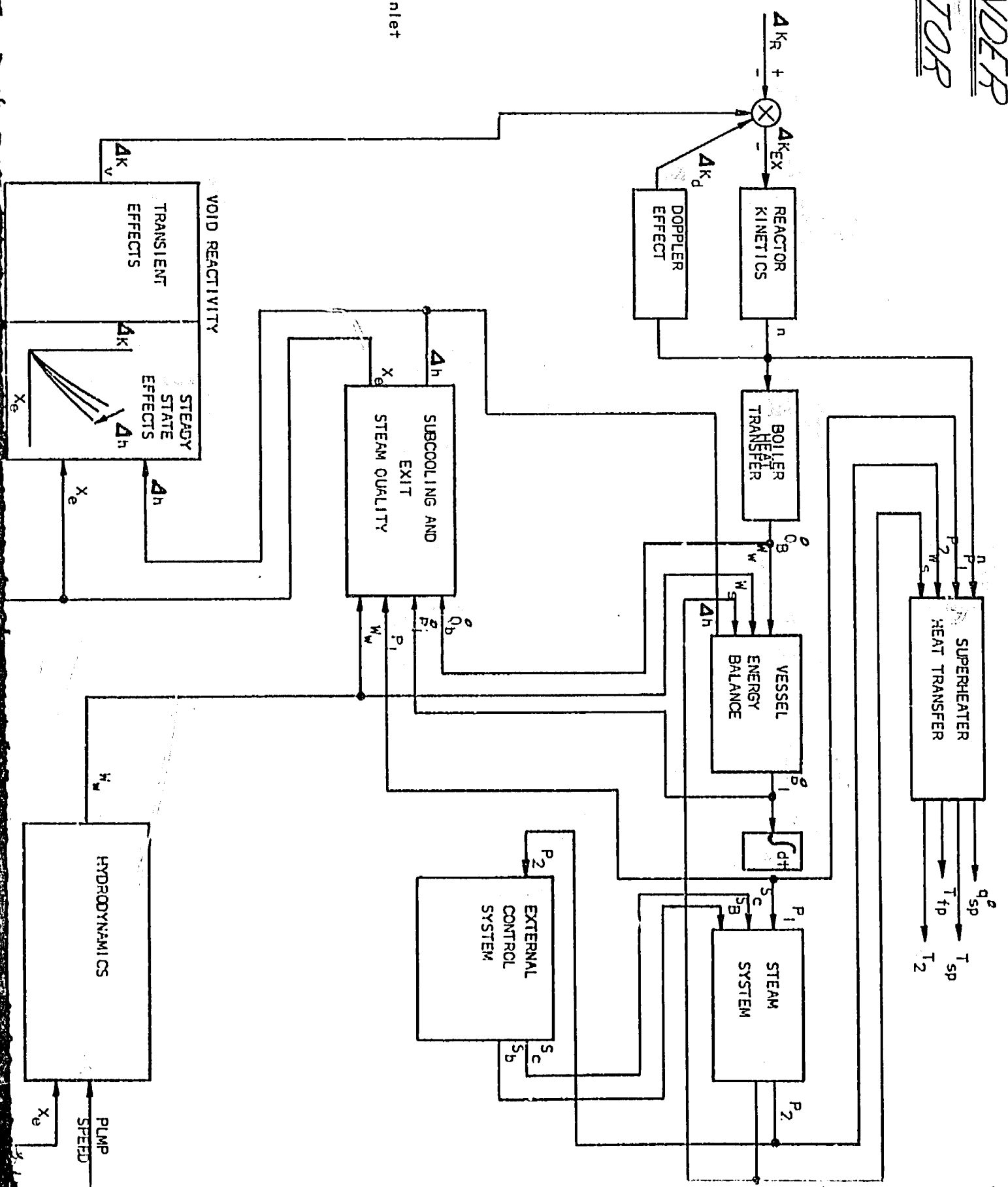
Isolation Valve Closure With No Scram Or Pressure Relief Valves, Figure 5.11:

This represents the fictitious condition that the radioactivity monitor causes the isolation valve to close, and the reactor fails to scram and the pressure relief valves fail to operate. With the reactor still producing power and no steam exiting, the reactor pressure and power rise very quickly. A simulation will be done in which the action of the pressure relief valves is included by means of relays.

The time for the isolation valve to close was 10 seconds, less than the expected actual time.

SIMPLIFIED PATHFINDER TRANSIENT SIMULATOR BLOCK DIAGRAM

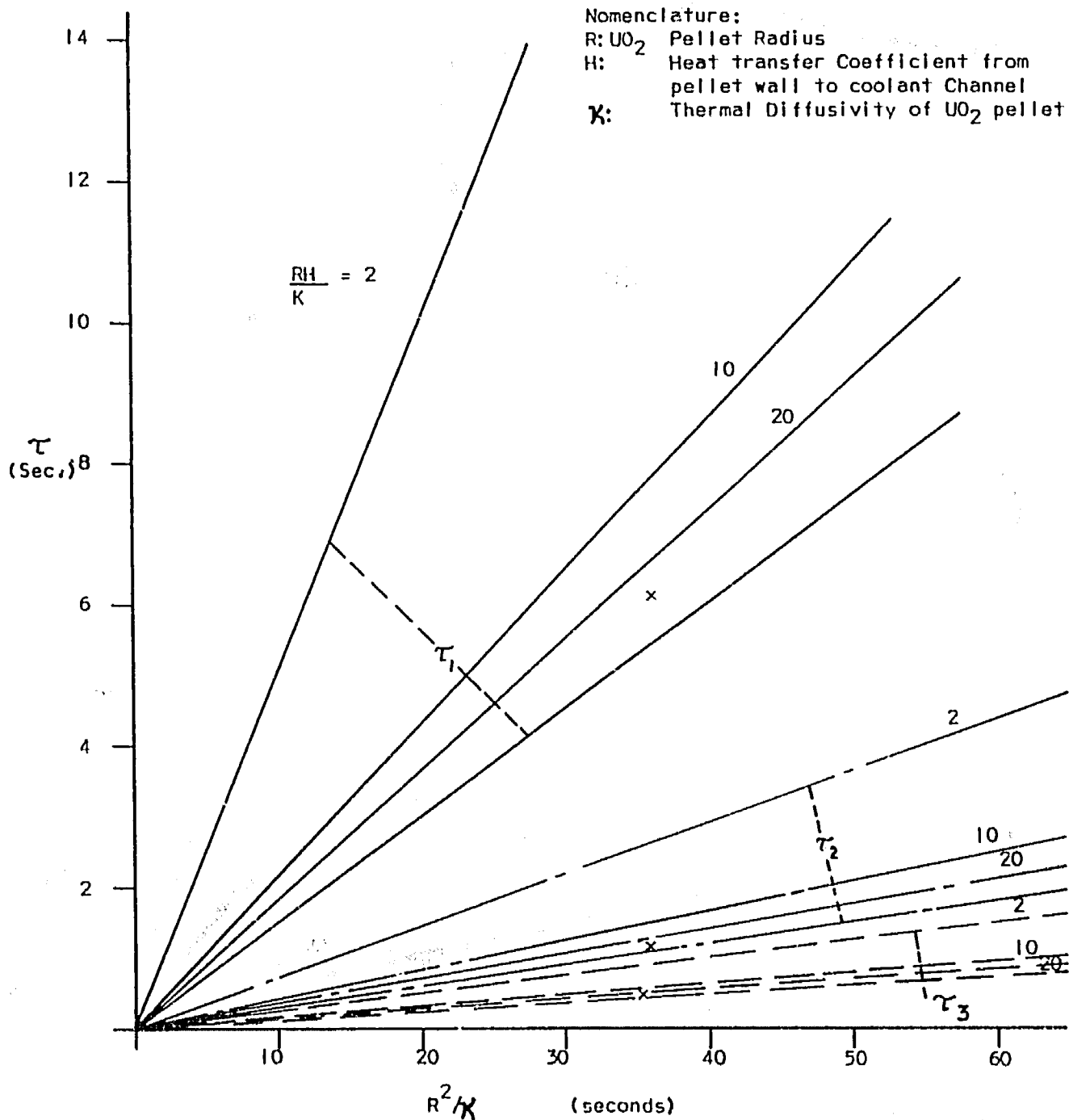
- ΔK_R - Reactivity in Control Rods
- ΔK_D - Reactivity Due to Doppler Effect
- ΔK_V - Reactivity in Voids
- ΔK_{EX} - Excess (Net) Reactivity
- n - Neutron Population
- $\dot{Q}_B$ - Heat Transfer Rate from Boiler
- $\dot{W}_S$ - Steam Flow Through Superheater
- $\dot{W}_W$ - Recirculation Rate Through Core
- Δh - Subcooling of Recirculating Water at Core Inlet
- P_1 - Reactor Dome Pressure
- $\dot{P}_1$ - Rate of Change of Reactor Pressure
- P_2 - Pressure at Superheater exit
- T_2 - Steam Temperature at Superheater Exit
- T_{SP} - Steam Temperature at Superheater Hot Spot
- T_{fp} - Fuel Surface Temperature at Hot Spot
- $\dot{q}_{sp}$ - Heat Flux at Hot Spot
- S_c - Capacity Coefficient of Turbine
- S_b - Capacity Coefficient of Bypass Valves
- X_e - Steam Quality at Core Exit



FUEL ELEMENT TIME CONSTANTS AS FUNCTIONS OF THE
THERMAL PROPERTIES OF THE ELEMENT

$$\frac{Q(s)}{n(s)} = \frac{0.79}{1+\tau_1 s} + \frac{0.15}{1+\tau_2 s} + \frac{0.06}{1+\tau_3 s}$$

(The values for Pathfinder are denoted by "x")

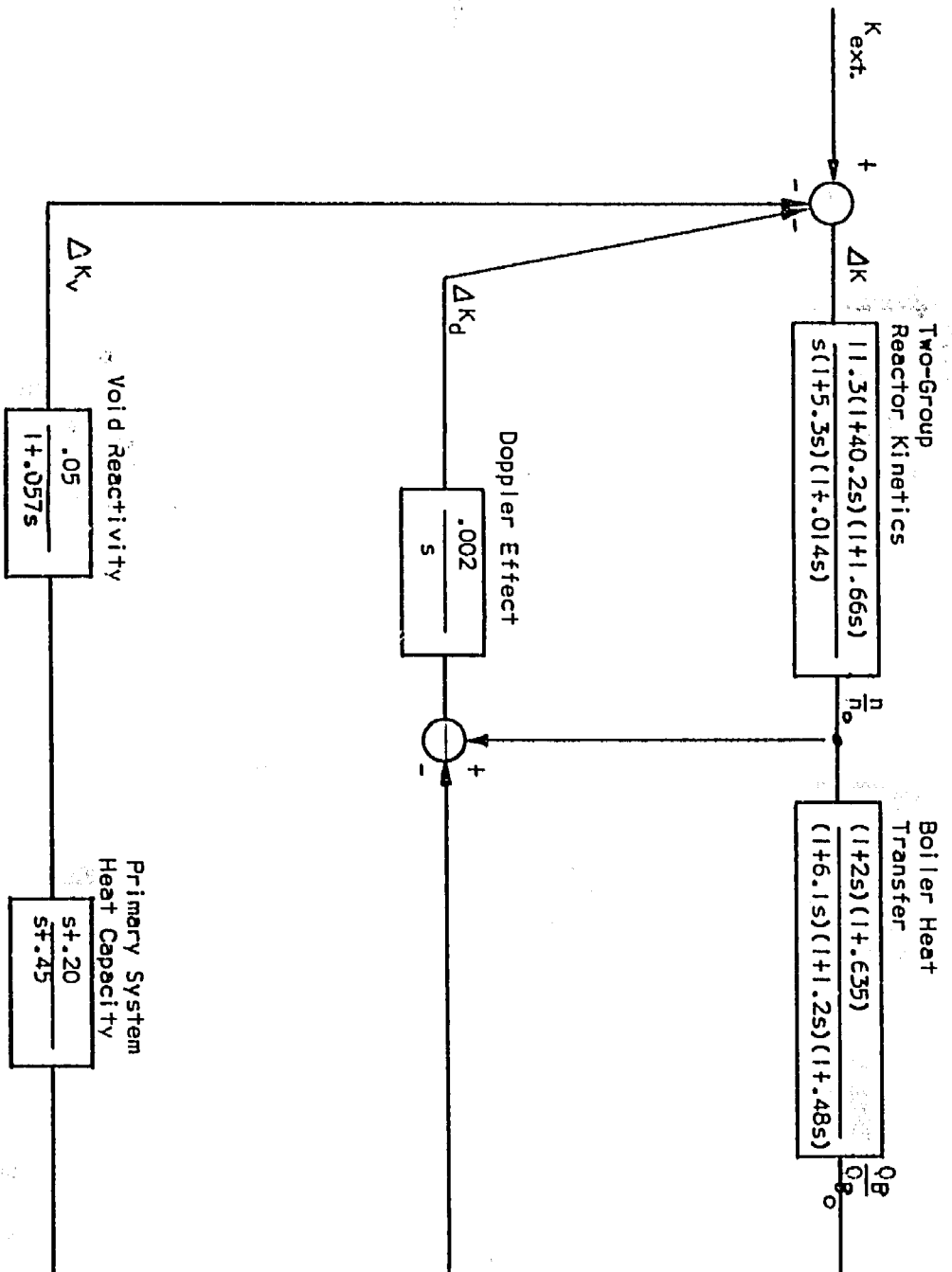


FUEL ELEMENT TIME CONSTANTS

FIG. 5.2

October 31, 1960

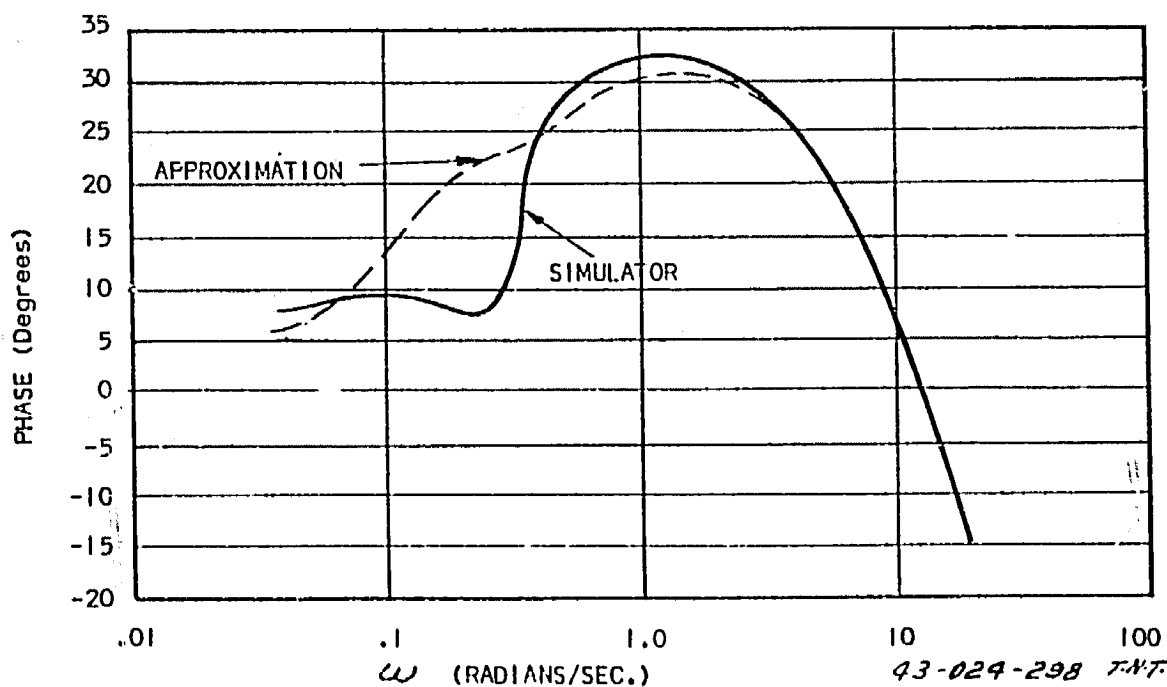
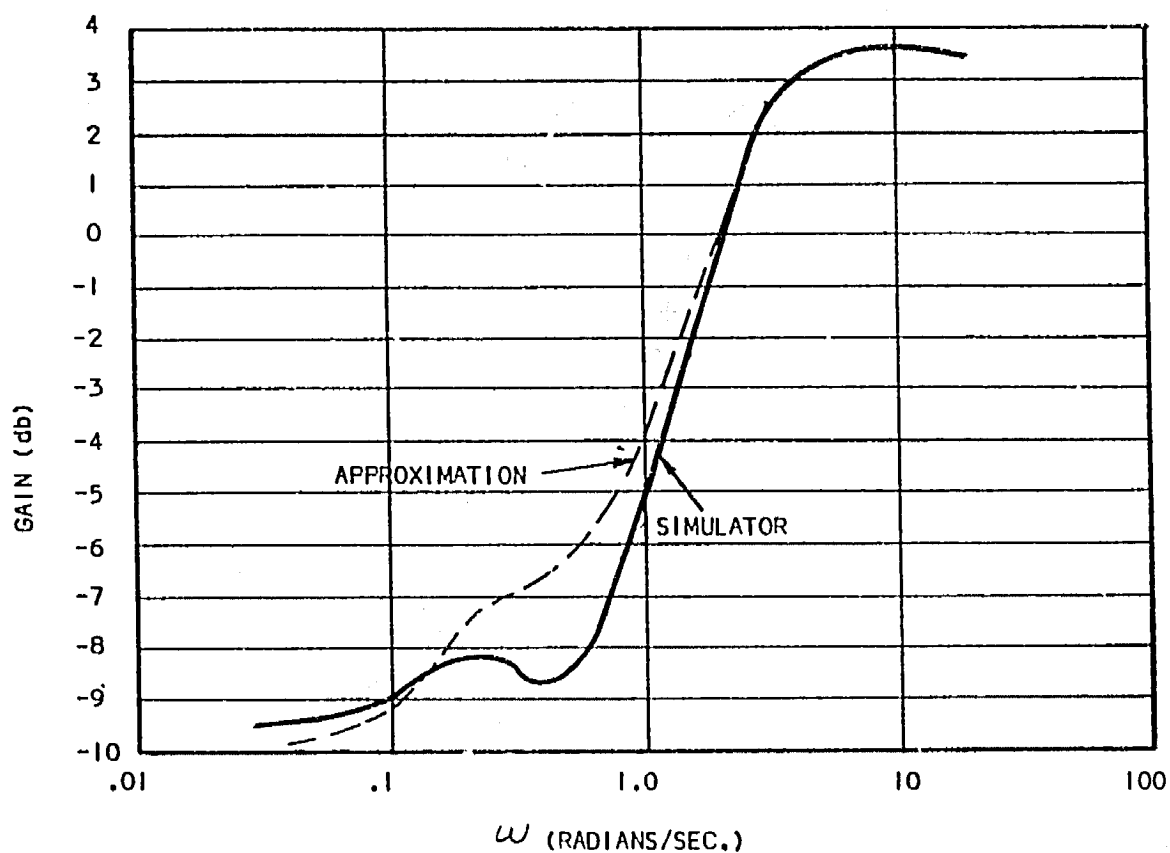
LINEARIZED BLOCK DIAGRAM OF REACTOR CORE DYNAMICS



43-024-296

FIG. 5.3
 LINEARIZED BLOCK DIAGRAM
 October 31, 1960

PATHFINDER CLOSED - LOOP FREQUENCY RESPONSE

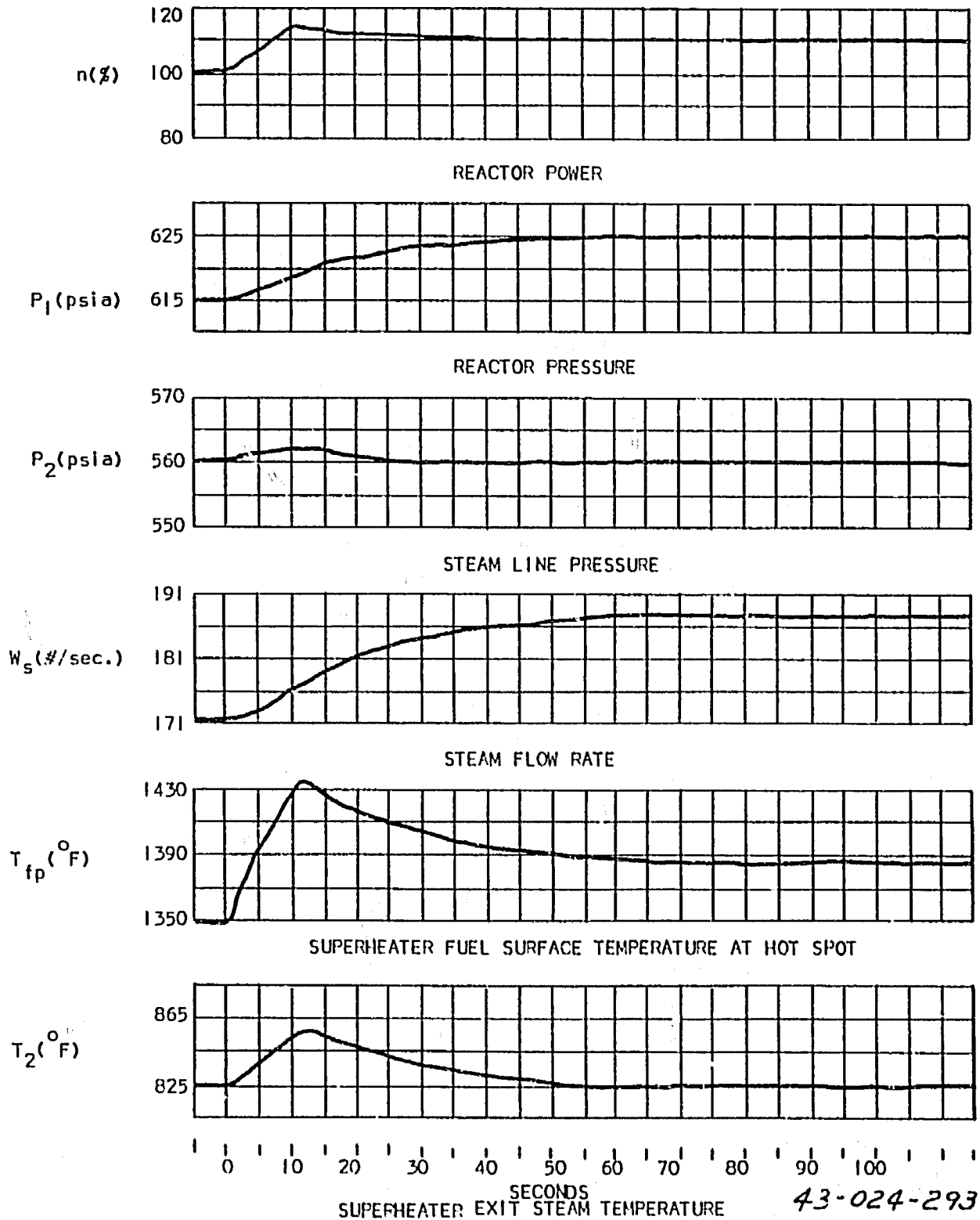


CLOSED-LOOP TRANSFER FUNCTION

FIG. 5.4
October 3, 1960

CONTROL ROD RUN-OUT

Operation at 100% power linear reactivity addition of 5¢/sec. for 10 sec. Total reactivity added 50.50



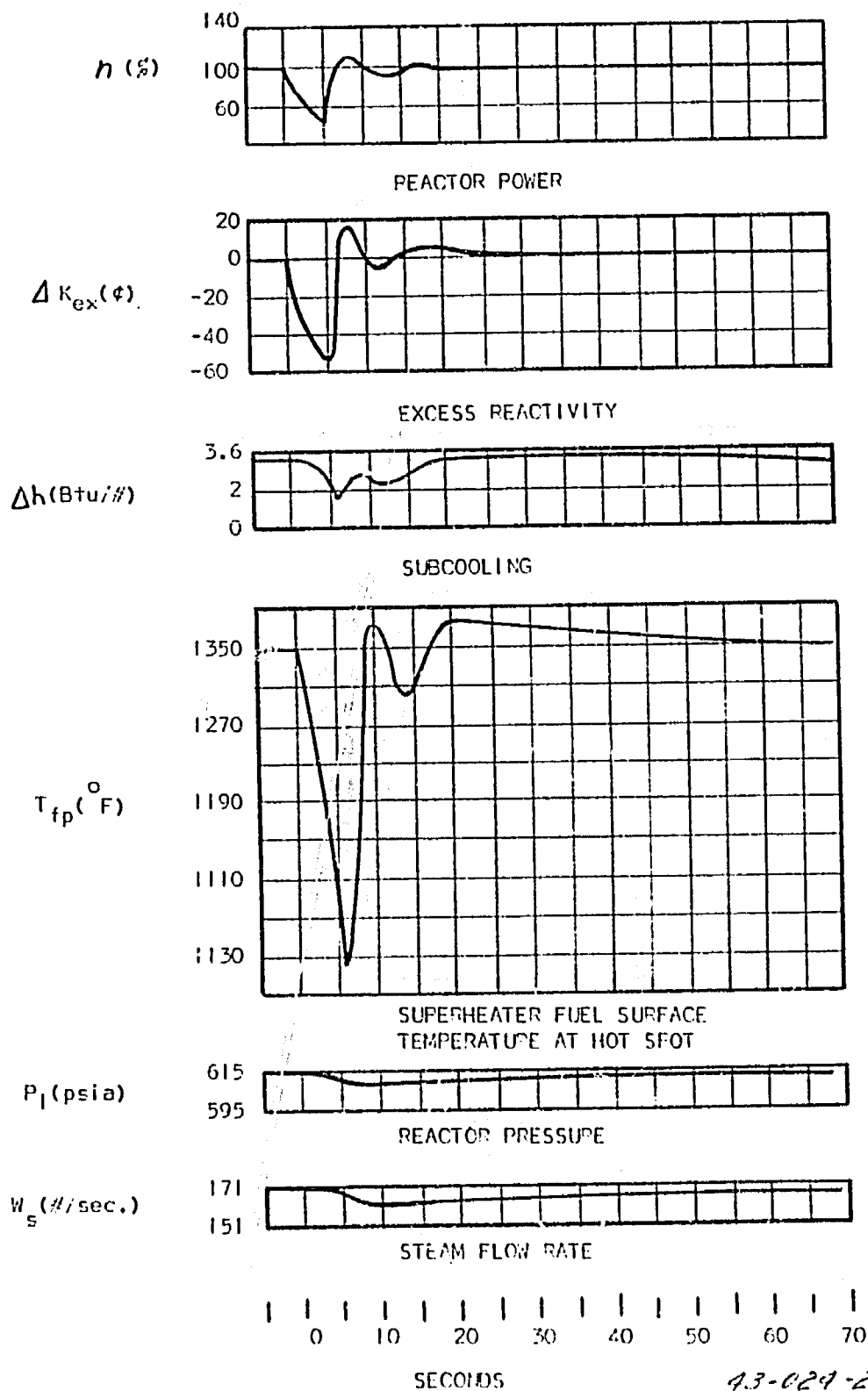
43-024-293

CONTROL ROD RUN-OUT

FIG. 5.5

October 31, 1960

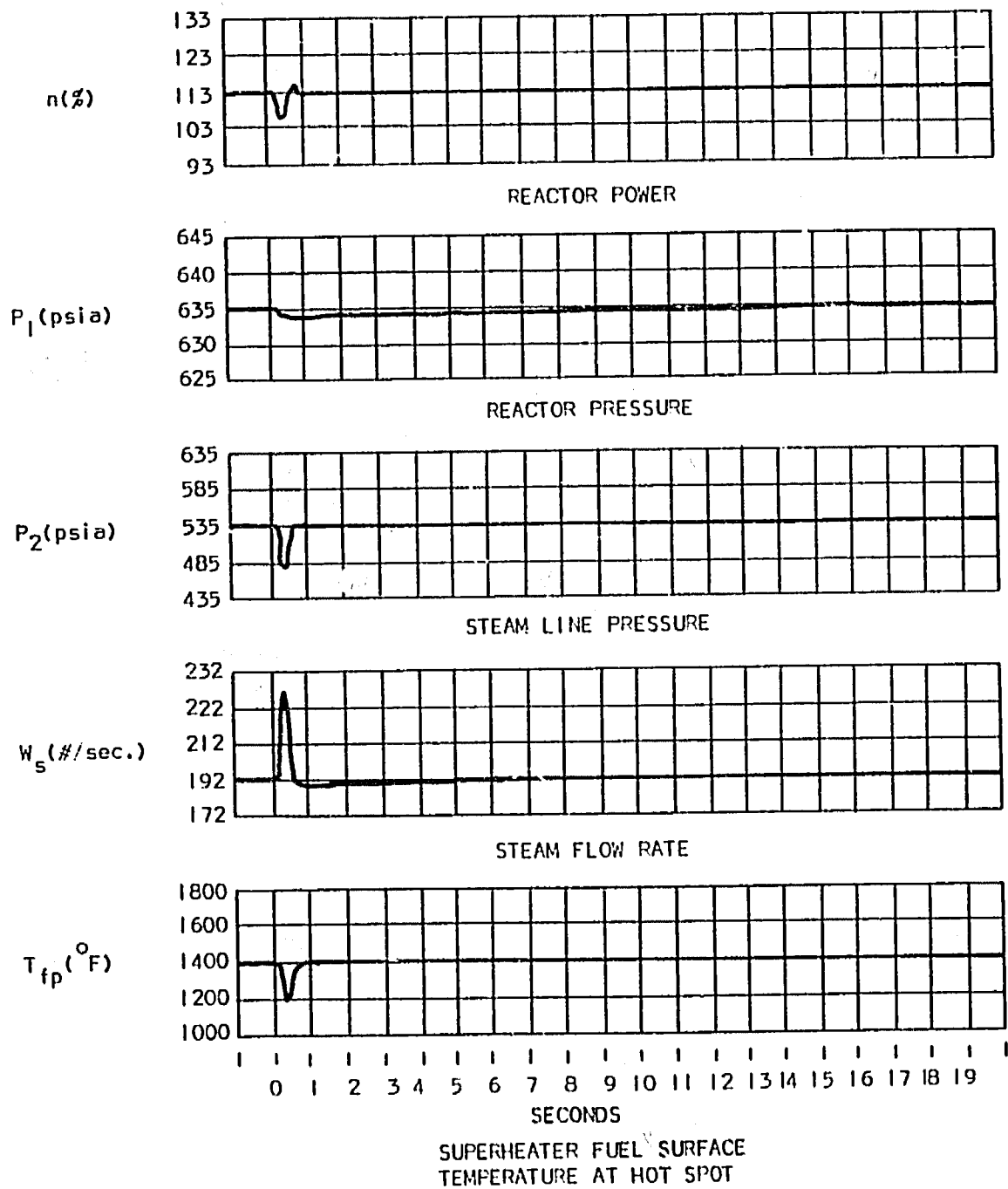
VOLTAGE LOSS TO ALL THREE RECIRCULATION PUMPS -
RESTART IN 5 SECONDS



RECIRCULATION PUMP FAILURE

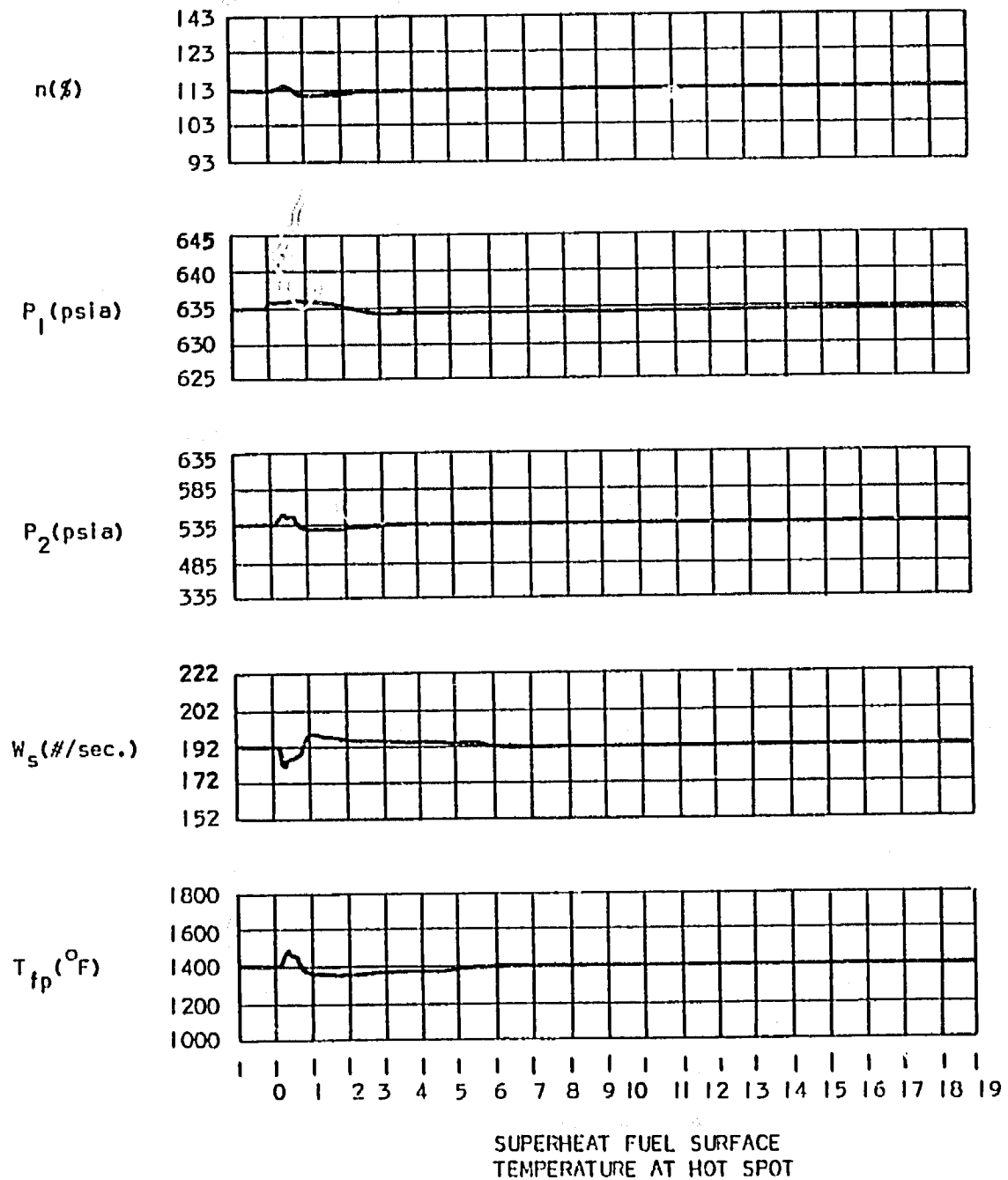
FIG. 5.6
October 31, 1960

TURBINE TRIP WHEN INLET VALVES ARE WIDE
OPEN - AUTOMATIC ACTUATION OF BY PASS VALVE



43-024-299

TURBINE INLET VALVE RUNBACK IN 0.6 SECONDS WHEN
THEY WERE WIDE OPEN - AUTOMATIC ACTUATION OF BYPASS
VALVE (LINEAR)

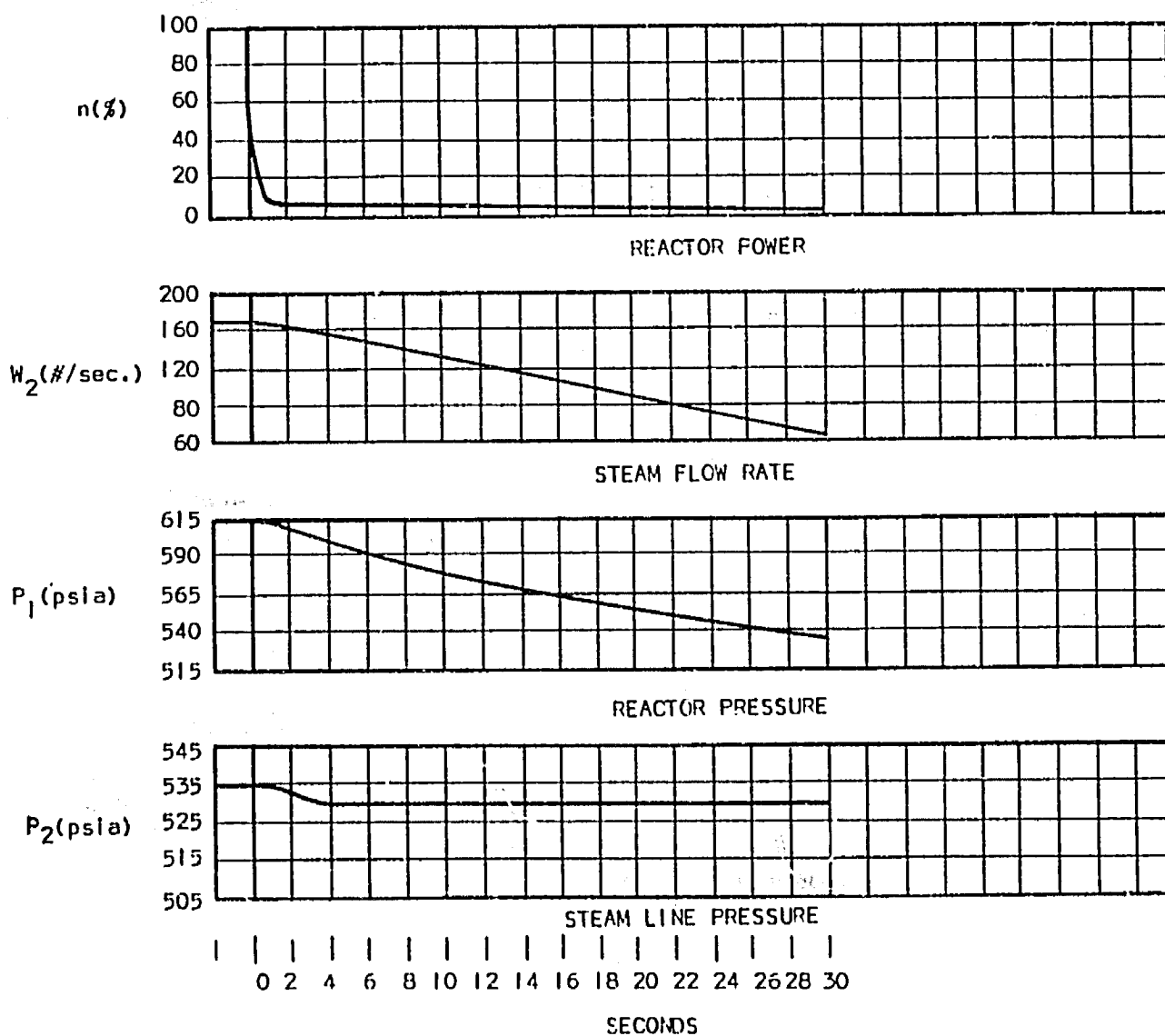


43-024-300

TURBINE RUN-BACK

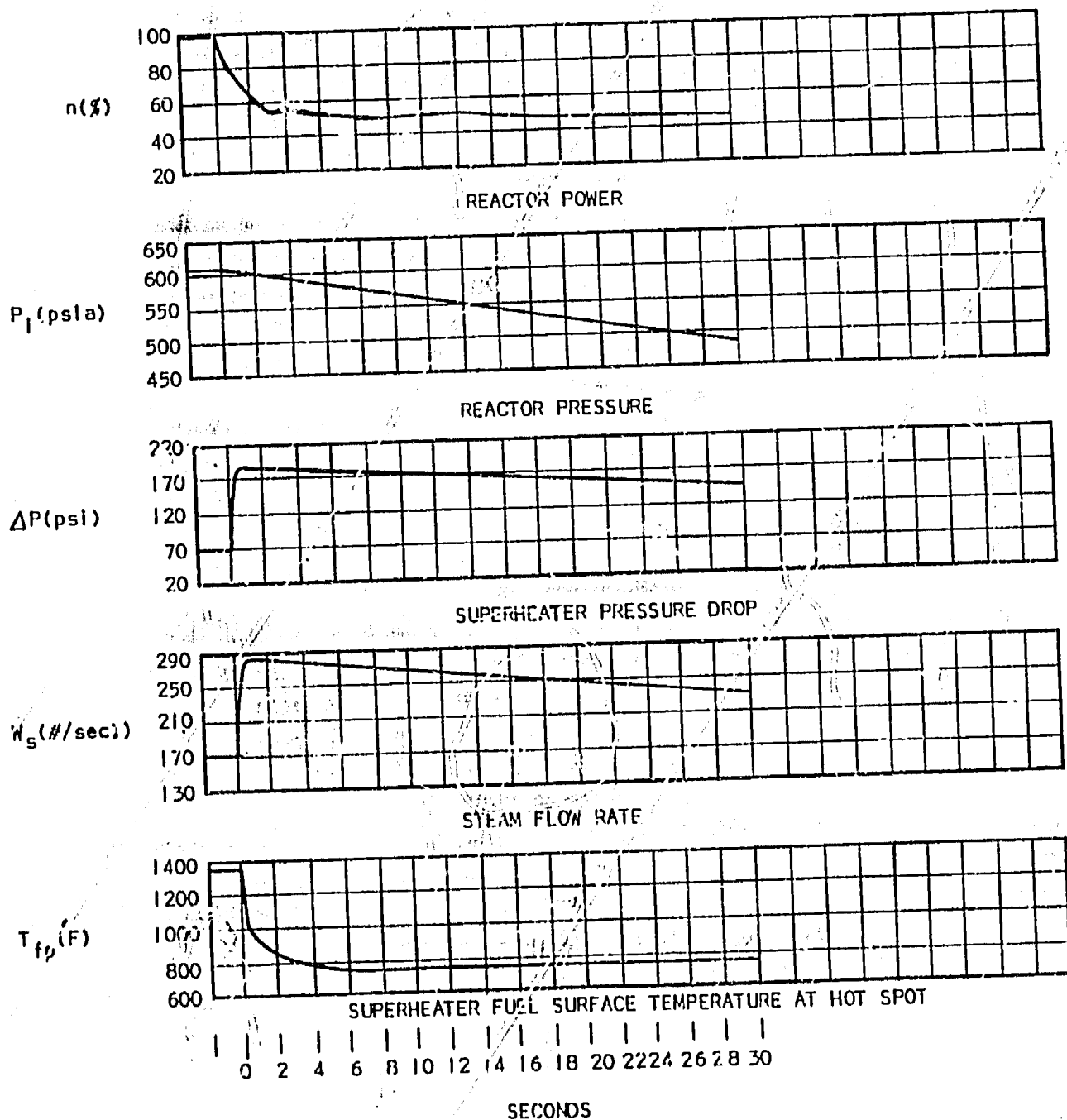
FIG. 5.8
October 31, 1960

REACTOR SCRAM FROM 100% POWER LEVEL
TEN DOLLARS NEGATIVE REACTIVITY
ASSUMED IN SCRAM RODS



43-029-302 T.N.T.

ACCIDENTAL BYPASS VALVE OPENING
NO AUTOMATIC PRESSURE CONTROL

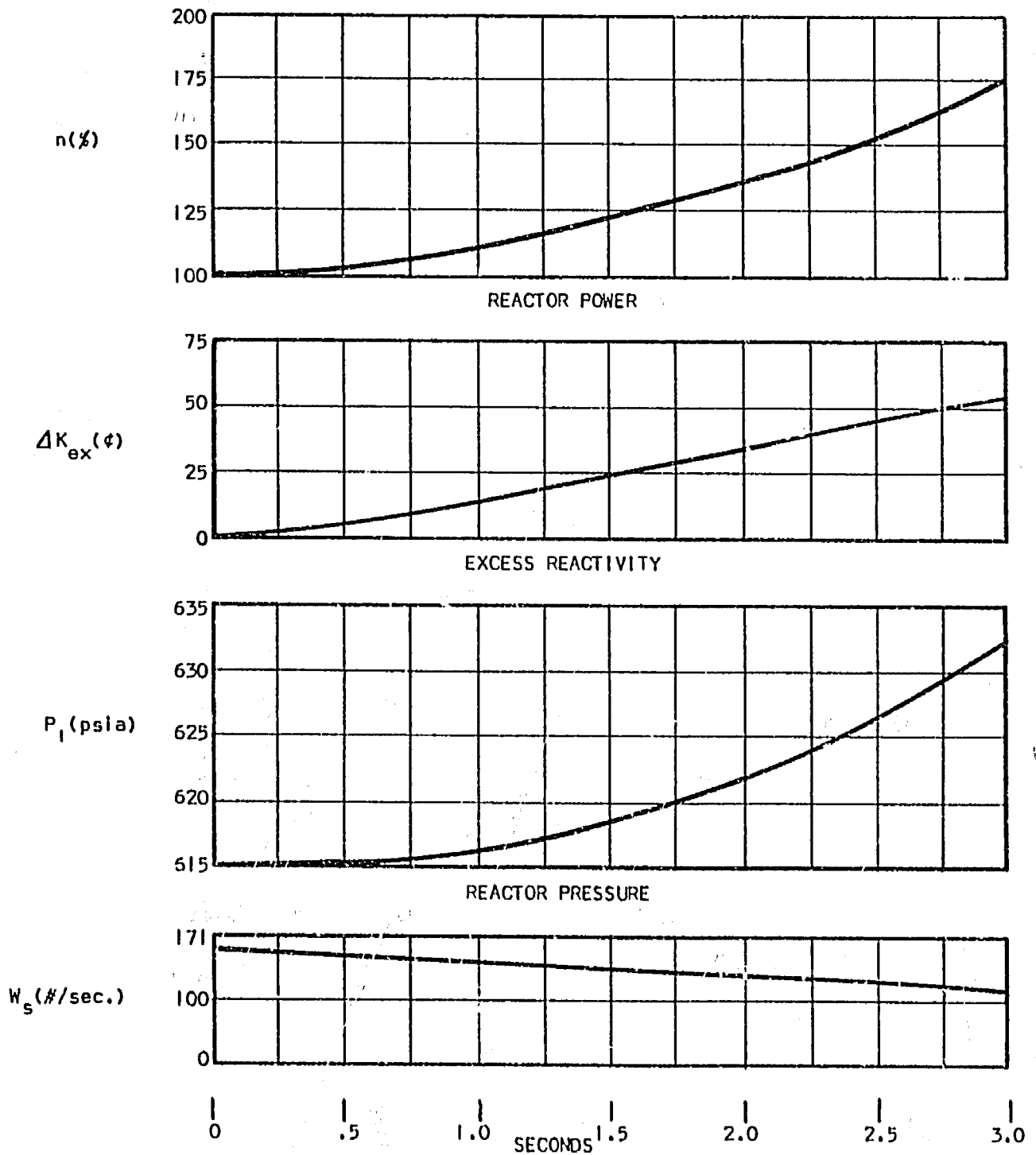


43-029-301 T.N.T.

ACCIDENTAL BYPASS VALVE OPENING

FIG. 5.10
October 31, 1960

10-SECOND CLOSURE OF ISOLATION VALVE
WITH NO SCRAM OR SAFETY VALVE RELIEF



43-024-294 T.H.T.

ISOLATION VALVE CLOSURE

FIG. 5.11
October 31, 1960

1-3, 2-3, 3-3, 4-3, 7-3, 8-3, 41-3
42-3, 43-3, 61-3, 70-3, 519-3, 519-3A,
561-3 & 742-3

**South Dakota Department of
Water & Natural Resources**

Joe Foss Building
Pierre, South Dakota 57501

August 15, 1979

Neal Nelson-Construction Manager
Northern States Power Co.
Box 988, 500 W Russell St.
Sioux Falls, SD 57101

Dear Mr. Nelson:

This will confirm our discussion regarding water rights presently held by Northern States Power Co. in the Sioux Falls area.

Permit No. 1-3 was issued with a diversion of 500 cfs at a point in the NE $\frac{1}{4}$ SW $\frac{1}{4}$, Section 16, T101N, R49W, with a priority date of July 2, 1907.

Permit No. 2-3 was issued with a diversion of 500 cfs at a point in the NE $\frac{1}{4}$ SW $\frac{1}{4}$, Section 16, T110N, R49W, with a priority date of July 2, 1907.

Permit No. 3-3 was issued with a diversion rate of 400 cfs at a point in the NE $\frac{1}{4}$ SW $\frac{1}{4}$, Section 16, T101N, R49W, with a priority date of July 2, 1907.

Permit No. 4-3 was an uncompleted permit to use up to 300 cfs from the Sioux River in Hamlin County at a point in the NE $\frac{1}{4}$ SW $\frac{1}{4}$, Section 19, T114N, R51W.

Permit No. 7-3 was issued with a diversion rate of 500 cfs at a point in the NE $\frac{1}{4}$, Section 16, T101N, R49W, with a priority date of September 17, 1907.

Permit No. 8-3 was issued with a diversion rate of 500 cfs at a point in the NE $\frac{1}{4}$, Section 16, T101N, R49W, with a priority date of September 17, 1907.

On August 21, 1912, the Sioux Falls Power and Light Company petitioned the State Engineer to consolidate permits 1-3, 2-3, 3-3, 7-3 and 8-3. This action was approved by the State Engineer on August 24, 1912.

With the Abandonment of the Hydro Operations, by resolution dated December 6, 1961, Northern States Power Co. surrendered and abandoned its right to appropriate 2,325 cfs of the 2,400 cfs authorized under Permits No. 1-3, 2-3, 3-3, 7-3 and 8-3, retaining 75 cfs for operation of the steam facilities.

A letter from G.V. Welk dated August 9, 1971 indicated Northern States Power Co. had conveyed its Sioux Falls Generating Plant and associated land to the City of Sioux Falls, and requested that the 75 cfs retained under the above permits also be transferred to the City. Inasmuch as the water rights held by the Northern States Power were essentially non-consumptive, it was determined that they would be of no value to the City, and the Permits could be cancelled.

Equal Opportunity Employer

Page 2
August 15, 1979

Under the above relinquishment and abandonment, the Permits 1-3, 2-3, 3-3, 7-3 & 8-3 all pertaining to the Hydro Plant and subsequently the steam plant, had not been officially cancelled by the Water Rights Commission. In official action by the Commission the above permits were cancelled on November 14, 1974. Uncompleted Permit No. 4-3 was also cancelled under this action. The above permits except for 4-3 were used in connection with the Bennett Dam and/or what you referred to as the Weber Plant.

The following Water Rights were issued in connection with the Lawrence Plant.

Water License No. 41-3 covers Well #1 and authorizes diversion of 1.11 cfs (500 gpm) with a priority date of July 18, 1946.

Water License No. 42-3 covers Well No. 2 and authorizes diversion of .067 cfs (30 gpm) with a priority date of July 18, 1946.

Water License No. 43-3 covers diversion from the Sioux River authorizing diversion of 2.67 cfs (1200 gpm) with a priority date of January 17, 1947.

Water License No. 61-1 covers Well No. 3 and authorizes diversion of 1.0 cfs (450 gpm) with a priority date of October 10, 1960.

Water License No. 70-3 covers Well No. 4 and authorizes diversion of 1.55 cfs (700 gpm) with a priority date of April 21, 1951.

In our discussion you indicated that the Lawrence Plant had been deactivated on September 30, 1977, but because of energy requirements, that it may be reactivated. South Dakota Water Laws state that a 3 year period of non-use is a basis for forfeiture of water rights. If the plant is reactivated prior to September 30, 1980, the water rights would be valid, and remain in force as long as the water is used beneficially. We request that you notify us if the plant is reactivated.

The following water rights were issued in connection with the Pathfinder Plant.

Water License No. 519-3 covers diversion from the Sioux River, and authorizes diversion of 6.0 cfs, with a priority date of February 10, 1958.

Water License No. 519-3A covers diversion from the Sioux River (enlargement of 519-3) and authorizes diversion of 1.77 cfs (700 gpm) with a priority date of December 12, 1962.

Water License No. 561-3 covers Well A, and authorizes diversion of 1.77 cfs (700 gpm) with a priority date of December 18, 1958.

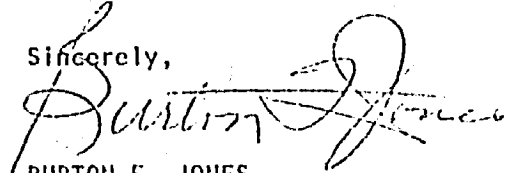
Water License No. 742-3 covers Well B and authorizes diversion of .33 cfs (150 gpm) with a priority date of September 17, 1960.

These permits were primarily for cooling water and plant use for the Atomic generators. You indicated that the plant has now been converted to an oil burning plant, and the water is used in connection with this operation. These are considered valid permits and remain in force as long as the water is used beneficially.

page 3
August 15, 1979

This summarizes the water rights that are presently active and disposition of those no longer used. We would like to thank you for the time spent discussing the status of your existing use. If you have questions, feel free to contact this office.

Sincerely,



BURTON F. JONES
Water Rights Specialist

BFJ/gy

41-3
42-3
61-3
70-3
561-3
742-3

Water Rights Division - DWNR
Conversation or File Documentation

File No. 70-3

NAME OF PERSON OR FILE: Dean Greer, Safety Coordinator, Northern States
Power Company

ADDRESS: 500 W Russell St., Box 988, Sioux Falls 57104 COUNTY Minnehaha

DATE: March 21, 1989 TELEPHONE 339-8200

RE: status of water rights & wells for Northern States Power Co at the Lawrence
Plant and the Pathfinder Plant

COMMENTS:
Mr. Greer stated Well #1 (the 12" well near the Lawrence Plant) has been capped with a steel plate welded across casing and will no longer be used for purposes specified in Water Right No. 41-3. The well may be used for testing purposes by the City of Sioux Falls. Wells #2, #3, & #4 for the Lawrence Plant (Water Right Nos. 42-3, 61-3 and 70-3) have been plugged. He thought that Lacey Well Drilling had plugged the wells. The Sioux Falls Construction Company had the contract for demolition of the plant. I told him that Water Right Nos. 41-3, 42-3, 61-3 and 70-3 would be scheduled for cancellation at the May Meeting. He stated this was fine.

Mr. Greer indicated the two wells at the Pathfinder Plant (Water Right Nos. 561-3 and 742-3) are still in use. I questioned whether or not the wells were being used for the purposes specified in the water rights, he stated that they were.

File in Permit or other file as necessary. Use to document conversations and what the other party was told; why action or decision was made.

NAME: Deany Mumaek