OCT 1 5 1975

Mr. R. G. Bock, Manager
Development Applications
Mail Code 588
General Electric Company
175 Curtner Avenue
San Jose, California 95125

Subject: Contract AT(04-3)-189, Project Agreement No. 58,
Tenth Quarterly Progress Report, GEAP 13317-10

Dear Mr. Bock:

I am in receipt of your letter of September 30, 1975, requesting prompt patent review of the subject report.

Be advised that my office approved the report for publication and distribution on October 1, 1975. I am sure that you will soon receive official confirmation of this fact, if you have not already received it.

If there are any further questions regarding this matter I may be reached at A/C 301-492-7241.

Very truly yours,

/s/

J. A. Cooke, Patent Counsel
Office of Executive Legal
Director (OCOA)

cc: J. McCully
F. A. Robertson

RD-8-2
GE

OFFICE	OELD(OCOA)	OELD(OCOA)				
SURNAME	JACooke:LL	JWMaynard				
DATE	10-15-75	10-15-75				

Form AEC-318 (Rev. 9-53) AECM 0240 ☆ U.S. GOVERNMENT PRINTING OFFICE: 1974-526-166

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Wacichel
Pacific Gas and Electric Co
San Francisco 5, Calif

TO: Beck

DATE OF DOCUMENT: 6/20/59
DATE RECEIVED: 6/23/59
NO.: 53548

LTR.: X
ORIG.: X
CC:
OTHER:

REPLY NECESSARY ☐
NO REPLY NECESSARY ☐
DATE ANSWERED:
BY:

CLASSIF.: U
POST OFFICE
REG. NO.:

DESCRIPTION: (Must Be Unclassified)

Would like to discuss enclosures GEAP 3143 Test Report for the Pressure Suppression Development Program Prepared for Pacific Gas and Electric Co

ENCLOSURES:

3 Ans. in Mtg with PG+E on 6/23

REMARKS:

REFERRED TO	DATE	RECEIVED BY	DATE
Beck	6/23	DJL 6/28	
Case, Waterfield, Grossman		HRK	
Reply made in Meeting with PG+E on 6/23/59			

U. S. ATOMIC ENERGY COMMISSION

MAIL CONTROL FORM FORM AEC (3-52)

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HEB Project File 5357

PACIFIC GAS AND ELECTRIC COMPANY

245 Market Street
San Francisco 6
SUtter 1-4211

A I R   M A I L

In reply please refer to

Pressure Suppression Reactor Containment Research Project.

April 20, 1959

Dr. Clifford K. Beck
Chief, Hazards Evaluation Branch
Division of Licensing & Regulations
U.S. Atomic Energy Commission
Washington 25, D.C.

Dear Dr. Beck:

Since we discussed the PG&E-GE research project with you in Washington on February 18, the experimental field work and the test report have been completed. /See Reports File

As you suggested, I am sending you herewith copies (3) of the General Electric GEAP-3143 "Test Report for the Pressure Suppression Development Program Prepared for Pacific Gas and Electric Company" dated April 2, 1959. From our conversation with you, I understood that you plan to have this report reviewed and that perhaps within the next two or three weeks ask us to come to Washington to discuss it.

In the meantime we are working on the reactor containment design for Humboldt based on the results of the research project and, again, as you suggested, will plan to review this design with you some time after our next meeting and before formally submitting the Enclosure Report.

If the pressure suppression system of reactor containment is accepted for Humboldt, we and GE expect to publish a paper on the subject. In the meantime we would like to have the information treated as confidentially as it can be and yet not hinder in the least a full examination of the proposed scheme.

Please let me know whether there is any additional information that you wish at this time; and as soon as convenient, I would appreciate getting a general idea as to when you would like to see us next.

Very truly yours,

170

C. C. Whelchel
C. C. WHELCHEL
Chief Mechanical Engineer

CCW:ca
Encs.

7540

DOCKET NO. 50-133
Suppl. File Cy.

BEFORE THE UNITED STATES ATOMIC ENERGY COMMISSION

Application of PACIFIC GAS AND ELECTRIC COMPANY for a Class 104b. License to Construct and Operate a Nuclear Reactor as a Part of Unit No. 3 of Its Humboldt Bay Power Plant	Docket No. 50-133 Amendment No. 2

Now comes PACIFIC GAS AND ELECTRIC COMPANY and amends its above numbered application in response to the Commission's request in its letter dated June 17, 1959 for information relating to environmental aspects of proposed Unit No. 3 of Applicant's Humboldt Bay Power Plant. The information submitted herewith supplements that included in Exhibit B of said application, which is the Preliminary Hazards Summary Report.

Section I of this amendment sets forth and answers the questions contained in the Commission's letter dated June 17, 1959. Because of the very close relationship between site suitability and reactor containment there is included under Section II of this amendment a discussion of the pressure suppression system for reactor containment being considered for this project. After the choice between pressure suppression and conventional dry containment has been made the containment section of the Preliminary Hazrds Summary Report will be submitted.

SECTION I

ANSWERS TO COMMISSION'S QUESTIONS

1. The distance to the nearest site boundary.

   The nearest site boundary is 700 feet from the reactor and is along the right of way of the Northwestern Pacific Railroad.

2. The shortest distance to Humboldt Bay.

   The shortest distance from the reactor to Humboldt Bay is 470 feet.

on the site only under the supervision of responsible Company personnel. The maximum number of visitors to be permitted on the site at one time has not yet been established but it will be limited to an acceptable number.

10. At what points on the various incoming roads will access to the public be restricted?

Referring to Figure 2 of the Preliminary Hazards Summary Report, the present access to the Plant is the entrance road from Salmon Avenue. Buhne Drive is currently abandoned; it will be reactivated for plant construction, then closed again. Access will then be restricted on the entrance road at the point where it joins Salmon Avenue, a distance of about 1150 feet from the reactor. Again referring to Figure 2, the 1" = 100' scale note is in error because the site drawing was reduced from its original size. The attached revised Figure 2 with the correct scale should be substituted.

11. A description should be provided of the method by which the Bay area will be marked to keep the public at a safe distance from the plant.

Access to the plant site from the shore line will be restricted by a suitable fence. If it can be demonstrated that reactor containment and other safety features will preclude hazards to persons in the Bay, warning markers to keep the public at a safe distance should not be required.

In addition to the questions above, information was requested concerning relative heights of the stack, reactor building, and power plant buildings. A stack height of 200 feet has been selected, but the subject is still under consideration. The height of the reactor building is not known at this time but it is not likely to exceed 40 feet. The two existing boiler buildings are each 88 feet high and the existing auxiliary bay is 37 feet high. The auxiliary bay will be extended at this height for the new unit.

The tentatively selected 200-ft. stack height is sufficiently greater than the height of the tallest nearby buildings to avoid the complicating effects of atmospheric eddy currents on the stack discharge. Consideration is being given to a taller stack in order to decrease the maximum stack discharge ground concentrations and thereby help assure continuity of plant operation without exceeding permissible discharge limits.

Referring to Appendix I of the Preliminary Hazards Summary Report the following additional information is presented:

Atmospheric soundings were made at Arcata during the period September, 1943 through March, 1945 by the U.S. Navy. The soundings were made at 0700 PST and 1900 PST. A frequency distribution of inversion heights for each sample is tabulated below:

Temperature Inversion Heights at Arcata, California

Elevation of Inversion	Frequency Distribution Percent — Time of Observation 0700 PST*	1900 PST**
Surface***	44	32
Surface to 500 ft.	1	0
501 to 1,000 ft.	5	3
1,001 to 1,500 ft.	7	6
1,501 to 2,000 ft.	7	6
2,001 to 2,500 ft.	4	5
2,501 to 3,000 ft.	3	3
3,001 to 3,500 ft.	2	2
Greater than 3,500 ft.	8	10
No inversion	19	33

* Includes 402 observations during the period September 1943 through March 1945.

** Includes 294 observations during the period January 1944 through March 1945.

*** Surface elevation 207 feet above sea level, other elevations given from sea level.

SECTION II

PRESSURE SUPPRESSION CONTAINMENT

1. General

The Preliminary Hazards Summary Report dated April 15, 1959, did not describe the reactor enclosure or the radiological effects of large accidents since the type of enclosure has not been selected and since radiological effects depend upon the enclosure design. The foregoing report however stated that a research and development program on pressure suppression reactor containment was underway.

Pressure suppression containment provides for venting into a water pool the steam-water mixture that would be released from the reactor in the event of a break in the primary system. The steam would be condensed and entrained fission products would to a large extent be retained in the pool.

The development program to establish the feasibility of designing a practical system based on this principle and to provide the necessary technical data for such design has been conducted by the General Electric Company and Pacific Gas and Electric Company. The results of the development program are now being applied in further work aimed at designing a pressure suppression containment scheme for the Humboldt Bay Power Plant reactor that would have important safety and other advantages. The design features of the containment system will be an outcome of this work.

The containment section of the Preliminary Hazards Summary Report will be submitted after the choice between pressure suppression and conventional dry containment has been made and the containment design established.

The purpose of the present discussion is to outline the principle of pressure suppression containment and to indicate the scope, nature, and general tenor of results of the development work, so as to assist the Commission in evaluating the Preliminary Hazards Summary Report.

2. Description of Pressure Suppression System

To illustrate the principle, a simplified form of a pressure suppression system is shown in Figure 1 attached hereto. The dry well (V2) is a compartment normally filled with air which contains the reactor vessel (V1). In the event of a reactor vessel rupture or primary system pipe break the escaping water and steam would first enter the dry well and then be released into the water pool, where the steam would be condensed. The water pool is part of the containment volume (V3).

3. Design Requirements

The reactor system, including the primary vessel, dry well, and pressure suppression pool, together with shielding and containment provisions, will be designed to minimize environmental hazards from leakage of fission products and radiation shine under the most severe credible accident conditions.

The general objective of the plant protective features is to limit the external radiation exposure at off-site locations to the order of 25 rems, and to similarly limit internal radiation exposure due to inhalation to biologically equivalent doses to organs such as the lungs, bone, and thyroid.

With regard to post-accident protection of nearby inhabitants it is considered reasonable to assume that evacuation, if necessary, can be accomplished within a very few hours from the time of an incident.

4. Advantages of Pressure Suppression

The water pool containment design concept offers important safety advantages:

a) Any fission products released from the reactor primary system must either remain in the dry well, where the driving pressure for leakage would be very low after the first few seconds, or pass into the water pool. Any fission products not retained by the water pool would be held in the vapor container above the pool. The most dangerous fission products, the "solids", would probably not reach the space above the pool in any important concentration.

b) By quickly absorbing the bulk of the energy which may be released in a reactor accident the pressure suppression system removes the large driving pressure for fission product leakage from the system to the environment.

c) As a result of features a) and b) above, the pressure suppression system is less sensitive to possible partial failure of containment than the conventional dry system. The effectiveness of pressure suppression does not depend on mechanical barrier integrity over an extended period of time to retain pressure and fission products.

5. Development Program

A development program has been conducted by the General Electric Company and Pacific Gas and Electric Company to determine the extent to which the advantages listed above may be expected to be realized in any chosen design.

The program consisted of three phases:

Phase I -- preliminary tests, development of methods of analysis and literature survey;

Phase II -- tests to establish a firm basis for final design of the pressure suppression system;

Phase III -- evaluation of the results and establishment of design basis for a pressure suppression system.

Tests and analyses have been necessary to make it possible to predict with confidence how pressure suppression would work if ever called on. The following specific areas have been under investigation:

a) How must the dry well be designed so that it will not rupture and allow the steam to bypass the condensing pool?

b) What is required to make sure that steam introduced to the water pool is condensed and does not enter the vapor space and rupture the container?

c) How effective is the water pool in removing entrained fission products?

d) What accidents should pressure suppression be required to protect against?

As part of Phase II of this development program, extensive tests have been performed in two major test facilities. One used a large condensing tank in order to optimize the design of steam vents. The test results with the large-scale facility indicate that condensation of steam and water is extremely rapid and that there should be no problem in designing the steam vents and water pool to operate satisfactorily. Steam flow rates of up to 100,000 lbs/hr were condensed in hundreds of tests from jets, some discharging under less than one foot of water.

A scale model of a complete pressure suppression system was operated to determine pressure transients in the various volumes following rupture of the primary system, and to demonstrate operation of the system. Parameters were varied to substantiate analytical methods of predicting dry well pressures. The predictions have been well supported by the test results, as follows:

a) The time after rupture for occurrence of the peak was very nearly the same for both experiment and prediction;

b) The experimental peak dry well pressure was always less than 75% of the predicted; and

c) The effects of change in hole size, dry well volume, depth of submergence of vents, or vent area were found to be about as predicted.

Other small-scale tests with simulated fission products have provided approximate experimental verification of the expected nearly complete retention of entrained solid and halogen fission products in the water pool. The measurements suggest the likelihood of partial noble gas retention.

In parallel with the development and design phases of the pressure suppression containment program, work is being done on the safeguard aspects of the concept. The objectives of this safeguard effort are:

a) To define the maximum credible reactor accident for which the pressure suppression containment scheme must provide; and

b) To attempt to establish what safety margin it is appropriate to include in the design in order to protect against residual risks beyond the "maximum credible accident".

The subjects investigated and evaluated to date include the following:

a) The statistics related to reactor system piping and vessel failures;

b) The metallurgical considerations related to reactor system failure;

c) The nuclear and chemical energy relationships with respect to reactor system failure;

d) Radiological aspects of a pressure suppression containment scheme; and

e) Design requirements for a pressure suppression system which result from the conclusions of the various accident considerations.

The "maximum credible accident" is tentatively considered to be the worst coolant loss accident which can result from near instantaneous severance of any pipe penetrating the reactor vessel or an equivalent ductile failure of the reactor vessel at any location. Design of protective features for this accident is to be in accordance with the normal engineering and structural practices.

6. Refueling Considerations

Various possible refueling accidents are being studied as part of the safeguard evaluation of the reactor.

Among these accidents the following may directly affect containment and shielding provisions:

a) Nuclear excursion due to inadvertent rapid insertion of excess reactivity while the reactor pressure vessel is open; and

b) Release of radiogases and halogens from damaged fuel.

The fuel cask and handling equipment will be designed to accommodate possible damaged fuel. Refueling or fuel handling accidents will be analyzed in order to provide assurance that potential dose rates resulting from such accidents will not exceed those given under Part 3 "Design Requirements".

Subscribed in San Francisco, California, this 22nd day of July, 1959.

Respectfully submitted,

PACIFIC GAS AND ELECTRIC COMPANY

By N. R. Sutherland
President

RICHARD H. PETERSON
FREDERICK W. MIELKE, JR.
PHILIP A. CRANE, JR.
Attorneys for Applicant

By Philip A. Crane, Jr.

Subscribed and sworn to before me

this 22nd day of July, 1959.

Marie H. Stanley
Notary Public in and for the City

and County of San Francisco,

State of California.

My Commission Expires November 22, 1959.

FROM:	DATE OF DOCUMENT:	DATE RECEIVED:	NO.:
C.C. Whelchel PG&E	11/9/59	11/13/59	HEB 36169

TO:	LTR.	MEMO:	REPORT:	OTHER:
Dr. Clifford K. Beck	X			Project 170
	ORIG.: X	CC:	OTHER:	

REPLY NECESSARY ☐ DATE ANSWERED: HEB Project File
NO REPLY NECESSARY ☐

CLASSIF.: U
POST OFFICE REG. NO.:

DESCRIPTION: (Must Be Unclassified)

"HUMBOLDT BAY POWER PLANT, UNIT NO. 3 DOCKET NO. 50-133."

ENCLOSURES:

1. Statement by C.C. Whelchel Before the ACRS Washington, D.C., November 13, 1959. 3 cys.

REMARKS:

REFERRED TO	DATE	RECEIVED BY	DATE
Dr. Beck	~~11/13~~		
filed	11/20		

RETURN TO CENTRAL MAIL ROOM
U. S. ATOMIC ENERGY COMMISSION
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* U. S. GOVERNMENT PRINTING OFFICE: 1959—506355

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5 p.

HEB Project File

PACIFIC GAS AND ELECTRIC COMPANY

245 Market Street
San Francisco 6
SUtter 1-4211

In reply please refer to

A I R M A I L

November 9, 1959

Dr. Clifford K. Beck
Chief
Hazards Evaluation Branch
Div. of Licensing & Regulation
U.S. Atomic Energy Commission
Washington 25, D.C.

Dear Dr. Beck:

Humboldt Bay Power Plant, Unit No. 3
Docket No. 50-133

Confirming our telephone conversation with your secretary on November 6, we will plan to be in Room 1147 at 1717 H Street, Washington, D.C. at 2:30 PM, Friday, November 13, 1959.

Attached are copies of a proposed statement along the lines I discussed with you and a list of the men expected to attend.

We plan to show 3-1/4"x4" and 2"x2" slides and a short 16 mm silent film showing Moss Landing condensation tests. If a movie projector is not available, please wire me; and we will endeavor to get one.

Very truly yours,

C. C. Whelchel

C. C. Whelchel
Chief Mechanical Engineer

CCW:ca
Attach.

PACIFIC GAS AND ELECTRIC COMPANY

STATEMENT BY C. C. WHELCHEL BEFORE THE
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C., NOVEMBER 13, 1959

Since our appearance before the Committee on September 10, Pacific Gas and Electric Company filed on September 24, 1959 Addenda A and B to the Humboldt Unit No. 3 Preliminary Hazards Summary Report.

Addendum A states that pressure suppression reactor containment has been selected in preference to dry containment and the general features and requirements for its design are included therein. The Amendment also contains a discussion of major accidents and the protection afforded by pressure suppression containment, the refueling building, and other safeguards.

Addendum B brings up to date information previously submitted on gaseous waste disposal and reactor refueling.

On October 28, representatives of PG&E met with Dr. Beck and members of his staff; and on the following day, with Dr. Silverman's ACRS subcommittee. A number of questions were raised at these two meetings and it was suggested that we be prepared to answer them here, today. This we wish to do, along with any others you may have. In answering these questions, I believe we will cover most of the information in Addenda A and B, so that they will not be reviewed separately.

We have grouped the AEC and ACRS questions under seven general subjects.

1. Pressure Suppression Containment

The first subject is Pressure Suppression Containment. The question was, "How does one go from the field experiments and analytical work that has been done on this subject, to the numbers needed to design the Humboldt plant?" Mr. Robbins of General Electric, under whose direction all the GE pressure suppression work was performed, will take this subject up to the point of power plant design. Mr. Utegaard of Bechtel Corp. will explain how the results of the experimental and analytical work were used to determine the design criteria for the Humboldt reactor containment. He will also discuss containment design features.

2. Containment Leakage Rates

The second subject is concerned with the methods for measuring gaseous leakage rates from the pressure suppression containment structure and from the reactor refueling building. Mr. Utegaard will discuss this subject.

3. Earthquakes and Their Effect on Design

The third subject deals with earthquakes. It is our desire to keep the Humboldt nuclear unit in operation during earthquakes without scramming the reactor. Mr. Coltrin of Pacific Gas and Electric will discuss the general subject along with plant design considerations. Dr. McCrocklin of General Electric will discuss reactor design and instrumentation from this standpoint.

4. Site Hydrology

The fourth subject deals with site hydrology including Humboldt Bay flow patterns during incoming and outgoing tides and the flushing action in the bay and will be discussed by Mr. Coltrin. He will also give information on wells and other water supplies near the site.

5. Site Meteorology

Mr. ~~[illegible]~~ Parsons of PG&E will answer the question on inversions which are not surface based, and is prepared to answer other questions on site meteorology.

Mr. Smith of General Electric is prepared to answer questions on site suitability, stack height, and waste discharge considerations.

HEARING BEFORE THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

NOVEMBER 13, 1959

REPRESENTATIVES FOR PACIFIC GAS & ELECTRIC COMPANY

PACIFIC GAS & ELECTRIC COMPANY

C. C. Whelchel, Chief Mechanical Engineer
J. O. Schuyler, Project Engineer
G. L. Coltrin, Project Civil Engineer
P. A. Crane, Attorney
~~G. W. Lunn~~, Meteorologist
F. J. Parsons

GENERAL ELECTRIC COMPANY

H. W. Huntley, Manager PG&E Project
G. Sege, Manager, Safeguard Evaluations
A. J. McCrocklin, Technical Leader, PG&E Project
C. H. Robbins, Manager, Mechanical and Process Development
J. M. Smith, Radiological Engineer
E. G. Holzmann, Safeguard Evaluations Engineer
J. Forster, Senior Instrument Engineer

BECHTEL CORPORATION

J. H. Utegaard, Project Engineer

Docket No. 50-133

DEC 2 1 1959

Pacific Gas and Electric Company
245 Market Street
San Francisco 6, California

Attention: Mr. N. R. Sutherland
President

Gentlemen:

This is to advise you that we are prepared to set down for hearing your application for license to construct and operate a nuclear reactor as part of your Humboldt Bay Power Plant.

We believe that a reactor of the general type proposed is suitable for construction at the Humboldt Bay site, provided there is adequate containment. We are not yet convinced, however, from our review of the information submitted, including Amendments No. 4 and No. 5 to the application, that the design plan and specifications for containment which you have presented are acceptable. Also, after its November 13, 1959 meeting, the Advisory Committee on Reactor Safeguards informed us that the information presented thus far is not adequate with respect to the containment proposed. There is attached to this letter a listing of points on which additional information concerning the proposed containment is required.

If your license application were set down at this time for hearing, the notice of hearing would be issued substantially in the form attached. At the hearing, or prior thereto, PG&E could present additional data regarding the containment system. If analysis of these data would permit the conclusion that there is reasonable assurance that the health and safety of the public would not be endangered, the AEC staff's proposed findings and conclusions

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DOCKET NO. 50-133

PACIFIC GAS AND ELECTRIC COMPANY

HUMBOLDT BAY POWER PLANT

STAFF LISTING OF POINTS REQUIRING ADDITIONAL INFORMATION

1. The basis for ~~drawing~~ deriving the design of the proposed facility containment from the model tests.

   a. What basic hydrodynamic principles were utilized in determining the behavior, size, and location of the steam nozzles in the suppression pool?

   b. What methods were used to arrive at and to justify the design pressure of the principal containment components; the dry well, the suppression pool, the vent pipes and nozzles, and the refueling building?

   c. Will steam which has become superheated by expanding from 1,000 psi to 72 psi condense just as well as the 100 psi saturated steam used in the Moss Landing tests? What are the experimental and theoretical considerations involved in reaching this conclusion?

2. The design criteria used to determine the design pressure and other features of the principal containment components. Examples of questions in this area are:

   a. What assurance is there that the equilibrium pressure in the suppression pool is also the maximum pressure? Is it not possible that at some time during the release a portion of the steam might not be condensed, and that the partial pressure due to it would make the total larger than the equilibrium value obtained later after the steam had condensed?

   b. What are the sizes, locations, and number of penetrations of the dry well? What will be their affect on the integrity and function of the dry well? What are the design criteria for the dry well wall to assure the integrity of the concrete from the initial blast of steam?

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could then include a recommendation to the Hearing Examiner that a construction permit be issued.

Please let us have your comments promptly on this matter.

Sincerely yours,

Director
Division of Licensing
and Regulation

Enclosures:
Draft Notice of Hearing
Listing of Points requiring additional information

CC: M. M. Mann, INS (2)

AIR MAIL

OFFICE ▶	DLR:LB	Johnson	Director	HEB
SURNAME ▶	Edwards:hgw			CKB
DATE ▶	12/18/59	12/21/59	12-21-59	

Form AEC-318 (Rev. 9-53)   U. S. GOVERNMENT PRINTING OFFICE 16—62761-3

PACIFIC GAS AND ELECTRIC COMPANY

A I R M A I L

SPECIAL DELIVERY

245 Market Street
San Francisco 6
SUtter 1-4211

In reply please refer to

Humboldt Bay Power Plant
Unit No. 3
Construction Permit Application

March 4, 1960

Dr. Clifford K. Beck
Chief, Hazards Evaluation Branch
Division of Licensing & Regulation
U. S. Atomic Energy Commission
Washington 25, D.C.

Dear Dr. Beck:

At the meeting at Oak Ridge, Tennessee, February 25, information was requested on a number of different subjects; and where possible, we were asked to mail the answers to you as soon as they were completed rather than wait to present them to you on March 11, particularly, where calculations were involved.

Twenty-five copies of the "Blast Pressure Analysis" are included at this time. We expect to mail additional information next week.

In accordance with the point of view adopted in other recent analyses, the reactor pressure, in the foregoing analysis, is assumed to be equal to the design pressure of 1250 psig rather than to the operating pressure of 1000 psig used for the MCOA in Addendum A. This change accounts for the increase in the calculated blast pressure from less than 250 to 256 psig.

As was stated in Addendum A, the blast pressure is below the crushing strength of the concrete which backs up the dry well steel liner. Therefore the shock wave is of no consequence where the impulse can be transmitted to the concrete. Even where the dry well vessel is not backed by concrete, shock waves would be expected to have negligible effect, since their total energy would be quite small.

Very truly yours,

C. C. Whelchel

C. C. Whelchel
Chief Mechanical Engineer

CCW:ca
Enc-25

~~8604220552~~

10 pp

BLAST PRESSURE ANALYSIS

The model for blast pressure determination is shown schematically in Figure 1. The pressure P_4* behind the reflected shock is the blast pressure. We proceed to evaluate P_4.

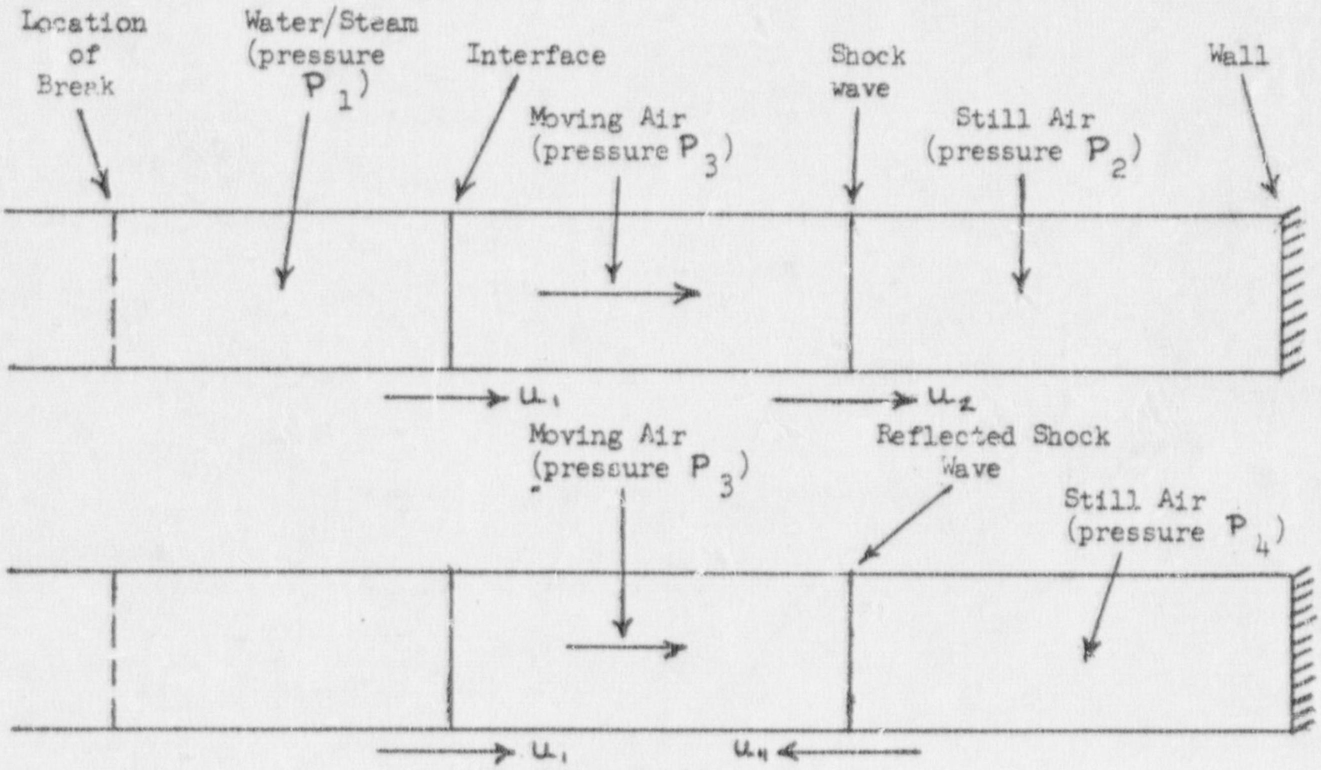

Figure 1

In this model the steam/water expands isentropically from its original (liquid) state to two phases at some lower pressure, in accordance with the conservation of energy and the equation of state for steam/water. The velocity u_1 at the interface is a function of the pressure P_1.

$$u_1 = f_1(P_1) \tag{1}$$

* Symbols are identified in Table of Notation. Page 4

The Rankine-Hugoniot equation relates conditions upstream and downstream of the shock wave.

$$\frac{u_2}{u_2 - u_1} = \frac{1 + \frac{\gamma+1}{\gamma-1} \cdot \frac{P_3}{P_2}}{\frac{\gamma+1}{\gamma-1} + \frac{P_3}{P_2}} \tag{2}$$

The momentum equation may be written

$$u_2 - (u_2 - u_1) = \frac{P_3}{\frac{W_3}{g}(u_2 - u_1)} - \frac{P_2}{\frac{W_2}{g} u_2} \tag{3}$$

and the energy equation

$$J c_p T_3 + \frac{(u_2 - u_1)^2}{2g} = J c_p T_2 + \frac{u_2^2}{2g} = e \tag{4}$$

or

$$\frac{\gamma}{\gamma-1}\left(\frac{P_3}{W_3}\right) + \frac{(u_2 - u_1)^2}{2g} = \frac{\gamma}{\gamma-1} \frac{P_2}{W_2} + \frac{u_2^2}{2g} = e \tag{5}$$

Equations (3) and (5) may be combined to eliminate $\frac{P}{W}$.

$$u_2 - (u_2 - u_1) = \left[u_2 - (u_2 - u_1)\right]\left\{\frac{g e}{u_2(u_2 - u_1)}\left(\frac{\gamma-1}{\gamma}\right) + \frac{\gamma-1}{2\gamma}\right\} \tag{6}$$

The non-trivial solution of equation (6) is

$$u_2(u_2 - u_1) = \frac{2(\gamma-1)}{\gamma+1} g e \tag{7}$$

Combining (5) and (7) and noting that

$$\frac{P_2}{W_2} = R T_2 \text{ AND } \frac{\gamma-1}{\gamma R} = \frac{1}{J c_p}$$

$$u_2(u_2 - u_1) = \frac{2\gamma}{\gamma+1} R g\left[T_2 + \frac{u_2^2}{2 g J c_p}\right] \tag{8}$$

T_2 and P_2 are known. Combining (2) and (8) to eliminate u_2, a relationship is established between P_3 and u_1.

$$u_1 = f_4(P_3) \tag{9}$$

There is no acceleration of the steam/water or the air adjacent to the interface; hence, $P_3 = P_1$. Equations (1) and (9) may be solved for P_3 and u_1. Equation (2) may then be solved for u_2. From equation (4)

$$T_3 = T_2 + \frac{u_2^2 + (u_2 - u_1)^2}{2gJc_p} \tag{10}$$

Considering now the reflected shock, the following relationships apply,

$$\frac{P_4}{P_3} = \frac{\left(\frac{\gamma+1}{\gamma-1}\right)\left(\frac{u_4+u_1}{u_4}\right) - 1}{\frac{\gamma+1}{\gamma-1} - \frac{u_4+u_1}{u_4}} \quad \text{(Rankine-Hugoniot)} \tag{11}$$

and

$$u_4(u_4+u_1) = \frac{2\gamma R g}{\gamma+1}\left[T_3 + \frac{(u_4+u_1)^2}{2gJc_p}\right] \tag{12}$$

T_2, P_1 ($= P_3$), are known. Combining (11) and (12) to eliminate u_4, we may solve for P_4.

Let the initial (rest) state of the steam/water be liquid at 1265 psia, 574°F (saturation), and the initial state of the air be dry at 14.7 psia, 70°F. Calculations based on these initial states yield the following:

P_3	= 75.5 psia	T_3	= 921°R
u_1	= 1556 ft/sec	u_4	= 1150 ft/sec
u_2	= 2400 ft/sec	P_4	= 271 psia

The initial blast pressure is ~~492~~ 271 psia.

Notation

C_p -- Specific heat at constant pressure, Btu/lb °R

g -- Gravitational constant, ft/sec^2

J -- 778.26 ft-lb/Btu

P -- Dry well pressure, lb/ft^2

P_o -- Reactor vessel pressure, lb/ft^2

P_1 -- Pressure behind interface, lb/ft^2

P_2 -- Pressure of undisturbed air, lb/ft^2

P_3 -- Pressure ahead of interface, lb/ft^2

P_4 -- Pressure behind reflected shock, lb/ft^2

P_d -- Dynamic pressure, lb/ft^2

R -- Gas constant, ft-lb/lb °R

T_2 -- Temperature of undisturbed air, °R

T_3 -- Temperature ahead of interface, °R

u_1 -- Velocity of interface, ft/sec

u_2 -- Velocity of shock wave, ft/sec

u_4 -- Velocity of reflected shock, ft/sec

γ -- Ratio of specific heats

SAMPLE CALCULATIONS

Solve equation (1)

$$h_0 = 580.6 \text{ Btu/lb}$$

$$u_1 = \sqrt{2gJ(h_0 - h_1)}$$

$$s_1 = s_0 = 0.7794 \text{ Btu/lb }^{\circ}\text{F}$$

$$h_1 = f_1(s_1, p_1)$$

$$u_1 = 223.8\sqrt{(h_0 - h_1)}$$

p_1	s_f	s_{fg}	x_1	h_f	h_{fg}	h_1	$h_0 - h_1$	$\sqrt{(h_0 - h_1)}$	u_1
70	.4409	1.1906	.284	272.6	907.9	530.3	50.3	7.10	1587
75	.4472	1.1787	.282	277.4	904.5	532.1	48.5	6.96	1559
80	.4531	1.1676	.2795	282.0	901.1	534.0	46.6	6.83	1529

$$u_1 = f(p_1) \tag{1}$$

Consider equation (2). Let $B = \frac{\gamma + 1}{\gamma - 1}$

$$\frac{u_2}{u_2 - u_1} = \frac{1 + \frac{\gamma+1}{\gamma-1}\frac{p_3}{p_2}}{\frac{\gamma+1}{\gamma-1} + \frac{p_3}{p_2}} = \frac{1 + B\frac{p_3}{p_2}}{B + \frac{p_3}{p_2}} \tag{2}$$

Rearrange

$$u_2 = \frac{1 + B\frac{p_3}{p_2}}{(B-1)\left(\frac{p_3}{p_2} - 1\right)} u_1 \tag{2.1}$$

Subtract u_1 from both sides of (2.1)

$$u_2 - u_1 = \frac{B + \frac{p_3}{p_2}}{(B-1)\left(\frac{p_3}{p_2} - 1\right)} u_1 \tag{2.2}$$

Multiplying (2.1) and (2.2),

$$u_2(u_2 - u_1) = \frac{\left(1 + B\frac{p_3}{p_2}\right)\left(B + \frac{p_3}{p_2}\right)}{(B-1)^2\left(\frac{p_3}{p_2} - 1\right)^2} u_1^2 \qquad (2.3)$$

Combining (5) and (7),

$$u_2(u_2 - u_1) = \frac{2\gamma}{\gamma+1} RgT_2 + \frac{\gamma - 1}{\gamma + 1} u_2^2 \qquad (2.4)$$

Combining (2.1), (2.3) and (2.4) to eliminate u_2,

$$u_1^2 = \frac{\frac{1}{B}\frac{2\gamma}{\gamma+1} RgT_2 (B-1)^2}{\left(B - \frac{1}{B}\right)} \frac{\left(\frac{p_3}{p_2} - 1\right)^2}{\left(\frac{1}{B} + \frac{p_3}{p_2}\right)} \qquad (2.5)$$

$p_2 = 14.7$ psia $\qquad B = \frac{\gamma+1}{\gamma-1} = 6$

$T_2 = 530°R$

$Rg = 1715 \frac{ft\text{-}lb}{slug\,°R} \qquad \frac{\frac{1}{B}\frac{2\gamma}{\gamma+1} RgT_2 (B-1)^2}{\left(B - \frac{1}{B}\right)} = 0.757 \times 10^6$

$\gamma = 1.4$

$$u_1^2 = 0.757 \times 10^6 \frac{\left(\frac{p_3}{p_2} - 1\right)^2}{\left(\frac{p_3}{p_2} + \frac{1}{6}\right)} \quad (ft/sec)^2 \qquad (2.6)$$

p_3	$\frac{p_3}{p_2}$	$\frac{p_3}{p_2} - 1$	N	$\frac{p_3}{p_2} + \frac{1}{6}$	u_1^2	u_1
70	4.75	3.75	10.65×10^6	4.92	2.165×10^6	1471
75	5.10	4.10	12.72×10^6	5.27	2.415×10^6	1553
80	5.44	4.44	14.91×10^6	5.61	2.66×10^6	1630

$$u_1 = f_4(p_3) \qquad (9)$$

Noting that $p_1 = p_3$, and combining eqns (1) and (9)

$$p_1 = p_3 = \underline{\underline{75.5}} \text{ psia}$$

$$u_1 = \underline{\underline{1556}} \text{ ft/sec}$$

$$u_2 = \frac{1 + B\frac{p_3}{p_2}}{(B-1)\left(\frac{p_3}{p_2} - 1\right)} u_1 = \underline{\underline{2400 \text{ ft/sec}}}$$

$$T_3 = T_2 + \frac{u_2^2 + (u_2 - u_1)^2}{2gJc_p}$$

$$= 530 + \frac{(2400)^2 + (2400 - 1556)^2}{2 \times 32.17 \times 778 \times 0.24} = 530 + 421$$

$$T_3 = \underline{\underline{951\,^\circ R}}$$

Let $u_5 = u_4 + u_1$, and rearrange (11).

$$\frac{u_5}{u_4} = \frac{u_5}{u_5 - u_1} = \frac{1 + B\frac{p_4}{p_3}}{B + \frac{p_4}{p_3}}$$

$$u_5 = \frac{B\frac{p_4}{p_3} + 1}{(B-1)\left(\frac{p_4}{p_3} - 1\right)} u_1 \qquad (11.1)$$

$$u_5 - u_1 = \frac{B + \frac{p_4}{p_3}}{(B-1)\left(\frac{p_4}{p_3} - 1\right)} u_1 \qquad (11.2)$$

$$u_5(u_5 - u_1) = \frac{\left(B\frac{p_4}{p_3}+1\right)\left(B+\frac{p_4}{p_3}\right)}{(B-1)^2\left(\frac{p_4}{p_3}-1\right)^2} u_1^2 \tag{11.3}$$

But also, per equation (12)

$$u_5(u_5 - u_1) = \frac{2\gamma R g T_3}{\gamma+1} + \frac{\gamma-1}{\gamma+1} u_5^2 \tag{11.4}$$

Combining (11.2), (11.3) and (11.4) to eliminate u_5,

$$\frac{\left(B\frac{p_4}{p_3}+1\right)\left(B+\frac{p_4}{p_3}\right) - \frac{\gamma-1}{\gamma+1}\left(B\frac{p_4}{p_3}+1\right)^2}{(B-1)^2\left(\frac{p_4}{p_3}-1\right)^2} u_1^2 = \frac{2\gamma R g T_3}{\gamma+1}$$

Recall that $B = \frac{\gamma+1}{\gamma-1}$ and

Let $R = \frac{p_4}{p_3}$

$$\left(R+\frac{1}{B}\right)\left(B-\frac{1}{B}\right) u_1^2 = \frac{1}{B}\frac{2\gamma}{\gamma+1} R g T_3 (B-1)^2 (R-1)^2$$

Let $C = \left\{\frac{\left(B-\frac{1}{B}\right)u_1^2}{\frac{1}{B}\frac{2\gamma}{\gamma+1} R g T_3 (B-1)^2}\right\}$

Then

$$R^2 - 2\left[1+\frac{C}{2}\right]R + \left[1-\frac{C}{B}\right] = 0$$

$$R = 1 + \frac{C}{2} + \sqrt{\left(1+\frac{C}{2}\right)^2 - \left(1 - \frac{C}{B}\right)}$$

$$C = \frac{\left(6 - \frac{1}{6}\right)(1556)^2}{\frac{1}{6} \times \frac{2 \times 1.4}{2.4} \times 1715 \times 951 \,(6-1)^2} = 1.785$$

$$\frac{p_4}{p_3} = R = 1 + \frac{1.785}{2} \sqrt{\left(1 + \frac{1.785}{2}\right)^2 - \left(1 - \frac{1.785}{6}\right)} = 3.59$$

$$p_4 = 3.59 \times 75.5 = \underline{\underline{271 \text{ psia}}}$$

$$u_4 = u_5 - u_1 = \frac{B + \frac{p_4}{p_3}}{(B-1)\left(\frac{p_4}{p_3} - 1\right)} u_1 = \frac{6 + 3.59}{5 \times 2.59} \times 1556 = \underline{\underline{1150 \text{ ft/sec}}}$$

Summary

p_3 = 75.5 psia		T_3 = 921°R	
u_1 = 1556 ft/sec		u_4 = 1150 ft/sec	
u_2 = 2400 ft/sec		p_4 = 271 psia	

Based upon:

steam/water: p_0 = 1265 psia, h_0 = 580.6 Btu/lb

air: p_2 = 14.7 psia, T_2 = 70°F

DOCKET NO. 50-133
Suppl. File Cy.

PACIFIC GAS & ELECTRIC COMPANY
245 Market Street
San Francisco 6
SUtter 1-4211

AIR MAIL
SPECIAL DELIVERY

Humboldt Bay Power Plant
Unit No. 3
Construction Permit Application

March 9, 1960

DOCKETED USAEC Division of Licensing & Regulation MAR 11 1960 Docket Officer

Dr. Clifford K. Beck
Chief, Hazards Evaluation Branch
Division of Licensing and Regulation
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Dr. Beck:

At the meeting at Oak Ridge, Tennessee, February 25, information was requested on a number of different subjects; and where possible, we were asked to mail the answers to you as soon as they were completed rather than wait to present them to you on March 11.

Twenty-five copies of "The Effect on Drywell Pressure from Air in Vent Flow" are enclosed.

Very truly yours,

C. C. Whelchel

C. C. Whelchel
Chief Mechanical Engineer

sp
Enclosures

21 cys. to HEB 3-11-60
11:15 a.m.
R. Diggs

~~8602200598~~

14 pp

Docket No. 50-133
Suppl. File G.

PACIFIC GAS AND ELECTRIC COMPANY
MARCH, 1960

HUMBOLDT BAY POWER PLANT
UNIT NO. 3

THE EFFECT ON DRYWELL PRESSURE
FROM AIR IN VENT FLOW

According to calculations attached, air being a part of this vent flow will result in a lower drywell pressure than would occur if no air were present.

The calculations are based on the same equations as used previously in Amendment No. 6, Appendix II, Formulas (6) and (11). These equations are valid for mixtures as well as for single phase flows if the mixture is homogeneous.

To use these equations, however, it is necessary to determine the density variation of the air-water-steam mixture with pressure, and to do that, the fraction of air in the flow must be found. The following reasoning is applied:

> Due to the location of the six vent pipes equally spaced around the the drywell it is reasonable to assume that wherever the break occurs, some vents will be far from the break and will carry mostly air at the first instant after vent flow has been established due to expelling of water. Therefore, at the time peak pressure occurs, only a fraction of the air originally in the drywell will be present for mixing with the flow of water and water vapor. However, since the variation of the air flow rate is unpredictable, the following hypothetical and extreme case in considered, namely the condition where drywell design pressure (87 psia) has been reached without <u>any</u> air having been removed.

With an 87 psia total pressure existing in the drywell, and with all air present at the same temperature as the vapor, the air partial pressure would be 18.35 psia and the vapor partial pressure 68.65 psia. The density of the water-vapor mixture then would be 0.462 $\#/ft^3$ and, with a drywell volume of 12,100 cu ft, the total weight of water and water vapor at the time of the assumed peak pressure would be 12,100 x 0.462 = 5590 lbs.

Since the total amount of air in the drywell initially is approximately 800 lbs, the weight ratio of the air to the total air-water-vapor mixture would be 800/(800 + 5590), or 12.5%, and this is the absolute maximum possible air fraction which could exist at the drywell design pressure.

The air-mixing involves heating of the air from the initial temperature of 150°F to the vapor saturation temperature. This process absorbs heat from the water-vapor mixture and reduces flashing. This effect was taken into account in the computation of the density of the air-vapor-water mixture and this density and the function $\Delta\rho/\Delta p$ were plotted versus reduced pressures down the vent pipe in the range from 87 to 30 psia for the established 12.5% air mixture.

The following reasoning is used to determine the vent pipe flow rate while air is expelled at 87 psia:

> If no air were present at the design pressure of 87 psia, the water-vapor density then would be 0.604 #/ft^3 and the total weight of water-vapor would be 0.604 x 12,100 = 7310 lbs. In other words, the expelling of all 800 lbs of air from the drywell at 87 psia allows the drywell to accommodate an additional 7310 - 5590 = 1720 lbs of the mixture introduced from the break without increasing the total drywell pressure. This "extra storage" means, in effect, that while air is being disposed of the flowrate through the vents can be reduced some amount below that through the break without increasing the drywell pressure. The actual required total vent flowrate with 12.5% air in the mixture is calculated to be 8262 #/sec versus the 9450 #/sec design flow without air removal.

With flowrate and density variation thus established, computation on basis of the hypothetical condition results in a required vent pipe inlet pressure of 78.2 psia versus the assumed pressure of 87 psia. To obtain equality between assumed and calculated pressure, recalculations with somewhat lower assumed pressures would be required. This has not been considered necessary since the essential point has been to prove that a lower drywell pressure results from the presence of air in the vent lines.

FORM E-6Y 30M 8-58 DPH

CALCULATION SHEET

BECHTEL CORPORATION
TWO TWENTY BUSH STREET
SAN FRANCISCO 4, CALIFORNIA

SIGNATURE [signature] DATE 2/27/60

TITLE EFFECT ON DRY WELL PRESSURE FROM AIR IN VENT FLOW JOB NO. 3398

SUBJECT ______ SHEET NO. 1

1. AIR FRACTION IN VENT PIPE FLOW

VOLUME OF DRY WELL = 12,100 FT^3
AIR IN DRY WELL INITIALLY (BEFORE MCOA) @ 14.7 PSIA & 150°F WITH
SPECIFIC VOLUME $\bar{V}_{a_1} = 15.4\ FT^3/\#$
WEIGHT OF AIR IN DRY WELL = 12,100/15.4 = 786 SAY 800 LBS

AT THE DRY WELL DESIGN PRESSURE, 87 PSIA THE WATER-VAPOR MIXTURE DENSITY

$\rho_{MIX} = 0.604$ (CURVE C-1, AIRFREE MIXTURE)

WEIGHT OF MIXTURE THEREFORE 12,100 × 0.604 ≈ 7310 LBS

WITH THE DRY WELL @ 87 PSIA TOTAL PRESSURE AND ALL THE AIR PRESENT:
AIR PARTIAL PRESSURE = P_a, VAPOR PRESSURE = P_s. TEMPERATURE OF BOTH AIR AND VAPOR IS t_s = SATURATION TEMP. @ P_s

ESTIMATE $P_a = 18.35$ PSIA ∴ $P_s = 68.65$ PSIA & $t_s = 301.5$ °F

$$P_a = 14.7\ \frac{301.5+460}{150+460} = 14.7\ \frac{761.5}{610} = 18.35 \quad \text{(CHECK)}$$

AT 68.65 PSIA $\rho_{MIX} = 0.462$ (CURVE C-1, AIR FREE MIXTURE)

& MIXTURE WEIGHT = 12,100 × 0.462 ≈ 5590 LBS

AT THESE CONDITIONS, THE WEIGHT RATIO BETWEEN AIR AND MIXTURE OF AIR, WATER & VAPOR IS

$$800/(800+5590) = 800/6390 \approx 0.125 \text{ OR } \underline{12.5\%}$$

SINCE AT THE GIVEN DESIGN PRESSURE THIS IS THE MAXIMUM POSSIBLE AIR FRACTION THE FOLLOWING CALCULATIONS ARE BASED ON THIS VERY CONSERVATIVE AIR CONTENT.

FORM E-6V 20M 8-58 DPH

CALCULATION SHEET

BECHTEL CORPORATION
TWO TWENTY BUSH STREET
SAN FRANCISCO 4, CALIFORNIA

SIGNATURE Cohn

DATE 2/27/60

TITLE

JOB NO. 3298

SUBJECT

SHEET NO. 2

2. DENSITY OF AIR, WATER & VAPOR MIXTURE @ 12.5% AIR

AT VARIOUS SELECTED TOTAL PRESSURES THE WATER VAPOR PARTIAL PRESSURE P_s IS ESTIMATED, GIVING MIXTURE TEMPERATURE t_s. THE HEAT REQUIRED TO HEAT THE AIR FROM THE INITIAL 150° F TO t_s IS DETERMINED AND SUBTRACTED FROM THE INITIAL WATER HEAT CONTENT. ON BASIS OF THE REMAINING HEAT THE FLASHING FRACTION IS CALCULATED AND VOLUMES OF BOTH FLASH & WATER IS DETERMINED. THE VOLUME OF FLASH STEAM IS ALSO THE VOLUME THAT THE AIR WILL BE OCCUPYING AFTER MIXING. THE PARTIAL AIR PRESSURE CAN THEREFORE BE COMPUTED AND COMPARED WITH THE ESTIMATED. IF NOT IN AGREEMENT REPEATED CALCULATIONS GIVES THE CORRECT SOLUTION.

30 PSIA

ASSUME $P_s = 25$ PSIA & $t_s = 240$ °F

$\Delta h_{air} = 0.24(240 - 150) = 21.6$ BTU/# AIR

$= 21.6 \frac{0.125}{0.875} = 3.1$ BTU/# WATER

@ 25 PSIA: $h_f = 208.4$, $h_{fg} = 952.1$, $h_g = 1160.6$

$q = \frac{580.6 - 3.1 - 208.4}{952.1} = 0.3876$

∴ STM = 0.3876 × 0.875 = 0.3392 lbs

WTR = 0.5358 lbs

$\bar{v}_f = 0.01692$, VOL. OF WTR = 0.01692 × 0.5358 = 0.0091 FT³

$\bar{v}_g = 16.303$, VOL OF STM = 16.303 × 0.3392 = 5.5300 FT³

TOTAL VOL = 5.5391 FT³

VOL OF 0.125 lbs OF AIR @ 150°F & 14.7 PSIA = 0.125 × 15.4 = 1.925 FT³

$P_a = 14.7 \frac{(460+240)}{610} \cdot \frac{1.925}{5.53} = 5.87$ PSIA

FORM E-67 20M 5-58 DPH

CALCULATION SHEET

BECHTEL CORPORATION
TWO TWENTY BUSH STREET
SAN FRANCISCO 4, CALIFORNIA

SIGNATURE Ellolin DATE 2/27/60

TITLE JOB No. 3393

SUBJECT SHEET No. 3

TRY AGAIN WITH $P_s = 24.3$ & $t_s = 238.6$

$$\Delta h_{air} = \frac{0.24\,(238.8-150)\cdot 0.125}{0.875} = 3.05$$

@ 24.3 PSIA

$h_f = 207.1$

$h_{fg} = 952.9$

$h_g = 1160.0$

$$q = \frac{580.6 - 3.05 - 207.1}{952.9} = 0.3887$$

STM = 0.3887 · 0.875 = 0.3401 lbs

WTR = 0.5349 lbs

$\bar{v}_f = 0.016914$ VOL. OF WTR = 0.0090 FT^3

$\bar{v}_g = 16.684$ " " STM = 5.6742 FT^3

TOTAL VOL = 5.6832 FT^3

$$P_a = 14.7\,\frac{698.6 \cdot 1.925}{610 \cdot 5.6742} = 5.71 \quad \text{OK}$$

DENSITY OF AIR, VAPOR, WTR MIXTURE = 1/5.6832 = <u>0.176</u>

<u>50 PSIA</u> ASSUME $P_s = 40$ PSIA & $t_s = 267.3°$

$$\Delta h_{air} = 0.24(\overset{117.3}{267.3-150})\cdot 0.125/0.875 \cong 4.02$$

$h_f = 236.03$

$h_{fg} = 933.7$

$h_g = 1169.7$

$$q = \frac{580.6 - 4.02 - 236.03}{933.7} = 0.3647$$

STM = 0.3647 · 0.875 = 0.3191 lbs

WTR = 0.5559 lbs

$\bar{v}_f = 0.01715$ VOL. OF WTR = 0.0095 FT^3

$\bar{v}_g = 10.498$ VOL OF STM = 3.3499 FT^3

TOTAL VOL 3.3594 FT^3

$$P_a = 14.7\,\frac{727.3 \cdot 1.925}{610 \quad 3.3499} = 10.07 \text{ PSIA} \quad \text{OK}$$

$\rho = 1/3.3594 = \underline{0.298}$ $\#/FT^3$

Form E 8 5M 1-53 DDD

CALCULATION SHEET

BECHTEL CORPORATION
TWO TWENTY BUSH STREET
SAN FRANCISCO 4, CALIFORNIA

SIGNATURE Loin   DATE 7/27/60

TITLE   JOB No. 3298

SUBJECT   SHEET No. 4

80 PSIA   ASSUME $P_s = 64$ PSIA & $t_s = 297$ °F

$\Delta h_{air} = 0.24(297-150)\cdot 0.125/0.875 = 5.04$ BTU/# WTR

$h_f = 266.45$
h_{fg} 912.3
h_g 1178.8

$q = \dfrac{580.6 - 5.04 - 266.45}{912.3} = 0.3388$

STM = $0.3388 \cdot 0.875 = 0.2965$ lbs
WTR = 0.5785 lbs

$\bar{v}_f = 0.01742$ VOL OF WTR = 0.0101 FT³
$\bar{v}_g = 6.752$ VOL OF STM 2.0020 FT³

TOTAL VOL. 2.0121 FT³

$P_a = 14.7 \dfrac{757 \cdot 1.925}{610 \cdot 2.002} = 17.54$ PSIA

TRY $P_s = 62.9$ PSIA & $t_s = 295.8$°F $\Delta h_{air} = 5.02$

$h_f = 265.3$
$h_{fg} = 913.2$
$h_g = 1178.5$

$q = \dfrac{580.6 - 5.02 - 265.3}{913.2} = 0.3397$

STM = $0.3397 \cdot 0.875 = 0.2972$ lbs
WTR = 0.5778 lbs

$\bar{v}_f = 0.01741$ VOL OF WTR = 0.01006 FT³
$\bar{v}_g = 6.874$ VOL OF STM = 2.04295 FT³

TOTAL VOL = 2.053 FT³

$P_a = 14.7 \dfrac{756 \cdot 1.925}{610 \cdot 2.053} = 17.09$ ✓ & $\rho = 1/2.053 = $ <u>0.487 #/FT³</u>

THESE RESULTING ρ-VALUES ARE PLOTTED ON CURVE SHEET C-1 WHICH ALSO SHOWS FOR COMPARISON THE DENSITY VARIATION OF THE AIR-FREE

Form E 6 .5M 1-53 DDD

CALCULATION SHEET
BECHTEL CORPORATION
TWO TWENTY BUSH STREET
SAN FRANCISCO 4, CALIFORNIA

SIGNATURE Elder DATE 2/27/60

TITLE JOB NO. 3398

SUBJECT SHEET NO. 5

3. CRITICAL END OF LINE PRESSURE

AT THE CRITICAL PRESSURE THE FOLLOWING EQUATION MUST BE SATISFIED:

$$\frac{1}{2}\rho^2\left(\frac{dp}{d\rho}\right) = \frac{(W/A)^2}{288\,g} \qquad \text{(Eq. 3-1)}$$

WITH THE TOTAL DRY WELL AIR CONTENT PRESENT AT THE DESIGN PRESSURE OF 87 PSIA THE WATER-VAPOR CONTENT IS 5590 lbs (SEE PG. 1)

AT 87 PSIA AND NO AIR PRESENT, THE VAPOR-WATER CONTENT IS 7310 lbs (Pg 1)

THE DISPOSAL OF ALL AIR @ 87 PSIA THEREFORE MAKES IT POSSIBLE FOR THE DRY WELL TO ACCOMODATE

$$7310 - 5590 = 1720 \text{ lbs WATER-VAPOR}$$

TO DETERMINE THE TIME t REQUIRED TO DISPOSE OF ALL AIR:

(1) $W_{BREAK} \cdot t = 1720 + W_{STM+WTR} \cdot t$

(2) $W_{AIR} \cdot t = 800$ lbs

(3) $W_{AIR} = 0.125\left(W_{S+W} + W_a\right)$ OR $W_{S+W} = 7\,W_a$

SINCE AT 87 PSIA $W_{BREAK} = 9450$ lbs/SEC

$$9450 \cdot t = 1720 + 7 \times 800 = 7320 \quad \therefore \; t = 0.7746 \text{ SEC}$$

$$\text{TOTAL VENT FLOW RATE} = \frac{800}{0.125 \times 0.7746} = 8262 \text{ lbs/SEC}$$

OR FOR EACH OF THE SIX VENT PIPES: 1377 lbs/SEC

Form E 5 5-55 DDD

BECHTEL

CALCULATION SHEET

BECHTEL CORPORATION
TWO TWENTY BUSH STREET
SAN FRANCISCO 4, CALIFORNIA

SIGNATURE D. Cohn DATE 2/27/60

TITLE JOB No. 3398

SUBJECT SHEET No. 6

FLOW PER JET PIPE = 1377/8 $\approx$ 172 lbs/SEC

JET PIPE AREA A = 0.9575 FT^2

$\therefore$ W/A = 172/0.9575 = 179.6

$(W/A)^2/288g$ = 32256 /9274 = 3.48

Eq. 3-1 $\rho^2\left(\frac{dp}{d\rho}\right) = 6.96$

TRY FOR P = 33 PSIA WHERE ρ = 0.193 (CURVE C-2)

& $dp/d\rho$ = 166 (CURVE C-2)

$\therefore$ $\rho^2(dp/d\rho) = 0.193^2 \times 166 = 6.18$

TRY FOR P = 35 PSIA WHERE ρ = 0.206 & $dp/d\rho \approx 165$

$\therefore$ $\rho^2(dp/d\rho) = 7.00$ OK.

P_C = 35 PSIA

Form E 4 311 3-53 DDD

CALCULATION SHEET

BECHTEL CORPORATION
TWO TWENTY BUSH STREET
SAN FRANCISCO 4, CALIFORNIA

SIGNATURE D Cole   DATE 2/27/60

TITLE ______   JOB No. 3398

SUBJECT ______   SHEET No. 7

4 INTEGRATION OF $\int \rho \, dp$

(FOR 12.5 % AIR ; ρ-VALUES FROM CURVE C-1)

P_2	ρ_2	ρ_{avg}	Δp	$\rho_{avg} \cdot \Delta p$	$\Sigma \rho_{avg} \cdot \Delta p$
31	0.182				
		0.194	4	0.776	0.776
35	0.206				
		0.218		0.872	1.648
39	0.230				
		0.243		0.972	2.620
43	0.256				
		0.268		1.072	3.692
47	0.279				
		0.292		1.168	4.860
51	0.305				
		0.317		1.268	6.128
55	0.329				
		0.342		1.368	7.496
59	0.354				
		0.366		1.464	8.960
63	0.379				
		0.392		1.568	10.528
67	0.404				
		0.417		1.668	12.196
71	0.430				
		0.442		1.768	13.964
75	0.455				
		0.468		1.872	15.836
79	0.480				
		0.494		1.976	17.812
83	0.507				
		0.520	↓	2.080	19.892
87	0.533				

Form E 8, 5M 1-53 DDD

CALCULATION SHEET

BECHTEL CORPORATION
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SIGNATURE [signature] DATE 2/27/60

TITLE JOB No. 3398

SUBJECT SHEET No. 8

5. PRESSURE DROP THRU JET PIPES @ 172 lbs/SEC. w/ 12.5% AIR

$$\Sigma K + \frac{fL}{D} = \frac{\int_{P_c}^{P_x} \rho\, dp + \rho_x \frac{\rho_c \cdot H}{144}}{(W/A)^2/288g} - 2 \ln \rho_x/\rho_c$$

WHERE, AS BEFORE

$\Sigma K = 1.6$

$f = 0.01$ AND $\rho_c = 0.206$

$L = 20'$

$D = 1.1042'$ $(W/A)^2/288g = 3.48$

$H = 15'$

$$\therefore \quad 1.6 + \frac{0.01 \cdot 20}{1.1042} = \frac{1}{3.48}\left[\int_{P_c}^{P_x} \rho\, dp + \rho_x \frac{0.206 \cdot 15}{144}\right] - 4.605 \log_{10}(\rho_x/0.206)$$

$$1.7811 = 0.2874 \int \rho\, dp + 0.0062 \cdot \rho_x - 4.605 \log_{10}(\rho_x/0.206)$$

TRY $P_x = 71$ PSIA WITH $\rho_x = 0.430$ & $\Sigma_{31}^{71} = 12.196$

$$1.7811 = 0.2874(\overset{11.420}{12.196 - 0.776}) + 0.0062 \cdot 0.43 - 4.605 \cdot 0.32$$

$$1.7811 < 3.2603 + 0.0027 - 1.4736 = 1.8112$$ (CLOSE ENOUGH) OK

FORM 5-6Y 30M 8-55 DPH

CALCULATION SHEET

BECHTEL CORPORATION
TWO TWENTY BUSH STREET
SAN FRANCISCO 4, CALIFORNIA

SIGNATURE [signature] DATE 2/27/60

TITLE JOB No. 3398

SUBJECT SHEET No. 9

6. PRESSURE DROP THRU VENT PIPE @ FLOW OF 1377 #/SEC

$$\Sigma K + \frac{fL}{D} = \frac{\int_{P_x}^{P_y} \rho\, dp + \rho_y \frac{\rho_x \cdot H}{144}}{(W/A)^2/288g} - 2 \ln \rho_y/\rho_x$$

WHERE (AS BEFORE) $\Sigma K = 0.8$ $D = 3.27'$ $A = 8.4\ FT^2$

$f = 0.01$ $H = 25$

$L = 41'$

$fL/D = 0.1254$ ALSO $\rho_x = 0.43$

$$(W/A)^2/288g = (1377/8.4)^2/9274 = 2.8977$$

$$\therefore \quad 0.9254 = \frac{1}{2.8977}\left(\int_{P_x}^{P_y} \rho\, dp + \rho_y \frac{0.43 \cdot 25}{144} \right) - 4.605 \cdot \log_{10} \rho_y/0.43$$

$$0.9254 = 0.3451 \int_{P_x}^{P_y} \rho\, dp + 0.0258\, \rho_y - 4.605 \cdot \log_{10} \rho_y/0.43$$

TRY $P_y = 79$ PSIA WITH $\rho_y = 0.48$ & $\Sigma_{31}^{79} = 15.836$

$$0.9254 = 0.3451\left(\overset{3.64}{15.836 - 12.196} \right) + 0.0258 \cdot 0.48 - 4.605 \cdot 0.048$$

$$0.9254 < 1.2562 + 0.0124 - 0.2210 = 1.0476$$

TRY $P_y = 75$ PSIA WITH $\rho_y = 0.455$ & $\Sigma_{31}^{75} = 13.964$

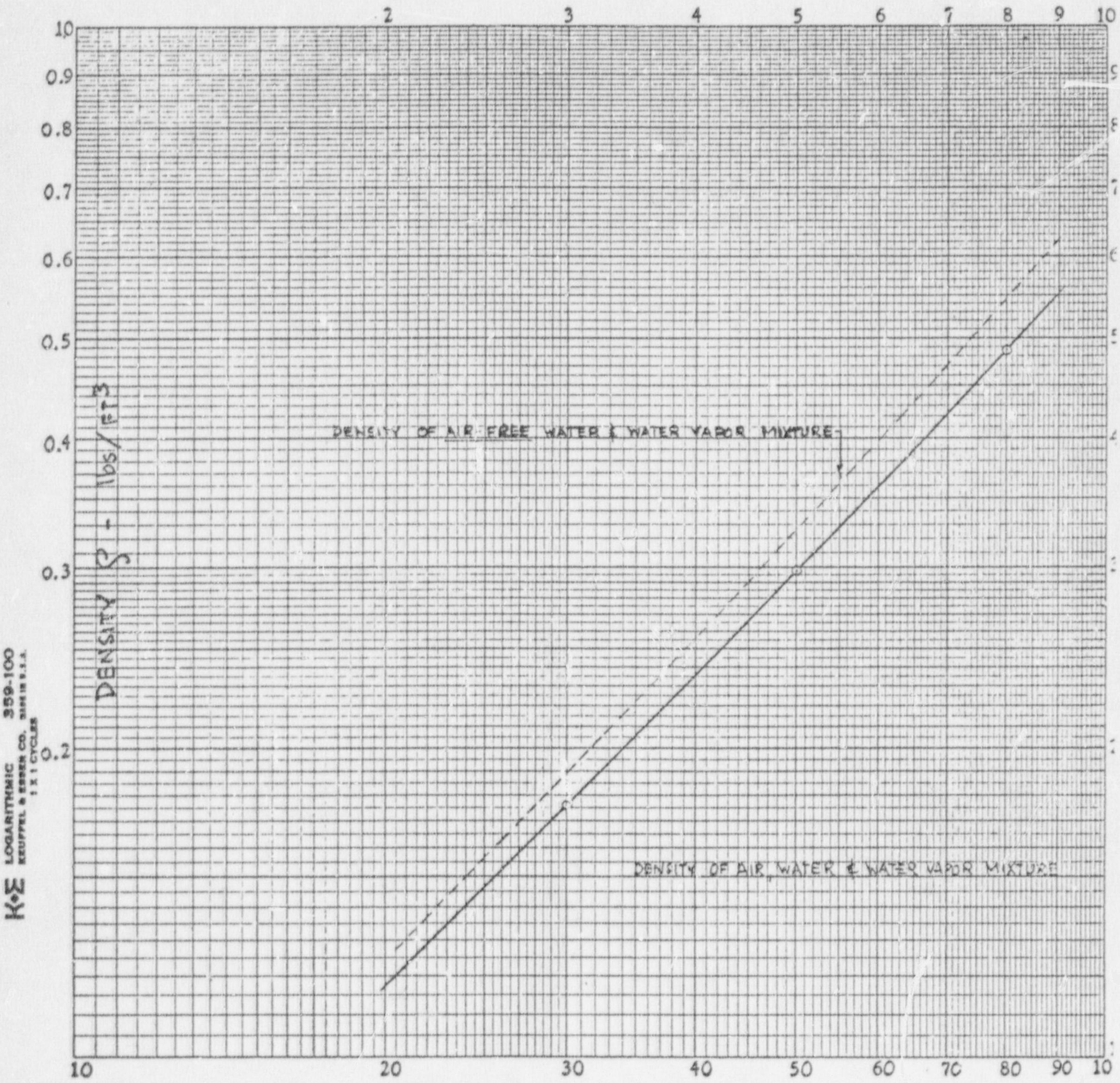
$$0.9254 = 0.3451(\overset{1.768}{13.964 - 12.196}) + 0.0258 \cdot 0.455 - 4.605 \cdot 0.023$$

$$0.9254 > 0.6101 + 0.0117 - 0.1059 = 0.5159$$

BY INTERPOLATION : $P_y = 78.2$ PSIA

MIXTURE DENSITY OF AIR, VAPOR & WATER

BASIS: CONSTANT ENTHALPY EXPANSION, AIR FRACTION = 12.5 % BY WEIGHT, WATER INITIALLY SATURATED @ 1265 PSIA, AIR INITIALLY @ 14.7 PSIA & 150°F

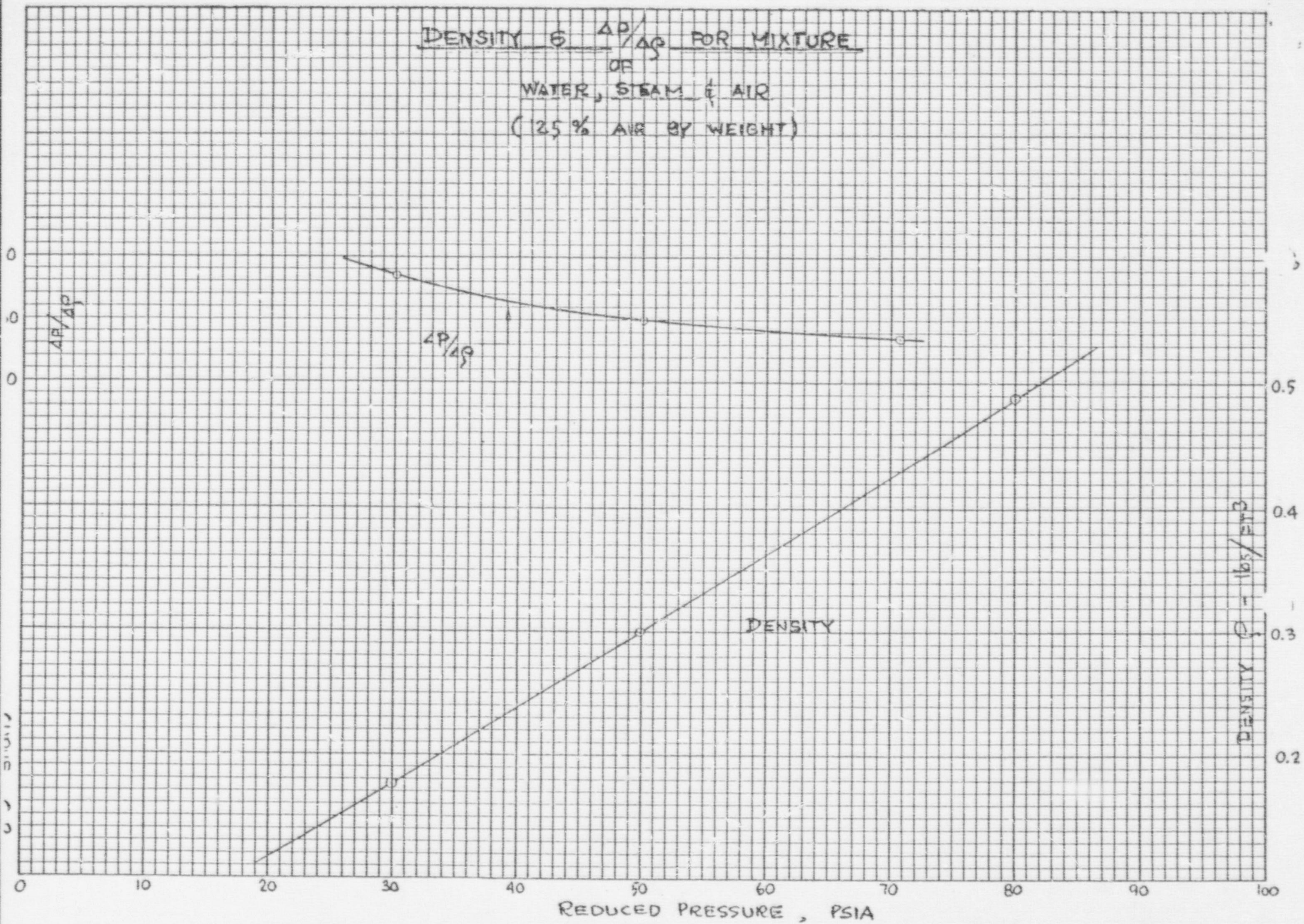


CURVE C-1

9/27/60

K•E 10 X 10 TO THE INCH KEUFFEL & ESSER CO. 359-5G MADE IN U.S.A.

2/27/60



P IFIC GAS AND ELECTRIC COMPANY
MARCH 11, 1960

#170

HUMBOLDT BAY POWER PLANT, UNIT NO. 3

DISCUSSION
OF
FULL SCALE TEST OF HUMBOLDT PRESSURE SUPPRESSION SYSTEM

I. INTRODUCTION

Investigations now underway indicate that a full scale transient test can be made to check out a model of 1/48 of the Humboldt pressure suppression system. These tests will be conducted at Moss Landing. The primary purpose will be to demonstrate the operation of one of the 14-inch diameter condensing pipes and the part of the water pool and air chamber associated with it. In addition, information could be obtained which will help verify the design pressure of the dry well and suppression chamber. The following paragraphs represent a tentative design of the tests.

II. TEST EQUIPMENT

A diagramatic arrangement of the principal testing equipment is shown on the attached sketch.

A compartment built inside the large condensing test tank at Moss Landing would be the same size and shape as the part of the Humboldt water pool associated with a single 14" condensing pipe. A single 14-inch diameter pipe would be installed for discharging steam and air into the water in the compartment.

The dry well would be simulated by using a tank filled with air equal in volume to 1/48 of the Humboldt dry well. The flow resistance between the dry well and the water pool would be simulated as well as possible, although some approximations will be required.

The hot water and flashing steam entering the dry well would be provided from a pressure vessel containing an amount of energy equal to 1/48 of the Humboldt reactor vessel at 1265 psia. Present plans are to heat the water up to 600 psig before a test. The orifice controlling flow from the vessel would be made big enough to simulate flow from a vessel initially at 1265 psia.

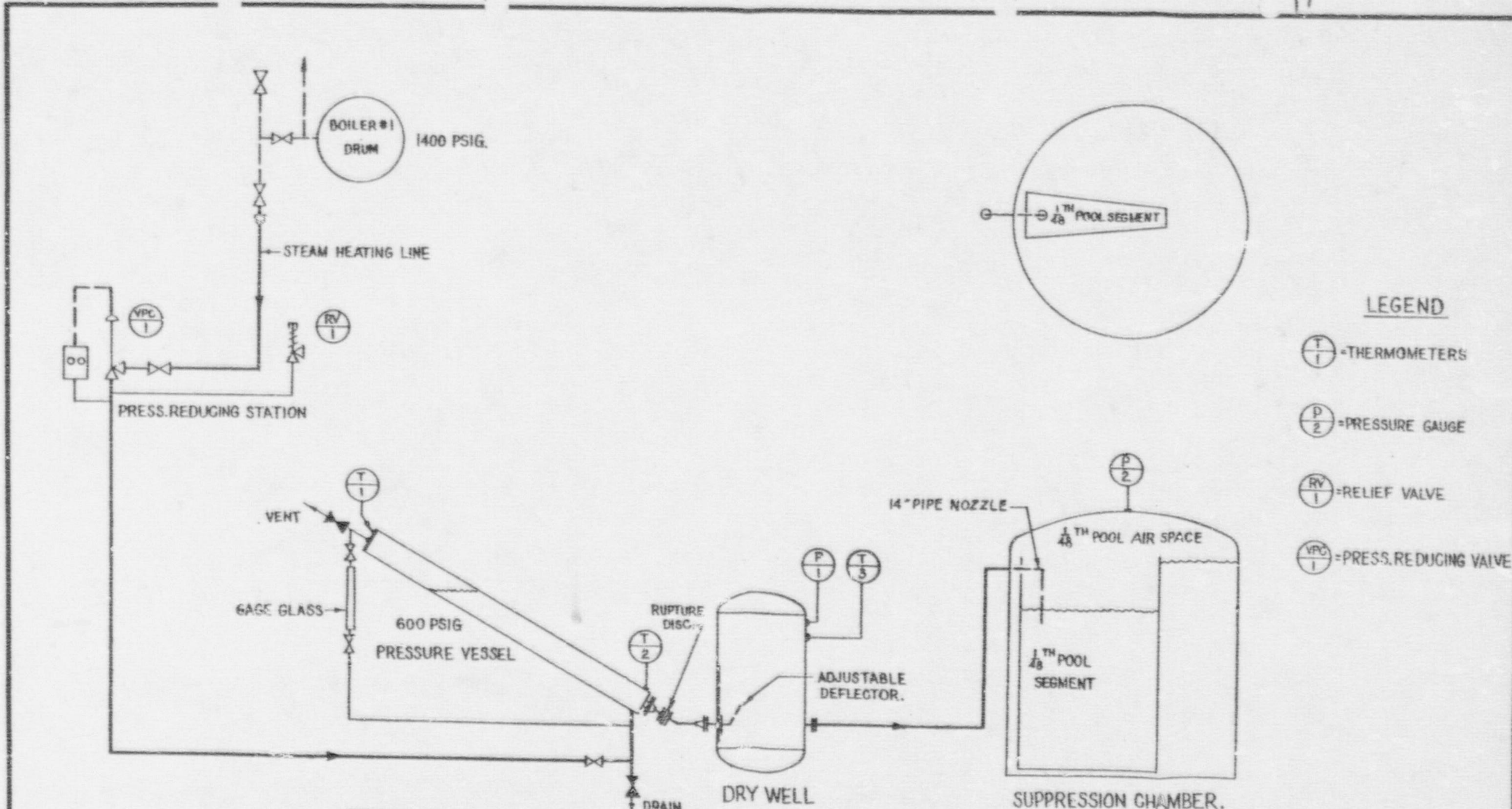
Instrumentation would be similar to that used previously on the transient test facility at San Jose. Transient pressures would be measured and recorded in the pressure vessel, dry well, end of the vent pipes, and in the closed condensing test tank above the water pool.

III. TESTING

Several tests would be conducted to determine the effect of variables including the following:

1. Initial pressure in reactor vessel.
2. Size of orifice controlling flow from vessel.
3. Relative time during transient that air is expelled from dry well.
4. Depth of submergence of vents.

Brought back from Cees mtg. by Dr. Beck Given Cees by PG&E decision Not announced by us



NO.	DATE	DESCRIPTION	APPRD

TABLE OF CHANGES

APPROVED BY: GM

DWG. LIST

BY S. K. BOGHOSIAN DSGN.

DR. G. S. BALOGHY

CH.

O.K.

DATE 3-8-60

SCALE NONE

SCHEMATIC DIAGRAM OF

FULL SCALE TRANSIENT CONDENSING TEST

MOSS LANDING POWER PLANT.

PACIFIC GAS AND ELECTRIC COMPANY

SAN FRANCISCO, CALIFORNIA

BILL OF MATERIAL

ELECT. EQUIP. LIST

SUPERSEDES

SUPERSEDED BY

SHEET NO. SHEETS

DRAWING NUMBER P236-1

CHANGE