March 7, 1997

LICENSEE: Commonwealth Edison Company (ComEd)

FACILITIES: Dresden Station, Units 2 and 3

SUBJECT: SUMMARY OF THE MEETING CONCERNING THE EMERGENCY TECHNICAL SPECIFICATION CHANGE REQUESTING THE USE OF CONTAINMENT OVER PRESSURE TO COMPENSATE FOR A NET POSITIVE SUCTION HEAD DEFICIENCY FOR THE EMERGENCY CORE COOLING PUMPS

On January 21, 1997, the staff met with ComEd to discuss an emergency Technical Specification (TS) change involving the use of containment over pressure to compensate for a deficiency in net positive suction head (NPSH) of the Emergency Core Cooling Pumps (ECCS). A list of attendees is provided as Enclosure 1.

The objective of the meeting was to resolve open issues from a previous meeting held with ComEd on January 16, 1997. The topics discussed were the NPSH calculations and the ECCS pump performance during pump cavitation. A copy of the licensee's presentation is included as Enclosure 2.

The licensee provided specific details and clarification on how the new NPSH calculations had been performed, including all input parameters and conservatisms. The licensee also provided the details and specific justifications for the ECCS pump flow under cavitating conditions.

/s/

John F. Stang, Senior Project Manager
Project Directorate III-2
Division of Reactor Projects - III/IV
Office of Nuclear Reactor Regulation

Docket Nos. 50-237 and 50-249

Enclosures: 1. List of Attendees
2. Licensee's Presentation

cc w/encls: see next page

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Ken Dempsey
Jack Kudrick
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Enclosure 1

COMED Meeting with NRC

Emergency Technical Specification Amendment
ECCS Suction Strainer Head Loss

January 21, 1997

ENCLOSURE 2

Question 1

Discuss Additional Conservatisms in the Methodology used to Calculate Peak Cladding Temperature

Additional Information Regarding Conservatism in PCT Evaluations

The purpose of this response is to provide additional information regarding the evaluation and assessment of PCT penalties with respect to the runout flow conditions predicted in SIL 151 scenarios. This is being provided to respond to NRC staff questions occurring during review of the Dresden amendment submitted for review on January 17, 1997. Specifically, the staff has requested that additional information be provided to facilitate a qualitative assessment of PCT margins inherent in the methodology applied in the amendment.

Original Basis of SIL 151

This SIL was primarily focused on the potential for loss of long-term containment cooling due to the potential for damage to the LPCI pumps under single failure assumptions that would cause LPCI pump injection to a broken recirculation piping discharge loop. The concern was that operation in cavitation conditions could cause loss of the LPCI pumps and subsequent loss of the containment heat removal function. The evaluations performed in response to this concern were reviewed and accepted by NRC staff in an SER dated January 4, 1977. This SER concluded that for recirculation discharge line breaks with failure of the loop select logic causing multiple pump injection to the faulted loop, that "...your facilities' design provides sufficient safety margin to preclude LPCI pump damage following a LOCA due to either pump cavitation or pump motor overload." It is important to note that none of the evaluations at this time were concerned with core spray pump operation, other than as an input to the overall flows used in LPCI pump runout Net Positive Suction Head (NPSH) evaluations.

Current Assessments

In the current assessments, the principal concern being addressed is the potential for the high LPCI flow rates to affect the total Core Spray pump flow. This concern surfaced as a result of review questions and investigations conducted during the recent Independent Safety Inspection. The design basis LOCA analysis for Dresden is the recirculation suction break with assumed single failure of the LPCI injection valve. This results in core recovery and reflood based on two Core Spray pumps injecting. The original calculations employed runout flows at depressurized vessel conditions of 5650 gpm per pump. The most recently reported assessments (November 6, 1996, 50.46 response) were also based on 5650 gpm per pump flow rates. Based on hydraulic characterizations of the LPCI and CS runout flows under bounding assumptions for this SIL 151 (recirculation discharge line break) case, a CS flow rate of greater than 5300 gpm per pump is expected. A value of 5276 gpm per pump was utilized in an evaluation performed by the vendor, Siemens Power Corporation (SPC) for the limiting recirculation suction break and shown to result in a PCT of 2163 F.

Margin in LOCA PCT Approach

The approach described above contains significant conservatisms, beyond those applied in the generation of CS pump flows under cavitation conditions. The most significant of these is that the PCT evaluations are being performed on the basis of a recirculation suction piping break. As noted above, the only break location of concern to this runout flow condition is a break of the recirculation discharge piping. Discharge piping breaks are less limiting than the suction side breaks due to the more restrictive blowdown flowpath. New break spectrum studies currently being performed indicate that a PCT difference of approximately 100 F is anticipated between these break locations, with the recirculation suction piping location bounding. Therefore, the use of recirculation suction break models to assess PCT penalties for this scenario is clearly conservative and results in additional margin in the overall assessment.

Question 2

Discuss the Applicability of NPSH Curves in the UFSAR with the Quad Cities SER Approval

Applicability of NPSH Curves in the UFSAR with the Quad Cities SER

The purpose of this response is to provide additional documentation for the proposed use of 2 psi over pressure (16.7 psia) as an input for ECCS pump NPSH calculations during short term runout conditions in the initial 10 minutes following a design basis LOCA. As indicated in a previous response, the Quad Cities SER states that a few psi of containment over pressure will be needed to ensure adequate ECCS pump NPSH for a period of 8 hours following a DBA LOCA. A comparison of key containment parameters for Dresden and Quad Cities has been provided, demonstrating that post-LOCA containment pressure response can be expected to be virtually identical for these units, particularly in the short term behavior. Additional questions have addressed the long term containment pressure NPSH curves in the Quad Cities UFSAR and the applicability of these curves to the original SER stated "few psi".

Long Term Response

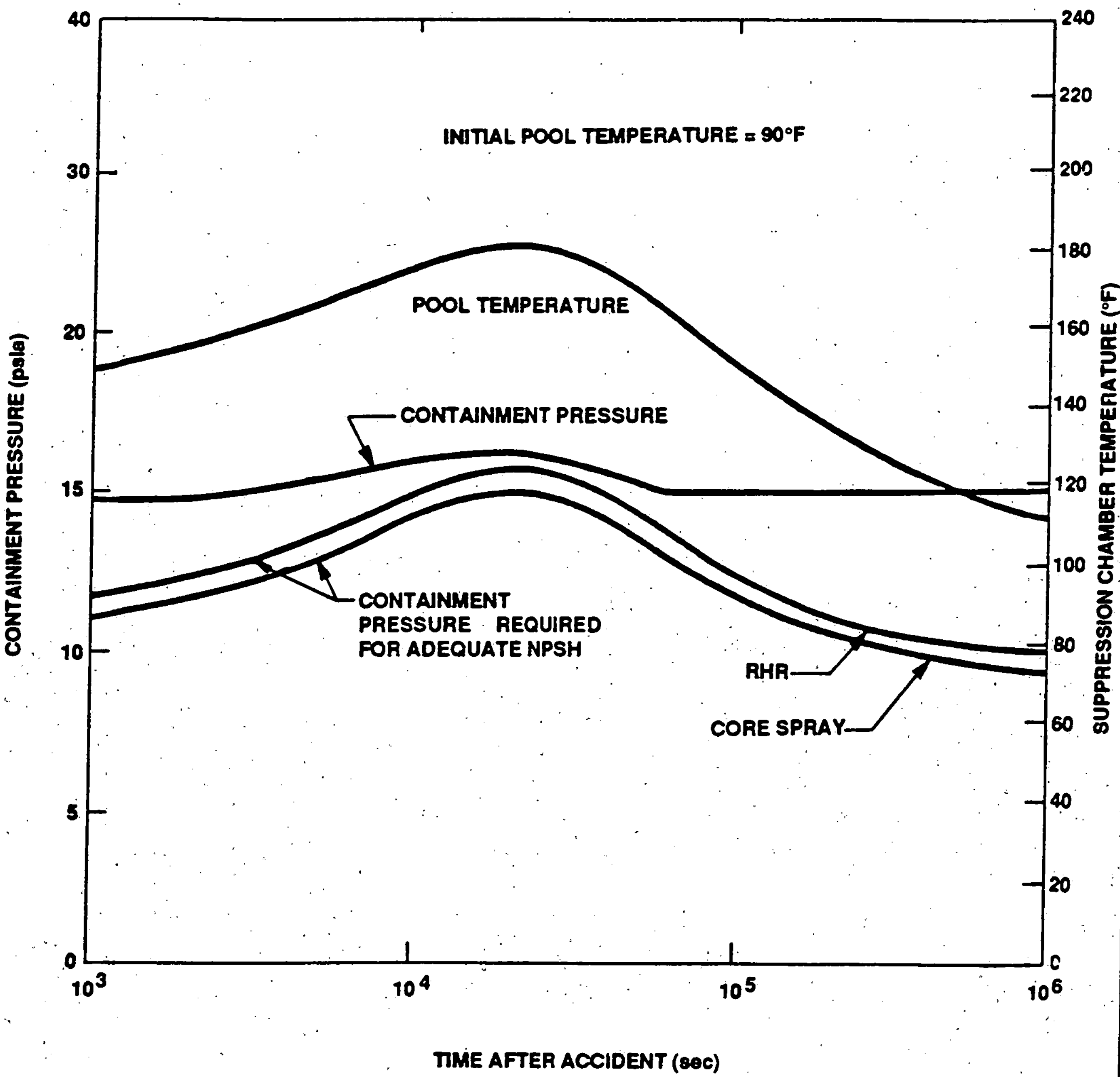
The Quad Cities and Dresden long term containment response curves, UFSAR Figures 6.3-41, 6.3.42, and Figure 6.3-80 respectively, generated to support ECCS pump NPSH during the post-LOCA suppression pool heatup transient have been reviewed. These response curves indicate very little long term overpressure exists, based on a number of conservative assumptions. Specifically, the UFSAR discussion supporting these curves indicates that they are based on minimum initial levels of non-condensibles as well as containment leakages of 5%/day (10 x the maximum allowable). Probably the most significant assumption applied in the generation of these curves was the assumption that the drywell temperature is calculated as being equal to the containment spray temperature, which is an implicit assumption of zero mixing of the break discharge fluid to the drywell. While these assumptions certainly do minimize the over pressure that would exist, especially in the long term analyses, the mechanisms for minimizing the pressure would not be active in the short term cases, with the exception of the minimum non-condensible assumptions.

ComEd believes that these very conservative assumptions underly the SER wording of "several psi of overpressure", since the actual pressure would be anticipated to be several psi above that predicted in this manner. This has been observed in recent reanalysis previously mentioned, where long term pressures of approximately 3 psi are predicted for the same containment temperatures as originally calculated. In contrast, the UFSAR containment over pressure calculation Figures 6.2-19 and 6.2-16 for Dresden and Quad Cities respectively, demonstrate that long term pressures of approximately 8 psig would exist. These pressures are based on a model that determines drywell temperature by adding 5 F to the temperature based on assuming the break fluid mixes completely with the drywell spray flow. Discussion with GE with respect to the break flow mixing assumptions used in containment analysis have indicated that best estimate values of mixing appear to be near 40%, and that 20% mixing is typically assumed in design applications where minimal mixing is desired.

Short Term Containment Pressure Response

The short term pressure response for both Dresden and Quad Cities are attached. As can be seen, the initial response is identical up to the end of blowdown. The Dresden pressure then decays more rapidly than the Quad Cities curves. The basis of this difference is at present unknown, since the original analysis has not been recoverable in either case. What is notable with respect to these curves is that a significant containment pressure is predicted throughout the initial 10 minutes, prior to initiation of containment spray. While these curves are intended to predict the maximum containment pressure to demonstrate compliance with containment pressure limits, it is clear that over pressure conditions will exist throughout this interval. Physically, significant overpressure should continue until the quench of the drywell steam occurs due to spray initiation. Prior to spray initiation, significant fractions of the initial non-condensibles are stored in the suppression pool airspace. Based on these curves, the minimum overpressure for the interval is between 10 and 20 psig. What has been proposed is the use of 2 psig over pressure for the ECCS pump NPSH calculations being performed in this time interval, at 200 seconds and at 600 seconds. The 200 second calculation point is the most significant with respect to PCT performance, since this is the time period when quench/reflood occurs, and at which the most Core spray flow is desired. At the 200 second point, both Dresden and Quad Cities containment analyses support containment pressures in excess of 20 psig. New containment studies currently in progress demonstrate that with the most conservative break flow mixing, minimization of non-condensibles in the drywell airspace, as well as heat sink modeling consistent with CSB 6-1 guidance, that the pressure in this interval remains above 5.5 psig. Therefore the use of minimal amounts of over pressure in the short term is conservative, particularly in the case of the 200 second data point important to the ECCS performance evaluation.

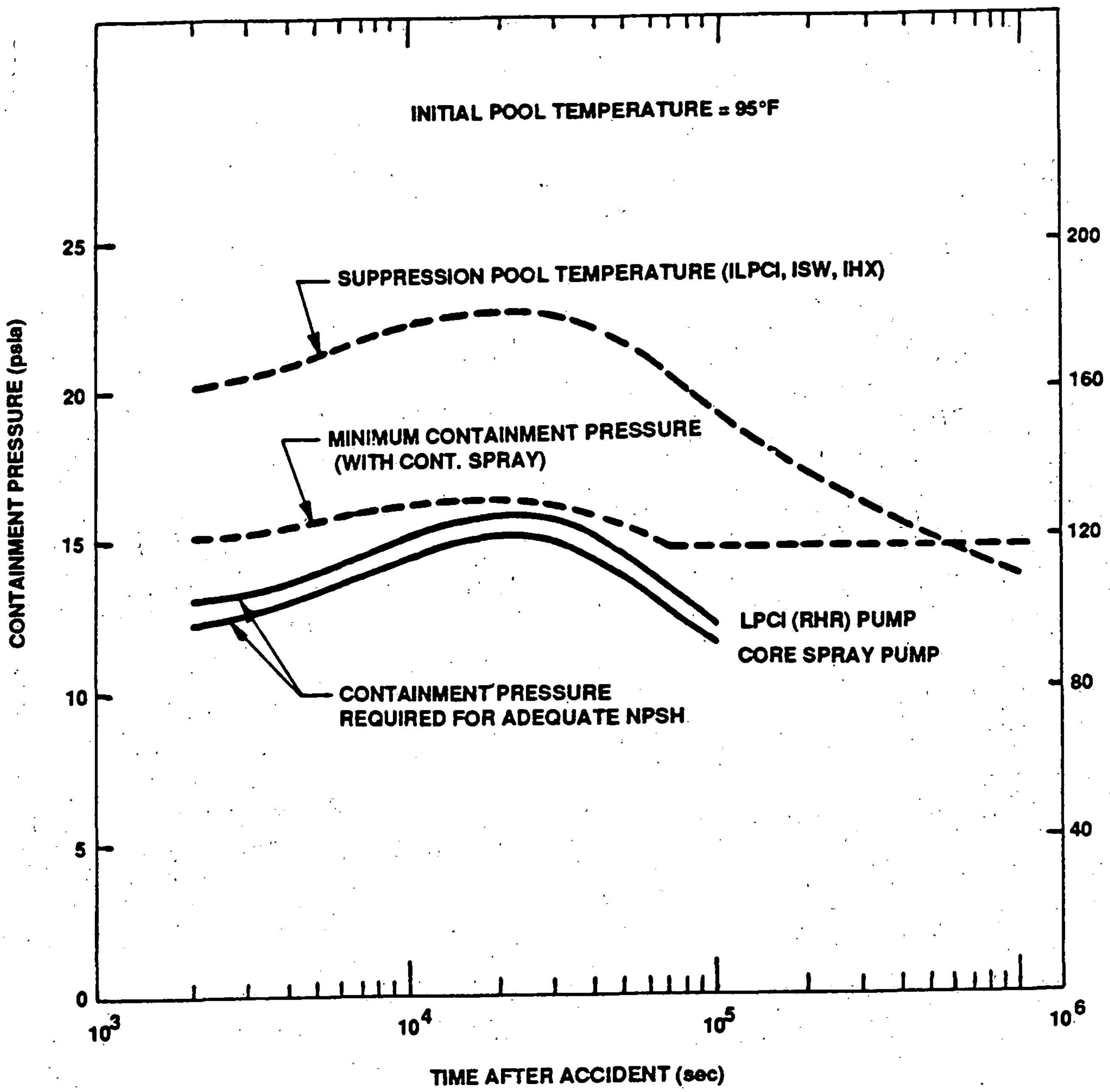
Additional factors that would ensure that the overpressure would not be less than 2 psig include the current tech spec requirement of maintaining the drywell at 1 psi greater pressure than the suppression pool. This requirement, used to provide mitigation of suppression pool loads, would cause a higher non-condensible mass than the original calculations assumed. In addition, it should be noted that subatmospheric conditions are precluded by the presence of the reactor building to suppression pool vacuum breakers. These factors as well as the fact that the guillotine failure of a recirc discharge line, with assumed single failure of the LPCI injection valve causing all LPCI flow to be directed to the faulted loop, is the only scenario leading to the severe runout conditions being evaluated, ensure that a minimum assumed overpressure for the short term evaluation of 2 psig is a conservatively low estimate of the actual conditions anticipated.



QUAD CITIES STATION
UNITS 1 & 2

CONTAINMENT PRESSURE REQUIRED AND CONTAINMENT PRESSURE AVAILABLE FOR ADEQUATE NPSH AT THE LPCI AND CORE SPRAY PUMPS FOLLOWING A DESIGN BASIS LOCA WITH AN INITIAL POOL TEMPERATURE OF 90° F

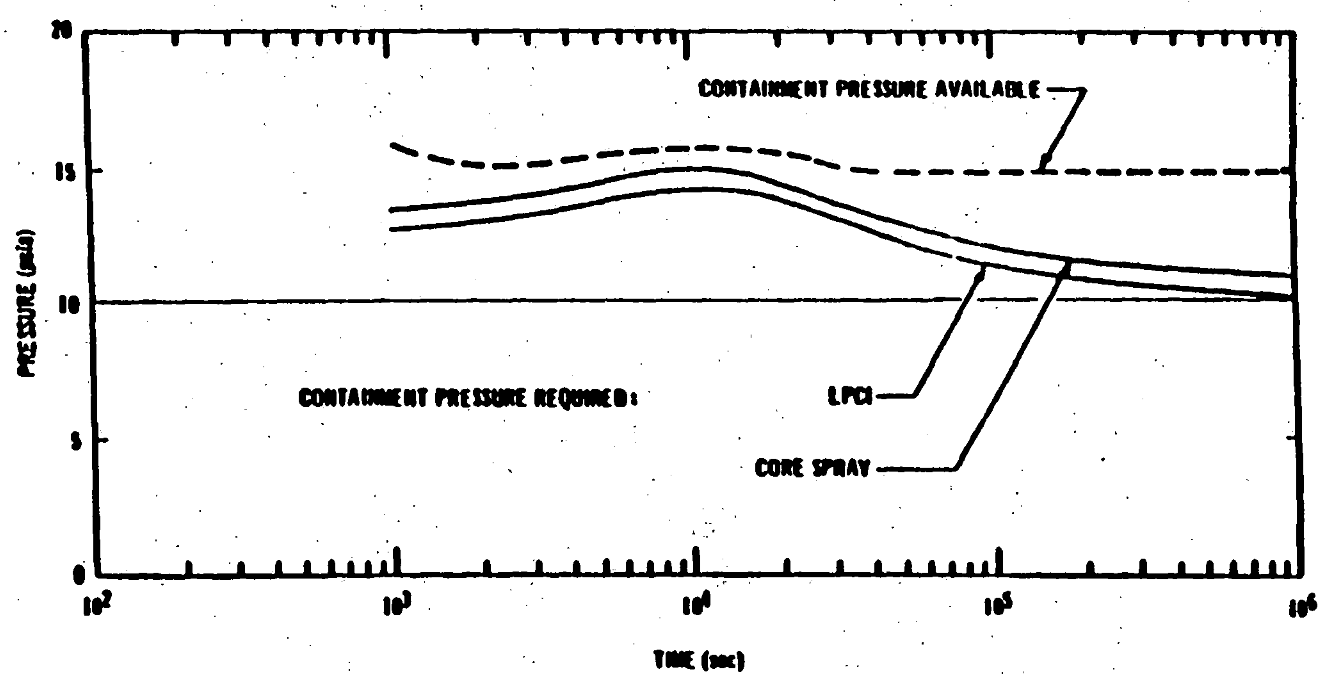
FIGURE 6.3-41



QUAD CITIES STATION
UNITS 1 & 2

CONTAINMENT PRESSURE REQUIRED AND CONTAINMENT PRESSURE AVAILABLE FOR ADEQUATE NPSH AT THE LPCI AND CORE SPRAY PUMPS FOLLOWING A DESIGN BASIS LOCA WITH AN INITIAL POOL TEMPERATURE OF 95° F

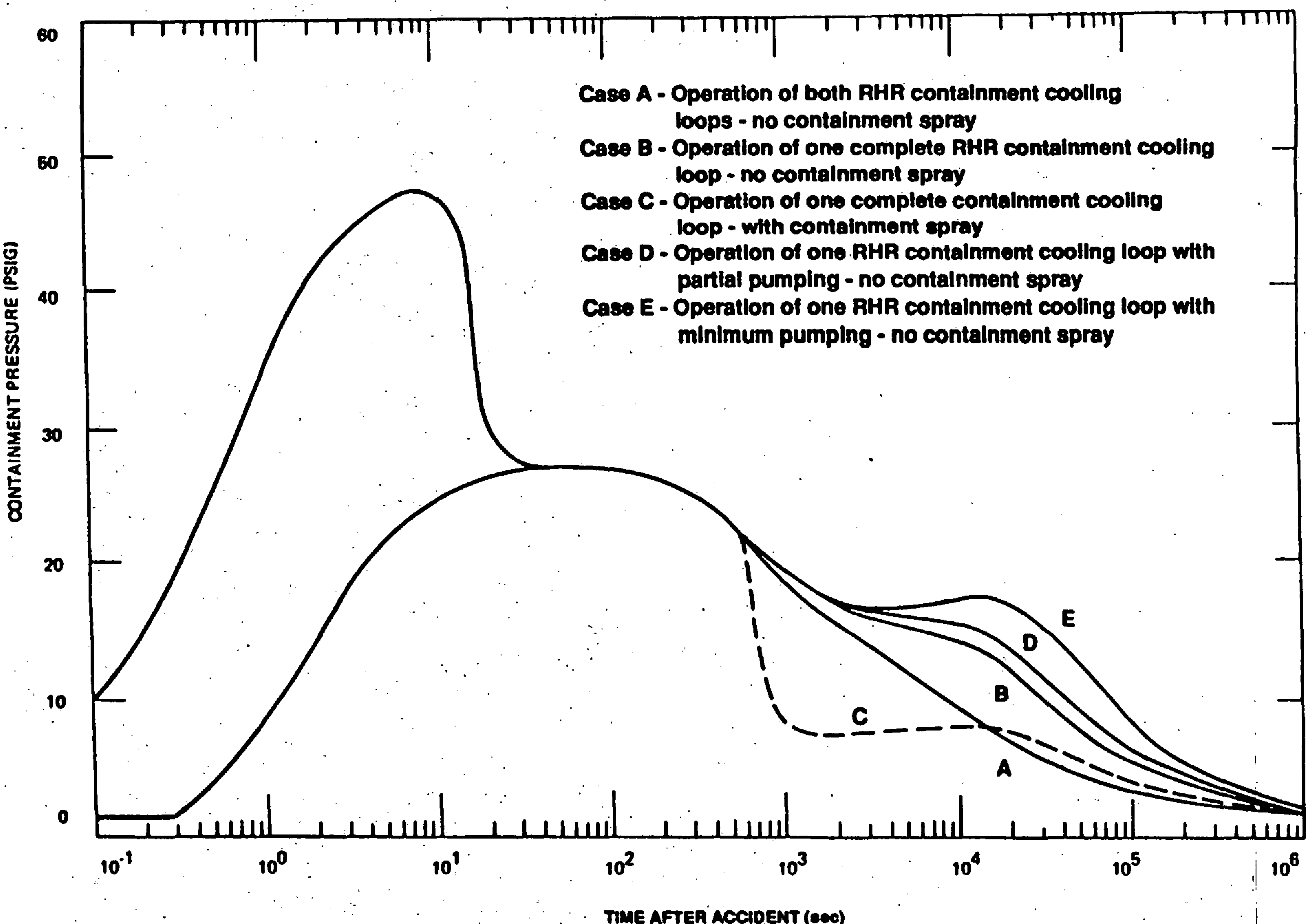
FIGURE 6.3-42



DRESDEN STATION
UNITS 2 & 3

MINIMUM CONTAINMENT PRESSURE AVAILABLE AND CONTAINMENT PRESSURE REQUIRED FOR PUMP NPSH

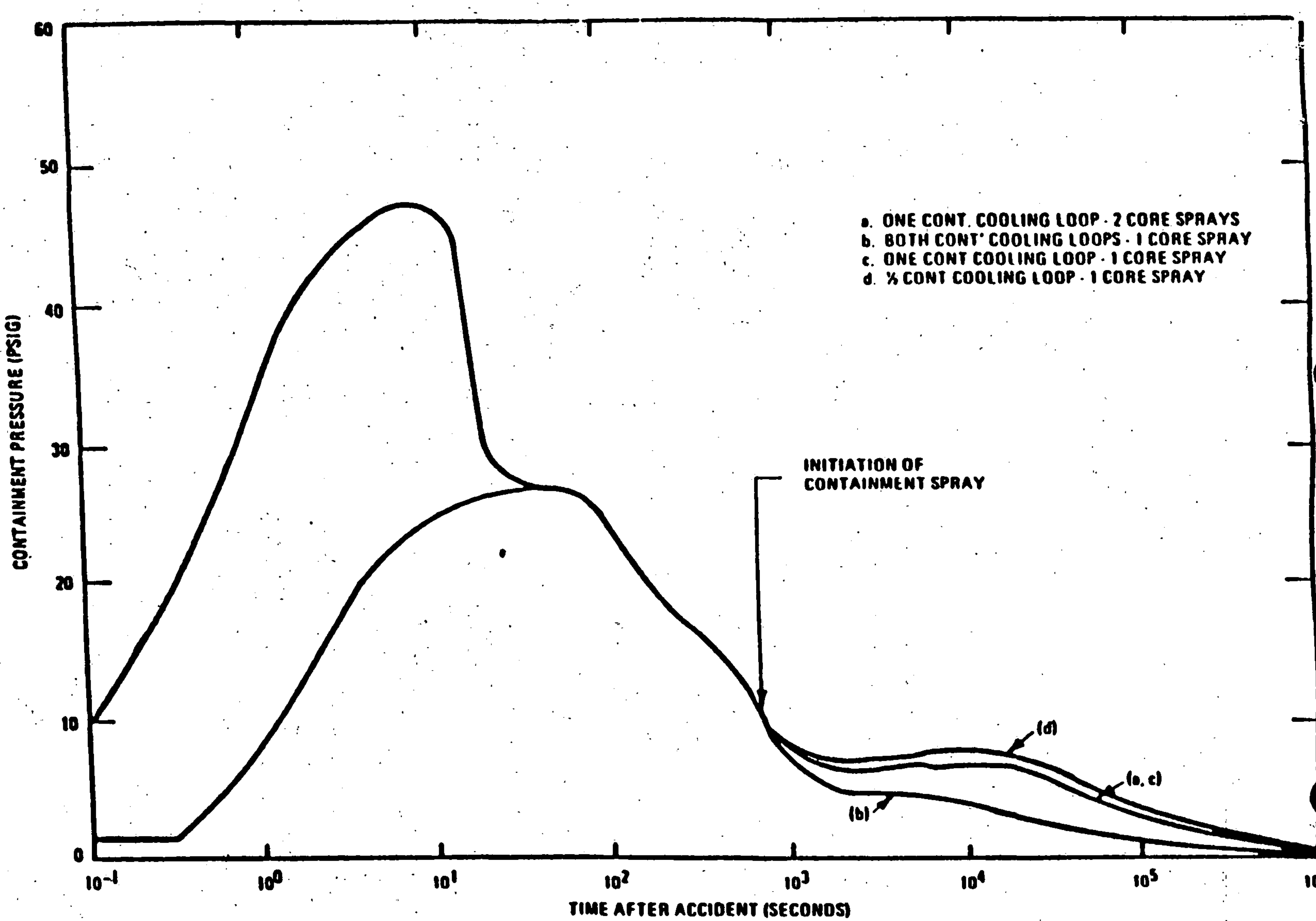
FIGURE 6.3-80



QUAD CITIES STATION
UNITS 1 & 2

CONTAINMENT PRESSURE RESPONSE FOLLOWING DESIGN LOSS-OF-COOLANT ACCIDENT

FIGURE 6.2-16

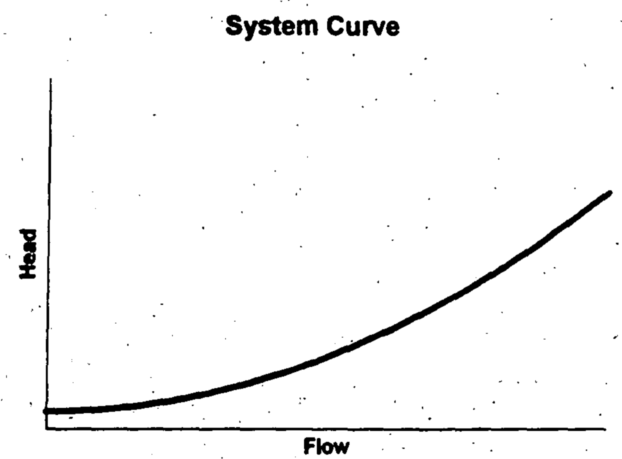


DRESDEN STATION UNITS 2 & 3
PRESSURE RESPONSE TO LOSS-OF-COOLANT ACCIDENT
FIGURE 6.2-19

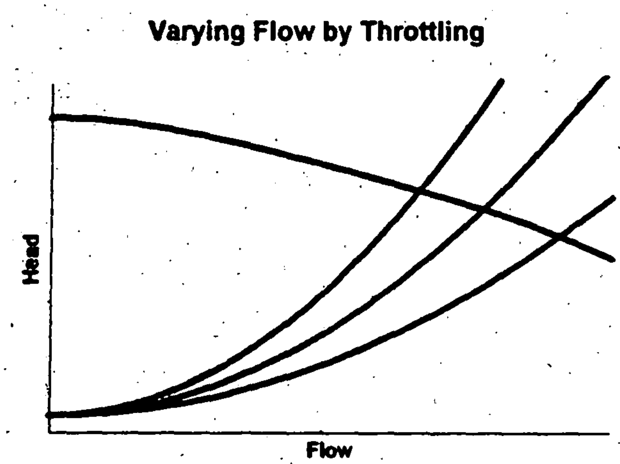
Response to Question 2.

The cavitation pump tests that were performed by the vendor involved setting the flow to a desired value and reducing the pump suction pressure (per Hydraulic Institute Standards - Attachment 1). As the suction pressure is reduced, at some point the pump begins to cavitate, resulting in a degradation of total developed head. If the test system were to remain unchanged (no change in valve position), the pump flow would also degrade due to cavitation. To understand why this occurs, a review of the pump and system interaction is warranted.

A system is defined by the piping and fittings that comprise the system, as well as any elevation changes that occur in the system. For a fixed set of valve positions, the system is also fixed and has a given system resistance curve which is quadratic in nature. Therefore, for any given flow rate through the system, the system resistance is proportional to the flow squared (Loss = K x Flow^2). A typical system curve is provided below:

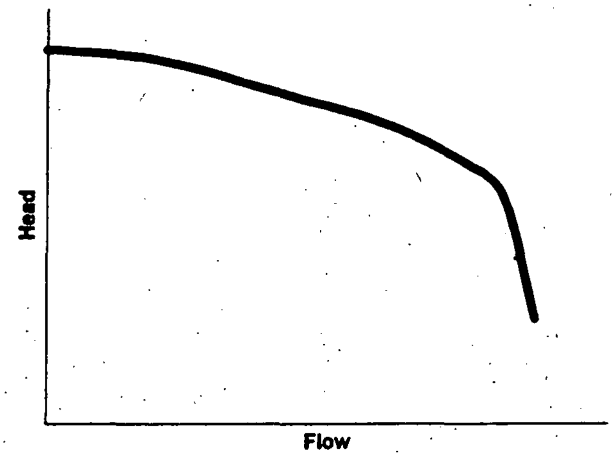


A pump that is in a given system will <u>always</u> operate at the intersection of its pump curve and the system curve. This is the point at which the pump and system reach an equilibrium; that is, at a certain flow rate the pump develops exactly enough head to match the system resistance. In order to vary the flow in a given system, a valve in the system can be throttled, which will result in a change to the system and the system curve as shown below:



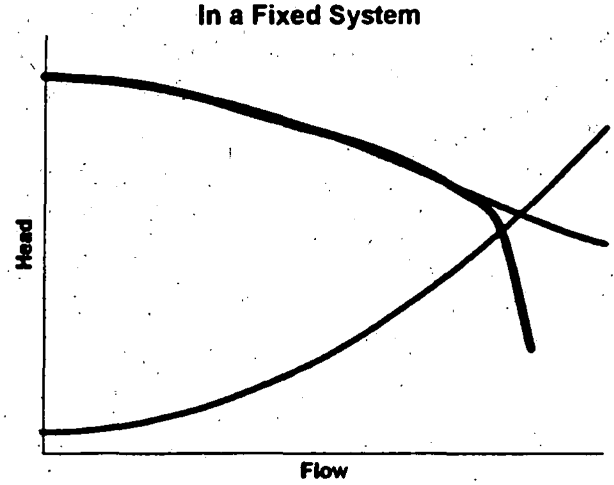
If the available NPSH is reduced below the required NPSH, the pump will cavitate, resulting in a degradation in the developed head, i.e. the pump performance curve changes. In other words, the pump will operate at the maximum flow that it can deliver with the available suction head and at a total head below that which it can develop with adequate NPSH. Cavitation tests can be performed to determine how the performance curve of a particular model and size pump changes when cavitation occurs. A typical degraded pump curve is shown below:

Degraded Pump Curve Due To Cavitation



Since a pump will always operate at the intersection of the pump and system curves, for a given system (e.g. the test system in the cavitation report), the flow at which the cavitating pump will operate can be illustrated as:

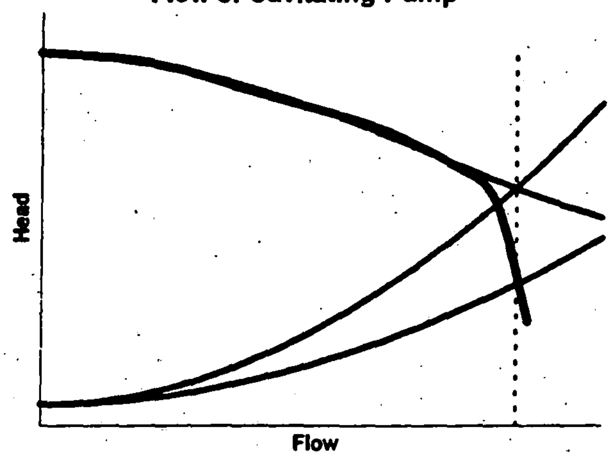
Operation of a Cavitating Pump In a Fixed System



In can be seen from the figure above that the degraded pump curve will intersect (reach equilibrium with) the system curve at a reduced flow and head as compared with the original pump curve. Essentially, the pump will deliver as much flow as it can given the available NPSH. It is the equilibrium point between the pump curve and the system curve that determines the reduced head at which the pump will operate.

Since the intent of the cavitation test is to maintain a fixed flow, the system throttle valve must be throttled further open, resulting in a lower system resistance, thus returning the pump/system combination to the original higher flow:

Throttling of System to Maintain Fixed Flow of Cavitating Pump



Since the LPCI/Core Spray systems post-accident cannot be throttled in the short-term (< 600 seconds), their system curves remain fixed. Therefore, when the pump cavitates, the pump curve will degrade and intersect the system curve at a reduced head and flow as described in the discussion above. It must be emphasized that pump will operate at this point of intersection because it is here that the pump and system reach equilibrium. It is at this reduced flow that the reduced head produced by the pump equals the system resistance.

As the NPSH available to the pump is reduced further, the pump curve degrades further and will intersect the fixed system curve at an even lower flow (see Fig. 30 below). It is the purpose of the proposed NPSH calculation to determine at what flow the pump will operate given a certain available NPSH. For the purpose of this calculation, the pump curve degradation is assumed to be perfectly vertical starting at the point of initial head collapse. Since the pump degradation is not perfectly vertical, this assumption results in the absolute minimum flow that the pump is expected to deliver. Since this NPSH calculation uses this conservative assumption, there is no further flow penalty to be assessed in determining the anticipated flow reduction due to cavitation. It should be noted that this methodology was discussed in detail with the pump vendor and with independent pump consultants. All parties involved agreed with the methodology presented in the proposed NPSH calculation.

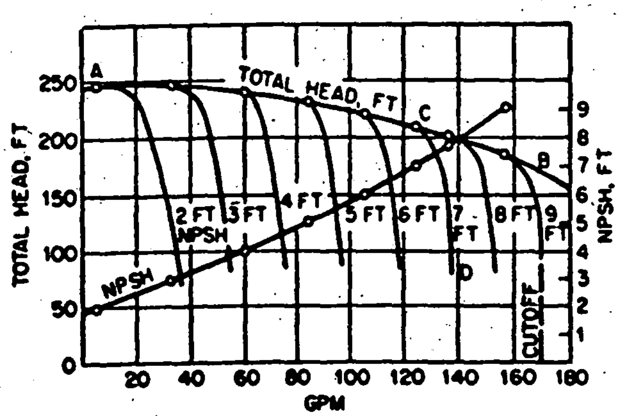


FIG. 30 Test of a 1.5-in (3.81-cm) single-stage pump at 3470 rpm, on water, 70°F (21°C) (ft × 0.3048 = m; gpm × 0.06309 = l/s). (Ref. 12)

page-1

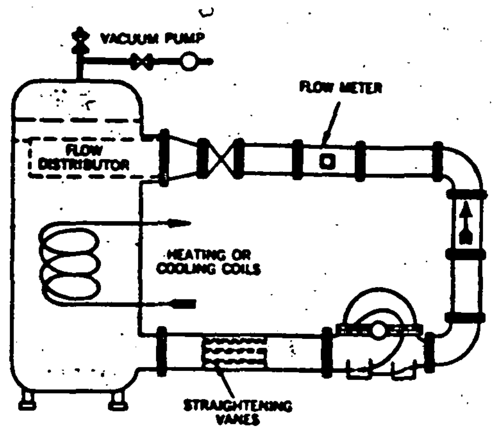


Fig. 49A
CLOSED LOOP SET-UP HORIZONTAL PUMP

ever, when the suction condition is specified as 0 ft. NPSH at the suction datum elevation, the test must be performed by reducing the distance between the elevation at the impeller eye entrance and the datum elevation through reduction of discharge column length, or removal of pump series stages. The test results must then reference the difference between test datum and application datum elevation.

Vertical pumps for free surface applications can, if practical, be tested in a deep sump in which the liquid level can be varied to establish the desired suction lift or NPSH requirements. A more desirable method is to locate the bowl assembly (first stage only for multi-stage pumps) in a suitable suction can or tank in which the pressure can be regulated and reduced to the desired level to meet the test criteria. See Fig. 49B for cavitation test set-up of vertical pump.

For large pumps cavitation testing may, for practical reasons, be performed on models. Reference is made to the section on model testing at the end of the Test Standard.

Determination of Limiting Suction Requirements

The suction requirements to be met by a pump are defined by the cavitation coefficients, sigma (σ) as determined by the specified field conditions. Sigma is defined as:

$$\sigma = \frac{NPSHA}{H}$$

where

NPSHA = Net positive suction head available, as defined on page 71 in feet
H = Total pump head per stage in feet

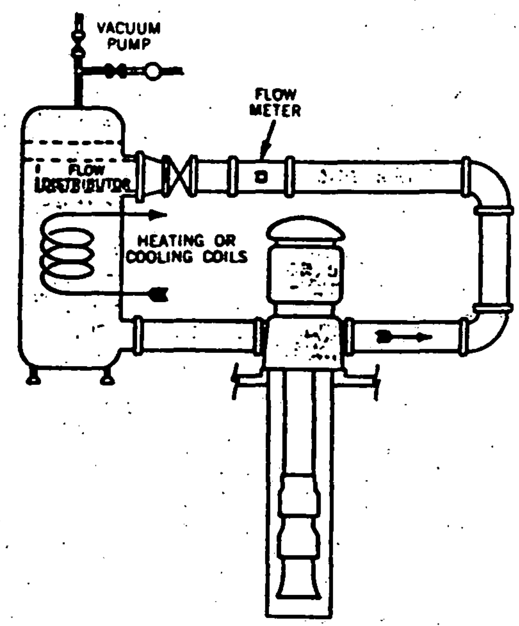


Fig. 49B
CLOSED LOOP SET-UP VERTICAL PUMP

The cavitation characteristics of a pump can be determined by one of the following procedures:

Using one of the test arrangements shown, the pump may be run at constant capacity and speed with the suction condition varied to produce cavitation. Plots of head, efficiency, and power input shall be made as shown in Fig. 50. For the higher values of sigma (σ), the values of head (H), efficiency (η), and horsepower (bhp) should remain substantially constant. As sigma (σ) is reduced, a point is reached where the curves break away from this trend, indicating a condition under which the performance of the pump may be impaired, the degree of which will depend upon the specific speed, size and service of the pump, and the characteristics of the liquid. Fig. 51 shows results typical of tests for sigma (σ) at capacities both greater and less than normal.

One alternate technique for determining the cavitation characteristics is to hold the speed and suction pressure (p_s) constant, and to vary the capacity. For any given suction pressure, the pump head may be plotted against capacity. A series of such tests will result in a family of curves, as shown in Fig. 52. Where the curve for any suction pressure (p_s) breaks away from the envelope, cavitation occurs. Sigma (σ) may be calculated at the break-away points.

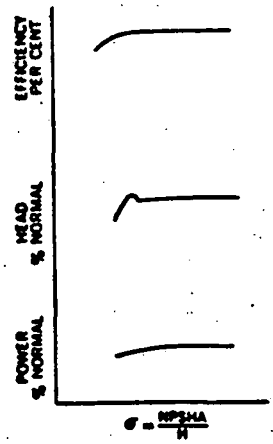


Fig. 50
PLOTS OF HEADS, EFFICIENCY AND POWER INPUT VS SIGMA

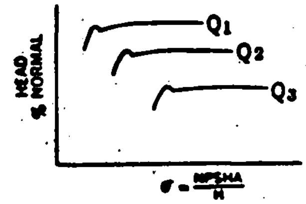


Fig. 51
SIGMA AT VARIOUS CAPACITIES

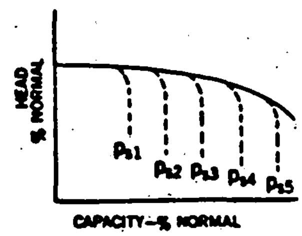


Fig. 52
ILLUSTRATION OF HEAD BREAKDOWN UNDER CAVITATION

Another alternate technique is to hold the speed constant and run head-capacity tests at several different suction throttle valve settings, bracketing the suction condition point. A series of such tests will result in a family of curves similar to those obtained above from which sigma (σ) may be calculated at the break-away points.

Accurate determination of the start of cavitation, i.e., the cavitation point, requires very careful control of all factors which influence the operation of the pump. A number of test points bracketing the point of change must be taken, and the data plotted to determine when the performance breaks away from normal. Any change in performance, either a drop in head, power or efficiency at a given capacity, or a change in sound or vibration may be an indication of cavitation, but because of the difficulty in determining just when the change starts, a drop in head of 3 per cent is usually accepted as evidence that cavitation is present.

When testing with water, an accurate temperature measurement usually is sufficient to establish the vapor pressure, but the degree of aeration of the water may have a considerable influence on performance. Consistent results are more readily obtained when the water is effectively deaerated. When testing with other fluids such as hydrocarbons, a vapor pressure bulb in the suction line not far from the

ATTACHMENT 2

Some of the conservatisms used in the NPSH calculations performed for Dresden are listed below. In order to quantify these values, the amount of conservatism is expressed in terms of a "Flow Penalty" that was applied to the estimated Core Spray pump flow. For example, the use of a conservative suppression pool temperature resulted in a Core Spray pump flow reduction of about 100 gpm.

PARAMETER	CONSERVATISM	CS FLOW PENALTY
Temperature	Recent GE analysis indicates pool temperature at 200 seconds is about 10°F lower than Quad Cities pool temperature that was used in the calculation (118°F v. 129°F)	100 gpm
Strainer plugging	Sensitivity analyses were performed that determined the worst-case strainer to be blocked. (Flow penalty based on comparison of worst to best blocked strainer)	60 gpm
Strainer plugging	One fully blocked strainer was assumed (three clean strainers); a more realistic assumption would have been to equally plug all four strainers 25%.	260 gpm
Reduced NPSHR	The NPSH resulting in initial head collapse was selected from the cavitation test report as opposed to the NPSH that results in total head collapse.	50 gpm
Pump Flows	LPCI runout pump flows based on calculations of system resistance that assume clean commercial steel pipe (no account for pipe aging)	40 gpm
Piping Model	Fitting lengths not subtracted from straight pipe runs	30 gpm
Pipe Aging	Original calculations use clean commercial steel pipe	120 gpm