WCAP-16406-P Rev. 2 DRAFT RAIs

By letter dated February 27, 2006, the Pressurized Water Reactor Owners Group (PWROG) submitted topical report, WCAP-16406-P, Revision 0, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191." In its review of the topical report, the Nuclear Regulatory Commission (NRC) staff evaluates not only the accuracy and conservatism of the methodology but also the clarity that the methodology is presented. In order to offer clear and conservative guidance for future users, the NRC staff request answers to the following questions.

RAI #1

Section 4.1.1 of the topical report describes the Emergency Core Cooling System (ECCS) for Babcock and Wilcox (B&W) designed plants. Plant specific information for Arkansas Nuclear Operations, Unit 1 (ANO-1) and Crystal River are provided. Please discuss the ECCS designs for Oconee, Davis Besse and Three Mile Island, Unit 1 (TMI-1).

RAI #1 Response

The material presented in this chapter is general in nature and is presented for information purposes only. The system descriptions in Section 4.1 are intended to provide an example of plant design and configuration. As stated in third sentence of the paragraph immediately under Section 4, all evaluations should be based on plant source documents. This plant-specific information is best presented and documented in the plant-specific evaluations and analyses performed to evaluate downstream effects.

RAI #2

In Section 4.2.3.3 and in several other places, it is stated that large flow holes in the core baffle plates preclude the need for hot leg recirculation in the B&W design. It is our understanding that in the past post-Loss of Coolant Accidents (LOCA) operator instructions have provided for hot leg recirculation at B&W plants by establishing reverse flow in the Residual Heat Removal (RHR) drop line which is connected to a hot leg or by establishing auxiliary pressurizer spray which flows to a hot leg through the surge line. Please provide reference to documentation that the NRC staff has reviewed and approved that demonstrates that hot leg recirculation is not needed for B&W plants.

RAI #2 Response

The use of the term, "hot leg recirculation" was inappropriately applied to B&W plants. The appropriate terminology should have been "core recirculation." This should have no impact on the application of the guidance of this report since, as stated in third sentence of the paragraph immediately under Section 4, all evaluations should be based on plant source documents. This plant-specific information is best presented and documented in the plant-specific evaluations and analyses performed to evaluate downstream effects.

However, the text will be amended as follows to clarify the information provided above and eliminate references to large flow holes in the core baffle plates precluding the need for hot leg recirculation in the B&W design.

> For B&W plants, core recirculation flow must be established for large cold leg pump discharge breaks at the reactor vessel inlet nozzle to control the boric acid concentration increase in the core region. Post-Loss of Coolant Accidents (LOCA) operator instructions have provided for core recirculation at B&W plants by various means. Some initiate forward flow through the core by establishing reverse flow in the Residual Heat Removal (RHR) drop line which is connected to the bottom of the hot leg pipe at the reactor vessel exit nozzle

elevation. Other plant specific methods establish a reverse flow through the core by establishing auxiliary pressurizer spray (which flows to a hot leg through the surge line) or hot leg injection via the RHR drop line. The B&W plant post-Loss of Coolant Accidents (LOCA) operator instructions have provisions for establishing some active boric acid dilution method that provides some core liquid throughput flow that controls the core boric acid concentrations if the core exit temperatures remain saturated. The NRC has reviewed these core recirculation flow paths and specific actions taken to establish a flushing flow of the core for B&W plants on a plant-specific basis.

RAI #3

The definition of "C^*_{CO}" in Equation 5.8-5 is described as the ratio of initial concentration of particulate bypass to initial volumetric concentration of debris in the sump fluid. The paragraph following the definition in Equation 5.8-5 appears to further define the bypass as that which will not settle out in the reactor vessel lower plenum. The sample calculation in Section 5.9 which appears to be for a large cold leg break gives a value of C^*_{CO} as 0.7X10-4. Equation 5.9-2 shows the sump concentration to approach this value of C^*_{CO} for long times after the accident. Since for cold leg breaks all material which enters the reactor lower plenum remains within the reactor vessel, shouldn't the value of sump concentration approach 0.0 for a large cold leg break?

RAI #3 Response

If cold leg recirculation were maintained indefinitely (no switchover to hot-leg recirculation) and the sump fluid inventory were recirculated an infinite number of times, the particulate debris concentration in the sump would tend towards zero (0). The equation formulation assumes and provides for small particulate debris to not settle in the lower plenum, be carried into the core by the liquid making up boiloff and finally to be carried by steam out the break. This provides for a conservative particulate debris concentration in the sump for other downstream effects considerations.

This clarification will be added to the text on Page 5-11.

RAI #4

Since use of the methodology in Section 5.8 for particulate debris depletion will be different for hot leg breaks than for cold leg breaks, wouldn't it be clearer to users if two example calculations were given in Section 5.9, one for hot leg breaks and one for cold leg breaks?

RAI #4 Response

The following text will be added into Section 5.9 of the WCAP before the sample evaluations take place. "Section 5.9 provides a sample for users to evaluate the time-dependent debris concentration for a postulated cold-leg break. The only difference between the application of the equation to a postulated hot-leg break and a postulated cold-leg break is the determination of the appropriate values of input parameters. Thus, by evaluating the appropriate values for flows used as inputs to Equation 5.8-5, this equation can be used to model both the hot-leg and cold-leg breaks.

A time-history of three cases, one cold-leg break and two hot-leg break scenarios is presented in Figure 5.9-1 to illustrate the effect of break locations. This figure illustrates that licensees should evaluate both hot-leg and cold-leg breaks and pick the case that provides for limiting values of debris concentrations for downstream effects."

RAI #5

It is noted that the methodology in Section 5.8 is only applicable to the cold-leg recirculation phase of a postulated LOCA. Shouldn't the methodology be extended to give guidance for hot leg recirculation? The NRC staff believes that following a postulated large cold leg LOCA that boiling in the core may extend for weeks even after hot leg recirculation is begun. Core boiling would extend for a longer period for a plant with low recirculation flow such as a Combustion Engineering (CE) design with recirculation provided by the High Pressure Injection System (HPIS) than for a plant with recirculation flow provided by the Low Pressure Injection System (LPIS) . The effect of debris and dissolved material on core boiling heat transfer needs to be evaluated during the total boiling period.

RAI #5 Response

The following text will be added to Section 5.8 of the WCAP before the methodology is discussed. "The methodology described in this section is directly applicable to hot-leg recirculation phase of the transient. The only difference between the application of the equation to a postulated hot-leg break and a postulated cold-leg break is the determination of the appropriate values of input parameters. Thus, by evaluating the appropriate values for flows used as inputs to Equation 5.8-5, this equation can be used to model both the hot-leg and cold-leg breaks.

This section describes a method to evaluate depletion of debris concentration due to settle-out and is applicable to both cold-leg and hot-leg recirculation. Addressing the effect of debris and dissolved materials on long-term core cooling is beyond the scope of WCAP-16406-P. The effect of debris and dissolved materials on long-term core cooling is being evaluated under a separate PWROG program. A final report for that effort, WCAP-16793, "Evaluation of Long-Term Cooling Considering Particulate and Chemical Debris in the Recirculating Fluid," is planned for the end of May 2007."

RAI #6

In the sample problem in Section 5.9, a core flow rate of $1.225X10^6$ lbm/hr is assumed following a large cold leg break for a core velocity of 0.1 ft/sec. This value is much larger than would be expected for long term core boiling and would be conservative for predicting accumulation of material within the reactor vessel. A large value of core flow would not be conservative for the calculation of the attenuation of debris in the sump water as it circulates through the reactor vessels. This should be pointed out in the text for the benefit of future users. Similarly the value of typical velocity in the region between the lower support plate and the core support plate, given as 0.06 ft/sec in Section 9.2.2, is higher than would be expected for long term core boiloff. The statement at the top of page 5.4 indicating that the particulate concentration in the sump may be depleted to less than 1 percent of its initial concentration within 20 hours may be optimistic for cold leg breaks for the same reason.

RAI #6 Response

As noted in the statement of inputs and assumptions to the sample calculation given on Page 5-11, the value for decay heat is taken at 20 minutes after the initiation of the break. The core boil-off rate and core region velocity (for a given fuel design) are representative of the time at switchover from RWST/BWST injection to recirculation from the containment sump. This is conservative for evaluating debris transport from the lower plenum into the core.

The following clarifying text will be added to the description of the sample calculation.

> The example calculation takes no credit for the sump screen capturing debris. Taking the capture efficiency of the sump screen into account, a reduction in the concentration of the particulate debris to <1% of the initial concentration is possible.

RAI #7

As noted on page 5-11, following a cold leg break during cold leg recirculation, "C_{CO}" is zero, meaning that no entrained debris will returned to the containment sump. It will either be retained in the lower plenum or in the reactor core. Methodology is discussed for determining the debris that would be deposited in the lower plenum. Shouldn't methodology be provided for determining the concentration of debris and chemical components that might be concentrated within the reactor core?

RAI #7 Response

The following text will be added as a note at the end of section 5.8 with a pointer (*) to the 5th item in the discussion on page 5-11. "This discussion relates to a method to evaluate depletion of debris concentration due to settle-out and is applicable to both cold-leg and hot-leg recirculation. Addressing the concentration of debris and chemical components that might be concentrated within the reactor core is beyond the scope of WCAP-16406-P. The effect of debris and dissolved materials on long-term core cooling is being evaluated under a separate PWROG program. A final report for that effort, WCAP-16793, "Evaluation of Long-Term Cooling Considering Particulate and Chemical Debris in the Recirculating Fluid," is planned for the end of May 2007."

RAI #8

On page 5-16, it is stated that the equation for depletion of fibrous debris on the containment sump screen is applicable only to the cold-leg recirculation phase and not to the hot-leg recirculation phase. It is unclear to the staff why the equation for sump screen operation would be affected by the location of water entry to the reactor system. Please explain. If the methodology is not applicable for hot-leg recirculation, the appropriate methodology should be provided.

RAI #8 Response

This statement will be amended as follows:

> It is noted that Equation 5.10-1 is applicable for recirculation of the containment sump inventory through the sump screen, regardless of the recirculation mode (cold-leg or hot-leg).

RAI #9

In Sections 5.6 and 5.12, it states that the total plant-specific debris concentration, should be within the 0.1 percent value identified in Assumption 10 of Section 5.5. The NRC staff does not understand this statement and notes that there is no Assumption 10 in Section 5.5.

RAI #9 Response

The phrase "within the 0.1-percent value..." will be changed to "within 0.1-percent of the value..." Also, "Assumption 10" will be changed to "Assumption 8."

RAI #10

Table 7.2-1 provides depletion coefficients for use in the exponential decrease in particulate concentration in the sump water as particulate debris settles in the reactor vessel lower plenum. These values are plant dependant and are also dependant on Emergency Core Cooling (ECC) flow rate for hot leg breaks and the core boiloff rate for cold leg breaks. The fact that the values are plant dependant and should be determined for each application, should be stated in the topical report. The NRC staff believes that the stated depletion rate for cold leg breaks is too high. Furthermore, the depletion rate for cold leg breaks will be a function of time as core flow decreases with decay heat. See question #6, above.

RAI #10 Response

The following statement will be added to the text introducing Table 7.2-1:

> The depletion coefficients in the table are a sample, and that plant-specific values as determined from their plant-specific calculations, by-pass testing, and other applicable sources may be different (greater or less than those listed in the table). It is recommended that plants consider both hot-leg and cold-leg break scenarios for the worst case conditions for use in plant-specific evaluations.

As was identified in the response to RAI #6, the sample calculation took no credit for the sump screen capturing debris. However, most of the debris depletion or clean-up comes from screen capture (as opposed to vessel settle out). Taking the capture efficiency of a plant-specific replacement sump screen into account, the reduction in the concentration depletion of the particulate debris shown in Table 7.2-1 is conservative.

RAI #11

Section 9 discusses methodology for investigating fuel inlet and internal blockage. However, the methodology for investigating the effect on heat transfer from long term boiling or the insulating effect of debris trapped behind grid straps is not discussed. This methodology should be provided. The evaluations should consider:

a. Trapping of debris behind the spacer grids might occur as the material is left behind by the long term boiling process. Under these conditions a layer of debris and steam might form which might insulate portions of the fuel rods from the water in the coolant channel.

b. The effect of debris on core boiling heat transfer including reaction products from the mix of chemicals that would be concentrated in the core by the boiling process following a large cold leg break needs to be considered. The effect of the high radiation field within the core on the chemical and physical nature of the mixture within the core also needs to be considered. Furthermore, the potential for heat transfer degradation resulting from a chemical film which might form or be plated out by the boiling process needs to be evaluated.

RAI #11 Response

Section 9 describes a method to evaluate the potential for blockage of flow paths from particulate and fibrous material that may be passed through the sump screen on the potential blockage of flow paths through the reactor vessel and fuel. This method is applicable to all debris that passes through the sump screen. The effects on boiling and heat transfer due to trapping of debris behind spacer grids, increased concentration of chemical products in the core region and potential plate-out of fuel cladding is beyond the scope of WCAP-16406-P.

The affect of radiation on the chemical and physical nature of the mixture within the core was addressed in the RAIs for WCAP-16530-NP, Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191, February 2006.

Addressing the affect of debris and dissolved materials on long-term core cooling is beyond the scope of WCAP-16406-P. The effect of debris and dissolved materials on long-term core cooling is being evaluated under a separate PWROG program. A final report for that effort, WCAP-16793, "Evaluation of Long-Term Cooling Considering Particulate and Chemical Debris in the Recirculating Fluid," is planned for the end of May 2007.

RAI #12

In Appendix K, page K-1, it states that large dense non-fibrous debris can be shown to settle in the low velocity portion of the ECC flow path, the reactor vessel plenum, using Stokes Law. The NRC staff does not believe that Stokes Law, which is based on the settling of spherical bodies, would be appropriate to describe the settlings of flattened objects such as paint chips. This fact should be stated.

RAI #12 Response

Stokes Law may be used to evaluate settling of non-spherical bodies by using an appropriate hydraulic drag coefficient. This is discussed in Reference 8.1-13. The following clarification will be added to the subject text:

> Stokes Law may be used to evaluate settling of non-spherical bodies by using an appropriate hydraulic drag coefficient. These drag coefficients may be determined using standard handbooks or text books.

RAI #13

The NRC staff understands that the methodology in WCAP-16406-P is intended to be used by Westinghouse as well as non-Westinghouse personnel. Please describe the measures which will be applied in terms of qualification, training, and quality assurance of the results to ensure that the methodology of WCAP-16406-P is being utilized correctly.

RAI #13 Response

The qualification, training and quality assurance requirements for personnel performing work a nuclear power plants is defined in Title 10 Code of Federal Regulations Part 50.120, "Training and qualification of nuclear power plant personnel." The requirements of 10CFR50.120 assure that personnel are appropriately trained prior to being assigned work at a nuclear power plant. Requirements are passed from licensees to contractors performing a work scope through contract requirements and assure that qualified personnel that have been appropriate trained to perform work at a nuclear power plant.

Similarly, the quality assurance program for nuclear plants is identified in Appendix B to Title 10 Code of Federal Regulations Part 50, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." The requirements of 10CFR50 Appendix B provide for a quality assurance program to be applied to the design, fabrication, construction, and testing of the structures, systems, and components of the facility. These requirements are passed from licensees to contractors performing a work scope through contract requirements and assure that contractors have established and implemented an appropriate quality assurance program for the scope of work they are performing.

RAI #14

Page 4-23 contains a sub-section "CSS Recirculation Alignment Summary for CE Plants." It has been corrected in response to previous NRC comments, however it does not belong here. Page 4-13 also contains the same sub-section (the proper location), but it does not have the correction. (Editorial)

RAI #14 Response

Although the PWROG requested that Section 4 be excluded from review as it was general in nature and was presented as an example only, the error is noted. The corrected subsection and text will be removed from page 4-23, and placed on page 4-13.

RAI #15

On page 4-30, the first sentence of paragraph beginning near the top of the page begins with "In terms of minimum flow rate, the limiting scenario is the large hot-leg break..." This assertion is not correct, for minimum flow rate, the limiting scenario is a cold-leg break. The remainder of the paragraph also appears to be more related to cold-leg break than hot-leg break. (Editorial, or clarification required)

RAI #15 Response

The PWROG requested that Section 4 be excluded from review as it was general in nature as this material was presented for information purposes only. However, sentence will be amended as follows:

> In terms of minimum flow rate, the limiting scenario is the large cold-leg break.

RAI #16

Page 4-31, Table 4.2-1 is missing McGuire and Wolf Creek. (Table not complete)

RAI #16 Response

The material of Section 4.2 was not intended to be all-inclusive of all plants. Rather, the material presented in Section 4.2 is intended to provide examples of plant designs and configurations. All evaluations should be based on plant-specific system alignments and capabilities. This system alignment and capability information is best presented in the plant-specific evaluations and analyses.

RAI #17

Page 4-32, Section 4.2.2 discusses mission times for CE plants. In this section it indicates that mission time could be related to hot-leg switchover. According to Table 4.2.1 and Figures 4.1-2 and 4.1-3, the CE plant design has limited capability for hot-leg recirculation. It is understood that these are generic discussions and simplified P&IDs, so individual plants may have configurations that could be used/credited. The topical report should discuss the CE configurations/capabilities in more detail.

RAI #17 Response

The material presented in this chapter is general in nature. The system descriptions and alignments in Section 4.2 are intended to provide only examples of plant designs and configurations. All evaluations should be based on plant-specific source documents such as P&ID drawings and system descriptions. The following statement will be added immediately following the section designation 4.2.2, "Combustion Engineering Plants:"

> The following information is general in nature and is provided only as an example. Plant-specific analyses should be based on plant-specific source documents such as P&IDs and system descriptions.

RAI #18

Page 5-2, near the bottom, lists what are considered to be the two most important factors for screen penetration as items 1.a (hole size) and 1.b (screen open/closed ratio). The staff expects that a number of other factors (approach velocity, strainer differential pressure, overall strainer surface area, flat/complex configuration, strainer surface smoothness, debris mix/characteristics, etc.) are also important, maybe even more than these. Please provide an explanation that shows that the two items listed are the most important, or are the most important for the bounding conditions of modern strainers.

RAI #18 Response

Items 1.a and 1.b are identified as two factors affecting debris bypass through the sump screen, not that they are necessarily the most important two factors. However, the text will be amended to note that there are a number of factors affecting debris bypass through the sump screen. These factors include, but are not limited to, the hole size, the ratio of open to closed area of the screen, the fluid approach velocity to the screen and the screen geometry.

RAI #19

On page 5-3, the first sentence of paragraph beginning near the top of the page begins with "The NRC is conducting research...". This should be changed to reflect that "The NRC and industry are conducting research...". (Editorial)

RAI #19 Response

The clarification is noted, this sentence will be changed to read "The NRC and industry are conducting research on the passing of debris through sump screens."

RAI #20

On page 5-7, Assumption 7, the correction missed deletion of word "that." (Editorial)

RAI #20 Response

The typographical error is noted and will be corrected; the extra word "that" will be removed from Assumption 7, page 5-6.

RAI #21

On page 5-7, the last sentence of the middle paragraph states, "...should be confirmed to be within the 0.1 percent value identified in Assumption (10) from Section 5.5." With the re-numbering of Assumptions in Section 5.5, number 10 no longer exists. It looks like it should be assumption 7. (Editorial)

RAI #21 Response

The typographical error is noted and will be corrected; the phrase "within the 0.1-percent value..." will be changed to "within 0.1-percent of the value..." Also, "Assumption 10" will be changed to "Assumption 8."

RAI #22

On page 5-9, there is a Cso definition spelling error, "our" should be "out." (Editorial)

RAI #22 Response

The typographical error is noted and will be corrected; "separate our" will be changed to "separate out."

RAI #23

Page 5-12 uses a core flow area of 55ft^2 and a fluid velocity of 0.1 ft/sec. These do not seem to be reasonable values. Please provide a basis for these values.

RAI #23 Response

The values in question were used in the sample problem. The conditions used in the selected were minimum flow area through the fuel, and the corresponding velocity in the fuel. The flow area in the lower plenum is actually larger than this. The value of 0.1 ft/sec was evaluated using the minimum flow area and a maximum decay heat value. Thus, the sample calculation provides for the prediction of lifting of conservatively large sized debris into the fuel.

The text will be amended as follows:

> Plant-specific values should be used in performing plant specific calculations of core flow. For the purposes of this example calculation, for a cold-leg break, using a decay heat rate at 20 minutes after core shutdown and assuming a core flow area of 55 ft^2 the fluid velocity in the core is estimated to be:

RAI #24

Page 5-12 (bottom paragraph) has a typographical error, "core support plant" should be "core support plate." (Editorial)

RAI #24 Response

The typographical error is noted and will be corrected; "core support plant" will be amended to "core support plate."

RAI #25

Page 5-13 lists C*co as 0.7×10^{-4}. Please provide the derivation of this value.

RAI #25 Response

The definition of C^*_{CO} is:

$$C^*_{CO} = \text{(particulate mass / particulate density) / (water volume)}$$

The definition of this is given in the middle of page 5-10. The value of 0.7×10^{-4} was selected for purposes of the sample calculation.

The following text will be added immediately following the listed values for C^*_{CO} and C^*_{O}:

> The value of 0.7×10^{-4} is selected for purposes of the sample calculation. Plants should use a plant-specific debris generation and transport calculations to evaluate a value of C^*_{CO} for their plant-specific evaluations.

RAI #26

Page 5-13 lists 3 cases where calculations were done to demonstrate the effect of break location and flow rate on debris depletion. Please provide information on the use and/or development of the carry-over factors used for these three cases.

RAI #26 Response

The development of Case 1, cold-leg break with a single train of ECCS operating, is described in Section 5.9. The hot-leg break scenarios, with one or two trains of ECCS operating, parallel the development of Case 1, using appropriate values for the parameters in Equation 5.8-5. The following clarification will be added to the text immediately following the identification of the three cases:

> The development of Case 1, cold-leg break with a single train of ECCS operating, is described in Section 5.9. The hot-leg break scenarios, with one or two trains of ECCS operating, parallel the development of Case 1, using appropriate values for the parameters in Equation 5.8-5. Plant specific inputs should be used to evaluate the three cases for plant-specific evaluations.

RAI #27

On page 5-16, the inserted text contains an editorial error, "value dimensionless value."

RAI #27 Response

The typographical error is noted and will be corrected; "value dimensionless value" will be changed to "dimensionless value" on pages 5-10 and 5-16.

RAI #28

Page 5-17 shows a table of results from testing conducted at Las Alamos National Laboratory (LANL) for fibrous debris passing through a screen for various velocities. One of the conclusions from evaluating this data is stated as:

> "2. For a given velocity, the smaller the sump screen mesh, the greater the percentage of fiber that is passed through the sump screen."

Based on more recent test results from modern strainer vendors, it is recognized that the LANL data in this area may be suspect, and the resulting conclusion may be inaccurate. This information needs to be addressed for its impact on the evaluation methodology.

RAI #28 Response

At the time that the report was being prepared, only the LANL data was available. The text of Section 5.10 recommends the use of a default capture efficiency of 95% for replacement sump screens. The text goes on to note, at the top of page 5-18, that the value of 95% capture efficiency provides for a conservative value for fibrous debris collection. Available bypass data from replacement sump screen testing appears to suggest that the 5% bypass number remains bounding.

However, the following text will be added immediately before the last sentence of Section 5.10, page 5-18:

> At the time that this report was initially prepared, only the LANL screen penetration data was available. By-pass data from testing of replacement sump screen strainers should be used, when available, to assess the actual performance of the replacement sump screen under plant-specific debris loading conditions.

RAI #29

Page 5-17 lists a number of reasons why the LANL data is applicable to Pressurized Water Reactors (PWRs). Reasons 4 and 5 contradict each other in regards to the referenced construction material for replacement screens (4 indicates screen will be made of similar or thicker wire, 5 indicates perforated plate will be used). All modern strainers use perforated plate.

RAI #29 Response

At the time the report was prepared, the construction of replacement sump screens had not been identified across the industry. It is acknowledged that, today, all known replacement sump screens or strainers are being made of perforated plate.

Reason 4 will be amended to delete any reference to replacement sump screens being made of wire.

RAI #30

On page 9-3, Section 9.2.2, the second paragraph states, "A typical fluid velocity in the region between the lower support plant (typo/spelling) and the core support plate at about the time of initiation ECCS recirculation from the containment sump is about 0.06 ft/sec." This value contradicts the value of 0.1 ft/sec found on page 5-12 (see question/comment 10), and Appendix K (page K-1).

RAI #30 Response

The typographical error is noted and will be corrected; "lower support plant" will be changed to "lower support plate".

The fluid velocities cited in Sections 5, 9 and Appendix K are approximate values and when rounded, agree to one decimal place (0.1 ft/sec). For a specific plant, the fluid velocity would be a function of the decay heat rate of the fuel at the time of switchover to recirculation.

RAI #31

Page 9-8, item 3 has a typographical error, "lower support plant" should be "lower support plate" (Editorial)

RAI #31 Response

The typographical error is noted and will be corrected; "lower support plant" will be changed to "lower support plate".

RAI #32

The flow charts in Section 10.2 appear to be incomplete, and contain many errors. There appears to be no chart referring to Chapter 9 for an evaluation of reactor internals and fuel.

RAI #32 Response

A flow chart was not included as the for the Chapter 9 evaluations as they were considered to be straight-forward with no decision or "branch" points to consider.

The Evaluation Flow Diagrams were provided as upper level guideline for performing the evaluation of a component with the details given in the body of the report. Placing the details on the Evaluation Flow Diagrams is evaluated to make the diagrams too unwieldy to use.

RAI #33

Page 10-7, Figure 10.4-1 indicates that a default HPSI mission time of 250 hours can be used. What is the technical justification for this value?

RAI #33 Response

The mission time discussion in Chapter 4 is presented for information only. The 250 hours mentioned in Figure 10.4-1 on page 10-7 was taken from the sample calculation discussed in Chapter 4. It is expected that any credit for a mission time below 720 hours will be supported by a plant-specific calculation to be independently justified.

The text of Figure 10.4-1 will be augmented to indicate that plant-specific mission times should be used.

RAI #34

Page 10-8, Figure 10.4-2 implies that Category 2 and 4 plants can justify LHSI for hot-leg recirculation, but these categories of plants only have one hot-leg injection pathway. How can these plants verify that the hot-leg injection path is not the source of the break?

RAI #34 Response

The mission time discussion in Chapter 4 is presented for information only. The 250 hours mentioned in Figure 10.4-1 on page 10-7 was taken from the sample calculation discussed in Chapter 4. It is expected that any credit for a mission time below 720 hours will be supported by a plant-specific calculation to be independently justified. It is assumed that the single hot leg injection pathway for Category 2 and 4 plants is consistent with the current hot leg recirculation licensing basis for the plants and no that no additional justification is required.

The text of Figure 10.4-2 will be augmented to indicate that plant-specific mission times should be used.

The evaluation method presented in this WCAP does not alter or modify current licensing basis of plants with regard to hot-leg recirculation. Thus, the current licensing basis of plants with only 1 hot leg injection pathway is not altered by the evaluation of downstream effects. Furthermore, if there is a hot-leg break, then there should be a continuous flowpath through the vessel.

RAI #35

Page 10-9, Figure 10.4-3 asks Category 5 plants if the HPSI pump is required for hot-leg recirculation. However, category 5 plants, by definition, have no hot-leg switchover capability.

RAI #35 Response

The question was included for completeness and consistency with the previous two logic diagrams for Category 1, 2, 3 and 4 plants. Category 5 plants, by definition, have no hot-leg switchover capability. Therefore, the answer to the question, "Is HPSI pump required for hot leg recirculation?" is always "NO", which leads the evaluator to note that the mission time is the time at which the LHSI pump meets boiloff requirements.

RAI #36

On page J-4, the second bullet explains using a "pencil drop test" to justify a penetration factor of 0.06%. However, no detailed information is provided regarding the configuration of the screen being used for this test or it's similarity to an ECCS sump screen. Page 5-2 identifies two critical factors for screen configuration, and question/comment 5 identifies a number of others that may be relevant. Some additional information should be provided regarding this test before it can be used to justify a position.

RAI #36 Response

The following clarification will be added to the text.

The objective of the "pencil drop" test was to evaluate the probability of long, rigid particles passing through holes. The pencil used had a diameter of 5/16-inches and the strainer holes had a diameter of ½-inches. The pencil was randomly located above the strainer and then dropped lengthwise from a height of 15 inches above the strainer. This orientation was favorable for the pencil passing through the strainer. The pencil velocity calculated to be about 16 ft/s upon reaching the strainer. Of the 100 times the pencil was dropped, only six (6) times was the pencil observed to orient itself such that it would penetrate the strainer.

In the drop test, the pencil was oriented lengthwise, which maximized its potential for passing through the strainer. The approach velocity of the pencil was much larger than the approach fluid velocities to replacement sumps (16 ft/sec versus < 0.2 ft/sec), giving the pencil little time to change or alter its orientation. Yet, only 6% of the time, the pencil was observed to pass through the strainer. In the plant, a random orientation of the debris is expected. Furthermore, local turbulence in the flow would be expected to maintain debris in a random orientation. Thus, it expected that for hard, long objects randomly oriented in a flow stream, less than 6% would pass through the strainer screen. However, as the characteristic or maximum dimension of debris approaches the same dimension as the diameter as the strainer hole, the shape of the debris approaches a sphere.

WCAP-16406-P Rev. 1 RAIs

By letter dated May 31, 2006, the Pressurized Water Reactor Owners Group (PWROG) submitted topical report, WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191." In its review of the topical report, the Nuclear Regulatory Commission (NRC) staff evaluates not only the accuracy and conservatism of the methodology but also the clarity of the methodology presented. In order to offer clear and conservative guidance for future users, the NRC staff offers the following comments and requests answers to the following questions.

Technical Comments:

RAI T-1

Section 5.5.3, Debris Ingestion Model Assumptions - This section notes that "The particulate and fibrous debris sizes identified in the previous steps may be modified if supported by plant specific data." Please provide information on how to interpret and modify the testing and plant specific data so that it can be used with the WCAP guidance.

RAI T-1 Response

The following text will be added to Section 5.5 Item 3:

Plant-specific calculations require the same inputs as the sample calculations presented using the assumptions of Section 5.5.3. The data necessary to obtain plant-specific particulate and fibrous debris sizes identified in Section 5.5 Item 2 would be developed by testing of plant-specific debris mixes with the plant-specific replacement sump screens. The test protocol for performing these tests is the responsibility of the licensee. The plant-specific evaluation would use the particulate and fibrous debris sizes obtained from the collected and measured size distribution of the particulate and fibrous debris that are passed by the replacement sump screen.

RAI T-2

Section 7.2.4, Debris Buildup in Running Clearances, Page 7-7 - Provide clarification and basis on how the "debris packing" provides greater bearing support than a 2X clearance.

RAI T-2 Response

This issue is discussed in detail in the attached white paper. The relatively wear hydrostatic centering force provides significantly less support stiffness for the shaft than the debris packing (solid material) riding on the impeller hub.

RAI T-3

Section 7.3.2, Erosive Wear, page 7-13 - Third paragraph, throttling a valve is also a factor for the wear rate of a valve. Explain how this is incorporated into evaluations.

RAI T-3 Response

Sections 7.3.2 and 7.3.3.4.2 have been modified in the WCAP as follows:

Section 7.3.2 Paragraph 3:

Valves subjected to debris-laden water experience erosive wear. The wear rate depends on a number of factors: the debris type, debris concentration, material

hardness and velocity of input.
For this evaluation two models were developed. The first is a constant debris size model and the second is a distributed debris size model. These are presented below

Section 7.3.3.4.2:To evaluate globe valves that are throttled or hermitically sealed and needle valves, vendor input may be required. These valves are susceptible to plugging and will need the vendor to confirm whether or not the valve can be sufficiently open to pass the debris.
By throttling, it is meant either one of the following:

- Valves that are partially open
- Valves that have special trim for high-pressure breakdown (for example, using labyrinth flow paths in the cage or using special plug configuration)

The following subsections detail the typical valve designs that are used in throttling applications. See Figures 7.3-1 through 7.3-5. The valve trim configurations in throttling applications make them susceptible to debris entrapment. To evaluate their capability to pass the debris, vendor input is required for clearance area versus lift (Figure 7.3-6) and minimum flow area in the valve flow path. The valves shall be evaluated for compliance with NRC IN 96-27 (Reference 7.3-2)

RAI T-4

Chapter 8, General - Westinghouse, Babcock and & Wilcox and Combustion Engineering all use slightly different design strategies i.e. 7 vs 9 vs 11 stage HPSI pumps. Please provide drawings of a representative sample of HSPI, LPSI, Charging and CS pumps. This information is needed for the staff to verify that the wear models and rotor dynamic reviews bound all pump configurations.

RAI T-4 Response

The requested representative drawings are attached in Appendix A.

RAI T-5

Chapter 8, General - Westinghouse, Babcock and & Wilcox and Combustion Engineering all use slightly different design strategies i.e. 7 vs 9 vs 11 stage HPSI pumps. Please provide Pump curves for a representative sample of HSPI, LPSI, Charging and CS pumps. This information is needed for the staff to verify that the wear models and rotor dynamic reviews bound all pump configurations.

RAI T-5 Response

The requested drawings are attached in Appendix B.

RAI T-6

Chapter 8, General - Westinghouse, Babcock and & Wilcox and Combustion Engineering all use slightly different design strategies i.e. 7 vs 9 vs 11 stage HPSI pumps. Please provide nominal bearing loadings for a representative sample of HSPI, LPSI, Charging and CS pumps. This information is needed for the staff to verify that the wear models and rotor dynamic reviews bound all pump configurations.

RAI T-6 Response

Archard's wear model requires a determination of bearing loads. However, the WCAP wear model does not require the same determination of bearing loads because the WCAP wear model was developed empirically. Please refer to RAI T-20 for Westinghouse discussion of Archard's model versus the WCAP model. See also Appendix P of the WCAP-16406-P for additional discussion.

Plants who wish to use the Archard's wear model will be instructed in Section 10.5 the WCAP to obtain the bearing loads from their pump suppliers.

RAI T-7

Section 8.1, Evaluation of ECCS Pumps for Operation with Debris-Laden Water from the Containment Sump - How is Stop/Start operation of ECCS pumps addressed?

RAI T-7 Response

The WCAP addresses only the operability issue for operating auxiliary pumps. Start/Stop operation has not been addressed separately since that is dependent on plant specific conditions and accident mitigation procedures, and should be addressed as plant specific issues. The potential impact of the buildup of a debris packing in the wear rings is that it could add to startup torque requirements. However, considering that the diameter of the debris packing (~ 2.5 inch) is small, and at startup there is no pressure on the packing, the additional required torque should be small compared with the hydraulic torque requirement for the impellers.

RAI T-8

Section 8.1.1.2 Evaluation of ECCS Pumps for Operation with Debris-Laden Water from the Containment Sump, page 8.5, and Section 10.6, Instrumentation Tubing - Secondary recirculation of debris laden flows, such as at cyclone separators or at instrument tubing connections, may allow rapid clogging of the flow area. Explain how this phenomena is to be evaluated in the context of cyclone separator and instrument tubing evaluations. The evaluation of the cyclone separator is a plant specific analysis, which depends on the cyclone separator design and the piping arrangement for the seal injection system.

RAI T-8 Response

As stated in the WCAP, Westinghouse does not have specific data on cyclone separators used to remove debris from seal injection flow. However, there is anecdotal information and opinion from Flowserve (Appendix H, page 35) indicating that cyclone separators have had clogging problems specifically with fibrous debris.

RAI T-9

Section 8.1.1.2 Evaluation of ECCS Pumps for Operation with Debris-Laden Water from the Containment Sump, page 8.6 - Provide the basis for the statement that "Sufficient time is available to isolate the leakage from the failed pump and start operation of the an alternate ECCS or CS train."

RAI T-9 Response

The WCAP states that 30 minutes is sufficient to isolate the pumps with failed primary and failed disaster bushing, and start up an alternate train. NRC has generally accepted operator action within 30 minutes as part of accident mitigation.

RAI T-10

Section 8.1.1.3, Evaluation of ECCS Pumps for Operation with Debris-Laden Water from the Containment Sump, page 8.6 - States: " For most pumps of this type there is sufficient damping ... see reference 8.1.7 and 8.1.8." The quoted statement was not a conclusion of Reference 8.1.7. Provide Reference 8.1.8 for review.

RAI T-10 Response

Reference 8.1.8 is publicly available. A copy will be provided to NRC.

RAI T-11

Section 8.1.3, Mechanical Shaft Seal Assembly, page 8.9 - Please provide basis for the statement "Should the cooling water to the seal cooler be lost, the additional risk for seal failure is small for the required mission time for these pumps."

RAI T-11 Response

The design temperature for most mechanical shaft seals used in auxiliary system pumps is 350F to 400F. The seal cooler is included to extend the service life of the seal by allowing the seal to operate at conditions which gives extended seal life due to low wear rate. As long as these seals operate at or below their design temperature, the probability of short term failure is very low. If coolant flow to the seal cooler (from CCW or SW) is lost, the seals are going to heat up to slightly above the temperature of the pumped fluid, which could be as high as 270F. This is still below the design temperature for the seal, and therefore should not result in short term seal failure. The seal injection flow (although no longer cooled by the seal cooler) will under these conditions still protect the seal against short term failure.

RAI T-12

Section 8.1.5, Wear Margin for SI Pumps - The generic statement that all SI pumps "have wear rings that are good "as new" based solely upon "very little service beyond inservice testing", is not adequate justification. A stronger basis is needed e.g. maintenance and operational history.

RAI T-12 Response

The following words will be added to the WCAP directly before the discussion of the wear margin for SI pumps. "Westinghouse has experience with maintaining and rebuilding centrifugal charging pumps (CCP), which generally has similar wear ring designs and materials as the SI pumps. Since the CCPs have charging duty, they are operated during normal plant operation and can accumulate thousands of hours between maintenance cycles, compared with the SI pumps seeing a few hours every time they are subjected to in-service testing. The Westinghouse experience with the CCPs wear rings is that the amount of wear in most cases is negligible and seldom exceeds 3 mils on the diameter for those rings that do show wear. On the basis of the similarity in design and materials used for the wear rings, and the difference in operating duty, it is justified to assume that the SI pump wear rings are essentially "as new" throughout their service life."

RAI T-13

Section 8.1.6, Evaluation Template for ECCS Pumps, Figures 8.1-7, 8.1.8 and 8.1.9 - Explain how the guidelines, approaches and criterion in the figures are appropriate for types and systems other than Westinghouse designed plants.

RAI T-13 Response

It is the intent that the evaluation methodology be sufficiently generic to allow evaluation of all auxiliary system pumps that do not employ internal water lubricated hydrostatic bearings. The evaluation methodology documented in the WCAP is generic in the sense that it covers vertical and horizontal pump designs, and for each category single stage and multistage models. This covers all potential variations of centrifugal pumps used in the auxiliary systems. PWRs from different reactor manufacturers all have similar auxiliary systems, and accordingly similar pumping requirements. The evaluation template for ECCS pumps covers all centrifugal pumps currently employed in PWRs, with the exception of pumps employing internal water lubricated hydrostatic main bearings (such as the Davis-Besse HPSI pumps). The template guides the evaluation of the parts of the pumps that are significantly affected by the enhanced wear due to debris in the pumped fluid over the required duty cycle for LBLOCA recovery.

RAI T-14

Section 8.1.6, Evaluation Template for ECCS Pumps, Figure 8.1.9 Decision Tree for performing Pump Operability Evaluation and Note b - Provide the basis for the 2X ring gap clearance acceptance criteria.

RAI T-14 Response

Pump manufacturers in their tech manuals as a suggested PM generally recommends the replacement of wear ring when the clearance has increased to twice the "as new" clearance (2X). Based on the analysis performed in support of the WCAP, this appears to be a conservative limit for both hydraulic and dynamic effects.

RAI T-15

Section 8.1.7, References - Provide Reference 8.1.14 for review.

RAI T-15 Response

Reference 8.1-14 was provided to the NRC Document Control Desk via OG-07-172 on April 16, 2007.

RAI T-16

Section 8.2, Valves - From a review of flowchart, Figure 8.2-1, and Table 8.2-3, throttling of caged globe valves is not addressed. Either include in the discussion or explain why this situation is not valid.

RAI T-16 Response

Figure 8.2-1 and Table 8.2-3 will be modified to include discussion of cage guided valves.

RAI T-17

Section 8.2.4, Valve Recommendations/Modifications, Table 8.2-5, Recommended Actions and Modifications - Item 3, Check Valves <1", IN 97-76 is referenced in the Plugging Issue column. IN 97-76 pertains to throttle valves, not check valves. Please provide the appropriate reference or evaluation.

RAI T-17 Response

The reference will be deleted. The following test will be added in Section 8.2.4. "The basis is that for valve flow area open to be equal to pipe area, the lift must equal 25% of inside pipe diameter. For 1 inch valve in a 1" schedule 160 pipe, the lift is estimated to be 0.204". The permissible debris particle size should be checked with the vendor to ensure that there is no blockage."

RAI T-18

Section 9.3.2, Remedial Actions - The meaning of the second sentence is unclear. Please clarify.

RAI T-18 Response

The WCAP text will be revised to state "However, for a plant with large amounts of fibrous insulation, the ability of a preconditioned sump screen to provide sufficient flow, such that NPSH requirements are satisfied, must be carefully evaluated, taking into consideration plant-specific debris loading in the evaluation."

RAI T-19

Section F.2, Abrasive Wear - Provide a discussion on why the two-body wear model "is not important to this investigation." The WCAP-referenced testing suggests abrasive wear and not three-body wear. The generally accepted predictive methodology is Archard's model for abrasive wear. Archard's model is the most conservative, i.e., results in the most severe and rapid wear rate. Why was a three-body wear model utilized in the report and not an abrasive wear model?

RAI T-19 Response

A discussion of the Westinghouse abrasive wear model based on the free flowing abrasive wear (three-body wear) bounds the and packing type wear (two-body wear) is documented in a paper "Wear Models for use in Close Running Clearance Evaluation of Pumps" (attached).

RAI T-20

Section F.2, Abrasive Wear - Bearing loads are not specifically discussed in the report. Bearing loads are critical for both wear and bearing dynamic analyses. Provide justification for not including these loads.

RAI T-20 Response

The wear rings in multistage pumps are not subjected to radial hydraulic loads during operation. The natural deflection (sag)of the shaft due to weight of the total rotating assembly, may result in contact between the impeller hub and the wear rings when pumps are not operating. When a pressure drop develops between the stages, the wear rings will develop a hydrostatic bearing support force (centering force). A correctly assembled and aligned pumps has as such essentially no bearing load associated with the wear rings. Also, there is no hydrodynamic lubrication associated with the wear rings during pump operation, only hydrostatic centering force.

RAI T-21

Section F.2, Abrasive Wear - Stage to Stage differential pressure and pump speed and their effect on abrasive wear rates are not discussed in the report. Provide a discussion of their impact on wear analysis.

RAI T-21 Response

The data shown in the WCAP as basis for the wear analysis was only limited to two conditions: 1) running clearance with a pressure drop providing flow, and 2) running clearance with no pressure drop. The data show that a pressure drop was required to generate wear. This is discussed in detail in Appendix F. The wear rings fall into the second category (pressure drop), and are therefore subject to the wear analysis based on the wear model. The wear data presented in Appendix F was generated at a pump speed typical for many auxiliary system pumps. The effect of pump speed on the rate of wear could not be determined, and assumed to minor within the range of operating speeds for these pumps.

RAI T-22

Section F.3.1, Debris Characterization - The particle composition value in 360 gallons of water at 100 °F, 92 ppm, appears to be incorrect. Using a total of 146.86 grams (95.8g + 31.9g + 19.16g = 146.86g) of particulate and a density of 62.0 lb/cu.ft. for water at 100 °F:

C = mdebris / mwater + mdebris

mdebris = 146 g

mwater = 360 gal (1 cu.ft./7.48052 gal)(62.0 lb/cu.ft) = 2983.7 lb

Converting lb water to grams: 2983.7 lb (0.4536 kg/1 lb)(1000g/1 kg) = 1.353E+6 g.

C = [146 g / (1.353E+6 g + 146g)][1 ppm /(1 g/ 1E+6 g)] = 108 ppm

Please explain the difference between this calculated value and the 92 ppm presented in section F.3.1.

RAI T-22 Response

This section, as drafted before all the results of the dynamics evaluation were available, will be updated in its entirety based on the latest results.

RAI T-23

Section F.4.3, Effect of Debris Concentration Decay on Wear Rate - Section 4.2 notes that "wear (is) from an abrasive particle trapped between two surfaces in motion". Since there is no mechanism to flush wear particles from tight clearances in pump internals, clarify why the depletion rate as defined in Eqn F.4-15 is applicable.

RAI T-23 Response

This issue was discussed in detail in the attached white paper.

RAI T-24

Section F.4.4.1, Davis-Besse/MPR Data - The wear model discussed in Appendix F appears to be based on earlier Westinghouse test results at 920 ppm debris concentration. The discussion in section F.4.4.1 states that the debris concentration in the Davis-Besse test used as a benchmark is unknown. What is the rationale for assuming that the Davis-Besse debris concentration was at the 920 ppm level and hence a suitable benchmark for the model?

RAI T-24 Response

The following text will be added to the WCAP in the text of the first full paragraph on page F-16. "Westinghouse has the results of the debris transport analysis and the debris concentration in the containment sumps for many plants. The debris concentration varies from plant to plant, but an average value of approximately 1000 PPM. Davis-Besse removed most of the fibrous insulation within the containment as a result of the qualification of the HPSI pump, and it was therefore estimated that approximately 920 PPM would be conservative for the residual debris concentration in the sump. In the attachment Westinghouse is showing wear calculation with debris from 500 PPM to 1200 PPM in a comparison with Davis-Besse analysis."

RAI T-25

Section F.4.4.1, Davis-Besse/MPR Data - Provide details of the Davis-Besse special effects testing such as pump models, speed, test temperatures, pressure drop, flow rates, visual observations, etc. or other pertinent data to allow comparison with other style RHR pumps.

RAI T-25 Response

All available date from the Davis-Besse testing are documented in two open literature references (given as References 8.1-7 and 8.1-8 in the WCAP). These references do not generally contain information, such as that requested. Since Westinghouse did not use the Davis-Besse data in the abrasive wear model development (only as an order-of-magnitude validation), this data was not required. The Davis-Besse pump was HPSI multistage design, and not comparable to a single stage RHR pump design.

RAI T-26

Section F.4.5, Abrasive Wear Model References - Reference F.4-1 describes results for erosion not abrasion. Clarify how this information is applicable to abrasive wear models.

RAI T-26 Response

Sheldon's paper (Reference F.4-1) provides an overview of wear models covering erosive and abrasive wear. The inverse relationship between wear and hardness is described and the relationship is used in the WCAP model development. The model went further to employ the 0.58 hardness index from the reference in the development.

RAI T-27

Section F.5.1, Erosive Wear Model, General - The methods presented in this section do not address wear due to turbulent flow around bends, fluid changes in direction, turbulent flow downstream of restrictions such as valves or orifices or other pipeline interferences. Explain why the methods bound these conditions.

RAI T-27 Response

The following text will be added to the WCAP at the end of Section F.5.1. "The method used is based on flows in coal slurries typically 40% -50% by mass concentration. Generally, these slurries wear at elbows and valves. The model coefficients derived from empirical data is bounding given that the debris concentration in the sump is two to three orders of magnitude less than the flow in coal slurries. Further the impact angle relationship $F(\alpha)$ is maximum at $\alpha = 30°$. For all other angles, it is less than 1. Hence the elbows are susceptible to wear as the flow path changes from 0° to 90°. Therefore, elbows and fittings are applicable and the model is conservative."

RAI T-28

Section F.5.1, Erosive Wear Model, Equation F.5-1 - Define term "Mf".

RAI T-28 Response

M_f is the total mass fraction of the fluid that entrained the debris. The definition will be made in the WCAP.

RAI T-29

Section F.5.1, Erosive Wear Model - In developing the general equation for erosive wear (eqn. F.5-4), the impact angle relationship described in eqns. F.5-3, F(□), appears to have been dropped. Is there a general assumption that the worst case value of 1.0 be used? Please provide an explanation.

RAI T-29 Response

The impact angle relationship $F(\alpha)$ is maximum at $\alpha = 30°$, at which time $F(\alpha) = 1$. The text will be modified to explain the relationship.

RAI T-30

Section F.5.2, Industry Data, Table F.5-2, Wear Rates of Metals under Abrasive Slurries - For steel, the major material of concern, the results of Table F.5-2 do not demonstrate a clear "wear rate is proportional to velocity squared relationship" as is stated on page F-20, third paragraph. (Wear rates are at a ratio of 2.7846 vs. 4.591 as predicted by the velocity squared relationship.) The velocity squared relationship is used later in equation F.5-11b. In the case of steel, the velocity squared relationship yields conservative results. Please add a discussion on the basis for the velocity term since it is not clearly a squared function.

RAI T-30 Response

Table F.5-2 provides data based on the wear rate of different materials. Since the data set is sparse, a geometric average was used to estimate the average wear rate ratio between the wear at 15 ft/sec and wear at 7 ft/sec. The geometric average of the wear rate ratios was shown to be 4.618. It was noted that if wear is proportional to V^a, then the velocity exponent (a) is

$a = \ln(4.618)/\ln(15/7) = 2.007$

Hence, the velocity squared relationship reported in literature is confirmed. The text will be modified to clarify the derivation.

RAI T-31

Section F.5.2, Industry Data, page 21 - The first sentence in the second paragraph is inconsistent. Earlier, the discussion on page 20 states that material wear rate increases from 0% volume (0% mass) concentration to 12% volume (18% mass) concentration. The sentence in question states that the erosive wear rates at 0% mass (0% volume) and 18% mass (12% volume) are essentially the same, which appears to be a conflict. Additionally, the following equation (F.5-8) only works for concentrations less than or equal to 18%. For any value above 18%, the equation predicts wear rates greater than that associated with a 46% mass slurry. Add an explanation regarding the bounds of expected concentrations being well below the equation's range of validity.

RAI T-31 Response

Agreed. The first sentence will be deleted.

RAI T-32

Section H.2.1, Flowserve - Pump Input, pages H-3 thru H-7 - Provide information on how the comments from Flowserve were incorporated into Appendix F.

RAI T-32 Response

The information from Appendix H-3 to H-7 was factored into the report revision as applicable. Further, in paragraph 1 of H-3, Flowserve stated "... the abrasive model is a well-founded, conservative method for predicting this type of wear on pumps..." This provides confidence that the WCAP model is appropriate.

RAI T-33

Section H, Summary Report - Lateral Rotor Dynamic Analysis, Background, page H-21 - Provide a discussion on the basis for use of American Petroleum Institute (API) Standard 610 eighth edition in the evaluation of the 2.5" RLIJ 11 stage pump and the 3.0" JHF 10 Stage Pump.

RAI T-33 Response

The selection of using the API-610 as a basis for the dynamics analysis was based on a recommendation by the pump designers/manufacturer: Flowserve R&D Division. Flowserve also performed the analysis. This evaluation can be used for all ECCS Pumps, from any pump manufacturer.

RAI T-34

Section H, Summary Report - Lateral Rotor Dynamic Analysis - The rotor dynamic instability analysis references the American Petroleum Institute (API) methodology in ANSI/API Standard 610 Annex I. This analysis is for newly manufactured pumps and API not worn or damaged bearings, damaged rotors, damaged impellers, etc. Please provide and justify an appropriate criterion to determine catastrophic failure for post-LOCA ECCS pump operation with wear, erosion or damage to components.

RAI T-34 Response

API-610 Annex I is used as a screening criteria, not a failure criteria. If the screening indicates that the pump may have a dynamic performance problem, response analysis can be performed to evaluate the performance further.
Auxiliary pumps in nuclear plants are maintained and tested to the highest standards. Pumps with damaged impellers, rotors and bearings are promptly repaired, and not used for plant service until they are repaired. The wear limits provided in the WCAP are not to predict catastrophic failures of the pumps, but the limits the pump manufacturer indicate as limits for normal good performance.

RAI T-35

Section H, Summary Report - Lateral Rotor Dynamic Analysis - There are several types of dynamic instability that may result in catastrophic failure of pump bearings and rotors.
- Synchronous Unbalanced Forced Response (once per revolution forces)
- Non-synchronous Forced Response (forces that are not once per revolution)
- Instability Responses such as whip or whirl for lightly loaded rotors (bending rotor modes, rotational forces and bearing dynamic loads combined)

Please explain how these possible instabilities been considered or the basis for excluding any of these dynamic instability modes.

RAI T-35 Response

The ECCS pumps have been designed, manufactured and tested to meet very strict nuclear requirements. As operating in the plant, vibration issues and effects such as those listed, are expected to be absent since they are resolved as part of the pump prototype development and testing.
The evaluation being performed by the methodology described in the WCAP looks for the additional effects of wear due to debris in the pumpage for a required duty (such as 720 hours service). Due to the limited initial debris concentration (such as 1000 to 2000 PPM) and decay in debris concentration with time, erosive wear and significant damage to the hydraulics causing previously unobserved vibration issues to develop, is considered unlikely by this analytical approach.. The residual issue is therefore the change in support stiffness at the hydrostatic support locations (wear rings). This is what is being evaluated by the dynamics analysis.

RAI T-36

Section H, Summary Report - Lateral Rotor Dynamic Analysis - The report does not describe in detail the stiffness important for rotor dynamic analysis. The API 610 Standard indicates that all stiffness must be included in the analysis to adequately analyze pump rotor instabilities. Total stiffness = shaft stiffness + bearing stiffness + housing and support stiffness.

Have all of these stiffnesses been evaluated for the pump rotor dynamic analysis? What are the criteria for including or ignoring various stiffnesses that may be critical to rotor instability and catastrophic failure?

RAI T-36 Response

The dynamics model used by Flowserve included the shaft stiffness, the casing stiffness and the bearing support structure stiffness. The dominant factor for the dynamic response is the stiffness of the hydrostatic centering force in the wear rings. Therefore, the softest support for the shaft is the close running clearance in the wear rings. The only parameter that was changed in the analysis (as it would be for an installed pump) was the hydrostatic support stiffness in the running clearances of the pump due to increased gap. To evaluate this effect only, the floor stiffness becomes less important and was not included in this generic analysis. Also, the stiffness of the floor is orders of magnitude greater than the support stiffness of the wear rings, and has insignificant impact on the result of this analysis.

RAI T-37

Section H, Summary Report - Lateral Rotor Dynamic Analysis - How is starved flow due to close clearance debris buildup though a wear ring, bushing or other dynamic support structure incorporated into the analysis?

RAI T-37 Response

The starved flow due to the packing buildup is ignored since it will reduce the parasitic flows inside the pumps. The reduced parasitic flow will tend to counteract general hydraulic losses in the pumps. Also, the stiffness of the "packing" in the close running clearance is expected to be greater than the hydrostatic centering force provided by the open running clearance. This makes the approach used for dynamics analysis shown in the WCAP conservative.

RAI T-38

Section H, Summary Report - Lateral Rotor Dynamic Analysis - When rubbing or contact occurs, a non-linear stiffness model for the rotor system is applied to analyze the dynamic rotor response. Explain how such a model been considered or evaluated for possible rotor instability analysis.

RAI T-38 Response

For a properly assembled pump (such as a horizontal multistage model), there is little evidence of rubbing in the running clearances except briefly during startup and coastdown. .For normal operation the hydrostatic centering forces are sufficient to prevent metal to metal contact. The hydrostatic centering force is approximately linear with off-center displacement of the shaft, until the film thickness becomes small enough to generate a hydrodynamic lubrication and shaft support. This will provide a much stiffer support, but also increased possibility of direct contact. There is no evidence that loss of film thickness occurs at other than startup and coastdown. However, these conditions are part of the pumps normal operating regime, and the wear ring materials and design have been chosen to perform under these conditions without damage

RAI T-39

Section H, Summary Report - Lateral Rotor Dynamic Analysis - Most classical analyses of fluid bearings lubricated with oil neglect the fluid inertia effects because viscous effects in the bearing annular region dominate over the fluid inertia effects with oil lubricated bearings. This may not be true for water-lubricated bearings, and the inertial fluid forces may be important or perhaps critical to rotor instability analyses. Please elaborate on the importance of fluid inertia in the rotor dynamic analysis considering worn or damaged ECCS pump bearings.

RAI T-39 Response

The running clearances for the multistage pumps mostly used in ECCS have diametric running clearances in the wear rings of approximately 10 mils and up. The support loads in the wear rings are therefore purely hydrostatic, which is dependent on pressure drop and gap, and independent of fluid inertia.

RAI T-40

Section J.2, Estimate of Debris Size - Provide the basis for the statement: "...fibrous debris was judged to be the most important contributor to abrasive wear."

RAI T-40 Response

The WCAP will be edited to state that "....fibrous debris was judged to be an important contributor to abrasive wear.

RAI T-41

Withdrawn.

RAI T-41 Response

No response necessary.

ADMINISTRATIVE COMMENTS:

RAI A-1

Section 4.1.2, Combustion Engineering Design, Page 4-13, first paragraph - Change "provide" to "provided."

RAI A-1 Response

The typographical error is noted and will be corrected.

RAI A-2

Section 5.10, Fibrous Debris Concentration Depletion, Page 5-16, second paragraph - Change "the value dimensionless value" to "the dimensionless value."

RAI A-2 Response

The typographical error is noted and will be corrected.

RAI A-3

Section 5.10, Fibrous Debris Concentration Depletion, Page 5-16, third paragraph - Change "opening" to "openings."

RAI A-3 Response

The typographical error is noted and will be corrected.

RAI A-4

Section 7.3, Valves, Page 7-12, Table 7.3-1, Failure Modes of ECCS Valves from Debris Ingestion - Note 1, delete the word "a" in the last line.

RAI A-4 Response

The typographical error is noted and will be corrected.

RAI A-5

Section 7.3, Valves, Page 7-13, Table 7.3-1, Failure Modes of ECCS Valves from Debris Ingestion - Note 4, second sentence, change "increase" to "increased."

RAI A-5 Response

The typographical error is noted and will be corrected.

RAI A-6

Section 7.3.2.2.1, Particulate Distribution, Page 7-15, - In the second sentence, change "The leads to" to "This leads to."

RAI A-6 Response

The typographical error is noted and will be corrected.

RAI A-7

Section 7.3.2.3, Material Hardness Effect, Page 7-16, third paragraph - Change "Information Notice 97096" to "Information Notice 97-76."

RAI A-7 Response

The typographical error is noted and will be corrected.

RAI A-8

Section 7.3.3.4.1, Globe Valves (Not Throttled), Page 7-18,- Change IN 96-97 to IN 96-27.

RAI A-8 Response

The typographical error is noted and will be corrected.

RAI A-9

Section 7.3.4, References, Reference 7.3-1 - The issue date of IN 97-76 is October 30, 1997.

RAI A-9 Response

The issue date of of October 30, 1997 will be added to Reference 7.3-1, Information Notice 97-76.

RAI A-10

Section 8.1, Pumps, Page 8-1 - In the first paragraph, spell out Stone and Webster and put S & W in parenthesis.

RAI A-10 Response

The typographical error is noted and will be corrected.

RAI A-11

Section 8.1, Pumps, Page 8-1 - In the second paragraph, change "use internal sleeve bearing" to "use an internal sleeve bearing."

RAI A-11 Response

The typographical error is noted and will be corrected.

RAI A-12

Section 8.1.3, Mechanical Shaft Seal Assembly Evaluation, Page 8-9, second paragraph - In the first sentence, change "Mechanical shaft seal" to "Mechanical shaft seals." In the second sentence, change "These seal" to "These seals."

RAI A-12 Response

The typographical error is noted and will be corrected.

RAI A-13

Section 8.1.4, Pump Mechanical Evaluation (Vibration), Page 8-12, third paragraph - Change "documents" to "document."

RAI A-13 Response

The typographical error is noted and will be corrected.

RAI A-14

Section 8.1.4, Pump Mechanical Evaluation (Vibration), Page 8-13, last paragraph - Change "This analysis is document" to "This analysis is documented."

RAI A-14 Response

The typographical error is noted and will be corrected.

RAI A-15

Section 8.1.6, Evaluation Templates for ECCS Pumps, Page 8-16,- In the first paragraph, change "The mission time for the ECCS and CSS pumps are discussed" to "The mission time for the ECCS and CSS pumps is discussed."

RAI A-15 Response

The typographical error is noted and will be corrected.

RAI A-16

Section 9..2.2.6.b.ii.1, Cold-Leg Recirculation, Page 9-8 - Change "to the size maximum size of debris" to "to the maximum size of debris."

RAI A-16 Response

The typographical error is noted and will be corrected.

RAI A-17

Section 9.2.3.5.a, Hot-Leg Recirculation, Page 9-10 - Change "particulate sizes distributions" to "particulate size distributions."

RAI A-17 Response

The typographical error is noted and will be corrected.

RAI A-18

Section 10.1, Plant Implementation, second sentence - Change "valve" to "valves."

RAI A-18 Response

The typographical error is noted and will be corrected.

RAI A-19

Section 10.5.1, Hydraulic Performance Evaluation, Page 10-10, first paragraph - Change "the ECCS pumps must provide a required flow the reactor coolant system" to "the ECCS pumps must provide a required flow to the reactor coolant system."

RAI A-19 Response

The typographical errors are noted and will be corrected.

RAI A-20

Section 10.5.1, Hydraulic Performance Evaluation, Page 10-10, third paragraph - Change "a flow margins of 10 percent" to "a flow margin of 10 percent."

RAI A-20 Response

The typographical error is noted and will be corrected.

RAI A-21

Section 10.5.1, Hydraulic Performance Evaluation, Page 10-10, fourth paragraph - Change "for calculating the how the wear ring gap increases" to "for calculating how the wear ring gap increases."

RAI A-21 Response

The typographical error is noted and will be corrected.

RAI A-22

Section 10.5.2, Mechanical Shaft Seal Assembly Evaluation (All Pumps), Page 10-11, first paragraph - Change "plant" to "plants' in the second sentence and the last sentence and "separator" to "separators" in the last sentence. Second paragraph, fourth sentence, change "This is the conditions" to "These are the conditions."

RAI A-22 Response

The typographical errors are noted and will be corrected.

RAI A-23

Section 10.7, Reactor Internal and Fuel, Page 10-12, first paragraph - Change "The major flow paths thought the reactor internals is larger" to "The major flow paths through the reactor internals are larger." Second paragraph, change "(such as slot and holes in the baffle/barrel regions)" to (such as slots and holes in the baffle/barrel regions), ." Third paragraph, change "fuel region this may require" to "fuel region may require."

RAI A-23 Response

The typographical errors are noted and will be corrected.

RAI A-24

Section F.4.2, Wear Rate of Carbon as a Proxy, Page F-12, Equation F.4-8 - Typo, 0.00005554 should be 0.000005554.

RAI A-24 Response

The typographical error is noted and will be corrected.

RAI A-25

Section F.4.2, Wear Rate of Carbon as a Proxy, Page F-12, near bottom - Typo, "harsesses" should be "hardnesses".

RAI A-25 Response

The typographical error is noted and will be corrected.

RAI A-26

Section F.4.3, Effect of Debris Concentration Decay on Wear Rate, Page F-13, near bottom - Decay coefficient should be "λ", not "l".

RAI A-26 Response

The typographical error is noted and will be corrected.

RAI A-27

Section 4.4.1, Davis-Besse/MPR Data, page F-16 - Reference to Figure "F.4-1" should be to "F-4.2" for wear rate versus debris concentration.

RAI A-27 Response

The typographical error is noted and will be corrected.

RAI A-28

Section F.4.4.1, Davis-Besse/MPR Data, page F-17 - Typo, "abrasisve" should be "abrasive".

RAI A-28 Response

The typographical error is noted and will be corrected.

RAI A-28

Section F.5.1, Erosive Wear Model, page F-19, mid-page - Reference to equation "F.5-3" should be to "F-5.4.

RAI A-28 Response

The typographical error is noted and will be corrected.

RAI A-29

Section F.5.1, Erosive Wear Model, page F-19, mid-page - "A" subscript "c" should be "A" subscript "e".

RAI A-29 Response

The typographical error is noted and will be corrected.

RAI A-30

Section F.5.1, Erosive Wear Model, page F-19, mid-page - Close parenthesis on kg/m3.

RAI A-30 Response

The typographical error is noted and will be corrected.

RAI A-31

Section F.5.2, page F-20, first sentence - Typo, "simply" should be "simplify".

RAI A-31 Response

The typographical error is noted and will be corrected.

RAI A-32

Section F.6, page F-24, before References - Typo, "(m" should be "µm" and "Ip" and "fsp(I)" should be subscripted.

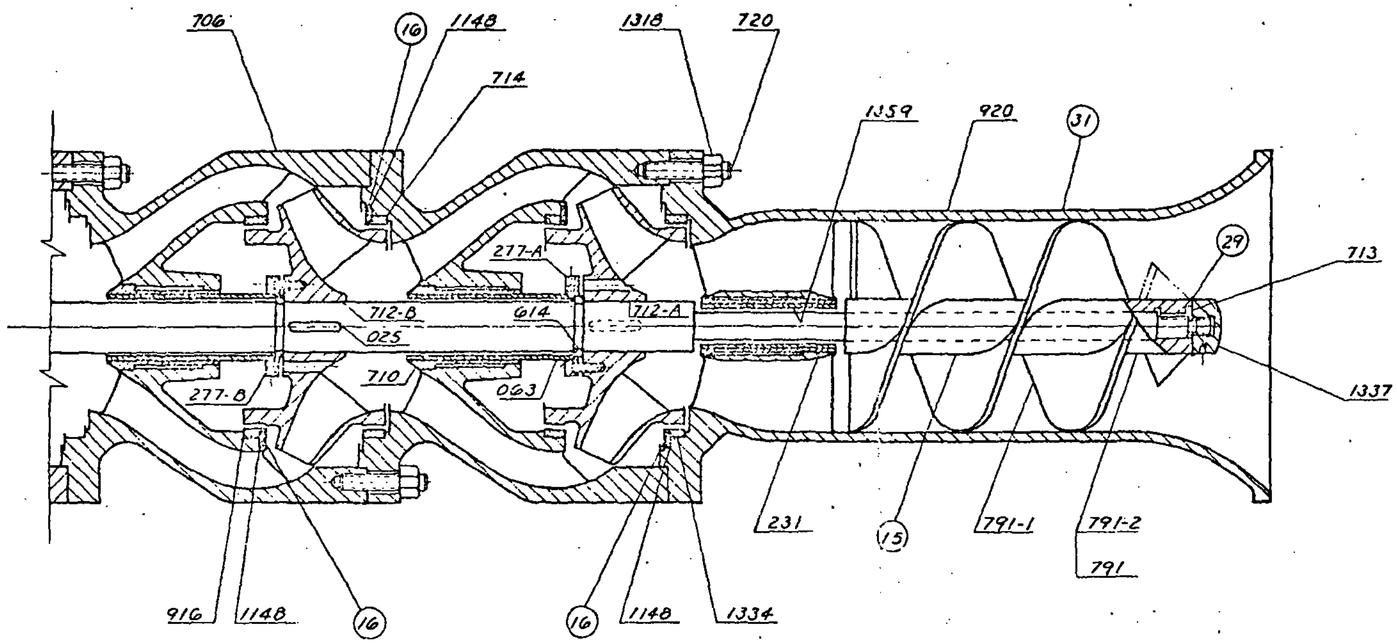
RAI A-32 Response

The typographical errors are noted and will be corrected.

Appendix A: Samples of the Assembly Drawings of the HPSI, LPSI, Charging and CS Pumps

LEGEND:

1. A NUMBER WITHIN A CIRCLE (X) INDICATES A WELDING PROCEDURE, SEE WELD TABLE, SHT. 7 OF 8.
2. ALL OTHER NUMBERS INDICATE GENERIC PART NUMBER.
   A. A GENERIC PART NUMBER FOLLOWED BY A DASH NUMBER INDICATES A PART OF A WELDED ASSEMBLY.
   B. A GENERIC PART NUMBER FOLLOWED BY A LETTER OF THE ALPHABET INDICATES SIMILAR PARTS WITH SPECIFIC STAGE APPLICATION.



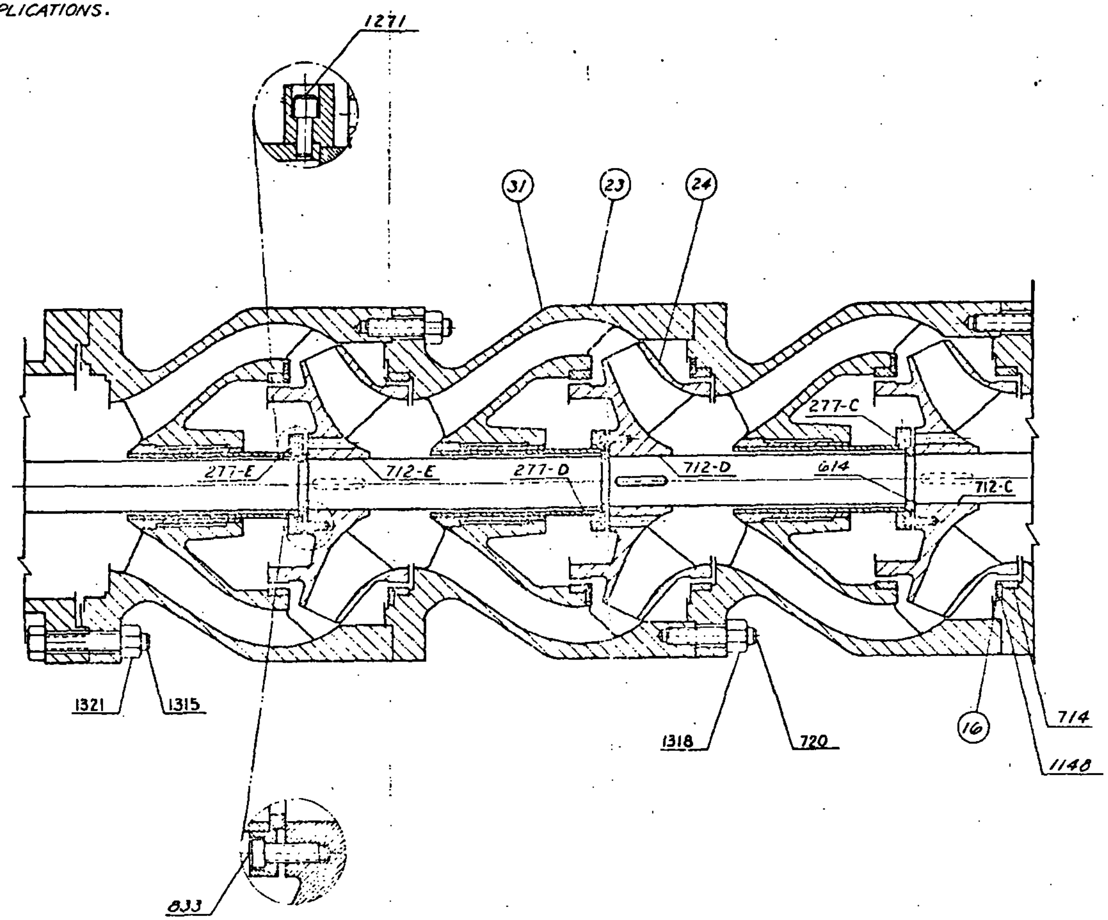
PACIFIC PUMPS DIVISION
DRESSER INDUSTRIES, INC.

TITLE	PUMP ASSEMBLY
SHEET 4 OF 8	PRODUCT ENG. DWG. NO. 500-VN49754

Westinghouse Proprietary Class 2

LEGEND:

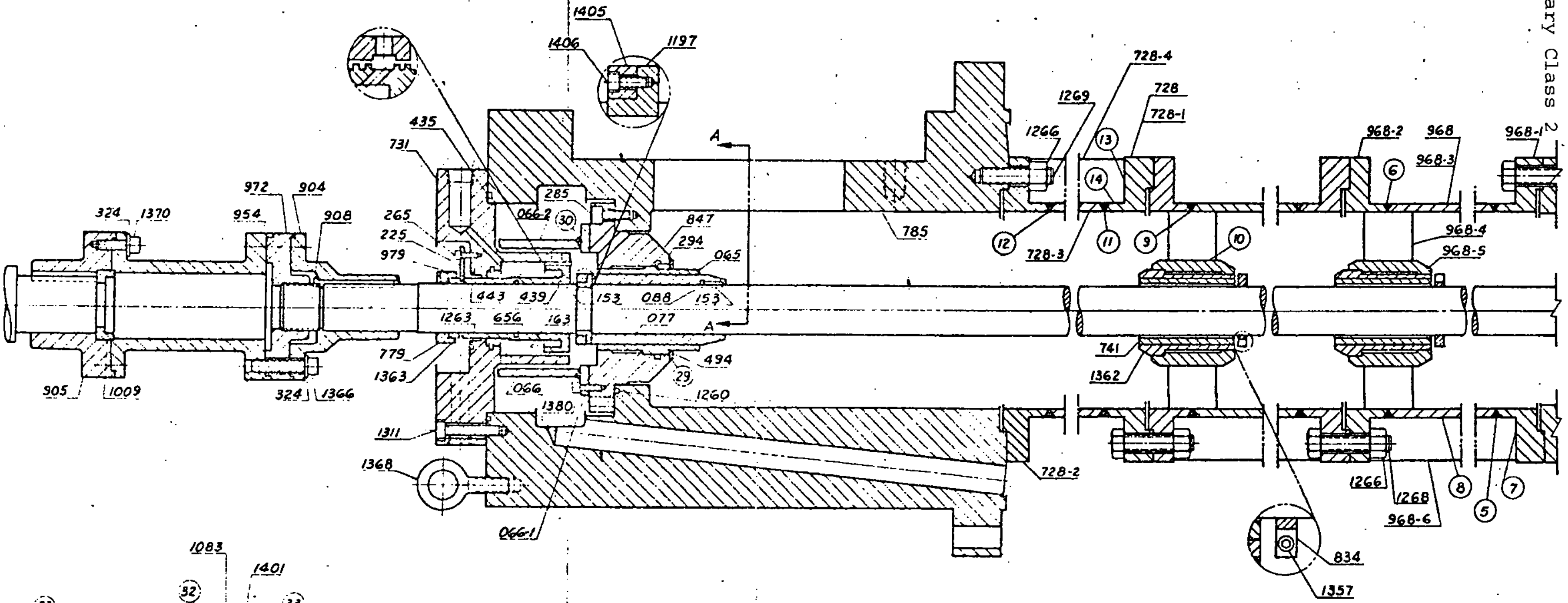
1. A NUMBER WITHIN A CIRCLE (X) INDICATES WELDING PROCEDURE, SEE WELD TABLE, SHT. 7 OF 8.
2. ALL OTHER NUMBERS INDICATE GENERIC PART NUMBERS.
   A. A GENERIC PART NUMBER FOLLOWED BY A LETTER OF THE ALPHABET INDICATES SIMILAR PARTS WITH SPECIFIC STAGE APPLICATIONS.

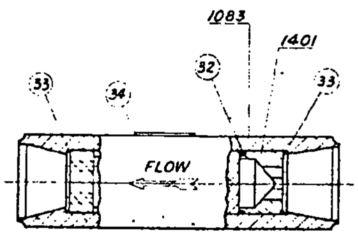


PACIFIC PUMPS DIVISION DRESSER INDUSTRIES, INC.		
TITLE PUMP ASSEMBLY		
SHEET 3 OF 8	PRODUCT ENG. DWG. NO. 500-VN49754	REV. 4

LEGEND:

1. A NUMBER WITHIN A CIRCLE (X) INDICATES A WELDING PROCEDURE, SEE WELD TABLE, SHT. 7 OF 8
2. ALL OTHER NUMBERS INDICATE GENERIC PART NUMBER.
   A. A GENERIC PART NUMBER FOLLOWED BY A DASH NUMBER INDICATES A PART OF A WELDED ASSEMBLY.





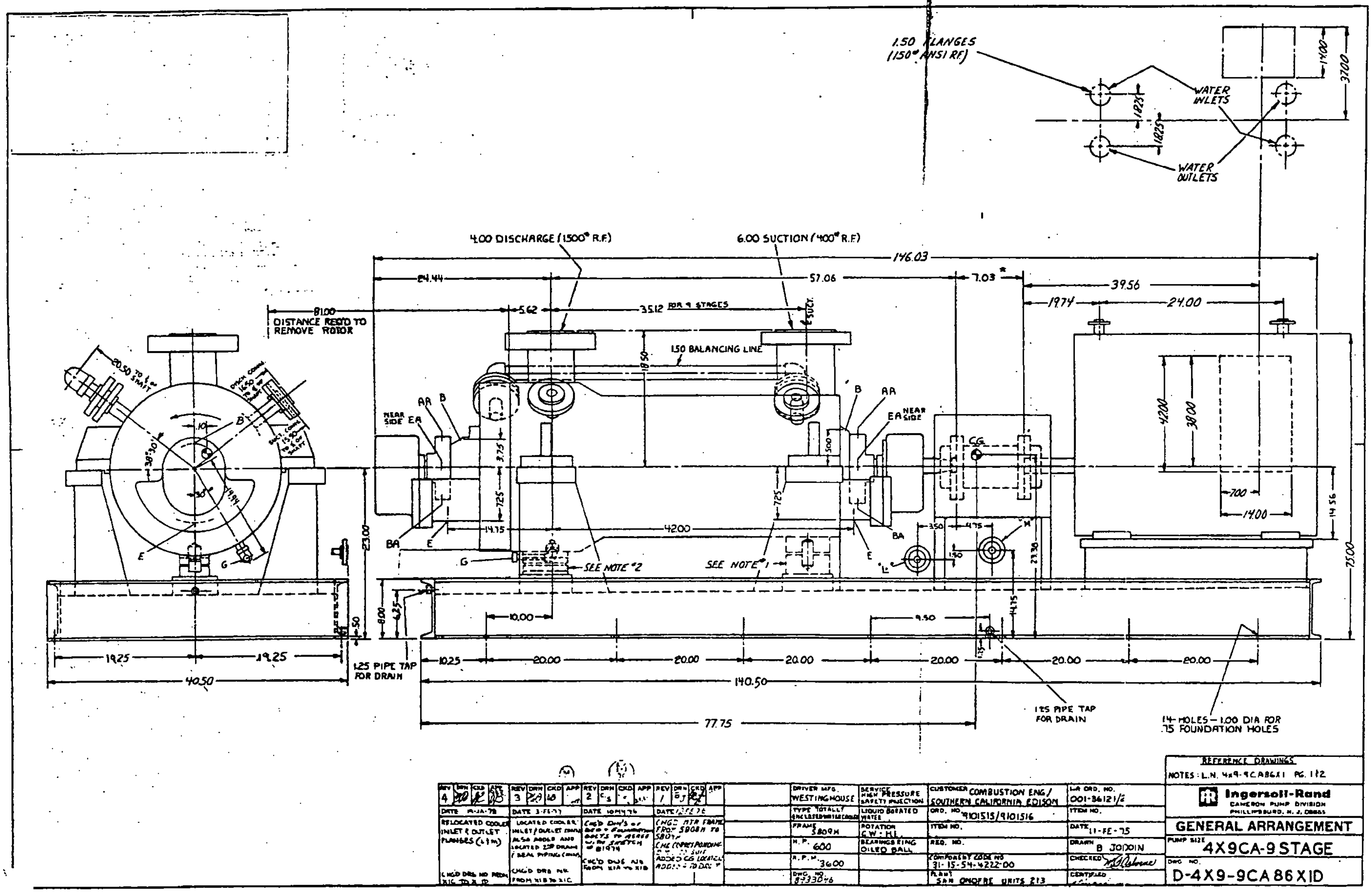
MINIMUM FLOW ORIFICE
THIS DETAIL APPLIES TO JOBS:

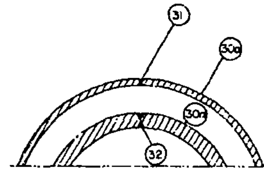
THX-SIAPLH	VN49755	51704,05,07
TGX-SIAPLH	VN49754	51701,02,03

PACIFIC PUMPS DIVISION
DRESSER INDUSTRIES, INC.

TITLE: PUMP ASSEMBLY

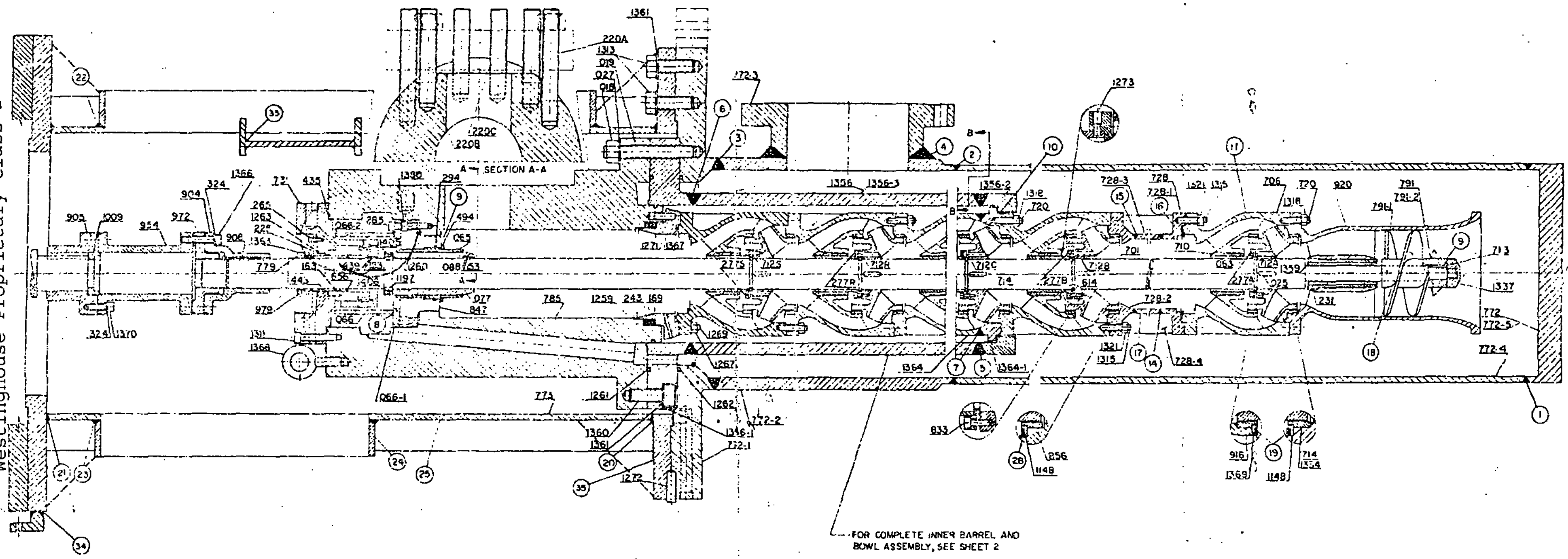
SHEET	PRODUCT ENG. DWG. NO.	REV
2 OF 8	500-VN49754	4

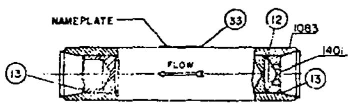

1.50 FLANGES (150# ANSI RF)
WATER INLETS
WATER OUTLETS
4.00 DISCHARGE (1500# R.F.)
6.00 SUCTION (400# R.F.)
146.03
24.44
57.06
7.03
39.56
19.74
24.00
81.00 DISTANCE REQ'D TO REMOVE ROTOR
5.62
35.12 FOR 9 STAGES
1.50 BALANCING LINE
NEAR SIDE
SEE NOTE *2
SEE NOTE *1
42.00
1.25 PIPE TAP FOR DRAIN
140.50
77.75
14-HOLES — 1.00 DIA FOR .75 FOUNDATION HOLES
40.50
REFERENCE DRAWINGS
NOTES: L.N. 4x9-9CA86X1 PG. 1 & 2
DRIVER MFG. WESTINGHOUSE
SERVICE HIGH PRESSURE SAFETY INJECTION
CUSTOMER COMBUSTION ENG./ SOUTHERN CALIFORNIA EDISON
ORD. NO. 9101515/9101516
FRAME 5809H
H.P. 600
R.P.M. 3600
ROTATION CW-HI
BEARINGS RING OILED BALL
COMPONENT CODE NO 31-15-54-4222-00
PLANT SAN ONOFRE UNITS 2 & 3
DATE 11-FE-75
DRAWN B JODOIN
Ingersoll-Rand
CAMERON PUMP DIVISION
PHILLIPSBURG, N.J.
GENERAL ARRANGEMENT
PUMP SIZE 4X9CA-9 STAGE
DWG NO. D-4X9-9CA86X1D



LEGEND.

1. A NUMBER WITHIN A CIRCLE (X) INDICATES A WELDING PROCEDURE, SEE WELD TABLE.
2. ALL OTHER NUMBER INDICATE GENERIC PART NUMBERS.
   A. A GENERIC PART NUMBER FOLLOWED BY A DASH NUMBER INDICATES A PART OF A WELDED ASSEMBLY
   B. A GENERIC PART NUMBER FOLLOWED BY A LETTER OF THE ALPHABET INDICATES SIMILAR PARTS WITH SPECIFIC STAGE APPLICATION.





MINIMUM FLOW ORIFICE

SPIN NUMBER	S. O. NO.	SERIAL NO.
TGX/SIAPHH-01, 02 & 03	V49752	51693, 6 & 7
THX/SIAPHH-01, 02 & 03	V49 753	51698, 9 & 700

CONTRACTOR: WESTINGHOUSE N.E.S.
SERVICE: HIGH HEAD SAFETY INJECTION
SIZE & TYPE: 6 X 10 WYRF/MULTI-STAGE VERTICAL

PACIFIC PUMPS DIVISION
DRESSER INDUSTRIES, INC.

TITLE: PUMP ASSEMBLY

DWN RM | CKD | CERTIFIED | DATE

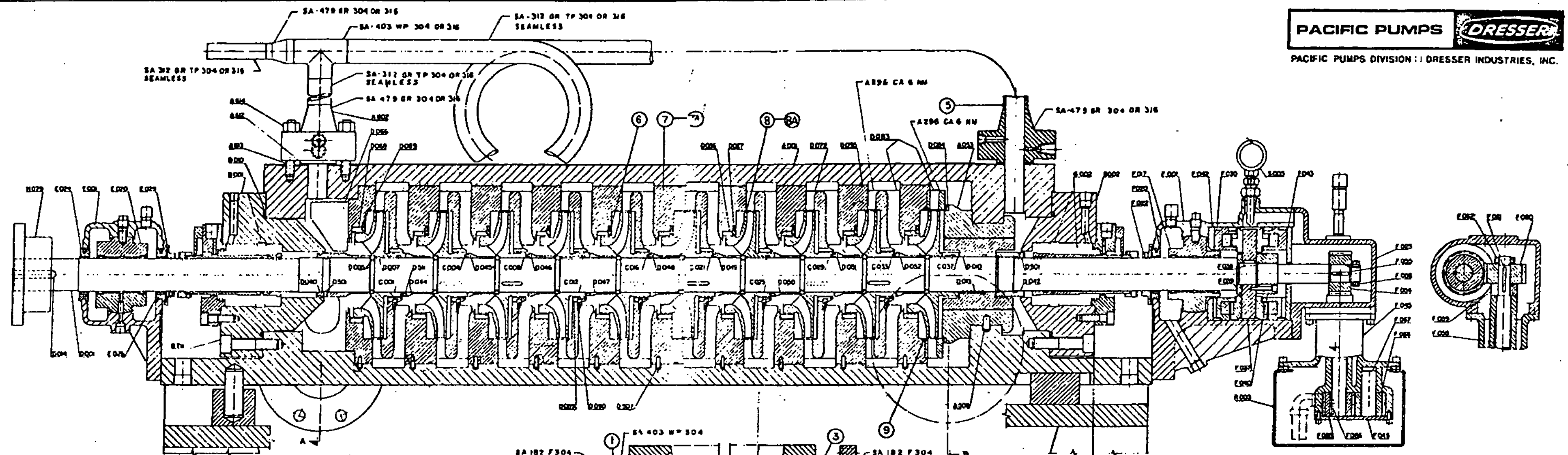
SHEET 1 OF 3 | PRODUCT ENGINEERING DWG NO 500-V49752 | REV 3

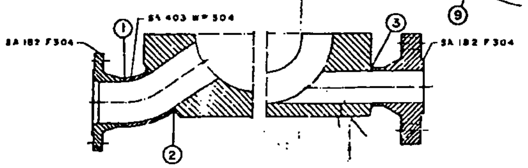
REV	DATE	MD	CK	ZONE	DESCRIPTION
3	6-4-78				REV MATL ON PART NO. 713, WAS 304, ADD PART NO. 1337 TO TORQUE CHART, REV WELD TABLE ON SHT 3, ADD MTR MNT. RIBS $ GUSSETS & ALIGNING LUGS
2	4-4-77				REVISED AND REDRAWN
1	10-6-76		RM		REVISED & REDRAWN, AND ADDITIONAL STAGE ADDED.

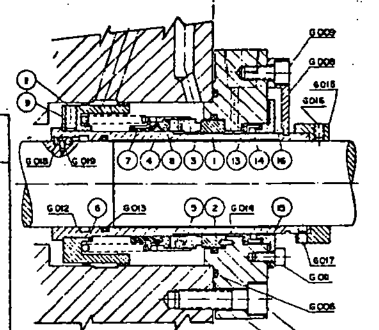
8 | 7 | 6 | 5 | 4 | 3 | 2 | 1

PACIFIC PUMPS DRESSER

PACIFIC PUMPS DIVISION : I DRESSER INDUSTRIES, INC.







DETAIL G002

PB-A001	CASE – SEE NOTE 2	SA 182 F304
A053	PRESSURE REDUCING BUSHING	A276 TYPE 440A
A508	DOWEL	A276 TYPE 304
PB-A602	BY-PASS ASSEMBLY	
A612	GASKET	
PB A613	STUD	SA 193 GR B7
PB-A614	NUT	SA 194 GR 7
PB-B001	SEAL HOUSING - RADIAL	SA 182 F304
PB-B002	SEAL HOUSING - THRUST	SA 182 F304
B010	SEAL HSG GASKET	
PB-B711	SOCKET HEAD CAP SCREW	SA 193 GR B6
C001	IMPELLER 1ST STAGE	A296 CA 40
C004	IMPELLER 2ND STAGE	A296 CA 40
C008	IMPELLER 3RD STAGE	A296 CA 40
C012	IMPELLER 4TH STAGE	A296 CA 40
C016	IMPELLER 5TH STAGE	A296 CA 40
C021	IMPELLER 6TH STAGE	A296 CA 40
C025	IMPELLER 7TH STAGE	A296 CA 40
C029	IMPELLER 8TH STAGE	A296 CA 40
C033	IMPELLER 9TH STAGE	A296 CA 40
C037	IMPELLER 10TH STAGE	A296 CA 40
D001	PUMP SHAFT	A276 TYPE 414
D005	SPLIT RING	A582 TYPE 416
D007	IMPELLER KEY	A276 TYPE 304
D010	PRESSURE REDUCING SLEEVE	A276 TYPE 420
D013	PRESS RED SLV KEY	A276 TYPE 304
D014	FLEX CPLG KEY	
D040	IMPELLER LOCKNUT	A582 TYPE 416
D042	PRESS RED SLV LOCKNUT	A582 TYPE 416
D044	IMP SPACER SLV 1ST STAGE	A582 TYPE 416
D045	IMP SPACER SLV 2ND STAGE	A582 TYPE 416
D046	IMP SPACER SLV 3RD STAGE	A582 TYPE 416
D047	IMP SPACER SLV 4TH STAGE	A582 TYPE 416
D048	IMP SPACER SLV 5TH STAGE	A582 TYPE 416
D049	IMP SPACER SLV 6TH STAGE	A582 TYPE 416
D050	IMP SPACER SLV 7TH STAGE	A582 TYPE 416
D051	IMP SPACER SLV 8TH STAGE	A582 TYPE 416
D052	IMP SPACER SLV 9TH STAGE	A582 TYPE 416
D066	SUCTION SPACER	A296 CA 6 NM
D068	SUCT SPACER WEARING RING	A276 TYPE 440A
D069	LOCKING KEY	A276 TYPE 304
D072	INTERMEDIATE COVER	A296 CA 6 NM
D083	INTERM COVER DISCHARGE AND DISCHARGE DIFFUSER ASSEMBLY	
D084	SPACER RING	A276 TYPE 304
D086	INTERM CVR WEARING RING	A276 TYPE 440A
D087	LOCKING KEY	A276 TYPE 304
D089	INTERM CVR BUSHING	A276 TYPE 440A
D090	LOCKING KEY	A276 TYPE 304
D095	O-RING	
D501	SET SCREW	A276 TYPE 304
D507	DOWEL	A276 TYPE 304
D511	DOWEL	A276 TYPE 304

E001	RADIAL BEARING HOUSING	A216 GR WCB
E020	RADIAL BEARING SLEEVE	
E024	OIL BAFFLE - OUTER	
E025	OIL BAFFLE - INNER	
E075	DEFLECTOR RING	
F001	THRUST BEARING HOUSING	A216 GR WCB
F017	THRUST BEARING SLEEVE	
F020	OIL BAFFLE - INNER	
F022	DEFLECTOR RING	
F025	END COVER	A216 GR WCB
F030	THRUST BEARING	
F037	THRUST COLLAR	
F038	THRUST COLLAR KEY	
F039	THRUST COLLAR SPACER	
F040	THRUST NUT	
F042	RETAINER PLATE INNER	
F043	RETAINER PLATE - OUTER	
F045	GEAR PUMP HOUSING	
F046	GEAR PUMP COVER	
F054	WORM	
F055	WORM KEY	
F056	LOCKNUT & WASHER	
F058	GEAR PUMP SHAFT	
F059	THRUST COLLAR	
F060	WORM GEAR	
F061	WORM GEAR KEY	
F062	LOCKNUT & WASHER	
F065	GEAR PUMP	
F066	GEAR PUMP KEY	
F067	IDLER GEAR SHAFT	
F068	IDLER GEAR	
G002	SEAL - SEE DETAIL - G002	
PB-G003	SEAL PLATE	SA 182 F304
G006	O-RING	
PB-G007	SOCKET HEAD CAP SCREW	SA 193 GR B6
G008	RETAINER PLATE	A276 TP 410
G009	SOCKET HEAD CAP SCREW	
G011	SOCKET HEAD CAP SCREW	
G012	SEAL SHAFT SLEEVE	SEE NOTE 1
G013	SHAFT SLV SEAL RING	
G014	PIN	
G015	SHAFT SLV COLLAR	A276 TP 410
G016	SET SCREW	
G017	SET SCREW	
G018	SHAFT SLEEVE KEY	A276 TYPE 304
G019	MACH SCREW	A276 TYPE 304
H079	COUPLING PUMP HALF	
R003	OIL RESERVOIR	
S003	THERMOMETER	

PB - INDICATES PRESSURE BOUNDARY PART

NOTES 1 A-276 TP 410 WITH .003/.005 CR OXIDE PER LINDE PROCESS LC-4
2 HORIZONTALLY SPLIT CASE, PARTING FLANGE GASKET AND BOLTING ARE SHOWN ON DRAWING VBC 49347

WELD TABLE

JOINT NUMBER	PROCEDURE SPECIFICATION	WELD TECHNIQUE SHEET NUMBER	INSPECTION VISUAL	PT	MT	RT	REMARKS
1	042-2-6000-1	6000-6 REV 0	X	X		X	PT ROOT PASS
2	042-2-6000-1	6030-2 REV 1	X	X		X	PT ROOT PASS
3	042-2-6000-1	6009-2 REV 1	X	X		X	PT ROOT PASS
5	042-2-6000-1	6070-9 REV 0	X	X			PT ROOT PASS – RT PASS PIPING TYP
6	042-2-6000-0	NOT REQ'D	X				LOCKING KEYS
7A	042-2-5820-3	NOT REQ'D	X	X			REPAIR INTER COVERS & RAD DIFFUSERS
7	042-2-5440-1	NOT REQ'D	X	X			REPAIR INTER COVERS & RAD DIFFUSERS
8	042-2-3730-0 WITH ADDENDA	NOT REQD	X	X			IMPELLER REPAIR
8A	042-2-3230-3 WITH ADDENDA	NOT REQD	X	X			IMPELLER REPAIR
9	042-2-5440-1		X				DISCH DIFFUSER TO DISCH INT COVER
10	042-2-6000-1	6000-7 REV 1	X	X			ORIFICE PLATES - NOT SHOWN
11	042-2-6000-0	6002-6 REV 1	X	X			ORIFICE PLATES TO TUBE - NOT SHOWN
12	042-2-5600-2		X	X			PT WELD - LUBE OIL PIPING, NOT SHOWN

J CRANE SEAL PARTS - TYPE 1B W/ PUMPING RING

1	MATING RING	1
2	"O" RING	1
3	PRIMARY RING	1
4	BELLOWS	1
5	RETAINER	1
6	SPRING	1
7	DRIVE BAND	1
8	DISC	1
9	PUMPING RING	1
12	SET SCREW	6
13	SPRING	1
14	PACKING ASS'Y	1
15	GASKET	1
16	AUX. GLAND	1

QUANTITIES ARE FOR ONE SEAL ASS'Y

FOR MATERIALS SEE J. CRANE DWG H-SP-1786-1

WESTINGHOUSE ELECTRIC CORPORATION
NUCLEAR ENERGY SYSTEMS
3" JHF 10-STAGE SAFETY INJECTION PUMPS

S/O NO.	W P.O. NO.	PUMP S/N	SPIN NO.
5J49-994	546-CAL 189533-BN	49347/48	SIA PSI-OH1
	189534-BN	49349/50	OH2

REV NO	REVISION
5	REMOVED SHEET NO FROM JOINT NO 9, 12. JOINT NO 12 - WELD WAS ROOT PASS
4	ADDED: JOINT NO. 7A TO WELD
3	12-2-74 AG. REMOVED: DISCHARGE NOZZLE DRAIN. ADDED: NOTE 2; CHANGED PART NAMES FOR J CRANE PART (2)
2	9-18-74 AG. ADDED: PB = PRESSURE BOUNDARY PARTS. PART NO. D083, PART NO D078 & D082 CONSOLIDATED. J CRANE DWG H-SP-1786-1. REVISED: MATERIAL OF PART A602
1	6-12-74 PL. ADDED: DETAIL G002; MATERIALS TO: BAL LINE, SECTS A & B. REVISED: SECTION A; SECTION B

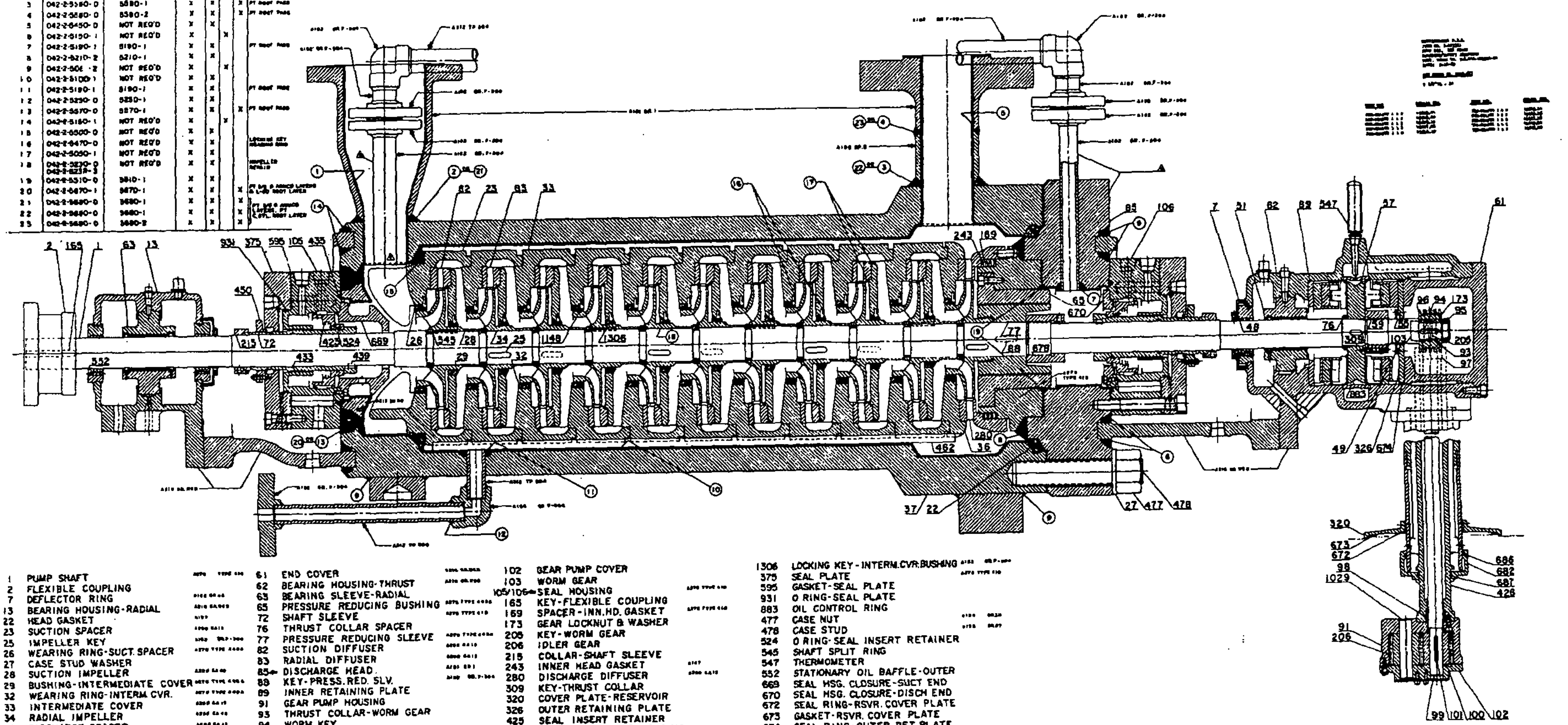
DWN	CKD	DATE
LMM	CMC	4-1-74

JHF ASSEMBLY

PACIFIC PUMPS PRODUCT ENGINEERING DRAWING NO. AXS- 49347 — REV 5

WELD TABLE

JOINT NUMBER	PROCEDURE SPECIFICATION	WELD TECHNIQUE SHEET NUMBER	INSPECTION VISUAL	PT	MT	RT	REMARKS
1	042-2-5450-0	NOT REQ'D	X	X			
2	042-2-5580-0	5580-1	X	X		X	PT ROOT PASS
3	042-2-5580-0	5580-1	X	X		X	PT ROOT PASS
4	042-2-5580-0	5580-2	X	X		X	PT ROOT PASS
5	042-2-6450-0	NOT REQ'D	X	X			
6	042-2-5150-1	NOT REQ'D	X		X		
7	042-2-5190-1	5190-1	X	X			PT ROOT PASS
8	042-2-5210-2	5210-1	X	X			
9	042-2-50[illegible]-2	NOT REQ'D	X		X		
10	042-2-5100-1	NOT REQ'D	X	X			
11	042-2-5190-1	5190-1	X	X			PT ROOT PASS
12	042-2-5250-0	5250-1	X	X			
13	042-2-5570-0	5570-1	X	X		X	PT ROOT PASS
14	042-2-5150-1	NOT REQ'D	X		X		
15	042-2-6500-0	NOT REQ'D	X	X			
16	042-2-6470-0	NOT REQ'D	X	X			[illegible]
17	042-2-5050-1	NOT REQ'D	X	X			
18	042-2-5230-0 042-2-5239-3	NOT REQ'D	X	X			[illegible]
19	042-2-5510-0	5510-1	X	X			
20	042-2-5670-1	5670-1	X	X		X	[illegible]
21	042-2-5680-0	5680-1	X	X		X	[illegible]
22	042-2-5680-0	5680-1	X	X		X	[illegible]
23	042-2-5680-0	5680-2	X	X		X	[illegible]



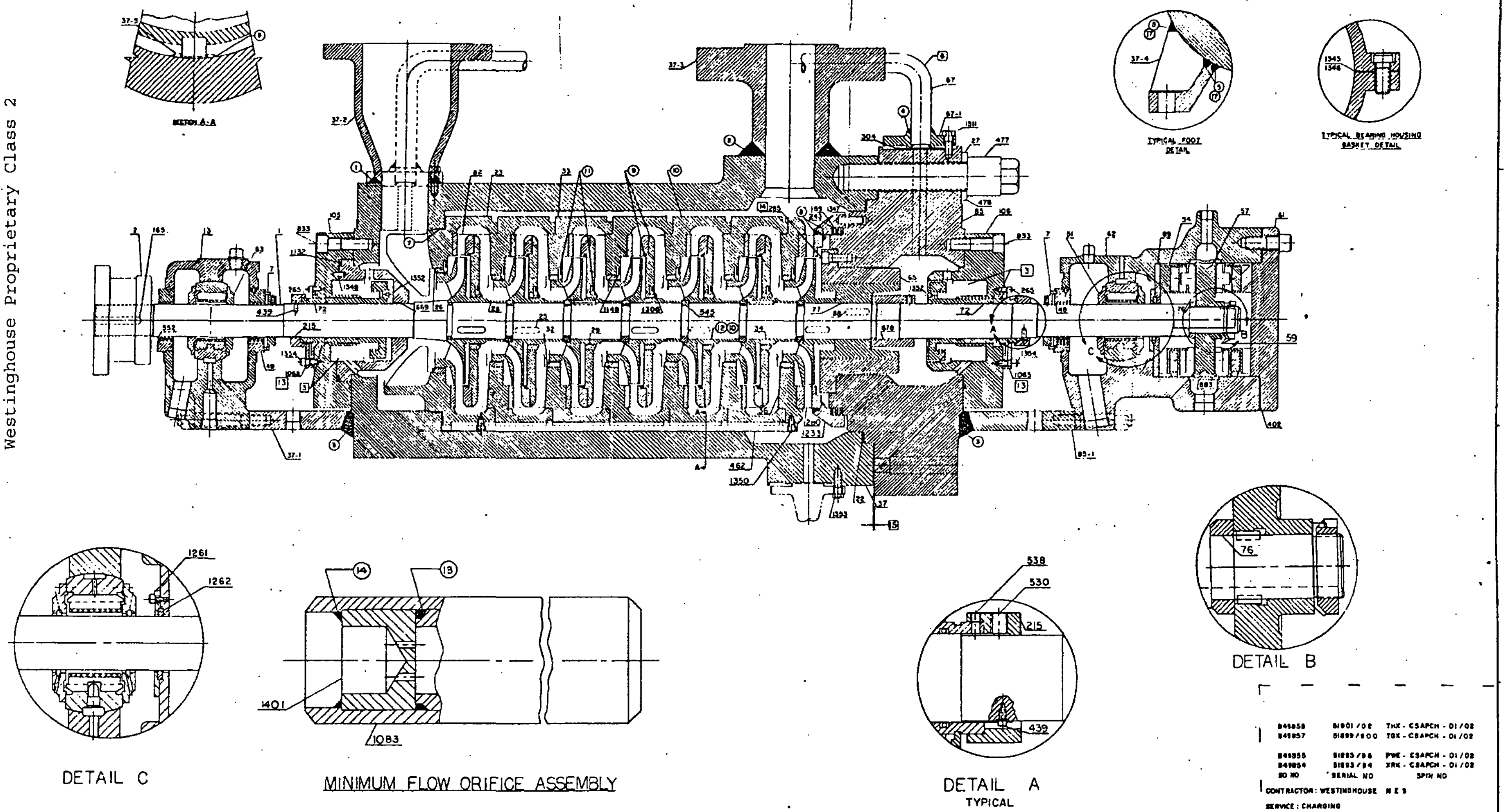
1	PUMP SHAFT	
2	FLEXIBLE COUPLING	
7	DEFLECTOR RING	
13	BEARING HOUSING-RADIAL	
22	HEAD GASKET	
23	SUCTION SPACER	
25	IMPELLER KEY	
26	WEARING RING-SUCT. SPACER	
27	CASE STUD WASHER	
28	SUCTION IMPELLER	
29	BUSHING-INTERMEDIATE COVER	
32	WEARING RING-INTERM. CVR.	
33	INTERMEDIATE COVER	
34	RADIAL IMPELLER	
36	DISCHARGE SPACER	
37←	CASE	
48	STATIONARY OIL BAFFLE-INNER	
49	RETAINER-OIL SEAL RING	
51	BEARING SLEEVE-THRUST	
55	OIL SEAL RING	
57	THRUST COLLAR	
59	THRUST NUT	
61	END COVER	
62	BEARING HOUSING-THRUST	
63	BEARING SLEEVE-RADIAL	
65	PRESSURE REDUCING BUSHING	
72	SHAFT SLEEVE	
76	THRUST COLLAR SPACER	
77	PRESSURE REDUCING SLEEVE	
82	SUCTION DIFFUSER	
83	RADIAL DIFFUSER	
85←	DISCHARGE HEAD	
88	KEY-PRESS. RED. SLV.	
89	INNER RETAINING PLATE	
91	GEAR PUMP HOUSING	
93	THRUST COLLAR-WORM GEAR	
94	WORM KEY	
95	WORM LOCKNUT & WASHER	
96	WORM	
97	GEAR PUMP BEARING SLEEVE-UPPER	
98	GEAR PUMP BEARING SLEEVE-LOWER	
99	GEAR PUMP SHAFT	
100	PUMP GEAR	
101	GEAR PUMP KEY	
102	GEAR PUMP COVER	
103	WORM GEAR	
105/106←	SEAL HOUSING	
165	KEY-FLEXIBLE COUPLING	
169	SPACER-INN. HD. GASKET	
173	GEAR LOCKNUT & WASHER	
205	KEY-WORM GEAR	
206	IDLER GEAR	
215	COLLAR-SHAFT SLEEVE	
243	INNER HEAD GASKET	
280	DISCHARGE DIFFUSER	
309	KEY-THRUST COLLAR	
320	COVER PLATE-RESERVOIR	
326	OUTER RETAINING PLATE	
425	SEAL INSERT RETAINER	
426	GEAR PUMP SHAFT HOUSING	
433	O RING-SHAFT SLEEVE	
435	O RING-SEAL HOUSING	
439	KEY-SHAFT SLEEVE	
450	PACKING RING	
462	ASSEMBLY RAIL	
1306	LOCKING KEY-INTERM. CVR. BUSHING	
375	SEAL PLATE	
595	GASKET-SEAL PLATE	
931	O RING-SEAL PLATE	
883	OIL CONTROL RING	
477	CASE NUT	
478	CASE STUD	
524	O RING-SEAL INSERT RETAINER	
545	SHAFT SPLIT RING	
547	THERMOMETER	
552	STATIONARY OIL BAFFLE-OUTER	
669	SEAL HSG. CLOSURE-SUCT END	
670	SEAL HSG. CLOSURE-DISCH END	
672	SEAL RING-RSVR. COVER PLATE	
673	GASKET-RSVR. COVER PLATE	
674	SEAL RING-OUTER RET. PLATE	
678	LOCKNUT-PRESS. RED. SLEEVE	
682	OIL RETURN CHAMBER	
686	OIL RET. CHAM. SEAL RING-UPP.	
687	OIL RET. CHAM. SEAL RING-LWR.	
1029	SHAFT-IDLER GEAR	
1148	LOCKING KEY-WRG. RING	

PACIFIC PUMPS
HUNTINGTON PARK, CALIF

ASSEMBLY

DRWN M.T. DATE 7-24-69 | TYPE 1J
TRCD
CHKD
APPVD
J-286

Westinghouse Proprietary Class 2



B49858	51901/02	THX - CSAPCH - 01/02
B49857	51899/900	TGX - CSAPCH - 01/02
B49855	51895/96	PWE - CSAPCH - 01/02
B49854	51893/94	XRK - CSAPCH - 01/02
SO NO	SERIAL NO	SPIN NO

CONTRACTOR: WESTINGHOUSE N E S

SERVICE: CHARGING

SIZE / TYPE: 2" RL IJ 7 STGS

PACIFIC PUMPS DIVISION
DRESSER INDUSTRIES, INC.

TITLE: PUMP ASSEMBLY

DWN S.C. | CKD EK | CERTIFIED [signature] | DATE 2-5-76

SHEET 1 OF 3 | PRODUCT ENGINEERING DWG NO 500-B849854 | REV 6

REV	DATE	DESCRIPTION	ZONE
6	8-30-78	ADDED BOLT TORQUES - SHT. 2 OF 3 AND ADDED NOTE 15	8-2,3
5	7-11-78	ADDED "DO NOT USE PRIMER" IN NOTE # 14. ADDED NOTE # 14 TO PART NO. 1352, (13)&(14) were (12)&(13)	
4	6-15-78	ADDED JT NO 4 TO PART NO. 67-1	D-3,4
3	5-11-78	ADDED JT NO.17, NOTE 14, MTL OF PART NO. 1271	ALL OVER
2	8-18-77	ADD DETAIL "C", PART NOS 530/538/1261/1262, CHANGED DESCR. OF PART NO 169, ADD ALT. MAT'L. TO PART NOS. 28 & 34 AND IN WELD TAB REMARKS REMOVED S.O. NO B49856, ETC.	
1	2-2-77	REDRAWN, ADDED PAGES 2,3	

8 7 6 5 4 3 2 1

Appendix B: Pump Curves of Representative Sample of HPSI, LPSI, Charging and CS pumps.

CONTRACTOR ____________

CUSTOMER WESTINGHOUSE NES

ITEM NO. CAE-01 P.O. 546-CAL-197091

IMPELLER PATTERN M-7278 | M-6534 (STGS 2,3,4,5,6-11)

MAXIMUM DIAMETER 8 1/4 | 8 1/4 | 8 1/4

RATED DIAMETER 8 1/4 | 8 1/4 | 8 1/8

MINIMUM DIAMETER 7 1/4 | 7 1/4 | 7 1/4

TEST PERFORMANCE CURVE NO. 37224E

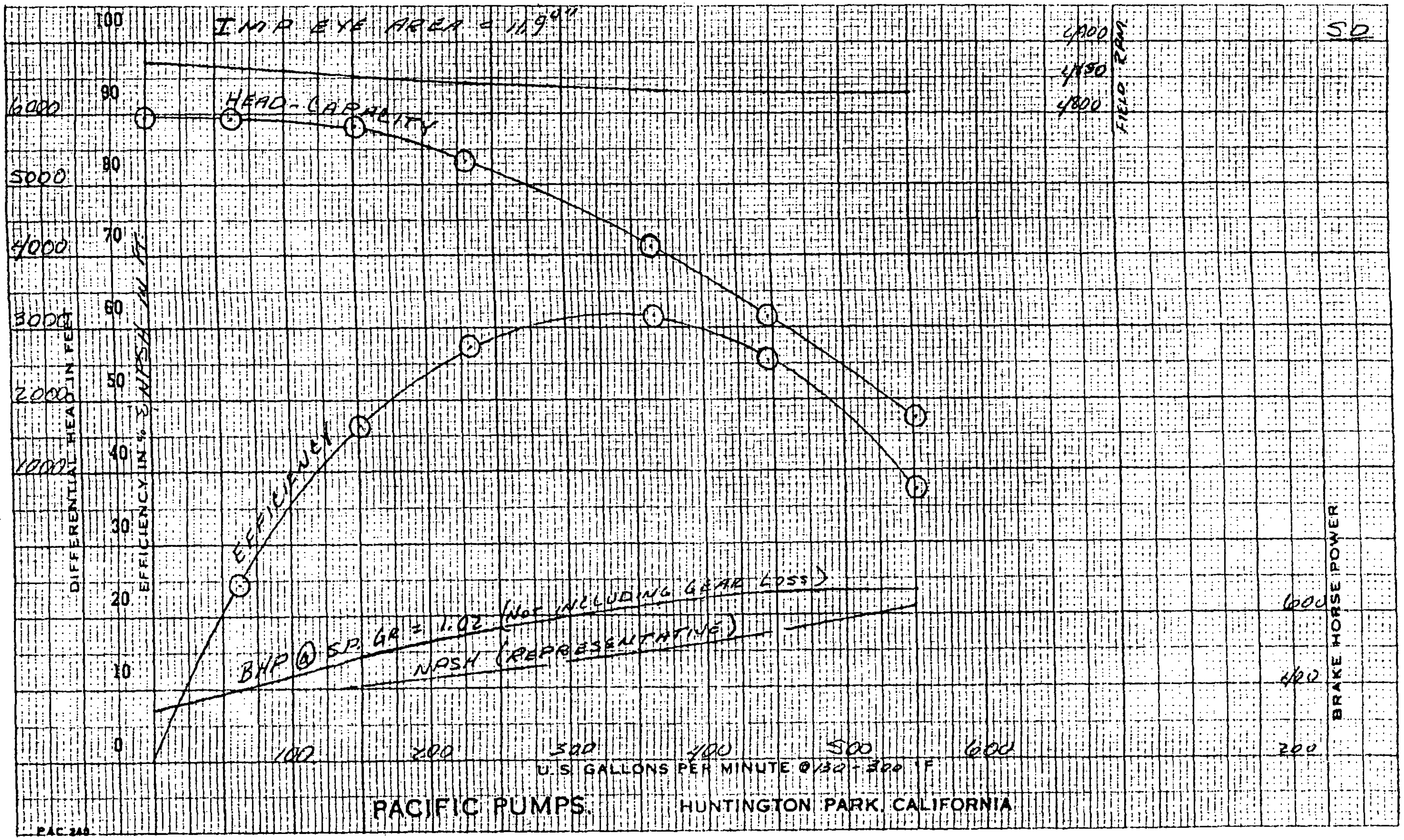
SIZE 2 1/2" RL TYPE 15 STAGES 11

R.P.M. FIELD DATE 10-11-76.

PUMP NUMBER 49770

PERFORMANCE ALSO APPLIES TO PUMP

NUMBER ____________



CONTRACTOR ____________

CUSTOMER WESTINGHOUSE NES

ITEM NO. CQL P.O. 546 - CAL -18950R

IMPELLER PATTERN M-7278 M-7475

MAXIMUM DIAMETER 8 5/16 8 5/16

RATED DIAMETER 8 5/16 8 5/16 STGS. 8,9,10 8

MINIMUM DIAMETER 7 5/16 7 5/16

TEST PERFORMANCE CURVE NO. 36898 A

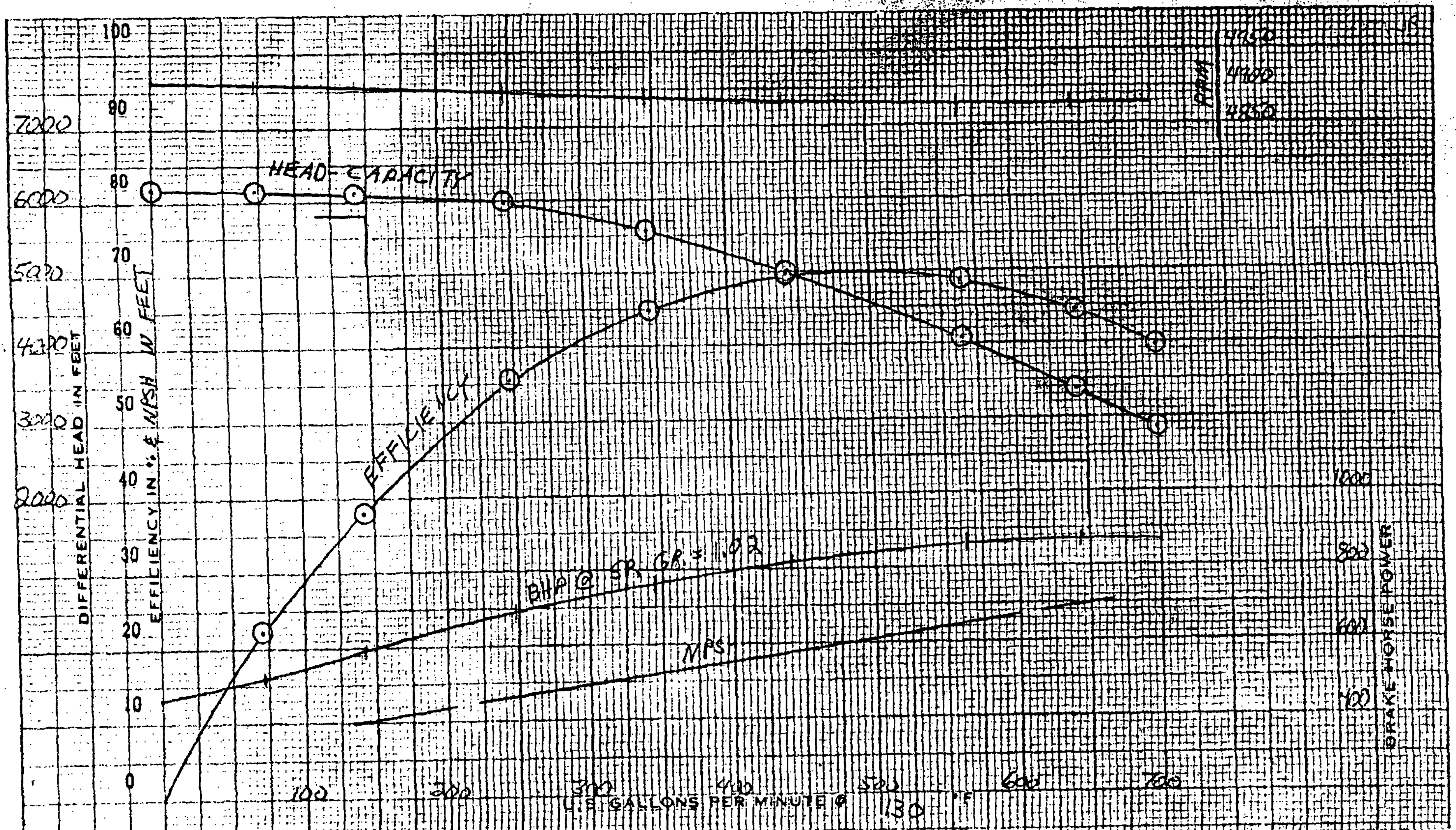
SIZE 2 1/2 RL TYPE IJ STAGES 11

R.P.M. FIELD DATE 4-14-75

PUMP NUMBER 49181

PERFORMANCE ALSO APPLIES TO PUMP

NUMBER ____________



PACIFIC PUMPS HUNTINGTON PARK, CALIFORNIA

PAC 240

CONTRACTOR ______________

CUSTOMER WESTINGHOUSE NES.

ITEM NO. DCP-01 P.O. 546-CAL-197097

IMPELLER PATTERN M-7278 M-6534

MAXIMUM DIAMETER 8 1/4 8 1/4

RATED DIAMETER 8 1/4 STGS 2,3,4; 5,6; 7-11 8 1/4 ; x 31° ; 8 1/8

MINIMUM DIAMETER 7 1/4 7 1/4

TEST PERFORMANCE CURVE NO. 37224 M.

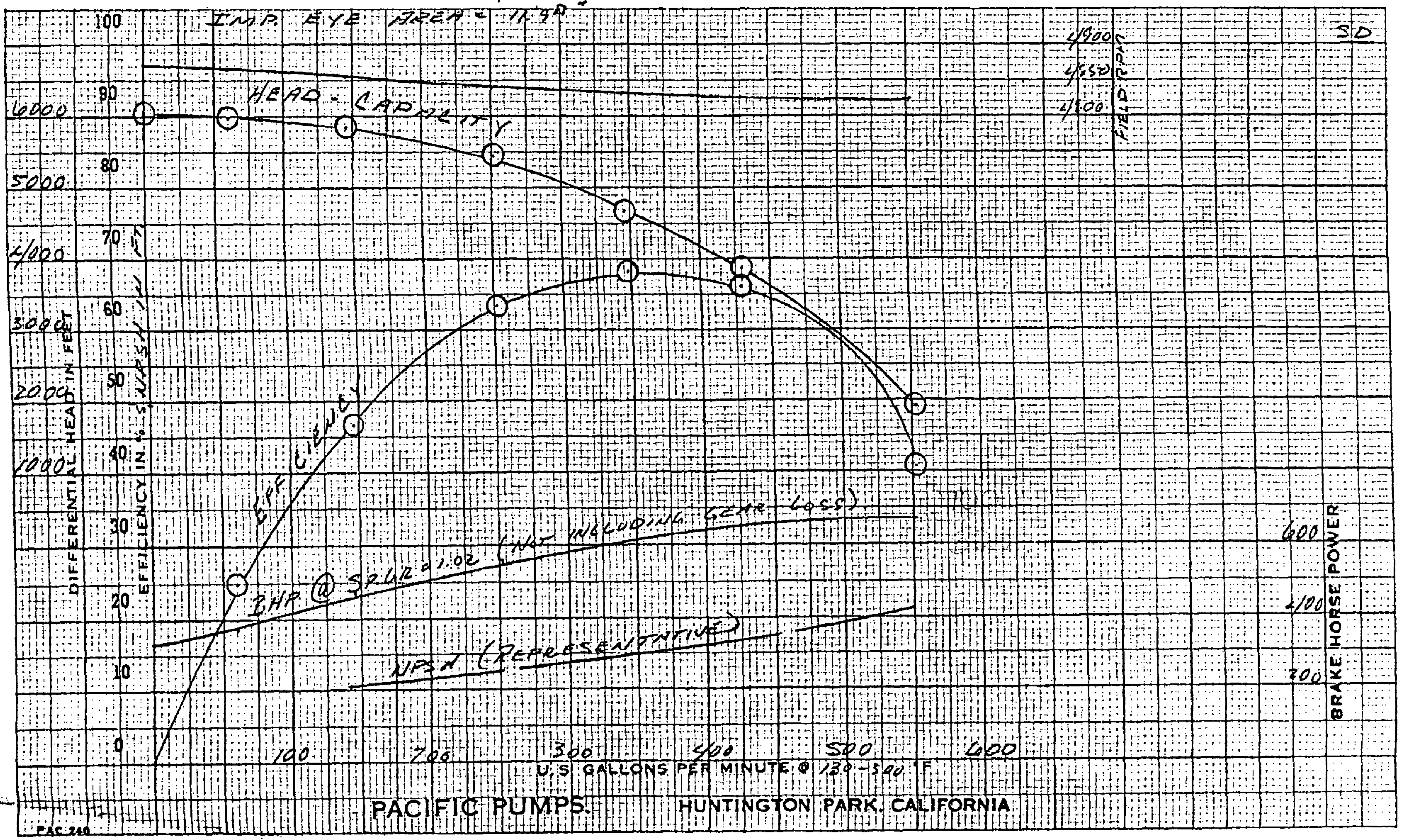
SIZE 2 1/2" RL TYPE 15 STAGES 11

R.P.M. FIELD DATE 11-29-76

PUMP NUMBER 49778

PERFORMANCE ALSO APPLIES TO PUMP

NUMBER ______________



Westinghouse Proprietary Class 2

HUNTINGTON PARK, CALIF NIA

TGX-01 SIAPHH

CONTRACTOR ______

CUSTOMER WESTINGHOUSE NES

ITEM NO. TGX-01 P.O. CAU 546 236991

IMPELLER PATTERN D-16714 Y-1054

MAXIMUM DIAMETER — STG 1-4 7 7/8 STG 5-16 7 7/8

RATED DIAMETER — 7 11/16 7 7/8

MINIMUM DIAMETER — —

TEST PERFORMANCE CURVE NO. 37752 A4

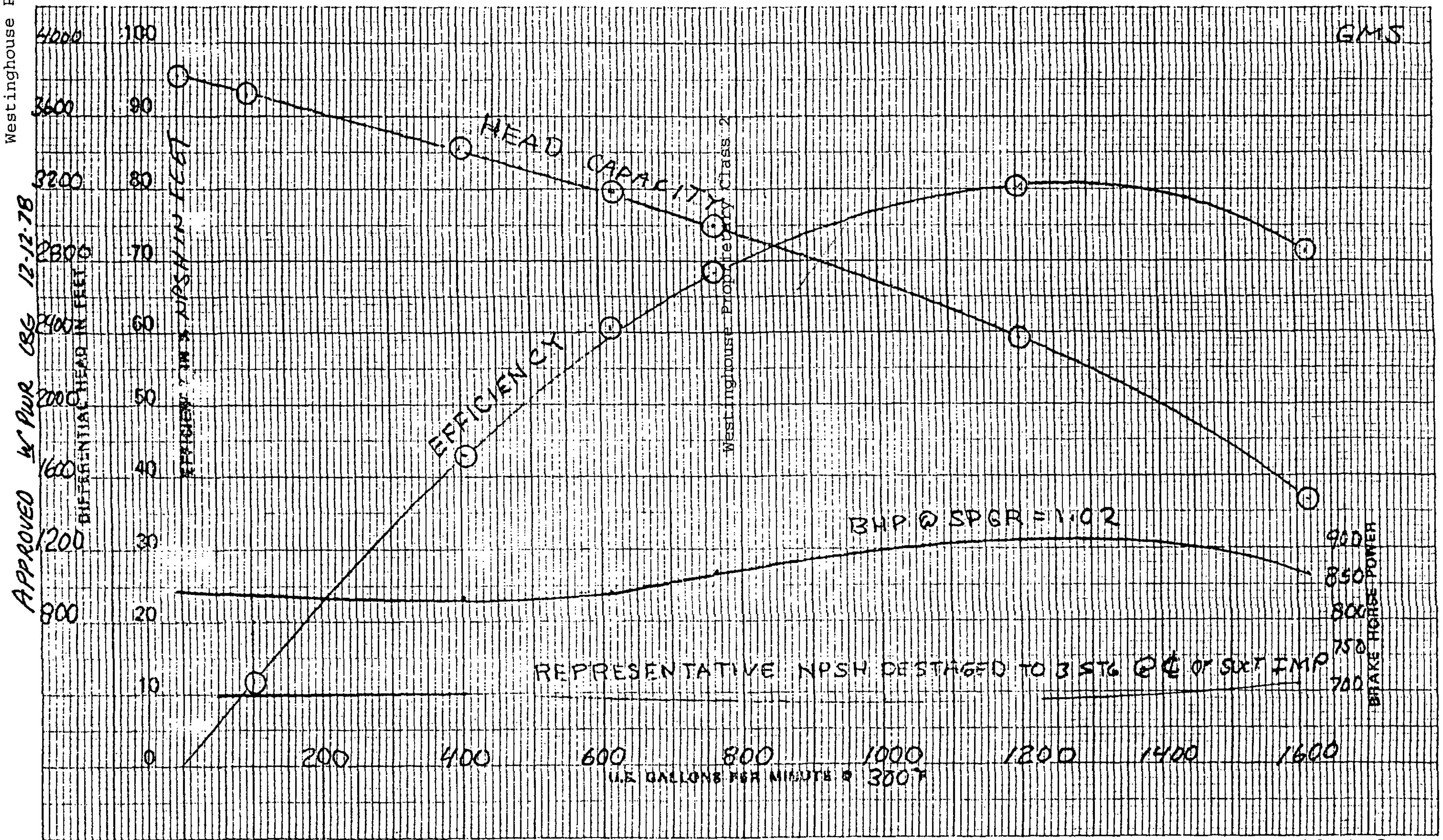
SIZE 6X10 TYPE WYRF STAGES 16+1

R.P.M. FIELD DATE 12-8-78

PUMP NUMBER 51695

PERFORMANCE ALSO APPLIES TO PUMP

NUMBER ______



PAC 240 1

PB 12/1/78

CUSTOMER CE/So Cal Ed

PROPOSAL NO. 001-36121 ITEM

SPECIAL NOTES 001-36122

HPSI PUMPS

DESIGN CONDITIONS

GPM 415* EFF

T. H. (FT.) 2830 BHP 435 SG. 1.0

RPM 3545 DRIVER 600 HP 1.15 S.F.

*INCL. 35 GPM MIN FLOW

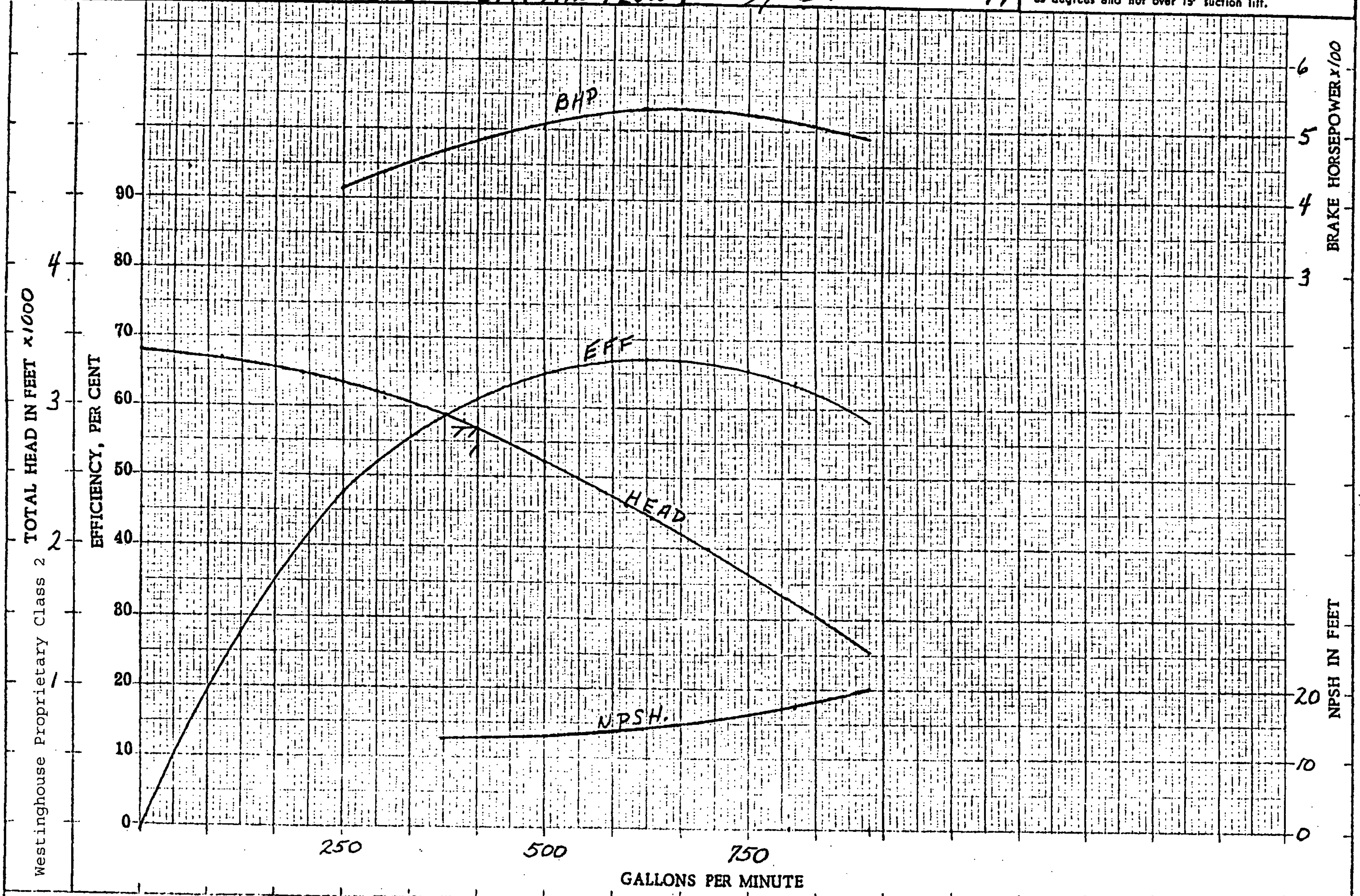
Ingersoll-Rand

DRAWN BY HSD DATE 13 DE 77

CURVE N-670 REV. 2

PUMP 4x9CA-9

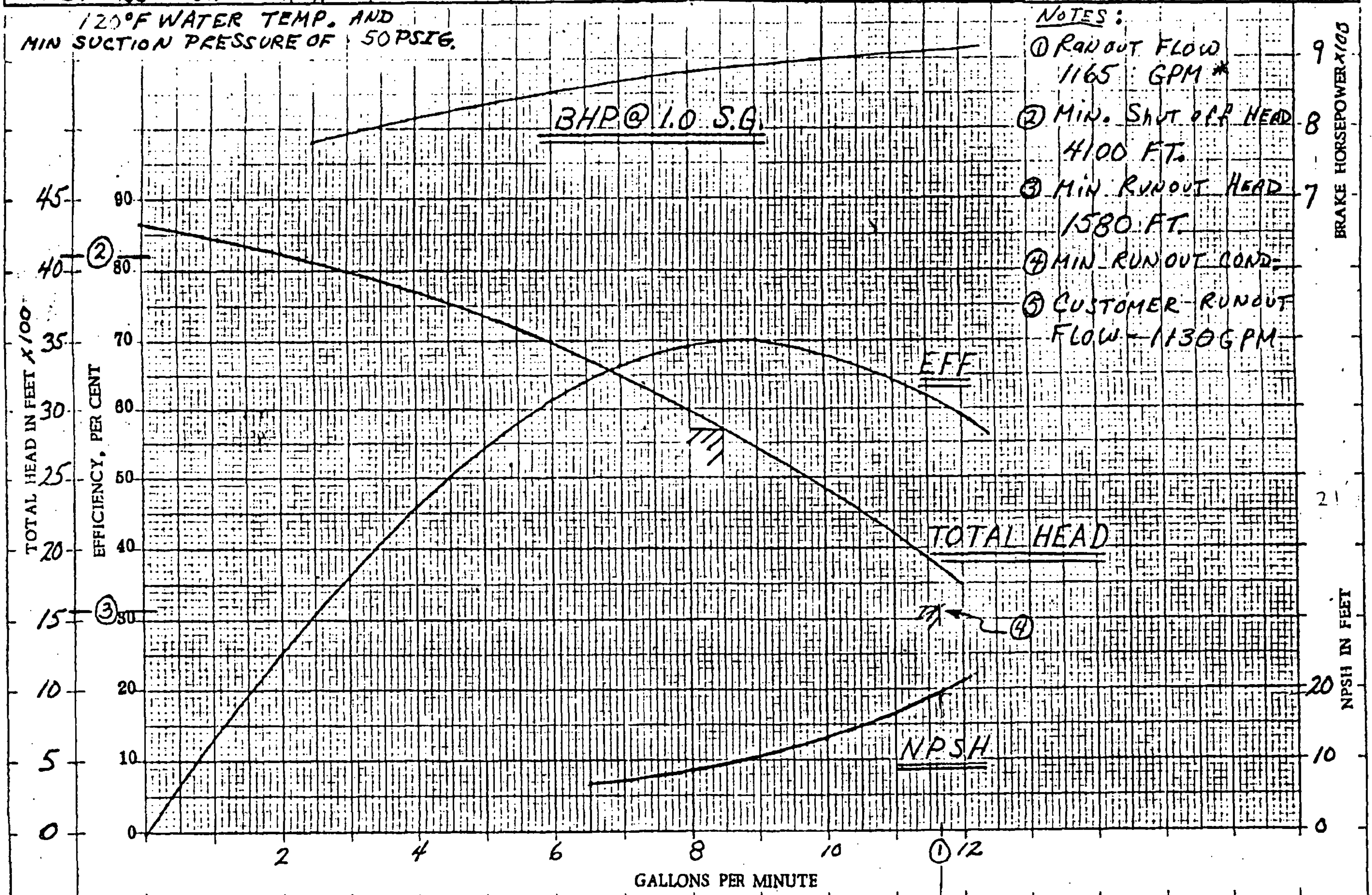
Curves are approximate. Pump is guaranteed for one set of conditions. Capacity, head and efficiency guarantees are based on shop test and when handling clear, cold, fresh water at a temperature of not over 85 degrees and not over 15' suction lift.



DATED 3 NV 76

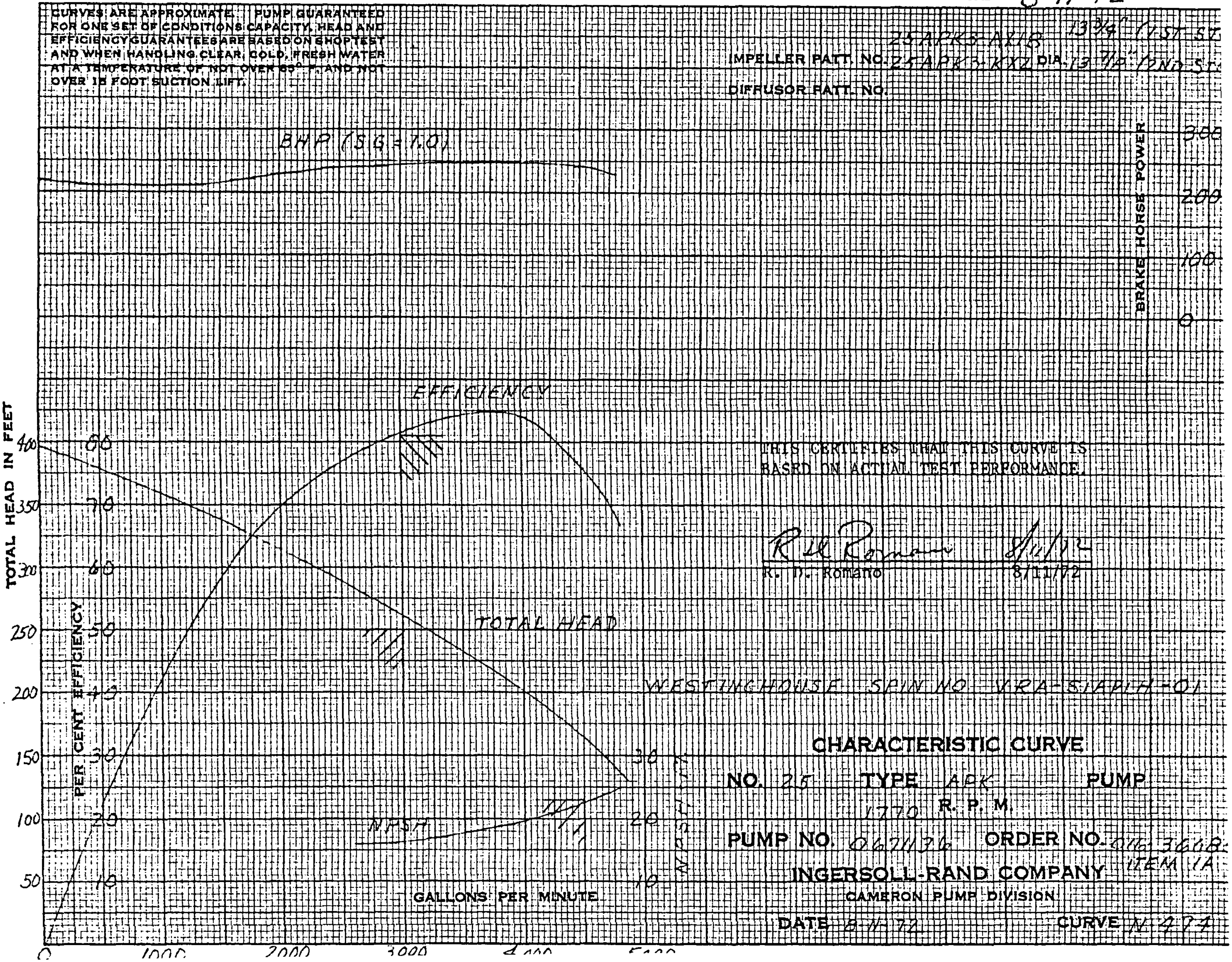
CUSTOMER CE / SYS 80	DESIGN CONDITIONS	Ingersoll-Rand	CURVE N-689 REV. 2
PROPOSAL NO. NEU-4299 ITEM	GPM 850* EFF 70%		PUMP 4x11CA-8
SPECIAL NOTES HPSI PUMP * INCLUDES 85 GPM BYPASS FLOW PUMP MAY BE RUN CONTINUOUSLY ON BYPASS FLOW WITH A	T.H. (FT.) 2850 BHP 895 SG. 1.0 RPM 3570 DRIVER HP CUST DESIGN FLOW 8-815	DRAWN BY MSD DATE 13 JE 75	Curves are approximate. Pump is guaranteed for one set of conditions. Capacity, head and efficiency guarantees are based on shop test and when handling clear, cold, fresh water at a temperature of not over 85 degrees and not over 15' suction lift.

120°F WATER TEMP. AND MIN SUCTION PRESSURE OF 50 PSIG.



G-1226 5M

CURVE NO. N-474
DATE 8-11-72



CONTRACTOR ________

CUSTOMER WESTINGHOUSE NES

ITEM NO. TGX-01 P.O. CAV-546-236992-BPE

IMPELLER PATTERN D-16715 Y-1057

MAXIMUM DIAMETER — 12 1/8

RATED DIAMETER — STGS 2-4 11 7/8 | 5,6 12 1/8

MINIMUM DIAMETER — —

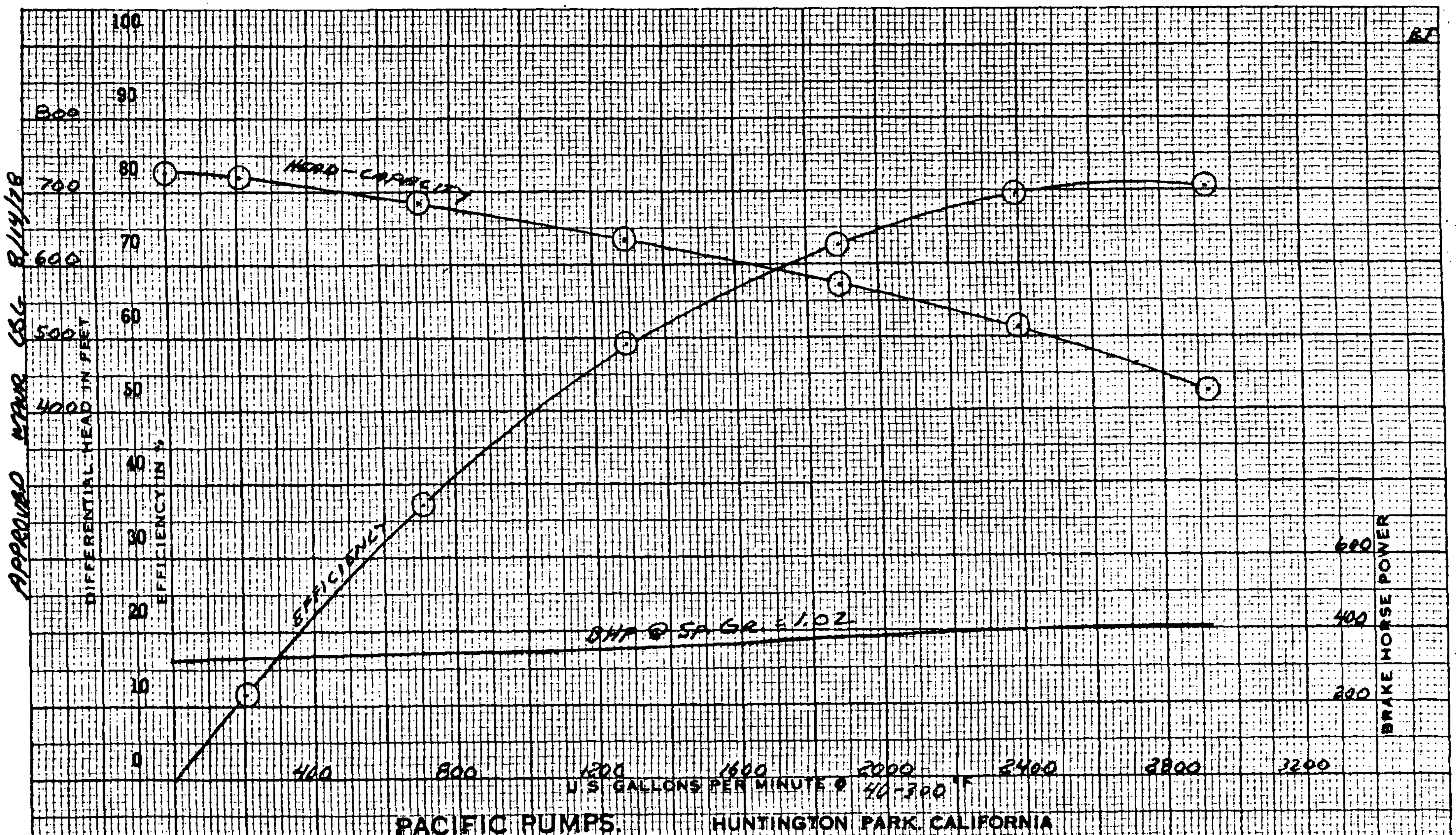
TEST PERFORMANCE CURVE NO. 37754A

SIZE 10X16 TYPE WYRF STAGES 5+I

R.P.M. FIELD DATE 8-11-78

PUMP NUMBER 51701

PERFORMANCE ALSO APPLIES TO PUMP NUMBER —

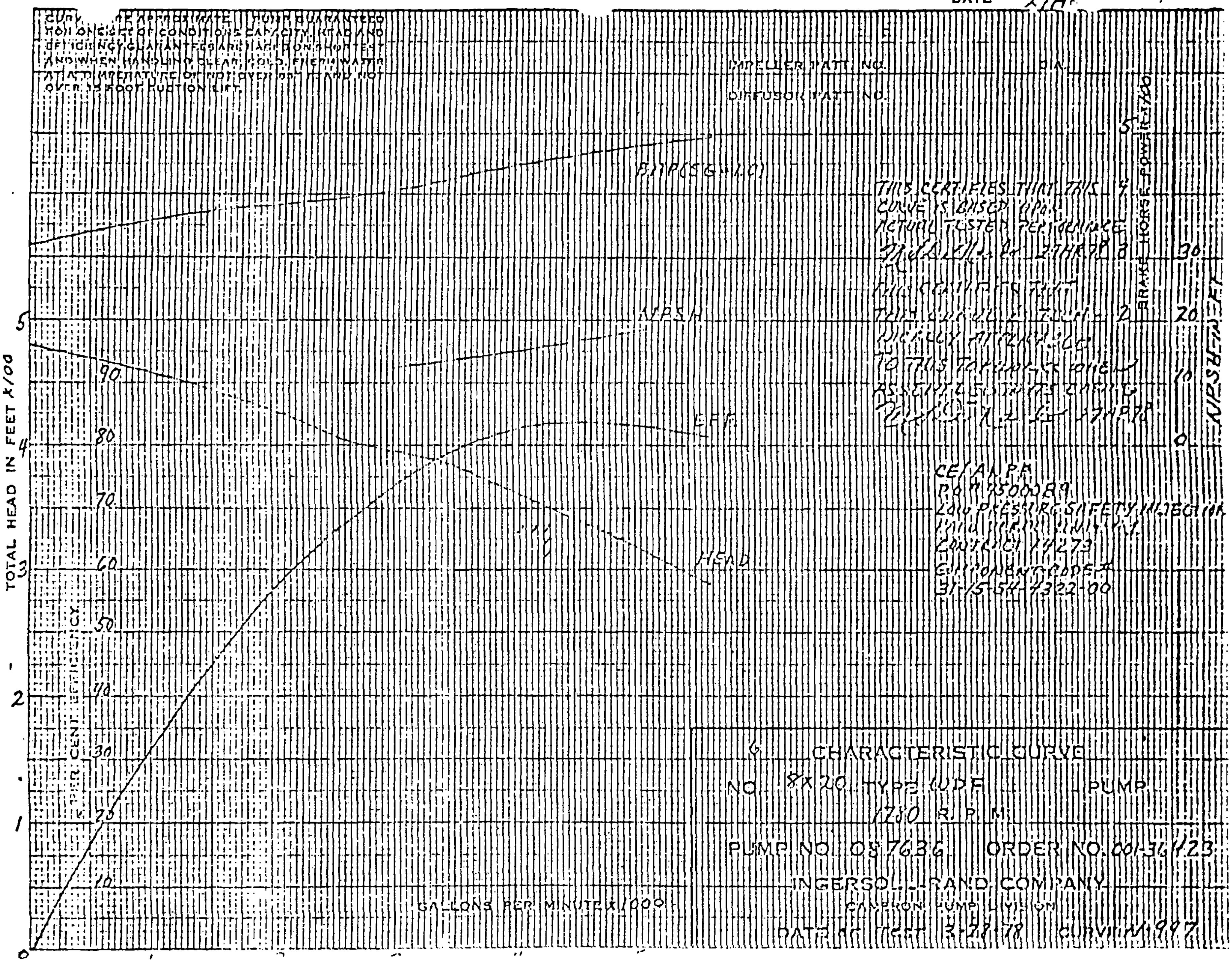


PACIFIC PUMPS. HUNTINGTON PARK, CALIFORNIA

Westinghouse Proprietary Class 2

G-1220 2

CURVE NO. N-9? Rev. 1
DATE 27A



CONTRACTOR ______________

CUSTOMER WESTINGHOUSE NES.

ITEM NO. DCP-01 P.O. 189537

IMPELLER PATTERN M-7593 M-7592

MAXIMUM DIAMETER 8 11/16 8 11/16

RATED DIAMETER 8 11/16 8 11/16

MINIMUM DIAMETER 7 11/16 7 11/16

TEST PERFORMANCE CURVE NO. 36997 A

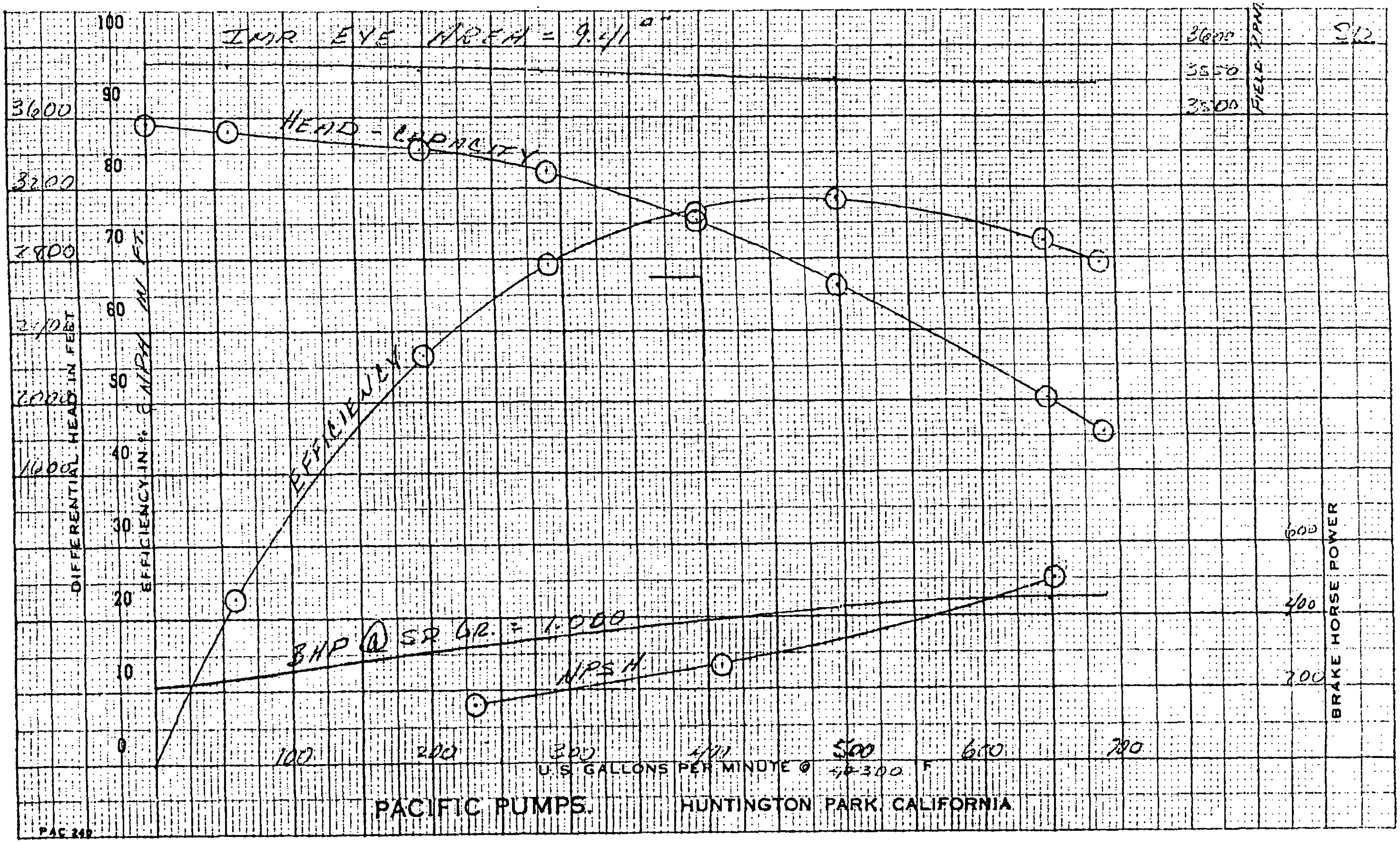
SIZE 3" TYPE JHF STAGES 10

R.P.M. FIELD DATE 9-15-76

PUMP NUMBER 49359

PERFORMANCE ALSO APPLIES TO PUMP

NUMBER ______________



Westinghouse Proprietary Class 2

CONTRACTOR ——

CUSTOMER WESTINGHOUSE

ITEM NO. OHI-02 P.O. 189533

IMPELLER PATTERN M-7593 M-7592

MAXIMUM DIAMETER 8 11/16 8 11/16

RATED DIAMETER 8 11/16 8 11/16

MINIMUM DIAMETER 7 11/16 7 11/16

TEST PERFORMANCE CURVE NO. 36994 B.

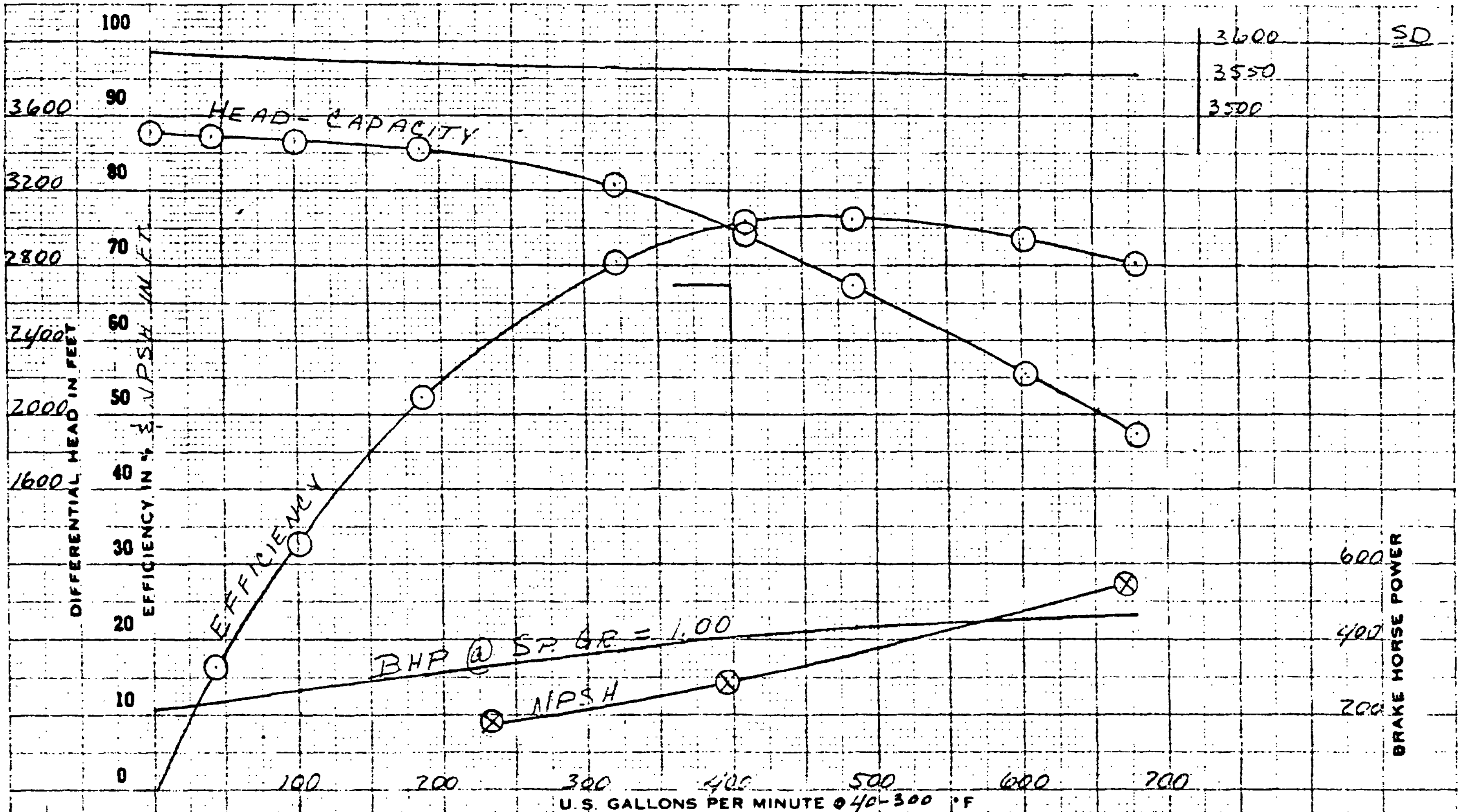
SIZE 3" TYPE JHF STAGES 10

R.P.M. FIELD DATE 9-20-75

PUMP NUMBER 49348

PERFORMANCE ALSO APPLIES TO PUMP

NUMBER ——



Westinghouse Proprietary Class 2

PACIFIC PUMPS. HUNTINGTON PARK, CALIFORNIA

PAC 240

PA..C PUMPS DRESSER HUNTINGTON PARK, CALIF...IA

CONTRACTOR ____

CUSTOMER WESTINGHOUSE NES

ITEM NO. PCJ-02 P.O. 197030

IMPELLER PATTERN M-7593 M-7592

MAXIMUM DIAMETER 8 3/4 8 3/4

RATED DIAMETER 8 3/4 8 3/4

MINIMUM DIAMETER 7 3/4 7 3/4

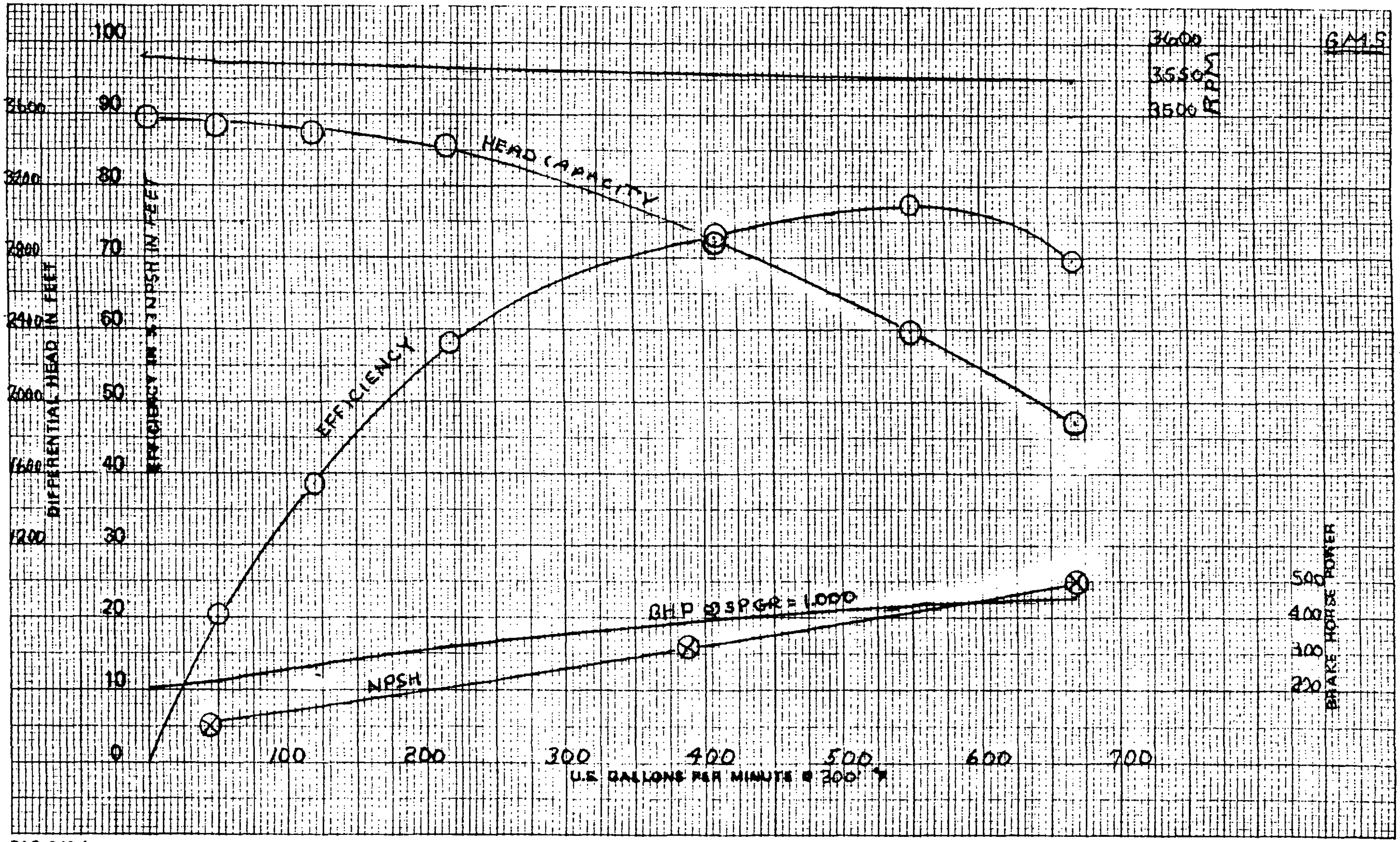
TEST PERFORMANCE CURVE NO. 37218 D

SIZE 3" TYPE JHF STAGES 10

R.P.M. FIELD DATE 8-9-79

PUMP NUMBER 49757

PERFORMANCE ALSO APPLIES TO PUMP NUMBER ____



Westinghouse Proprietary Class 2

PAC 240-1

CONTRACTOR ______

CUSTOMER WESTINGHOUSE NES.

ITEM NO. TGX-01 P.O. 546-CAV-237412-BPE.

IMPELLER PATTERN M-7846 M-7847

MAXIMUM DIAMETER 7 1/8" 7 1/8"

RATED DIAMETER 7 1/8" 7 1/8"

MINIMUM DIAMETER 6 1/8" 6 1/8"

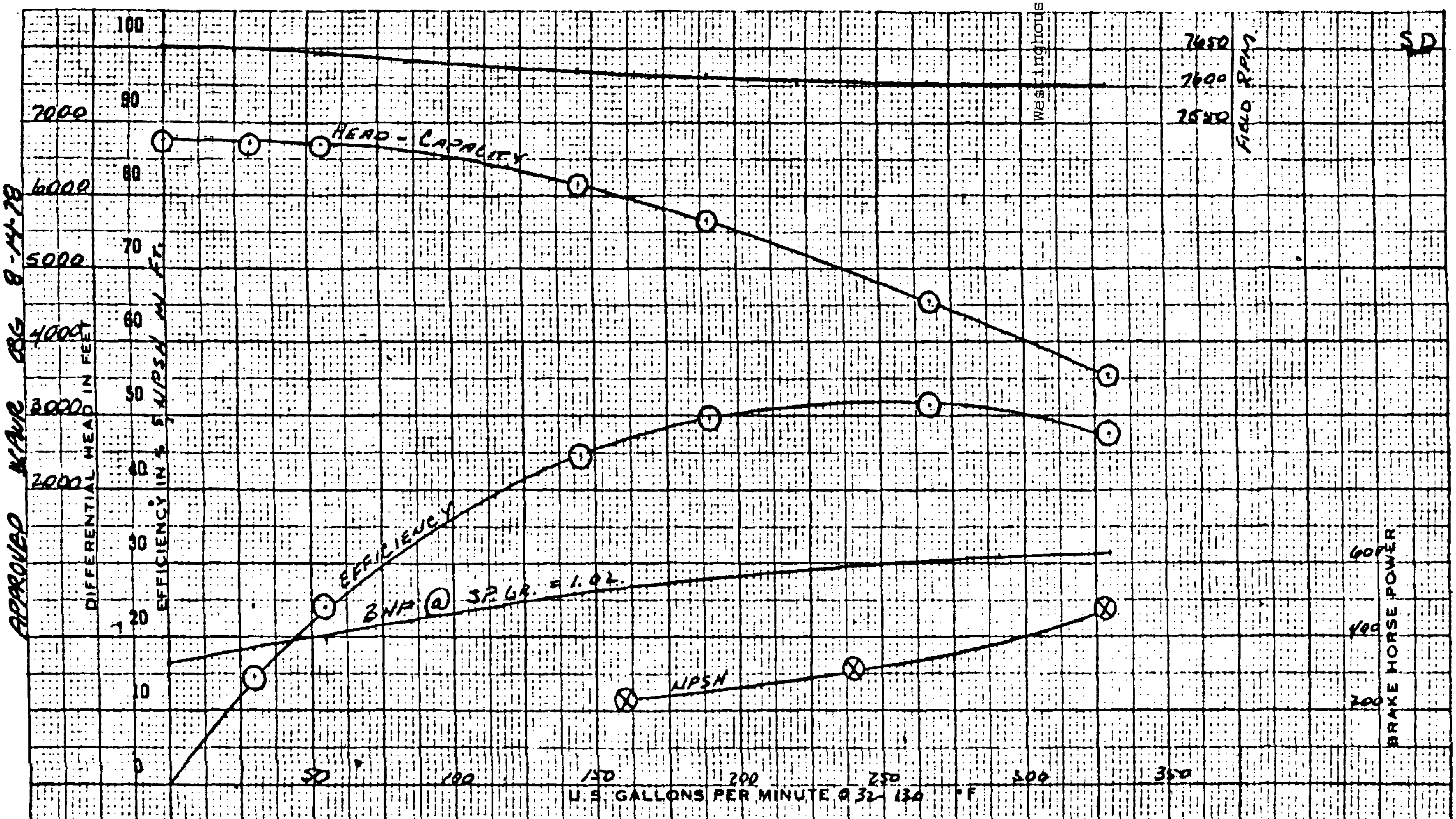
TEST PERFORMANCE CURVE NO. 37857A.

SIZE 7 RL TYPE 1J STAGES 7

R.P.M. FIELD DATE 8-11-78.

PUMP NUMBER 51899

PERFORMANCE ALSO APPLIES TO PUMP NUMBER ______



PACIFIC PUMPS HUNTINGTON PARK, CALIFORNIA

CONTRACTOR

CUSTOMER WESTINGHOUSE - N.E.S.

ITEM NO. PWE-01 P.O. 546-CAN-237414-BPE

IMPELLER PATTERN M-7846 | M-7847

MAXIMUM DIAMETER 7 1/8 | 7 1/8

RATED DIAMETER 7 1/8 | 2-5: 7 1/8 | 6,7: 6 7/8

MINIMUM DIAMETER 6 1/8 | 6 1/8

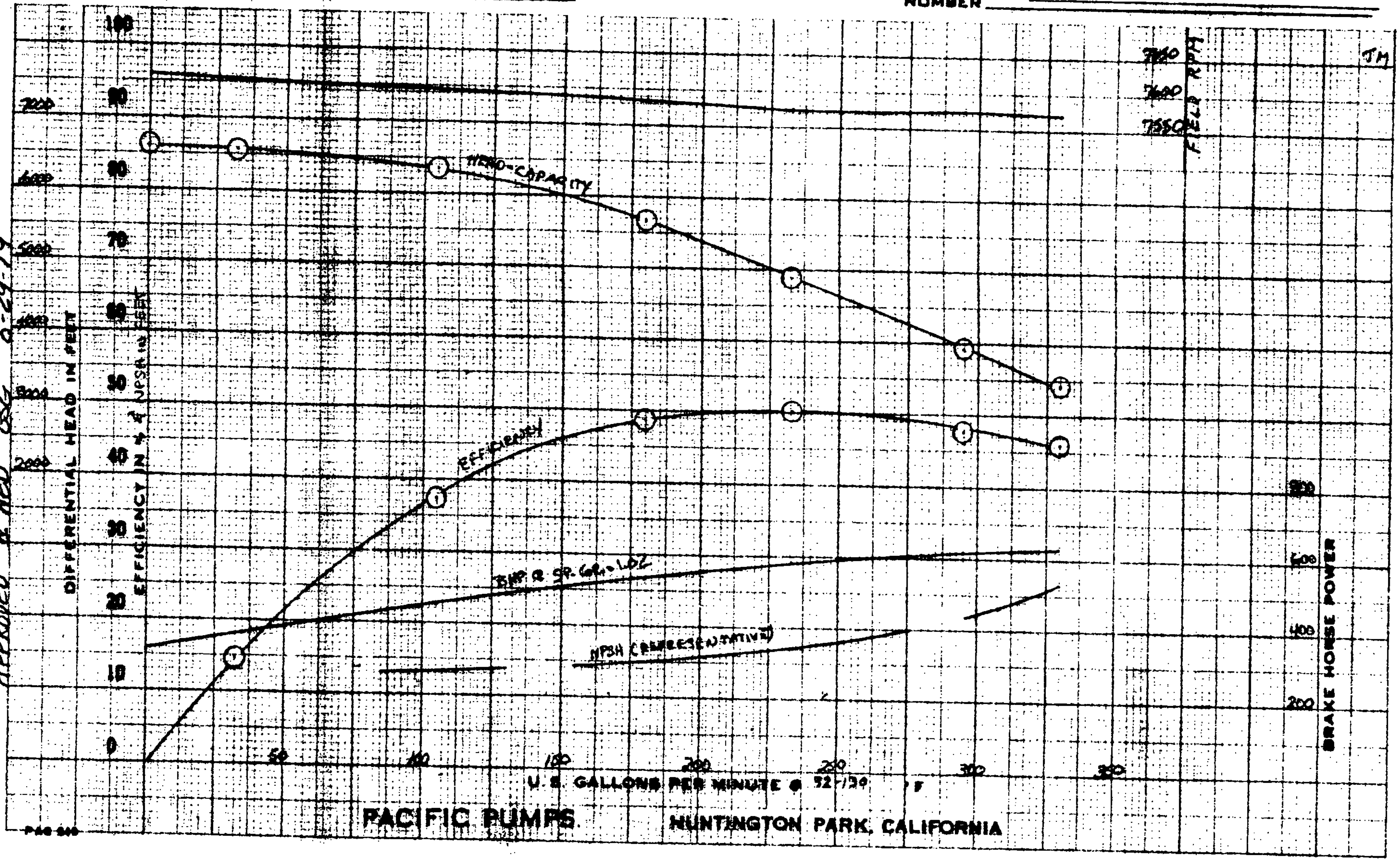
TEST PERFORMANCE CURVE NO. 37855 A

SIZE 2" RL TYPE 1J STAGES 7

R.P.M. FIELD DATE 5/25/79

PUMP NUMBER 51895

PERFORMANCE ALSO APPLIES TO PUMP NUMBER



PACIFIC PUMPS. HUNTINGTON PARK, CALIFORNIA

APPROVED W NED CBG 6-29-79

PACIFIC PUMPS HUNTINGTON PARK, CALIFORNIA

DSF D-0371
P.O. 446040

CONTRACTOR WESTINGHOUSE PWR

CUSTOMER NATIONAL POWER

ITEM NO. ____ P.O. ____

IMPELLER PATTERN M-7846 M-7847

MAXIMUM DIAMETER 7 1/8 7 1/8

RATED DIAMETER 7 1/8 7 1/8

MINIMUM DIAMETER 6 1/8 6 1/8

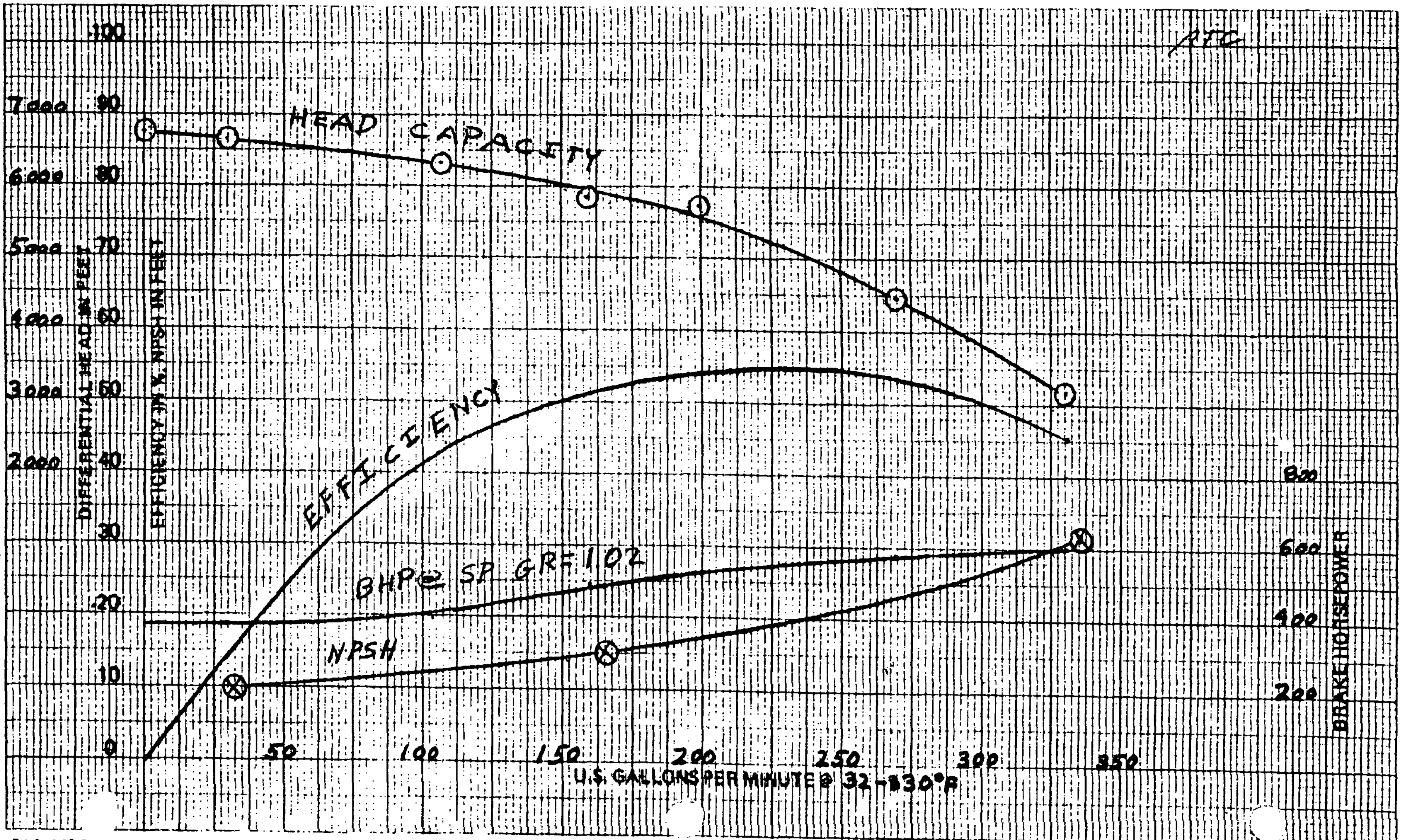
TEST PERFORMANCE CURVE NO. 38409 - SPARE

SIZE 2" RL TYPE IJ STAGES 7

R.P.M. FIELD DATE 12/6/82

PUMP NUMBER 52818/19 SPARE

PERFORMANCE ALSO APPLIES TO PUMP NUMBER NE 90936



Westinghouse Proprietary Class 2

PAC 240-2