S

ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 629896

Proj.
ECN

2. ECN Category (mark one) Supplemental ☐ Direct Revision ☒ Change ECN ☐ Temporary ☐ Standby ☐ Supersedure ☐ Cancel/Void ☐		3. Originator's Name, Organization, MSIN, and Telephone No. H.L. Roach, FDNW, H5-57, 376-5595		4. USQ Required? ☐ Yes ☒ No		5. Date June 7, 1999	
		6. Project Title/No./Work Order No. Spent Nuclear Fuels / Fuel Retrieval		7. Bldg./Sys./Fac. No. 105 KE / 105 KW		8. Approval Designator N/A	
		9. Document Numbers Changed by this ECN (includes sheet no. and rev.) HNF-3579, Rev 0		10. Related ECN No(s). N/A		11. Related PO No. N/A	
12a. Modification Work ☐ Yes (fill out Blk. 12b) ☒ No (NA Blks. 12b, 12c, 12d)		12b. Work Package No. N/A		12c. Modification Work Completed N/A Design Authority/Cog. Engineer Signature & Date		12d. Restored to Original Condition (Temp. or Standby ECNs only) N/A Design Authority/Cog. Engineer Signature & Date	
13a. Description of Change This change adds Appendix D, "FRS Test Specification for the Evaluation of Vacuum Wand for Fuel Retrieval System", and Appendix E, "FRS Test Report for the Evaluation of Vacuum Wand for Fuel Retrieval System". Details of additions: 1) Make a revision and incorporate the following changes to <u>Design Package for Vacuum Wand for Fuel Retrieval System</u> , HNF-3579, Rev 0: a) Add new Appendix D, "FRS Test Specification for the Evaluation of Vacuum Wand for Fuel Retrieval System". b) Add new Appendix E, "FRS Test Report for the Evaluation of Vacuum Wand for Fuel Retrieval System". c) Add new Appendix F, "Supplemental Calculations for Vacuum Wand".							
14a. Justification (mark one) Criteria Change ☐ Design Improvement ☒ Environmental ☐ Facility Deactivation ☐ As-Found ☐ Facilitate Const. ☐ Const. Error/Omission ☐ Design Error/Omission ☐		14b. Justification Details This change incorporates the verification documentation into the design package which keeps all documents pertaining to the vacuum wand tool in a single package.					
15. Distribution (include name, MSIN, and no. of copies) 1 Copy to each B.D. Groth X3-88 D.R. Jackson K5-22 H.L. Roach H5-57 SNF Proj. File X3-85 Central Files B1-07 DOE/RL Reading Room H2-53						RELEASE STAMP JUL 28 1999 DATE: STA: 15 MANFORD RELEASE ID: 220	

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1. ECN (use no. from pg. 1)

629896

16. Design Verification Required

☐ Yes

☒ No

17. Cost Impact

ENGINEERING

Additional ☐ \$ N/A

Savings ☐ \$ _____

CONSTRUCTION

Additional ☐ \$ N/A

Savings ☐ \$ _____

18. Schedule Impact (days)

Improvement ☐ N/A

Delay ☐ _____

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	☐	Seismic/Stress Analysis	☐	Tank Calibration Manual	☐
Functional Design Criteria	☐	Stress/Design Report	☐	Health Physics Procedure	☐
Operating Specification	☐	Interface Control Drawing	☐	Spares Multiple Unit Listing	☐
Criticality Specification	☐	Calibration Procedure	☐	Test Procedures/Specification	☐
Conceptual Design Report	☐	Installation Procedure	☐	Component Index	☐
Equipment Spec.	☐	Maintenance Procedure	☐	ASME Coded Item	☒
Const. Spec.	☐	Engineering Procedure	☐	Human Factor Consideration	☐
Procurement Spec.	☐	Operating Instruction	☐	Computer Software	☐
Vendor Information	☒	Operating Procedure	☐	Electric Circuit Schedule	☐
OM Manual	☐	Operational Safety Requirement	☐	ICRS Procedure	☐
FSAR/SAR	☐	IEFD Drawing	☐	Process Control Manual/Plan	☐
Safety Equipment List	☐	Cell Arrangement Drawing	☐	Process Flow Chart	☐
Radiation Work Permit	☐	Essential Material Specification	☐	Purchase Requisition	☐
Environmental Impact Statement	☐	Fac. Proc. Samp. Schedule	☒	Tickler File	☐
Environmental Report	☐	Inspection Plan	☐		☐
Environmental Permit	☐	Inventory Adjustment Request	☐		☐

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision

Document Number/Revision

Document Number/Revision

NONE

21. Approvals

Signature

Date

Signature

Date

Design Authority B.D. Gault B.D. Gault 7/26/99

Design Agent _____

Cog. Eng. _____

PE _____

Cog. Mgr. _____

QA _____

QA _____

Safety _____

Safety _____

Design _____

Environ. _____

Environ. _____

Other _____

Other _____

Design Agent/Test Engineer H.L. Roach 7/26/99

Test Director D.R. Jackson 7/27/99

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

Operations: W.H. Claps 7/27/99

J.D. Mathews 7/22/99

ADDITIONAL

Design Package For Vacuum Wand for Fuel Retrieval System

Hank L. Roach

for Duke Engineering and Services Hanford, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN:

UC: 2050

Org Code: 21371

Charge Code: CACN: 105491 COA: DM00 *PHN9F1511*

B&R Code: EW 7040000

Total Pages: 95

Key Words: Spent Nuclear Fuel, K-Basin, Vacuum, Fuel Retrieval System

Abstract: This is a design package that contains the details for the design, fabrication, and testing of a vacuum wand that will pick up sludge and corrosion products generated during fuel assembly handling operations at K-Basin. This document contains requirements, development design information, design calculations, tests, and test reports.

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James Aardal
Release Approval

7-28-99
Date

Release Stamp

Approved for Public Release

RECORD OF REVISION

(1) Document Number

HNF-3579

Page 1

(2) Title

Design Package Vacuum Wand for Fuel Retrieval System

Change Control Record

(3) Revision

(4) Description of Change - Replace, Add, and Delete Pages

Authorized for Release

(5) Cog. Engr.

(6) Cog. Mgr.

Date

0

(7)

EDT-603746, 3/2/99

1 RS

Added testing and additional Calculations
documentation per ECN-629896

W. H. Hough for DPG.

B.D. Groth → same 7/27/99

Design Package
Vacuum Wand for Fuel Retrieval System

HNF-3579, Rev 1

June 7, 1999

By *H. L. Roach*
Of

Flour Daniel Northwest
1200 Jadwin
Richland, WA 99352

For *Bruce D. Groth*
Representing

Duke Engineering & Services Company Hanford
P.O. Box 350
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Fuel Retrieval System Small Tools Design Package

Vacuum Wand

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1.0 Introduction

The K Basins Spent Nuclear Fuel (SNF) project consists of the safe retrieval, preparation, and repackaging of the spent fuel stored at the K East (KE) and K West (KW) Basins for interim safe storage in the Canister Storage Building (CSB).

Part of the preparation process involves the removal of the SNF from the K Basin storage canisters and the cleaning of the spent fuel to remove all sludge and corrosion products. These operations produce a layer of sludge and debris on the fuel handling table that must be removed. Since there is no system in place to handle the sludge buildup on the processing equipment a tool is needed to allow manual collection and clean up of the sludge and corrosion products. This design package documents the development of a vacuum wand that shall meet all of the design requirements of the Fuel Retrieval System (FRS) group for the collection and clean up of the sludge and corrosion products from the fuel processing equipment.

2.0 Scope

2.1 Objectives

The scope of this design package is to document the design, fabrication, and testing of a vacuum wand that will pick up and collect the sludge and corrosion products generated and deposited on the Fuel Retrieval System equipment during the fuel assembly handling operations.

2.2 Products Delivered

This package will deliver the following:

Documents

- 1) This document, which includes product requirements, analysis, graphical depictions, tests and reports.
- 2) Hanford formatted drawings will be provided.
- 3) Vendor information will be provided (If applicable).
- 4) Procurement documentation will be provided.

Fuel Retrieval System Small Tools Design Package

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Hardware

- 1) Two vacuum wands with associated hose and hardware to connect wands to existing FRS process equipment.
- 2) Long manual tools will be provided, as required, to operate and maintain the vacuum wand equipment.

3.0 Products Requirements and Constraints

The general design requirements/criteria for the Spent Nuclear Fuel Project Fuel Retrieval subproject is in HNF-S-0461, Specification for Design of the SNF Project Fuel Retrieval Subproject. The following requirements are additional or clarify it for the Vacuum wand.

3.1 Dimensional/Physical Constraints

- a) The Vacuum wand and hose must be able to reach 30 feet from the point the vacuum hose is connected to the existing 1-1/2" female coupler, BNFL drawing DW-205, Part 61.
- b) The Vacuum wand will be used manually by an operator standing on the K Basin grating. Distance to the bottom of the Primary Cleaning Machine (PCM) from the walkway is 16'-10".
- c) The Wand will be 20'-10" from the top of the handle to the bottom of the nozzle.
- d) Vacuum nozzle must work and fit within the PCM, decapper, and spent fuel station.
- e) Vacuum wand must be able to reach and fit inside the PCM, decapper and stuck fuel station.
- f) Vacuum wand and hose assembly must not interfere with operation of FRS in-pool process equipment when not being used.

3.2 Environmental Constraints

- a) Vacuum wand and hose and valve assembly material must be able to with stand the effects of high radiation field of 40 rem / hr.
- b) Vacuum wand and hose assembly must be able to be submersed in deionized water at a temperature of 50 °F for a period of its design life.

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- c) Vacuum wand and hose assembly must be able to handle a semi abrasive environment, suspended metal particulates with out deterioration for the period of its design life.
- d) No grease or petroleum based material lubricant can be used.

3.3 Operational Requirements

- a) Vacuum wand will be operated manually by an operator using gloves.
- b) An adjustable handle shall be installed to assist operator handling of the vacuum wand. The handle shall be designed to minimize possibility of small parts being dropped into the basin. Non-slip surfaces shall be used on the handle to allow for a good grip.
- c) The vacuum wand and hose assembly shall be designed for minimal weight to facilitate effective manual handling of the wand.
- d) The vacuum hose will have a male coupler that will connect to the existing 1-1/2" female coupler, BNFL drawing DW-205, Part 61.
- e) The water flow through the vacuum wand shall be adjustable using a ball valve located on a bypass adapter to be installed on the outer fuel brush assembly, BNFL drawing DW-339, part number -020. If necessary a special tool shall be provided for operating this ball valve or ball valve will be modified to accommodate existing tooling.
- f) The vacuum hose must be flexible and have smooth inner surfaces.
- g) The inlet nozzle on the vacuum wand shall not allow particles larger than 0.25 in from being picked up.
- h) The vacuum wand must have sufficient water flow to prevent the pump, that is providing water flow through the nozzle, from stalling.
- i) The vacuum hose shall be remotely detachable from the vacuum nozzle and the hose adapter on the other end of the hose.
- j) An operator standing on the K Basin grating will perform all operation of the vacuum wand and hose assembly.

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- k) The vacuum wand suction head shall be designed to allow debris to be remotely removed from the suction head screen to remove restrictions to the flow.

3.4 Maintenance Requirements

- a) Equipment shall be designed for no maintenance other than replacement of failed components.
- b) All parts of the vacuum wand assembly shall be remotely replaceable with manipulators and/or long pole tools and overhead cranes.

3.5 Applicable Laws, Regulations, and Standards

Use the applicable Fluor Daniel Hanford Engineering procedures for documenting development stages of design, reviewing, and approving engineering documents.

4.0 Development of Product

4.1 Management of Task

4.1.1 Engineering

Engineering will be done using Fluor Daniel Northwest. Documents will be reviewed and approved by Duke Engineering & Services Hanford.

4.1.2 Procurement

Developmental materials will be procured using credit cards from Numatec. Final parts will be ordered based on who is awarded the final fabrication.

4.1.3 Fabrication / Construction

Fluor Daniel Northwest will be responsible for fabrication and construction of prototype and the final design.

4.1.4 Prototype

Fluor Daniel Northwest will control prototype equipment. The Engineer in charge will have redline control of prototype fabrication sketches. Prototype testing and test results will be documented. The prototype information will be incorporated into this document.

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4.2 Discussion of Development

The customer provided sketches that depicted a conceptual design for the vacuum wand. The sketches show the overall configuration, size, and features desired for the vacuum wand. These sketches are included in Appendix A.

The customer provided sketches were used to produce the prototype sketches included in Appendix B. A prototype will be fabricated and tested in Bldg. 305. Refinements to the design will be made based on testing of the prototype and final design Hanford formatted drawings will be made after development is complete.

BNFL design calculations, 1998, *Head Loss Through the Decapper and the Process Table*, SNF-FRS-CAL-039, Rev. 0, BNFL Inc., Richland, WA, was used as a basis for the calculations found in Appendix C. Much of the BNFL head loss calculations were redone based on differences between the design that BNFL looked at and the current prototype design. The vacuum wand nozzle in particular required some work to develop a design that did not have excessive head loss.

4.3 Design Inputs

This section details the design inputs used for the development of the vacuum wand. All of the design inputs described in this section can be found in Appendix A. A description of the Appendix A materials are as follows:

Sketch 1

This sketch shows the overall length and configuration of the vacuum wand, requirement for an adjustable handle, top of wand detail, material recommendations, and tube size recommended.

Sketch 2

This sketch shows another view of the adjustable handle at the top of the vacuum wand.

Sketch 3

Sketch 3 shows a detail of the outer element brush bypass. The outer element brush bypass shown in this sketch prevents water flow through the outer element brush assembly. This increases water flow through the inner element brush assembly that directs water flow through the vacuum wand.

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Sketch 4

Sketch 4 shows a detail of the hose adapter that will connect the vacuum hose to the inner element brush assembly. The inner element brush assembly directs water flow through the vacuum wand.

Customer Provided Design Notes

There are six sheets of customer provided notes. Sheets one and two detail functional requirements for the vacuum wand. Sheets three to six are vendor catalog information on hose and hose connectors.

4.4 Prototype Sketches

The prototype design sketches are included in Appendix B. A description of the sketches is as follows:

H-1-83908, Sheet 1 – K Basin Vacuum Wand Installation:

This sketch shows installation details and parts list for the vacuum wand.

H-1-83908, Sheet 2 – K Basin Vacuum Wand Assembly:

This sketch shows the vacuum wand and bypass valve assembly.

H-1-83908, Sheet 3 – K Basin Vacuum Wand Detail:

This sketch shows details for the vacuum wand.

H-1-83908, Sheet 4 – K Basin Vacuum Wand Detail:

This sketch shows details for the suction hose connection, adjustable handle, flow control valve assembly.

4.5 Verification of Product Design

All equipment developed will be verified by performing physical tests and applicable calculations. This document will be changed via an ECN to incorporate verification documentation.

4.5.1 Analysis

Fluid head loss calculations were done by BNFL for the vacuum wand. Reference:

BNFL, 1998, *Head Loss Through the Decapper and the Process Table*, SNF-FRS-CAL-039, Rev. 0, BNFL Inc., Richland, WA.

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Additional Calculations are included in Appendix C. The calculations in Appendix C include the following calculations:

- Dry weight and in-pool weight of the vacuum wand assembly
- Stress analysis of vacuum wand
- Verify weld integrity
- Calculate fluid head loss through the vacuum system to verify that pump capacity is not exceeded. These calculations supplement the BNFL fluid calculations.

4.5.2 Required Testing

4.5.2.1 Hose Flexibility

This test shall demonstrate compliance with the following requirements:

- The vacuum hose is flexible and manageable through out the full travel of the vacuum wand.
- Verify that the hose doesn't kink during normal use.

4.5.2.2 Physical Functionality

This test shall demonstrate compliance with the following requirements:

- Verify the hose is of sufficient length to reach all parts of the fuel processing equipment.
- Verify that the shape and size of the inlet nozzle can effectively remove sludge deposited on the fuel processing equipment surfaces. Specifically verify adequate sludge removal access for the PCM, decapper, and the stuck fuel station.
- Verify vacuum wand head can be cleaned.

4.5.2.3 Operational Functionality

This test shall demonstrate compliance with the following requirements:

- The vacuum wand is capable of picking up sludge and small particles less than 0.25 in. in diameter.
- Verify that the vacuum wand can be manually handled without difficulty.
- Verify that the vacuum wand picks up sludge.
- The vacuum hose can be remotely disconnected and reconnected by the robot manipulator or special tool (if required).
- Hose on vacuum wand doesn't interfere or get in the way of operation of the fuel processing equipment.
- Adjustable handle provides good grip and can be adjusted with gloves on.

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Appendix A

Design Inputs

TOP OF WAND

8"

1"

$\frac{1}{4}$ " Aluminum

Aluminum Tubing

Adjustable Handle

BEST AVAILABLE COPY

16' 10" WALKWAY TO BOTTOM OF PCM

WAND TO BE 80' 10" FROM TOP OF
HANDLE TO BOTTOM OF NOZZLE

SKETCH 1

TOP OF WAND

SKETCH 2

Outer Element Bypass

SKETCH 3

Inner Element Flange
For Suction Hose

SKETCH 4

1 1/2

CUSTOMER PROVIDED NOTES

6 SHEETS

- .. nozzle and wand need to be light
 - .. Nozzle and wand must fit inside PCM, Decapper and stuck fuel S/S.
 - .. Hose must be flexible
 - .. Nozzle cannot pick up anything bigger than $\frac{1}{4}$ "
 - .. Hose must stay out of the way
 - .. Wand must have a positive grip on nozzle
 - .. Wand must be easy to use
 - .. nozzle must have enough flow so pump will not cavitate
 - .. Hose must be radiation tolerant
 - .. Hose must be smooth inside
- REMOVABLE HANDLE
- TOP PIECE ~~YEN~~
- BE ABLE TO REMOVE MATERIAL FROM BOTTOM
- ONE OR TWO WANDS
- BY PASS VALVE

Tests

Host flexibility

Nozzle being able to get into PCM, Decoder and stack fuel station

Will nozzle pick up sludge

Test unit that gives you secondary cleaning station

Does it work - can manipulator put it on and off.

easy of installation and removal

Will hose reach stuck fuel station

Will hose stay out of the way

Does the host kick

Can an operator use it

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Appendix B

Prototype Sketches

Error

An error occurred while processing this page. See the system log for more details.

SKETCH UN-RELEASED

[illegible]

6 WAND
SCALE: 1/2

8 STRAINER TIP ASSEMBLY
SCALE: 3/1

14 TRANSITION PIECE
SCALE: 2/1

2/25/99 CONTROL PRINT
CONTACT HANK L. ROACH
376-5595
FOR ANY REDLINE CHANGES

SKETCH UN-RELEASED

[illegible]

4 FLOW CONTROL ASSEMBLY
SCALE: 1/2"

12 COUPLER, MODIFIED
SCALE: 1/2

2/25/99 CONTROL PRINT
CONTACT HANK L. ROACH
376-5595
FOR ANY REDLINE CHANGES

SKETCH UN-RELEASED

11 NUT SCALE: 1/2

10 BLOCK
SCALE: 1/2

13 ADAPTER PLATE
SCALE: 1/2

7 HOSE ASSEMBLY
SCALE: 1/2

5 GRIP SCALE: 1/2

[illegible]

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Vacuum Wand

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Appendix C

Calculations

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT:	Mechanisms Engineering	ORIGINATED BY:	H.L. Roach	DATE:	12/18/98
ENG COMM NO:		CHECKED BY:	A. K. Biswas	DATE:	12/18/98
AREA:	100 K	REVISED BY:		DATE:	
SUBJECT:	Vacuum Wand for Fuel Retrieval System				

Client: Duke Engineering & Services Company Hanford

Task Order Number: 65100331 2F01

Design Calculations for Vacuum Wand for Fuel Retrieval System

Henry J. Roach 12/18/98

ORIGINATED BY: H.L. Roach

A. K. Biswas 12/18/98

CHECKED BY: A.K. Biswas

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT:	Mechanisms Engineering	ORIGINATED BY:	H.L. Roach	DATE:	12/18/98
ENG COMM NO:		CHECKED BY:	A. K. Biswas	DATE:	12/18/98
AREA:	100 K	REVISED BY:		DATE:	
SUBJECT:	Vacuum Wand for Fuel Retrieval System				

1.0 Purpose

The purpose of these calculations is to calculate the following for the Vacuum Wand:

- Dry Weight and in-pool weight of the vacuum wand assembly.
- Perform stress analysis of vacuum wand.
- Verify weld integrity
- Calculate fluid head loss through vacuum system to verify that pump capacity is not exceeded.

2.0 Design Inputs

Prototype drawings are as follows:

H-1-83908, Sheet 1 – K Basin Vacuum Wand Installation:

This drawing shows installation details and parts list for the vacuum wand.

H-1-83908, Sheet 2 – K Basin Vacuum Wand Assembly:

This drawing shows the vacuum wand assembly.

H-1-83908, Sheet 3 – K Basin Vacuum Wand Detail:

This drawing shows details for the vacuum wand.

H-1-83908, Sheet 4 – K Basin Vacuum Wand Detail:

This drawing shows details for the suction hose connection, adjustable handle, and bypass valve assembly.

Other References:

(1) I.E. Idelchik, *Handbook of Hydraulic Resistance*, 3rd Edition, CRC Press, 1993

(2) Crane, *Flow of Fluids through Valves, Fitting, and Pipe*, Technical Paper No. 410, 1991

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT:	Mechanisms Engineering	ORIGINATED BY:	H.L. Roach	DATE:	12/18/98
ENG COMM NO:		CHECKED BY:	A.K. Biswas	DATE:	12/18/98
AREA:	100 K	REVISED BY:		DATE:	
SUBJECT:	Vacuum Wand for Fuel Retrieval System				

(3) R. Chen, *Head Loss Through the Decapper Station and the Process Table*, SNF-FRS-CAL-039, Rev 0, BNFL, Richland, WA

(4) Roberson/Crow, *Engineering Fluid Mechanics*, Third Edition, 1985

Material Properties:

(a)	Type ¹	6061-T6 Aluminum	Type ¹	Steel, 304 Stainless
	Weight Density (lb/in ³)	0.098	Weight Density (lb/in ³)	0.28
	E (psi)	10.0 E+06	E (psi)	28 E+06
	G (psi)	3.75 E+06	G (psi)	12.5 E+06
	Poisons ratio	0.3	Poisons ratio	0.29
	Tensile - Yield (psi)	35 E+03	Tensile - Yield (psi)	78 E+03
	Compressive - Yield (psi)	35 E+03	Compressive - Yield (psi)	67 E+03
	Shear - Yield (psi)	20 E+03	Shear - Yield (psi)	39 E+03 ²

¹ Source of Material Data: Roark and Young, *Formulas for Stress and Strain*, Fifth Edition

² Assumed ½ of yield.

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT: Mechanisms
Engineering

ORIGINATED BY: H.L. Roach

DATE: 12/18/98

ENG COMM NO:

CHECKED BY:

A.K. BISWAS

DATE: 12/18/98

AREA: 100 K

REVISED BY:

DATE:

SUBJECT: Vacuum Wand for Fuel Retrieval System

3.0 Weight Calculations

(a)

Properties for Aluminum Tube					
OD (in)	ID (in)	t (in)	I (in^4)	Area (in^2)	* Weight lb/ft
1.5000	1.2500	0.1250	0.1287	0.5400	0.6350
1.5000	1.0000	0.2500	0.1994	0.9817	1.1545
1.625	1.509	0.058	0.0878	0.2855	0.336
* Aluminum is 0.098 lb/in^3					
Properties for 2" x .25 Aluminum Strip					
Height (in)	Thickness (in)	I (in^4)	Area (in^2)	* Weight lb/ft	
2.0000	0.2500	0.1667	0.5000	0.5880	
* Aluminum is 0.098 lb/in^3					

(b)

Estimate of Weight for Vacuum Wand
Reference prototype drawings H-1-83908

Item	Description	Material	Quantity	Unit	Weight Unit Quantity (lb)	Item Weight (lbs)
16	Coupler, Male 'BOSS-Lock' Type C	Al	1.00	each	0.740	0.740
18	Coupler, Female 'BOSS-LOCK' Type	Al	1.00	each	2.030	2.030
21	Male Adapter Modified 2.75 Long	Al	1.00	each	0.520	0.520
24	Hose, 1.52 OD x 1.25 ID	Plastic	30.00	ft	0.400	12.000
31	Tubing 1.5" x .125"	Al	5.00	ft	0.635	3.173
30	Tubing 1.5" x .25"	Al	17.5	ft	1.155	20.204
33	2" wide x .25" Strip	Al	0.7175	ft	0.588	0.422
12	Handle block	Al	1	each	0.210	0.210
5	Handle Grip	Al	1	each	0.633	0.633
32	0.125 Plate (Square Nozzle)	Al	1	each	0.140	0.140
35	Wire cloth	Al	1	each	0.050	0.050

← Not Added Below
← Not Added Below

Dry Weight W/O Hose 26.091 LBS
Add 5% uncertainty to weight 27.396

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT: Mechanisms Engineering

ORIGINATED BY: H.L. Roach

DATE: 12/18/98

ENG COMM NO:

CHECKED BY:

A.K. BISWAS

DATE: 12/18/98

AREA:

100 K

REVISED BY:

DATE:

SUBJECT:

Vacuum Wand for Fuel Retrieval System

(C) EFFECT OF BOUANCY ON VACUUM Wand Tool

- Appendix A, sketch 1, shows 16'-10" from walkway to top of PCM.

- BNFL Drawing, DW-328, shows elevation of water from walkway
 $K_E = -(3'-7")$
 $K_W = -(4'-9")$

- H-1-83908, SHT 3, shows distance bottom of vacuum nozzle to long pole is 49"

Assume density water 62.4 lb/ft³

Air void in pole is

$$V = \left[(16'-10'') - (4'-9'') - 49 \right] \frac{(1')^2 \pi}{4} = 75.398 \text{ in}^3$$

$$F_b = 75.398 \text{ in}^3 (62.4 \text{ lb/ft}^3) \frac{(1 \text{ ft})^3}{(12 \text{ in})^3} = 2.72 \text{ lb}$$

Weight of Vacuum Wand in water would be

$$\boxed{W_{\text{water}}} = 27.4 \text{ lb} - 2.72 + \frac{1}{2} (12) + 2.03 = \boxed{32.71 \text{ lb}}$$

Page C6 buoyancy Hose lb coupler

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CALCULATIONS AND SKETCHES SHEET

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SUBJECT:	Vacuum Wand for Fuel Retrieval System				

According to ERDA-76-45-2, HUMAN FACTORS IN Design, Allowable Lifting Force, Held Close to Body is 45 lbs.

Weight of Vacuum Wand is OK since

$$32.71 \text{ lbs} < 45 \text{ lbs}$$

actual allowable

4.0. STRESS ANALYSIS FOR VACUUM WAND

Loads on vacuum wand (Free body on next page).

Assume C_y is $\frac{1}{2}$ weight of hose.

$$C_y = \frac{1}{2} (12 \text{ lb}) = 6 \text{ lb} \downarrow$$

$$C_x = C_y = 6 \text{ lbs} \leftarrow$$

CALCULATIONS AND SKETCHES SHEET

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DATE:

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Hose connects
AT point C

$$\begin{aligned}\sum M_D = 0 &= 6(48.75) + 6(8.8) \\ &\quad - A_y(10.25) - A_x(248.75) \\ &\quad + 24.68(5) = 0\end{aligned}$$

EQ (1) $10.25 A_y + 248.75 A_x = 468.7$

EQ (2) $\sum F_x = 0 = A_x - 6/0 + D_x$

$$A_x + D_x = 6$$

EQ (3) $\sum F_y = 0 = -24.68 - 6 + A_y + D_y$

$$A_y + D_y = 30.68$$

$$W = 27.4 - 2.72 = 24.68 \text{ lbs}$$

I have 3 equations with 4 unknowns (indeterminate)
I will solve model using ANSYS 5.3 and verify
results with equations above.

FLUOR DANIEL NORTHWEST, INC.

HNF-3579, Rev. 1

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THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

	NODE	FX	FY	MZ
A	1	1.9296	-1.1015	
D	29	4.0704	31.781	

ANSYS 5.3
 NOV 29 1998
 20:07:17
 LINES
 TYPE NUM
 ZV = 1
 DIST=136.813
 XF = 9.066
 YF = -116.491
 Z-BUFFER

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checking Ansys Results:

$$EQ(1) \quad 10.25 A_y + 248.75 A_x = 468.7$$

$$10.25 (-1.1015) + 248.75 (1.9296) = 468.7 \quad \underline{\underline{\text{check}}}$$

$$EQ(2) \quad A_x + D_x = 6$$

$$1.9296 + 4.0704 = 6 \quad \underline{\underline{\text{check}}}$$

$$EQ(3) \quad A_y + D_y = 30.68$$

$$31.781 - 1.1015 = 30.68 \quad \underline{\underline{\text{check}}}$$

Now calculating Moment @ point E where long pole joins suction tube

$$\Sigma M_E = 0$$

$$= 1.10 (5.25) - 1.93 (200) + M_E$$

$$M_E = 380.22 \text{ in-lb}$$

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Bending stress @ E is

$$\sigma = \frac{MC}{I} = \frac{380.22 (.75)}{.1994} = 1430 \text{ psi} \quad 1\frac{1}{2} \times .25 \text{ tube}$$

Bending stress in suction tube 1.625 x .058 wall

$$\sigma = \frac{380.22 (.8125)}{.0878} = 3518 \text{ psi}$$

Allowable stress (assume) .6 x yield

$$\sigma_{all} = .6 (35,000 \text{ psi}) = 21,000 \text{ psi}$$

$$FOS = \frac{21,000}{1430} = 14.7 \times \quad 1\frac{1}{2} \times .25 \text{ wall tube}$$

$$FOS = \frac{21,000}{3518} = 6 \times \quad 1.625 \times .058 \text{ wall}$$

5.0 Weld Calculations

I will look where long pole joins the suction tube (point E) where we have largest moment.

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treating the weld as a line

$$\begin{aligned} \text{section } Z_w &= \frac{1}{4} \pi D^2 \\ \text{MOD} &= \frac{1}{4} \pi (1.50)^2 = 1.767 \text{ in}^2 \end{aligned}$$

Force per inch of weld at top and bottom is

$$F_b = \frac{M}{Z_w} = \frac{380.22 \text{ in-lb}}{1.767 \text{ in}^2} = 215.2 \text{ lb/in}$$

For transverse Loading REF: Schaums Outline in Machine Design, 1961

$$\text{allowable } F_{all} = S_{all} (0.765 W) / \cos 22\frac{1}{2}^\circ$$

$S_{all} = 11,500 \text{ PSI}$ FOR 6061-T6 shear in Fillet welds (mm)

$$F_{all} = 11,500 (0.765 W) / \cos(22.5)$$

$$F_{all} = 9522.34 \text{ lb/in}$$

Page C12

Required

$$\begin{aligned} \text{Fillet} &= \frac{F_{act}}{F_{all}} = \frac{215.2}{9522.34} = .022'' \\ \text{Weld} & \\ \text{SIZE} & \end{aligned}$$

weld OK since $.022 < .125''$ weld size

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6.0 Check Head Loss of Current Design6.1 Purpose

The purpose of these calculations is to calculate head loss through the vacuum wand to verify that the pump capacity is not exceeded.

Reference calculations by BNFL:

SNF-FRS-CAL-039, Rev 0, *Head Loss through the Decapper and the Process Table*, BNFL Inc., Richland, WA

6.2 Results from BNFL Calculation

(a) Fluid velocity of 19.1 ft/sec is required in the vacuum hose to carry a 1/4" Uranium particle through the vacuum system.

(b) Head Loss through vacuum wand is 31.32 feet in BNFL calculation. BNFL calculation is based on a 20 foot long vacuum hose with a 1 1/2" ID.

(c) Total Head available at the vacuum wand nozzle is 45.2 feet.

6.3 Head Loss Calculation Based on Current Design

Figures 1, 2, and 3 shows the K Factors that need to be calculated.

CALCULATIONS AND SKETCHES SHEET

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FIGURE 1 - VACUUM WAND

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Figure 2 Flow through VACUUM hose connections

REF DW-205, REV 10, SHEET 6

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FIGURE 3 Flow to pump.

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Summary of K Factors

K Label	Description
For Figure 1:	
Ka	Nozzle (entrance loss + screen loss + contraction to flow loss)
Kb	Long 90, R/D = 7.5/1.50 = 5
Kc	1.625 x .058 wall smooth tube, 55.25 inches long
Kd	Hose Coupler (Hose to Wand)
Ke	Smooth Plastic Vacuum Hose, 30' Long
Kf	Hose Coupler (Oposite end of Vacuum hose)
For Figure 2:	
Kw	1-1/2" Smooth Straight Pipe, 6" long
Kx	Welded 1-1/2" 90
Ky	1-1/2 to 3" Expansion
Kz	3" Welded T
Ka1	3" Coupler
For Figure 3:	
Ko	Smooth 3" Pipe, 69.6" long
Kp	Long 90 - R/D = 15/3.068 = 4.9
Kr	3" Coupler
Ks	Smooth 3" Pipe, 7" long

Flow through system is determined by the Vacuum Hose size. Fluid Velocity through hose must be 19.1 FT/SEC.

$$\text{Flow } Q = V A \quad \text{where} \quad V = 19.1 \text{ FT/SEC}$$

$$A = \text{Hose cross section Area FT}^2$$

$$Q = (19.1) \left(\frac{1.5}{12} \right)^2 \frac{\pi}{4} = .234 \text{ FT}^3/\text{SEC} \quad (105.3 \text{ gpm})$$

Flow through VACUUM SYSTEM .234 FT³/SEC

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KA CALC

SCREEN $3\frac{1}{2}$ " MESH, 0.035
wire, .250 SQUARE
OPENINGS.

77.2% OPEN

$$\text{SCREEN AREA} = (1.5)(2)(.636) \\ = 1.908 \text{ in}^2$$

.122

8 STRAINER TIP ASSEMBLY

SCALE: 3/1

$$\text{OPEN AREA} = 1.908 \text{ in}^2 (.772) = 1.473 \text{ in}^2$$

$$V_N = \frac{\text{DUCT AREA}}{\text{OPEN AREA}} (19.1 \text{ FT/sec}) = \frac{(1.5)(1.18)}{1.473} (19.1) = \underline{\underline{23 \text{ FT/sec}}}$$

This is $\left(\frac{23}{19.1} = 1.204\right)$ 20% higher than min hose
velocity.

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$$K_a = K_1 + K_2 = \text{Resistance Inlet} + \text{Resistance Expansion}$$

To Calculate K_1 , Resistance Inlet, I refer to Handbook of Hydraulic Resistance, 3rd Edition, page 522, DIA. 8-6

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Handbook of Hydraulic Resistance, 3rd Edition

Screens^{24,26,34,49}Diagram
8-6

$$\bar{f} = \frac{F_0}{F_1} = \frac{\sum f_{\alpha}}{F_1}$$

1. Circular metal wire

$$Re = \frac{w_0 \delta_m}{\nu} \geq 10^3$$

$$\zeta_{wr} = \frac{\Delta p}{\rho w_0^2 / 2} = 1.3(1 - \bar{f}) + \left(\frac{1}{\bar{f}} - 1\right)^2$$

see graph a; $50 < Re < 10^3$:

$$\zeta_{re} = \frac{\Delta p}{\rho w_0^2 / 2} = k'_{re} \zeta_{wr}$$

$$Re < 50: \zeta_{re} \approx \frac{22}{Re} + \zeta_{wr}$$

where for k'_{re} , see graph b.For n_{scr} number of rows of successively installed screens

$$\zeta_{scr} = \frac{\Delta p}{\rho w_0^2 / 2} \approx \sum_{i=1}^{n_{scr}} \zeta_i \quad \text{or} \quad \zeta_{scr} \approx \sum_{i=1}^{n_{scr}} \zeta_{re i}$$

2. Silk threads

$$Re > 500: \zeta_{st} = \frac{\Delta p}{\rho w_0^2 / 2} = 1.62 \zeta_{wr}$$

$$40 < Re < 500: \zeta_{re} = k'_{re} \zeta_{st}$$

$$Re < 40: \zeta_{re} \approx \frac{7}{Re} + \zeta_{st}$$

where for k'_{re} see graph c.

CALCULATIONS AND SKETCHES SHEET

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From Diagram 8-6'.

$$\zeta = 1.3(1 - \bar{f}) + \left(\frac{1}{\bar{f}} - 1\right)^2 = \frac{\Delta p}{\frac{\rho W_1^2}{2}}$$

where $\bar{f} = \frac{F_o}{F_i} = \frac{\text{OPEN SCREEN Area}}{\text{TOTAL SCREEN Area}} = .772$

Δp = pressure drop in Pa

W_1 = Fluid Velocity m/sec @ inlet.

$$W_1 = 23 \text{ FT/sec} \left(.3048 \frac{\text{m}}{\text{ft}} \right) = \underline{7.01 \text{ m/sec}}$$

$$\rho = \frac{\text{Kg}}{\text{m}^3} \quad \text{Density of water @ } 50^\circ\text{F} \quad 999.73 \frac{\text{Kg}}{\text{m}^3}$$

10°C

$$\zeta = 1.3(1 - .772) + \left(\frac{1}{.772} - 1\right)^2 = \underline{0.384}$$

$$\Delta p = \zeta \rho \frac{W_1^2}{2} = .384 (999.73) \left(\frac{7.01}{2}\right)^2 = \underline{9432.4 \text{ Pa}}$$

From Mark's Standard Handbook, 8th Edition

$$Pa = \text{PSI} \times 6894.8$$

$$\text{PSI} = \text{INCHES H}_2\text{O} \times .0361$$

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$$PSI = \frac{9432.4 \text{ Pa}}{6894.8} = 1.37 \text{ PSI}$$

$$\text{Inches H}_2\text{O} = \frac{1.37 \text{ PSI}}{0.0361} = 37.95 \text{ inches H}_2\text{O}$$

PRESSURE DROP @ INLET (K_1)

$$\underline{\underline{\Delta P_{K_1}}} = \frac{37.95 \text{ IN}}{12} = \underline{\underline{3.16 \text{ FT}}}$$

Now to Calculate Transition from Rectangle to Round TUBE SECTION.

EQ DIA OF 1.18 X 1.50 RECT. SECTION

$$D_h = \frac{4A}{P} = \frac{4(1.18)(1.50)}{2(1.18) + 2(1.50)} = 1.32''$$

DIA OF ADJOINING TUBE IS 1.50" so we have an expansion to flow, Referring to TABLE 6B, Next page.

$$\frac{D_h}{D_2} = \frac{1.32}{1.50} = .88$$

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SUBJECT: F.H. 1.8 Vacuum Wand for Fuel Retrieval System

TABLE 10-2 LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS

Description	Sketch	Additional Data	K	Source
Pipe entrance		r/d	K_e	(1)
		0.0	0.50	
		0.1	0.12	
$h_L = K_e V^2/2g$		> 0.2	0.03	
Contraction		D_2/D_1	K_C $\theta = 60^\circ$ $\theta = 180^\circ$	(1)
		0.0	0.08	0.50
		0.20	0.08	0.49
		0.40	0.07	0.42
		0.60	0.06	0.32
		0.80	0.05	0.18
$h_L = K_C V_2^2/2g$		0.90	0.04	0.10
Expansion		D_1/D_2	K_E $\theta = 10^\circ$ $\theta = 180^\circ$	(1)
		0.0		1.00
		0.20	0.13	0.92
		0.40	0.11	0.72
		0.60	0.06	0.42
$h_L = K_E V_1^2/2g$		0.80	0.03	0.16
90° miter bend		Without vanes	$K_b = 1.1$	(27)
$h_L = K_b \frac{V^2}{2g}$		With vanes	$K_b = 0.2$	(27)
90° smooth bend		r/d		(3) and (14)
		1	$K_b = 0.35$	
		2	0.19	
		4	0.16	
		6	0.21	
		8	0.28	
$h_L = K_b \frac{V^2}{2g}$		10	0.32	
Threaded pipe fittings	Globe valve—wide open		$K_v = 10.0$	(27)
	Angle valve—wide open		$K_v = 5.0$	
	Gate valve—wide open		$K_v = 0.2$	
	Gate valve—half open		$K_v = 5.6$	
	Return bend		$K_b = 2.2$	
	Tee			
	straight-through flow		$K_t = 0.4$	
	side-outlet flow		$K_t = 1.8$	
	90° elbow		$K_b = 0.9$	
	45° elbow		$K_b = 0.4$	

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REFERENCE: Robertson / Crowe, Engineering Fluid Dynamics, Third Edition

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Assume $\theta = 10^\circ$

Table shows $K_E = .03$ @ $\frac{D_1}{D_2} = .80$

Since table only goes to .80 and K decreases with increasing $\frac{D_1}{D_2}$ ratio I'll assume $\frac{D_1}{D_2} = .80$

$$K = .03$$

$$H_2 = .03 \frac{(19.1)^2}{2(32.2)} = \underline{\underline{.17 \text{ FT}}}$$

TOTAL HEAD LOSS at Nozzle is equal to

$$\boxed{H_A} = 3.16 \text{ FT} + .17 \text{ FT} = \underline{\underline{3.32 \text{ FT}}}$$

Now to calculate the remaining K-FACTORS

$$\boxed{K_b} \text{ long } 90^\circ, \frac{r}{d} = \frac{7.5}{1.5} = 5$$

From table 6B

$$2 \left[\begin{array}{l} \frac{r}{d} = 6, K = .21 \\ \frac{r}{d} = 4, K = .16 \end{array} \right]^{.05}$$

Page C23

$$\boxed{K_b} = .16 + \left(\frac{.05}{2} \right) (5-4) = \underline{\underline{.185}}$$

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Assume $\theta = 10^\circ$

Table shows $K_E = .03$ @ $\frac{D_1}{D_2} = .80$

Since table only goes to .80 and K decreases with increasing $\frac{D_1}{D_2}$ ratio I'll assume $\frac{D_1}{D_2} = .80$

$$K = .03$$

$$H_2 = .03 \frac{(19.1)^2}{2(32.2)} = \underline{\underline{.17 \text{ FT}}}$$

TOTAL HEAD LOSS at Nozzle is equal to

$$\boxed{H_A} = 1.92 \text{ FT} + .17 \text{ FT} = \underline{\underline{2.09 \text{ FT}}}$$

Now to calculate the remaining K-FACTORS

$$\boxed{K_b} \text{ long } 90^\circ, \frac{r}{d} = \frac{7.5}{1.5} = 5$$

From table 6B

$$2 \left[\begin{array}{l} \frac{K}{d} = 6, K = .21 \\ \frac{r}{d} = 4, K = .16 \end{array} \right]_{.05}$$

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$$\boxed{K} = .16 + \left(\frac{.05}{2} \right) (5 - 4) = \underline{\underline{.185}}$$

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K_c straight smooth pipe (REF 2), 55.25" long

$$R_e = \frac{123.9 d p V}{\mu}$$

d = dia (inch)

p = weight Density (lb/ft^3)

V = Fluid Velocity (ft/sec)

μ = Viscosity (centipoise)

$$d = 1.5"$$

$$V = 19.1 \text{ ft/sec}$$

$$p = 62.41 \text{ lb/ft}^3 @ 50^\circ\text{F}$$

$$\mu = 1.3 \text{ (Crane A-3)}$$

$$R_e = \frac{123.9 (1.5) (62.41) (19.1)}{1.3} = 1.704 \times 10^5$$

$$f \approx .016 \text{ (Crane A-24)}$$

$$K_c = \frac{f L}{D} = \frac{.016 \left(\frac{55.25}{12} \right)}{\left(\frac{1.5}{12} \right)} = .589$$

K_D Hose Coupler I'll use K Factor used in the BNFL Calc's (REF 3)

$$K_D = 1.5$$

K_E smooth plastic Vacuum Hose, 30' long
1.5" ID.

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Vacuum Wand for Fuel Retrieval System

Re & $\bar{f}$ is the same as calculated for
 K_c Factor:

$$Re = 1.704 \times 10^5 \quad (K_c \text{ Calc})$$

$$\bar{f} = .016 \quad (K_c \text{ Calc})$$

$$K_e = \frac{\bar{f} L}{D} = \frac{.016 (30)}{\left(\frac{1.5}{12}\right)} = 3.84$$

K_F Hose Coupler per BNFL Calc (REF 2)

$$K_F = .5$$

K_W 1-1/2" PIPE, smooth straight pipe, 6" long

$$Re = \frac{123.9 d \rho V}{\mu}$$

$$d = 1.610 \text{ inch}$$

$$\rho = 62.41 \text{ lb/ft}^3$$

$$\mu = 1.3$$

If A_3 is cross section
 Area of pipe & V_3 is
 Fluid velocity in the pipe

and

$$V_1 = 19.1 \text{ FT/sec}$$

$$A_1 = \text{Area } 1\frac{1}{2} \text{ ID TUBE}$$

$$V_3 A_3 = V_1 A_1$$

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SUBJECT:

Vacuum Wand for Fuel Retrieval System

$$V_3 = \frac{V_1 A_1}{A_3} = \frac{(19.1) \left(\frac{1.5}{24}\right)^2 \pi}{\left(\frac{1.610}{24}\right)^2 \pi} = 16.58 \text{ FT/sec}$$

$$R_c = \frac{123.9 (1.610) (62.41) (16.58)}{1.3}$$

$$R_c = 1.58 \times 10^5$$

$$\bar{f} = .0161 \quad (\text{CRANE A-24})$$

$$K_w = \frac{\bar{f} L}{D} = \frac{.0161 \left(\frac{6}{12}\right)}{\left(\frac{1.610}{12}\right)} = .06 @ 16.58 \text{ FT/sec}$$

$$K_x \text{ Welded } 90^\circ, 1\frac{1}{2} \text{ pipe } r = 2.25 \leftarrow \text{Tube-Turn Pipe FITTERS MANUAL}$$

$$d = 1.610$$

$$\frac{r}{d} = \frac{2.25}{1.610} = 1.398$$

From Table 6B

$$\left[\begin{array}{l} \frac{r}{d} = 1, K = .35 \\ \frac{r}{d} = 2, K = .19 \end{array} \right] .16$$

$$K_x = .19 + \left(\frac{.16}{1}\right) (2 - 1.398) = .29 @ 16.58 \text{ FT/sec}$$

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT:	Mechanisms Engineering	ORIGINATED BY:	H.L. Roach	DATE:	12/18/98
ENG COMM NO:		CHECKED BY:	A. K. BISWAS	DATE:	12/18/98
AREA:	100 K	REVISED BY:		DATE:	
SUBJECT:	Vacuum Wand for Fuel Retrieval System				

K_y 1 1/2 TO 3" Expansion, welded
From table GB assume $\theta = 10^\circ$

$$\frac{D_1}{D_2} = \frac{1.610}{3.068} = .525$$

$$.20 \left[\begin{array}{l} \frac{D_1}{D_2} = .40, K = .11 \\ \frac{D_1}{D_2} = .60, K = .06 \end{array} \right] .05$$

$$K_y = .06 + \frac{.05}{.20} (.60 - .525) = \boxed{.079} @ 16.58 \text{ FT/sec}$$

K_z 3" weld T, Flow through side outlet
From Table GB

$$K_z = \boxed{1.8} @ V_4 \text{ where } V_4 \text{ is } V \text{ through } 3" \text{ pipe and}$$

$A_4 = \text{Area of } 3" \text{ pipe}$

$$V_4 = \frac{V_1 A_1}{A_3} = \frac{(19.1) \left(\frac{1.5}{24}\right)^2 \pi}{\left(\frac{3.068}{24}\right)^2 \pi} = 4.57 \text{ FT/sec}$$

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT: Mechanisms Engineering

ORIGINATED BY: H.L. Roach

DATE: 12/18/98

ENG COMM NO:

CHECKED BY: A.K. BISWAS

DATE: 12/18/98

AREA: 100 K

REVISED BY:

DATE:

SUBJECT: Vacuum Wand for Fuel Retrieval System

Now beyond this point we have a combined flow of 150 gpm (through vacuum + bypass) using the conversion

$$\text{gallons} = \text{FT}^3 \times 7.4805$$

$$1 \text{ FT}^3 = \frac{7.4805 \text{ GALLONS}}{7.4805}$$

Converting Flow

$$Q = 150 \frac{\text{GAL}}{\text{min}} \times \frac{1 \text{ FT}^3}{7.4805 \text{ g}} \frac{1 \text{ min}}{60 \text{ sec}} = .334 \frac{\text{FT}^3}{\text{sec}}$$

Velocity in 3" pipe is

$$V = \frac{Q}{A} = \frac{.334 \frac{\text{FT}^3}{\text{sec}}}{\left(\frac{3.068}{24}\right)^2 \pi} = 6.51 \text{ FT/sec}$$

K_{A1}

coupling

$K_{A1} = .5$

(BNFL ASSUMPTION)

K_0

+ K_s

BOTH SMOOTH 3" PIPE, combined Length = 76.6"

$$R_e = \frac{(123.9)(3.068)(62.41)(6.51)}{1.3}$$

1.3

$$R_e = 1.19 \times 10^5$$

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT: Mechanisms Engineering

ORIGINATED BY: H.L. Roach

DATE: 12/15/98

ENG COMM NO:

CHECKED BY:

A.K. BISWAS

DATE: 12/18/98

AREA:

100 K

REVISED BY:

DATE:

SUBJECT:

Vacuum Wand for Fuel Retrieval System

$$\bar{f} \approx .0171$$

$$\boxed{K_o + K_s} = \frac{\bar{f} L}{D} = \frac{.0171 \left(\frac{76.6}{12} \right)}{\left(\frac{3.068}{12} \right)} = .427 \quad @ 6.51 \text{ FT/sec}$$

$\boxed{K_p}$ Long Radius 90°, R/D = 4.9, 3" pipe

From Table 6B

$$2 \left[\begin{array}{l} \frac{r}{d} = 6, K = .21 \\ \frac{r}{d} = 4, K = .16 \end{array} \right] .05$$

$$\boxed{K_p} = .16 + \left(\frac{.05}{2} \right) (4.9 - 4) = \boxed{.182}$$

$\boxed{K_r}$ 3" coupler as before $\boxed{K_r = .5}$

Now that all K factors and Fluid Velocities are known I tabulate head loss in the following Table using $h_L = K \frac{V^2}{2g}$

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT:	Mechanisms Engineering	ORIGINATED BY:	H.L. Roach	DATE:	12/18/98
ENG COMM NO:		CHECKED BY:	A. K. Biswas	DATE:	12/18/98
AREA:	100 K	REVISED BY:		DATE:	
SUBJECT:	Vacuum Wand for Fuel Retrieval System				

Calculation of Head Loss From Vacuum nozzle to Pump

K (Label)	Description	K Factor	V (Ft/sec)	Head Loss FL
For Figure 1:				
Ka	Nozzle (screen loss + expansion to flow)			3.32
Kb	Long 90, R/D = $7.5/1.50 = 5$	0.185	19.100	1.048
Kc	1.625 x .058 wall smooth tube, 55.25 inches long	0.589	19.100	3.337
Kd	Hose Coupler (Hose to Wand)	0.500	19.100	2.832
Ke	Smooth Plastic Vacuum Hose, 30' Long	3.820	19.100	21.639
Kf	Hose Coupler (Oposite end of Vacuum hose)	0.500	19.100	2.832
For Figure 2:				
Kw	1-1/2" Smooth Straight Pipe, 6" long	0.060	16.580	0.256
Kx	Welded 1-1/2" 90	0.290	16.580	1.238
Ky	1-1/2 to 3" Expansion	0.079	16.580	0.337
Kz	3" Welded T	1.800	4.570	0.584
Ka1	3" Coupler	0.500	6.510	0.329
For Figure 3:				
Ko + Ks	Smooth 3" Pipe, 76.6" long	0.427	6.510	0.281
Kp	Long 90 - R/D = $15/3.068 = 4.9$	0.182	6.510	0.120
Kr	3" Coupler	0.500	6.510	0.329

Total Head Loss: 38.48

The Net POSITIVE SUCTION HEAD FOR THE PROCESS TABLE
PUMP (NPSHA)

$$NPSHA = \text{ATM} - \text{Vapor Pressure @ Pump} - \text{Friction Loss} - \text{Elevation}$$

$$NPSHA = 33.9 - 0.42 - 38.48 - (-11.3) = +6.3 \text{ FT}$$

Fuel Retrieval System Small Tools Design Package

Vacuum Wand

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Appendix D

Test Specifications

**FRS Test Specification For The Evaluation Of
Vacuum Wand for Fuel Retrieval System**

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Approvals for Test Specification:

Bruce Groth
Design Authority

4-29-99
Date

David R. Jackson
FRS Test Engineer

4-28-99
Date

John Diehl
FRS QA

4-29-99
Date

Hank L. Roach
Cog Engineer/Author

4/26/99
Date

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1.0 PURPOSE

The purpose of this test specification is to evaluate the performance of the vacuum wand against the required testing discussed in section 4.5.2 of this document.

2.0 TEST DESCRIPTION

All evaluations and visual observations will be recorded in a test log and assembled in a test report. Pictures will be taken as necessary.

All testing will be performed in the 300 Area, Bldg. 305, Engineering Testing Laboratory. Testing will be performed in the K-Basin mockup wet Pit, and K-Basin mockup dry pit. The K-Basin mockup dry pit contains a dry mockup of the fuel processing equipment. The K-Basin mockup wet pit allows for underwater testing of equipment.

The following sections describe the required evaluation tests.

2.1 Hose Flexibility

There are two hose flexibility requirements (Refer to section 4.5.2.1).

- The vacuum hose must be flexible and manageable through out the full travel of the vacuum wand.
- The hose must not kink during normal use

This will be verified by conducting two tests. First the vacuum wand will be used in the K-Basin mockup dry pit which has a mockup of the fuel processing equipment. This will not be ideal since there will not be any water in the pit and the vacuum wand will not have water flowing through it. It anticipated that the hose will not be as manageable without the buoyant forces that come from using the vacuum wand in the water. It will however, allow for some evaluation to be made as to the manageability of the hose around the fuel processing equipment mockups. Hose kinking will also be evaluated based on movement of the vacuum wand around the fuel processing equipment mockups.

The second test will be done in the K-Basin mockup wet Pit. The vacuum wand will be in water and will be connected to a 150 GPM pump. After all testing in the K-Basin mockup wet pit is completed an evaluation will be made of hose

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manageability and kinking problems, if any, during the wet pit tests. See Figure D1 for the K-Basin mockup wet pit arrangement.

2.2 Physical Functionality

There are three physical functionality requirements (Refer to section 4.5.2.2).

- The hose must be of sufficient length to reach all parts of the fuel processing equipment.
- The vacuum inlet nozzle must demonstrate the ability to remove fuel sludge from the Primary Cleaning Machine (PCM), decapper, and stuck fuel station.
- Verify the vacuum head can be cleaned.

The first requirement will be met by a combination of physical test and drawing check. Since the K-Basin mockup dry pit is not large enough to locate a mockup of the stuck fuel station, it will not be possible to verify this test by doing a physical test only. The vacuum wand will be installed in the dry pit with the vacuum hose connected at the appropriate location. The vacuum wand will be moved to the last physical mockup in the dry pit and a measurement will be made of the excess hose to identify what the additional reach of the vacuum wand is at that point. Drawing H-1-83498, *FRS – KW Plan View – In Pool Equip, General Arrangement*, current revision, will be used to verify that the measured additional reach of the vacuum wand is sufficient to reach the stuck fuel station.

The second requirement will be met by verifying that simulated fuel sludge can be removed from a FRS Equipment mockup in the K-Basin mockup wet pit. Fuel sludge stimulant will be applied to a FRS Equipment mockup placed in the K-Basin mockup wet pit. The simulated fuel sludge is derived from the Appendix G of HNF-2735, *K Basin Sludge Treatment Process Description*, and is shown in Table D-1. Verification will be made that the vacuum wand is able to remove the stimulant from the mockup.

Table D-1 – Sludge Simulant Components		
Component	Micron Size	Grams per liter of water
Sand	<125	30
Al ₂ O ₃	<125	11
FeO ₃	<125	34
Tungsten (Uranium Simulant)	>500 <6350 (1/4")	12
Molybdenum (Uranium Co Simulant)	<125	27

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FIGURE D1 - BUILDING 305 K-BASIN MOCKUP WET PIT ARRANGEMENT

NOTE: GUARD RAILS ARE NOT SHOWN

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FIGURE D2 - FRS EQUIPMENT MOCKUP

- (1) MATERIAL IS CARBON STEEL
- (2) STAND DIMENSIONS ARE APPROXIMATE
- (3) PROVIDE LEGS OR SUPPORTS SO THAT ELEVATION OF PLATE IS EQUAL TO HEIGHT OF STUCK FUEL STATION.

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FIGURE D3 - VALVE STAND ARRANGEMENT

- (1) MATERIAL IS CARBON STEEL UNLESS SPECIFIED OTHERWISE
- (2) STAND DIMENSIONS ARE APPROXIMATE

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The last requirement requires verification that the vacuum head can be cleaned. Pieces of MK I fuel canister seal material will be broken into pieces larger than ¼" in length. The gasket pieces will be placed on the FRS Equipment mockup in the K-Basin mockup wet pit. The vacuum wand will be used to try to vacuum the gasket debris until it is judged that the vacuum wand is plugged. At that point the vacuum head will be cleaned using the following method:

- The bypass valve will be opened to minimize water flow through the vacuum wand.
- The vacuum will be moved side to side and up and down (shaken) to determine if the vacuum head can be cleared by this method.
- If additional debris remains on the vacuum head the long pole tool with a hook on one end will be used to clear the screen.

A written evaluation will be made in the test report of the effectiveness of the vacuum head cleaning method.

2.3 Operational Functionality

Operational functionality tests are listed in section 4.5.2.3 of this document. The following functional tests will be verified by testing:

- The vacuum wand is capable of picking up sludge and small particles less than 0.25 in. in diameter.
- Verify that the vacuum wand can be manually handled without difficulty.
- Verify that the vacuum wand picks up sludge.
- Hose on vacuum wand doesn't interfere or get in the way of operation of the fuel processing equipment.
- Adjustable handle provides good grip and can be adjusted with gloves on.

The first and third requirements will be verified during the physical functionality tests described in section 2.1.

The remaining requirements will be verified by objectively evaluating how well the requirements are met during physical testing. A written evaluation will be made in the test report on how well these requirements are met.

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3 CONDITIONS FOR TESTS

Testing will be done in the 305 facility located in the Hanford 300 Area. The K-Basin mockup dry and wet pits will be used for all tests.

4 REQUIRED SUPPORT

4.1 MANAGEMENT OF TEST

The Fluor Daniel Northwest Engineer will be responsible as the test engineer. Numatec will be responsible for providing support to testing through technician support. This support will include fabrication, erection, and minor operations of the testing apparatus.

This document will not be incorporated into HNF-3579 until completion of all testing. A master copy of this document will be used for testing and will be controlled by the test engineer. Changes will be made only by the approval of the FRS Test Engineer or the Test Director using redlines, their signature, and date of change.

4.2 EQUIPMENT

- Vacuum wand as shown in sketches
- Test Stand for flow and bypass valve assemblies
- 150 GPM pump (see figure D-3)
- FRS Equipment Mockup (see figure D-2)
- K-Basin sludge simulant
- Miscellaneous support tools (hammers, screw drivers,...)

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5 OBSERVATIONS

5.1 Hose Flexibility Tests

Date of test: _____

Technician: _____

Engineer: _____

TEST #	Acceptable	Not- Acceptable	Requirement
5.1.1			Vacuum hose is flexible and manageable through out the full travel of the vacuum wand.
5.1.2			Vacuum hose must not kink during use.

Test # 5.1.1 comments:

Test # 5.1.1 comments:

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5.2 Physical Functionality

Date of test: _____

Technician: _____

Engineer: _____

TEST #	Acceptable	Not-Acceptable	Requirement
5.2.1			Hose has sufficient length to reach all parts of the fuel processing equipment.
5.2.2			Vacuum inlet nozzle demonstrates ability to remove fuel sludge stimulant from a FRS mockup (Figure D-2).
5.2.3			Vacuum nozzle can be cleaned.

Test # 5.2.1 comments:

Test # 5.2.2 comments:

Test # 5.2.3 comments:

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5.3 Operational Functionality

Date of test: _____

Technician: _____

Engineer: _____

TEST #	Acceptable	Not-Acceptable	Requirement
5.3.1			Vacuum wand picks up small particles less than 0.25" in diameter.
5.3.2			Vacuum wand can be manually handled without difficulty.
5.3.3			Vacuum wand picks up the spent fuel sludge stimulant.
5.3.4			Hose doesn't interfere with operation of the fuel processing equipment
5.3.5			Adjustable handle provides good grip and can be adjusted with gloves on.

Test # 5.3.1 comments:

Test # 5.3.2 comments:

Test # 5.3.3 comments:

Test # 5.3.4 comments:

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Test # 5.3.5 comments:

5.4 Additional Comments

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Appendix E

Test Report

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1 INTRODUCTION

This test report documents the results of the testing of the vacuum wand at the 300 Area, Bldg. 305, Engineering Testing Laboratory. Testing was performed in the K-Basin mockup wet pit, and K-Basing mockup dry pit. All testing was conducted in accordance with the vacuum wand test specification in Appendix D of this document.

The arrangement of the test equipment in the wet pit was different from the arrangement shown in Appendix D, Figure D1. Figure E1 shows the arrangement of the test equipment in the wet pit.

2 TEST RESULT SUMMARY

The test result summary is as follows:

- All tests were completed with satisfactory results.
- The vacuum wand performed and handled well during testing.
- The vacuum wand worked well at flow rates lower than the 105 GPM that was calculated to be required. Water flow in the vacuum wand ranged between 55 to 67 GPM during testing.
- To clear a plugged vacuum wand nozzle it is necessary to completely stop all water flow through the vacuum wand. The 2" bypass ball valve (current design) will be eliminated and an inline ball valve will be placed in the vacuum line.

3 TEST LOG

All evaluations and visual observations were recorded in a test log and are included in this section of the report.

3.1 Test Log Entry May 10, 1999

- The approximate start time was 1:00 PM.
- The vacuum hose was straightened out. It was curled around the equipment.
- The pump was started to check the flow rate at inlet of pump. 5-micron bag filters were installed on the suction side of the pump. The flow rate was

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FIGURE E1 - BUILDING 305 K-BASIN MOCKUP WET PIT ARRANGEMENT

NOTE: GUARD RAILS ARE NOT SHOWN

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measured at 96 GPM. It appeared the pump was cavitating. When the 2" bypass ball valve was opened the flow rate jumped to 111 GPM.

Flow rate through wand 96 GPM.

Vacuum wand bypassed 111 GPM.

Delta flow was 15 GPM.

- Metal baskets were installed in the pump strainer housing. The 5-micron bag filters were removed and replaced with metal baskets made from perforated plates.

The metal baskets were made with perforated plate, 0.125 DIA. Holes with ~65% free area.

The flow rate was still about 96 GPM.

An unmeasured quantity of Tungsten particles was placed on the FRS equipment mockup and the vacuum wand was used to vacuum up the particles. This was done as a first test to see how well the vacuum wand worked. The vacuum wand picked up the particles with no problem.

- Next 160 grams of Tungsten particles were weighed out and placed on the FRS equipment mockup.

The flow was measured to be 100 GPM. All of the Tungsten particles were easily vacuumed up. The strainer baskets were removed and 97 grams of Tungsten particles were collected and weighed. 63 grams (39%) was unaccounted for.

It was noted that some of the Tungsten particles were smaller than the 0.125" diameter holes in the strainer basket. If the particles pass through the strainer they would pass through the pump and be discharged into the basin. A quantity of Tungsten was selected using a 0.125" screen to sift out particles smaller than 0.125". 142.2 grams of the selected Tungsten particles were weighed out.

The flow was measured at 99 GPM.

After vacuuming, the strainer baskets were removed and 82.2 grams of Tungsten particles were collected. 60 grams (42%) of the Tungsten was unaccounted for.

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3.2 Test Log Entry Wednesday, May 12, 1999

- The approximate start time was 1:00 PM.
- The main focus of this day's tests was to investigate the apparent loss of Tungsten during vacuuming operations. Approximately 90 grams of Tungsten was missing at this point. This was done to address a concern that the Tungsten particles may not be carried all the way to the strainer basket on the pump.
- The 2" vacuum hose, which connects the valve stand to the pump inlet, was disconnected. The flow rate jumped to 121 GPM. This was the flow rate with the vacuum wand and valve stand taken out of the loop.

The 2" line (manifold) on the valve stand was inspected and found to be clear of any particles. The 2" PVC line was shortened by 6 feet in an attempt to increase water flow. When the 2" PVC line was reconnected to valve stand and the flow rate increased to 100 GPM (was about 96 GPM).

- A thorough inspection of the pump finally solved the mystery of where the missing Tungsten particles went. The missing Tungsten particles were found in a dead spot on the pump. This spot is shown in Figure E1. The recovered Tungsten weighed in at about 100 grams. This was 10 grams more than the 90 grams of Tungsten that was missing. It was assumed that the additional 10 grams comes from the first vacuum test conducted. The mass of the Tungsten particles used in the first test was not weighed before or after the test.

3.3 Test Log Entry Thursday, May 13, 1999

- The pump and strainer baskets were carefully inspected to verify all of the tungsten particles were removed from the pump and strainer baskets. 136.55 grams of Tungsten particles were weighed out. The Tungsten selected for this test was the largest particles that could be found. Tim Vanreenen, K-basin lead operator was asked to perform this test to get operator input on the operation of the vacuum wand.

Tim vacuumed up the Tungsten with no problem. However, when the pump was turned off some of the material dropped off from the vacuum nozzle back onto the table. It was noted that many of these larger particles would pass through the vacuum wand screen only if the long axis of the Tungsten particles are perpendicular to the screen. Many of these larger particles

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selected for this test were longer than $\frac{1}{4}$ ".

The vacuuming operation was repeated five times. Each time the pump was turned on, the particles were vacuumed up, and the pump was turned off to see if any particles dropped out. Most particles were picked up on the 2nd try. There was one piece that remained difficult to pick up. When zoomed onto the vacuum nozzle it was noted that the particle would turn as the vacuum nozzle got close so that it's long axis (axis larger than $\frac{1}{4}$ ") was parallel to the screen. The nozzle was brought up towards the surface with the pump running to try to catch the remaining particle trapped against the screen. When the screen was brought to the surface the remaining particle was gone. It was not determined if the particle passed through the wand or was dropped to the pit floor.

The particles were collected from the pump (dead spot) and strainer baskets and weighed out at 135.95 grams. There was only a 0.6 grams (0.4%) loss. This was very close to the original mass of Tungsten placed on the table. It was judged from this test that the heavy particles were being transferred successfully through the system.

Tim's opinion was that the vacuum wand worked well and that the design was good. One recommendation that Tim made was that there should be a cut off switch for the pump at the location the operator is using the vacuum wand.

- At Tim's request a second batch of Tungsten particles were selected making sure that all particles were shorter than $\frac{1}{4}$ ". Tim vacuumed up this batch of Tungsten with no problem and no particles dropped out after the pump was turned off.
- The next test was conducted to test the ability to clear a plugged screen.

Pieces of old MK I canister grafoil seals were broken up and placed in a bucket on the FRS equipment mockup table. When the vacuum wand was placed in the bucket (with the pump on) the grafoil was immediately sucked up against the screen. It was not possible too completely block water flow through the wand but allot of grafoil material was held against the screen.

The 2" bypass ball valve was opened (with some difficulty) and the wand was shaken to try to remove the gasket material stuck against the vacuum wand screen. Very little of the grafoil material dropped off. The pump was turned off and immediately all the material dropped off the vacuum wand. Evidently the minimal flow through the wand was still sufficient to hold the light grafoil gasket material against the vacuum screen.

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The conclusion of this test was that the 2" bypass ball valve is not sufficient to allow a blocked nozzle screen to be cleared. A full flow ball valve will be installed inline with the vacuum wand hose to allow a complete cutoff of the water flow. A better solution would be to allow the pump to be turned on and off at the K-Basins.

- The last test in the wet basin was to do a vacuum test using the full K-Basin sludge simulant (Table D1). 251.47 grams of simulant were prepared. The 5 micron strainer baskets were re-installed on the pump since the simulant includes fine particles. The flow rate was measured at 108 GPM. The K-Basin sludge simulant was vacuumed without difficulty. It was noted that some of the fines passed through the 5 micron filter baskets.

3.4 Test Log Entry Monday, May 17, 1999

- The Approximate start was at 9:00 AM. All testing in the wet basin was completed last Thursday. The vacuum wand, 1 1/2" vacuum wand hose, 2" vacuum hose, and valve stand had already been removed from the wet basin.

The 2" vacuum hose was measured to be 16'-9" long

Free flow through pump (disconnected) was 158.40 GPM. Nothing was connected to pump inlet except for flow meter.

- The last test was to stretch out the 1 1/2" vacuum hose in the dry test pit and measure the length of hose from the decapper mockup in the pit.

There was approximately 10'-7" of hose measured.

Figure E2 shows that this additional 10'-7" reach is sufficient to reach the stuck fuel station.

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Figure D2 – Reach of Vacuum Hose

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4 OBSERVATIONS

4.1 Hose Flexibility Tests

Date of test: May 10-17

Technician: 305 Bldg. Technicians

Engineer: H.L. Roach

TEST #	Acceptable	Not-Acceptable	Requirement
4.1.1	YES		Vacuum hose is flexible and manageable through out the full travel of the vacuum wand.
4.1.2	YES		Vacuum hose must not kink during use.

Test # 4.1.1 comments:

The vacuum hose was flexible and manageable during all testing of the vacuum wand.

Test # 4.1.2 comments:

The vacuum hose did not kink during any of the tests.

4.2 Physical Functionality

Date of test: May 10-17, 1999

Technician: 305 Bldg. Technicians

Engineer: H.L. Roach

TEST #	Acceptable	Not-Acceptable	Requirement
4.2.1	YES*		Hose has sufficient length to reach all parts of the fuel processing equipment.
4.2.2	YES		Vacuum inlet nozzle demonstrates ability to remove fuel sludge stimulant from a FRS mockup (Figure D-2).
4.2.3	YES*		Vacuum nozzle can be cleaned.

Test # 4.2.1 comments:

The vacuum hose was laid out in the dry pit (see section 3.4 in this test report). The length of hose that extends beyond the edge of the Decapp Station in the dry pit was measured at 10'-7". Figure E2 was drawn to show that this additional hose length will allow the vacuum wand to easily reach the Stuck Fuel Station

* A change was recently made to the location where the vacuum hose connects to the FRS equipment (see DAG-205, Rev 8). The new connection point is 6'-9" further away from the stuck fuel station. The 1 1/2" vacuum hose length will have to be increased at least 6' in length to accommodate this change.

FRS Test Specification For The Evaluation Of Vacuum Wand for Fuel Retrieval System

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Test # 4.2.2 comments:

Refer to Section 3.3 of this test report, May 13, test log entry:

The K-Basin sludge simulant (Table D1) was vacuumed up without difficulty. Flow rate through the vacuum wand was approximately 67 GPM, which translates to a fluid velocity in the vacuum hose of 12.14 ft/sec. Although this velocity is less than the specified 19.1 ft/sec it proved to be more than adequate to vacuum the heavy Tungsten particles through to the pump strainer. The lower flow rate resulted from the inability of the pump used for the vacuum tests to provide the required flow rates.

Note that the flow through the vacuum wand is calculated by subtracting from the total measured flow the 41 GPM that is continuously diverted through the flow control valve. In the example above:

Total flow	108 GPM
Flow control valve	<u>- 41.0 GPM</u>
Vacuum wand flow	67 GPM

Vacuum wand flow ranged between 55 to 67 GPM (9.96 to 12.14 ft/sec) during testing. In all cases the heavy Tungsten particles were picked up without any difficulty.

Test # 4.2.3 comments:

* When the 2" bypass valve was opened to allow the vacuum nozzle to be cleaned it did not work well. After the 2" bypass valve was opened the minimal flow through the vacuum wand was still high enough to hold the light particles against the screen. When the pump was turned off all of the grafoil particles blocking the vacuum wand nozzle screen dropped off.

The bypass valve assembly, Figure E1, will be eliminated and a full flow ball valve will be installed inline with the vacuum wand hose to allow a total shutoff of all flow through the vacuum wand nozzle. This test proved that when the flow is completely stopped the vacuum wand nozzle could be cleared.

The flow control valve assembly, Figure E1, will not be replaced. This valve will assure a minimum 41 GPM flow through the process table pump even when the flow is completely blocked in the vacuum wand.

**FRS Test Specification For The Evaluation Of
Vacuum Wand for Fuel Retrieval System**

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4.3 Operational Functionality

Date of test: May 10-17, 1999

Technician: Bldg. 305 Technicians

Engineer: H.L. Roach

TEST #	Acceptable	Not-Acceptable	Requirement
4.3.1	Yes		Vacuum wand picks up small particles less than 0.25" in diameter.
4.3.2	Yes		Vacuum wand can be manually handled without difficulty.
4.3.3	Yes		Vacuum wand picks up the spent fuel sludge stimulant.
4.3.4	Yes		Hose doesn't interfere with operation of the fuel processing equipment
4.3.5	Yes		Adjustable handle provides good grip and can be adjusted with gloves on.

Test # 4.3.1 comments:

In every test conducted the heavy 0.25" diameter Tungsten particles were picked up and carried through to the pump strainer.

Test # 4.3.2 comments:

Tim Vanreenen, K-Basin Lead Operator, stated that vacuum wand handled well.

Test # 4.3.3 comments:

The K-Basin sludge simulant (Table D1) was vacuumed up without difficulty.

Test # 4.3.4 comments:

No interference problems were noted during testing.

Test # 4.3.5 comments:

The vacuum wand could be adjusted without difficulty.

4.4 Additional Comments

None.

Fuel Retrieval System Small Tools Design Package

Vacuum Wand

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Appendix F

Supplemental Calculations for Vacuum Wand

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT:	Mechanisms Engineering	ORIGINATED BY:	H.L. Roach <i>H.L. Roach</i>	DATE:	6/22/99
ENG COMM NO:		CHECKED BY:	<i>A. Z. Biswas</i>	DATE:	7/9/99
AREA:	100 K	REVISED BY:		DATE:	
SUBJECT:	Supplemental Calculations for Vacuum Wand				

1.0 Purpose

The purpose of these calculations is to re-calculate the head loss from the vacuum wand nozzle to the inlet of the Process Table Pump. This is necessary because of the following changes that were made since the original calculations in Appendix C were made:

- The connection point (interface) for the vacuum wand hose was moved 6'-9" further away from the stuck fuel station. This required the vacuum hose be increased in length by 6 feet. Reference: *Westinghouse Products Development*, Drawing DAG-205, Rev 8, Sheet 6.
- A 90-degree elbow was added where the vacuum hose connects to connection point on the process table. Two additional 90-degree elbows were added to the 3" line connecting the process table pump to the process table manifold.
- Vacuum wand nozzle screen was changed to make it stronger.
- A full port ball valve was added in-line with the vacuum wand hose to allow for a complete shutoff of water flow through the vacuum wand.

2.0 Vacuum Wand Configuration to Calculate Head Loss

The following two figures show the location for the K factors calculated for this system:

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Figure 1 Location For K factors

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3.0 CALCULATION OF K-FACTORS

The following table is used to calculate some of the K-Factors

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TABLE 3

LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS

Description	Sketch	Additional Data	K	Source
Pipe entrance		r/d	K_e	(1)
		0.0	0.50	
		0.1	0.12	
		>0.2	0.03	
$h_L = K_e V^2 / 2g$				
Contraction		D_2/D_1	K_C $\theta = 60^\circ$ $\theta = 180^\circ$	(1)
		0.0	0.08 0.50	
		0.20	0.08 0.49	
		0.40	0.07 0.42	
		0.60	0.06 0.32	
		0.80	0.05 0.18	
		0.90	0.04 0.10	
$h_L = K_C V_2^2 / 2g$				
Expansion		D_1/D_2	K_E $\theta = 10^\circ$ $\theta = 180^\circ$	(1)
		0.0	1.00	
		0.20	0.13 0.92	
		0.40	0.11 0.72	
		0.60	0.06 0.42	
		0.80	0.03 0.16	
$h_L = K_E V_1^2 / 2g$				
90° miter bend		Without vanes	$K_b = 1.1$	(27)
$h_L = K_b \frac{V^2}{2g}$		With vanes	$K_b = 0.2$	(27)
90° smooth bend		r/d	K_b	(3) and (14)
		1	0.35	
		2	0.19	
		4	0.16	
		6	0.21	
		8	0.28	
		10	0.32	
Threaded pipe fittings		Globe valve—wide open	$K_v = 10.0$	(27)
		Angle valve—wide open	$K_v = 5.0$	
		Gate valve—wide open	$K_v = 0.2$	
		Gate valve—half open	$K_v = 5.6$	
		Return bend	$K_b = 2.2$	
		Tee		
		straight-through flow	$K_t = 0.4$	
		side-outlet flow	$K_t = 1.8$	
		90° elbow	$K_b = 0.9$	
		45° elbow	$K_b = 0.4$	

Reference: Robertson / Crowe, Engineering Fluid Dynamics, Third Edition

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CALCULATE K, VACUUM SCREEN (No 33/c)

I will calculate the actual head loss
(Not K-Factor) for the No 33/c

SCREEN AREA IS:

$$1.5" \times 1.64" = 2.46 \text{ in}^2$$

MESH IS:

$$M = \frac{1}{O + D} \quad \begin{array}{l} O = \text{opening} \\ D = \text{wire dia} \end{array}$$

$$= \frac{1}{(.25) + (.063)}$$

$$= 3.2$$

No 33/c CONFIGURATION

REFERENCE McNICHIE
WIRE CLOTH CATALOG
98SCREEN OPEN AREA $A = (1 - MD)^2$

$$A = (1 - (3.2)(.0625))^2$$

$$= .64 \quad (64\% \text{ open})$$

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Supplemental Calculations for Vacuum Wand

Flow into Nozzle is 95 gpm OR $.212 \frac{\text{ft}^3}{\text{sec}}$

Nozzle Velocity is $= \frac{Q}{A}$ $Q = .212 \frac{\text{ft}^3}{\text{sec}}$

$A = \text{Screen Area}$

$$\text{Nozzle Vel} = \left(.212 \frac{\text{ft}^3}{\text{sec}} \right) = 19.39 \frac{\text{ft}}{\text{sec}}$$

$$(.64) (2.46 \text{ in}^2) \frac{1 \text{ ft}^2}{(12 \text{ in})^2}$$

To Calculate head loss through the screen I use, "Handbook of Hydraulic Resistance", 3rd Edition, pg 523, Dia. 8-6

(next page)

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SUBJECT: Supplemental Calculations for Vacuum Wand

Screens^{24,26,34,49}Diagram
8-6

Two-plane screen

3. Two-plane screen made from bars of circular cross section

$$\zeta = \frac{\Delta p}{\rho v_0^2 / 2} = 1.28 \frac{1 - \bar{f}}{\bar{f}}$$

$\bar{f}$	0.2	0.3	0.4	0.5	0.6	0.64	0.7	0.8	0.9	0.95
ζ	5.12	2.99	1.92	1.28	0.85	0.55	0.32	0.14	0.07	

$$\zeta = \frac{\Delta p}{\rho v_0^2 / 2} = 1.28 \frac{1 - \bar{f}}{\bar{f}} = 1.28 \frac{1 - 0.64}{0.64} = 0.72$$

where:

 $\bar{f}$ = Free area = 0.64 Δp = Pressure drop (Pa) ρ = Density of WATER @ 10°C ($\frac{\text{Kg}}{\text{m}^3}$) = 999.73 $\frac{\text{Kg}}{\text{m}^3}$

CALCULATIONS AND SKETCHES SHEET

DEPARTMENT: Mechanisms Engineering

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DATE: 7/9/99

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100 K

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SUBJECT:

Supplemental Calculations for Vacuum Wand

$$W_o = \text{fluid Velocity} \left(\frac{\text{m}}{\text{sec}} \right) = 19.39 \frac{\text{FT}}{\text{sec}} \cdot \frac{.3048 \text{ m}}{1 \text{ FT}} = 5.91 \frac{\text{m}}{\text{sec}}$$

$$\Delta p = f \rho \frac{W_o^2}{2} = .72 (999.73) \frac{(5.91)^2}{2}$$

$$= 12570.72 \text{ Pa}$$

$$Pa = \text{PSI} \times 6894.8$$

$$\text{PSI} = \text{Inch H}_2\text{O} \times .0361$$

Ref MARKS STANDARD HANDBOOK, 8th Ed

$$\text{Head loss @ } K_1 = 12570.72 (\text{Pa}) \frac{1 (\text{PSI})}{6894.8 (\text{Pa})} \times \frac{1 \text{ " H}_2\text{O}}{.0361 \text{ PSI}} \times \frac{1 \text{ FT}}{12 \text{ "}}$$

$$= \boxed{4.21 \text{ FT}}$$

 K_2 Transition Rectangle to Round

$$\text{wet Dia} = D_h = \frac{4A}{P} = \frac{4(1.18)(1.50)}{2(1.18) + 2(1.50)} = 1.32 \text{ "}$$

Area
perimeter

$$\frac{D_h}{D_2} = \frac{1.32}{1.50} = .88 \quad (\text{EXPANSION TABLE 3})$$

$$\theta = 10^\circ$$

$$K_1 \approx .03$$

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$$K_3 \text{ long } 90^\circ, \frac{r}{d} = \frac{8.0}{1.5} = 5.33$$

REF TABLE 3

$$\text{FOR } 2 \left[\begin{array}{l} \frac{r}{d} = 6, K = .21 \\ \frac{r}{d} = 4, K = .16 \end{array} \right] .05$$

$$K_3 = .16 + \left(\frac{.05}{2} \right) (5.33 - 4) = .19$$

$$K_4 \text{ straight Tube } 47.5'' \text{ long, } 1.5'' \text{ ID}$$

$$\text{REF APPENDIX C CALC FOR } K_C \quad Re = \frac{123.9 \text{ dpv}}{\mu}$$

$$d = \text{dia (in)} = 1.5$$

$$\rho = \text{Wastl density } \left(\frac{\text{Lb}}{\text{Ft}^3} \right) = 62.4$$

$$V = \text{Fluid Velocity } \left(\frac{\text{Ft}}{\text{Sec}} \right)$$

$$\mu = \text{Viscosity (centipoise)}$$

$$d = 1.5$$

$$\rho = 62.41 \frac{\text{Lb}}{\text{Ft}^3}$$

$$\mu = 1.3 \text{ (Crane A-3)}$$

$$V = .212 \frac{\text{Ft}^3}{\text{Sec}} = 17.28 \frac{\text{Ft}}{\text{Sec}}$$

$$\pi \left(\frac{1.5}{24} \right)^2$$

$$Re = \frac{123.9 (1.5) (62.41) (17.28)}{1.3} = 1.54 \times 10^5$$

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SUBJECT: Supplemental Calculations for Vacuum Wand

$$f \approx .0162 \quad (\text{Crane A-24})$$

$$K_4 = \frac{fL}{D} = \frac{.0162 \left(\frac{47.5}{12} \right)}{\left(\frac{1.5}{12} \right)} = .513$$

[K5] Hose Coupler - Assume [K5] = .50
Assumption made in original BNFL CALC

[K6] Smooth Plastic Hose 36' LONG, 1 1/2 ID
Re & f same as for [K4] factor calculation

$$K_6 = \frac{fL}{D} = \frac{.0162 (36')}{\left(\frac{1.5}{12} \right)} = 4.660$$

[K7] Hose Coupler, again Assume [K7] = .5

[K8] Full Flow VALVE, PORT ID = 1.5"

contraction, $\theta = 180$, $\frac{D_2}{D_1} = \frac{1.5}{1.610} = .93$

$$K_{8A} \approx .10$$

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$K_8 = K_{8A} + K_{8B}$
contraction $\rightarrow$ expansion

Expansion, $\theta = 180$, $\frac{D_1}{D_2} = \frac{1.5}{1.610} = .93$

$$K_{8B} \approx .16$$

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$$K_8 = K_{8a} + K_{8b} = .10 + .16 = .26$$

$$K_9 \text{ smooth } 1\frac{1}{2}'' \text{ PIPE } \times 10'', 1.610'' \text{ ID}$$

$$Re = \frac{123.9 (d) P V}{\mu} \quad \left. \begin{array}{l} P = 62.41 \\ \mu = 1.3 \end{array} \right\} \text{ same as } K_4 \text{ calc}$$

$$V = \frac{Q}{A} = \frac{.212}{\left(\frac{1.610}{24}\right)^2 \pi} = 15 \frac{\text{FT}}{\text{SEC}}$$

$$Re = \frac{123.9 (1.610) (62.41) (15)}{1.3} = 1.44 \times 10^5$$

$$\bar{f} \approx .0166$$

$$K_9 = \frac{\bar{f} L}{D} = \frac{.0166 \left(\frac{10}{12}\right)}{\left(\frac{1.610}{12}\right)} = .103$$

$$K_{10} \text{ } 90^\circ \text{ Elbow, } 1\frac{1}{2}'' \text{ PIPE, } \frac{r}{d} = \frac{2.25}{1.610} = 1.4$$

ANSI B16.9-93
Long Radius

$$\left[\begin{array}{l} \frac{r}{d} = 1, K = .35 \\ \frac{r}{d} = 2, K = .19 \end{array} \right] \cdot .16 \quad [\text{From table 3}]$$

$$K_{10} = .35 - .16 (.41) = .284$$

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SUBJECT: Supplemental Calculations for Vacuum Wand

$$K_{11} = \text{Hose Coupler} = .50, \text{ as before}$$

$$K_{12} \quad 1\frac{1}{2} \text{ PIPE, } 6'' \text{ long}$$

$$\left. \begin{array}{l} Re = 1.44 \times 10^5 \\ f = .0166 \end{array} \right\} \text{ same as } K_9 \text{ calc}$$

$$K_{12} = \frac{fL}{D} = \frac{(.0166)(\frac{6}{12})}{(\frac{1.610}{12})} = .062$$

$$K_{13} \quad \text{Welded } 1\frac{1}{2} \text{ } 90^\circ \text{ Elbow}$$

Same as K_{10}

$$K_{13} = K_{10} = .284$$

$$K_{14} \quad 1\frac{1}{2} \text{ to } 3'' \text{ expansion, Welded Fitting}$$

From table 3, assume $\Theta = 10^\circ$

$$\frac{D_1}{D_2} = \frac{1.610}{3.068} = .525$$

$$2 \left[\begin{array}{l} \frac{D_1}{D_2} = .40, K = .11 \\ \frac{D_1}{D_2} = .60, K = .06 \end{array} \right] .05$$

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SUBJECT: Supplemental Calculations for Vacuum Wand

$$K_{14} = .11 - \frac{.05}{.20} (.525 - .40) = .079$$

K_{15} 3" welded T, Flow through side outlet
From table 3.

$$K_{15} = 1.8$$

NOTE Flow beyond this point is full 150 gpm
OR $(.334 \frac{ft^3}{sec})$

$$K_{16} \text{ 3", 90° Elbow, } \frac{r}{d} = \frac{4.5}{3.068} = 1.5 \quad \text{ANSI B16.9-93 Long Radius}$$

table 3

$$\left[\begin{array}{l} \frac{r}{d} = 1, K = .35 \\ \frac{r}{d} = 2, K = .19 \end{array} \right] .16$$

$$K_{16} = .35 - .16 (1.5 - 1) = .27$$

$$K_{17} \text{ 3" coupling } K_{17} = .50, \text{ as before}$$

$$K_{18} \text{ smooth 3" Hose, 3" ID, 12' long}$$

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$$Re = \frac{123.9 (d) \rho V}{\mu} \quad \left. \begin{array}{l} P = 62.41 \\ \mu = 1.3 \end{array} \right\} \text{same as } K_9 \text{ calc.}$$

$$V = \frac{Q}{A} = \frac{.334 \frac{FT^3}{SEC}}{\left(\frac{3}{24}\right)^2 \pi (FT)} = 6.80 \frac{FT}{SEC}$$

$$Re = \frac{123.9 (3) (62.41) (6.80)}{1.3} = 1.2 \times 10^5$$

$$f \approx .0173$$

$$K_{10} = \frac{f L}{D} = \frac{(.0173) (12)}{\left(\frac{3}{12}\right)} = .830$$

$$K_{19} \quad 3" \quad 90^\circ \text{ ELBOW}$$

$$\text{same as } K_{16}$$

$$K_{19} = K_{16} = .27$$

$$K_{20} \quad 3" \text{ Coupler}$$

$$K_{20} = .50, \text{ AS BEFORE}$$

CALCULATIONS AND SKETCHES SHEET

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The following table tabulates K FACTORS,
Fluid Velocities, and HEAD LOSSES

(next page)

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DEPARTMENT: Mechanisms
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Flows →

	FT ³ /sec	GPM
Vacuum Wand	0.212	95.000
ByPass	0.122	55.000
Total Flow	0.334	150.000

Calculation of Head Loss From Vacuum nozzle to Pump

K Label	Description	Flow (GPM)	K Factor	V (Ft/sec)	Head Loss Ft	Dia (in)
For Figure 1 :						
K1	Nozzle (screen loss + Entry Loss)	95.000	—	19.390	4.210	—
K2	Expansion to flow	95.000	0.030	17.275	0.139	1.5
K3	Long 90, R/D = 8.0/1.50 = 5.33	95.000	0.190	17.275	0.880	1.5
K4	1.625 x .058 wall smooth tube, 47.5 inches long	95.000	0.513	17.275	2.377	1.5
K5	Hose Coupler (Hose to Wand)	95.000	0.500	17.275	2.317	1.5
K6	Smooth Plastic Vacuum Hose, 36 ' Long	95.000	4.666	17.275	21.623	1.5
K7	Hose Coupler (Oposite end of Vacuum hose)	95.000	0.500	17.275	2.317	1.5
K8	Full flow valve	95.000	0.260	17.275	1.205	1.5
K9	1-1/2 Sch 40 Pipe - approx 10"	95.000	0.103	14.995	0.360	1.61
K10	smooth 90 elbow	95.000	0.284	14.995	0.992	1.61
K11	Hose coupler	95.000	0.500	17.275	2.317	1.5
For Figure 2 :						
K12	1-1/2 " Smooth Straight Pipe, 6" long	95.000	0.062	14.995	0.217	1.61
K13	Welded 1-1/2" 90	95.000	0.284	14.995	0.992	1.61
K14	1-1/2 to 3" Expansion	95.000	0.079	14.995	0.276	1.61
K15	3" Welded T	95.000	1.800	4.130	0.477	3.068
K16	3" 90 elbow - r/d =1	150.000	0.270	6.506	0.177	3.068
K17	3" Coupler	150.000	0.500	6.506	0.329	3.068
K18	Smooth 3" Rubber Hose, 144" long	150.000	0.830	6.804	0.597	3
K19	3" 90 elbow - r/d =1	150.000	0.270	6.506	0.177	3.068
K20	3" Coupler	150.000	0.500	6.506	0.329	3.068

Total Head Loss: 42.31

Calculation of NPSHA (33.9 - 0.42-HEAD LOSS + 11.3)

+ 2.473 Ft

OK > 0

A minimum amount of suction pressure (head) is needed for a pump to operate without cavitating. The term used to describe this suction pressure is Net Positive Suction Head (NPSH). The amount of NPSH available to the pump from the suction line is termed NPSHA. The calculated NPSHA is must be positive to avoid cavitation.