CALCULATION ANALYSIS

Nuclear Engineering Department

HEP&T SECTION SHEET 1 OF 3

I.D. NO. HXP900904JEW	PLANT Cook Nuclear UNIT 1 2
SAFETY RELATED YES ✓ NO ___ SYSTEM Residual Heat Removal (RHR)	COMPANY Indiana Michigan Power
TITLE NPSH CALCULATION	CALCULATED BY: John E. Wagner 9/11/90 DATE
FILE LOCATION 41.2	CHECKED BY: John J. Rifak 10/30/90 DATE
MICROFILM NO. ___	APPROVED BY: J.A. Berns 10/30/90 DATE

PROBLEM DESCRIPTION: Determine if there is adequate NPSH with the RHR Pumps taking Suction From the Reactor Coolant System (RCS) hot leg at Saturated Conditions.

DESIGN BASIS OR REFERENCES: Westinghouse Owners Group (WOG) Letter OG-90-44 dated August 2, 1990.

METHOD OF VERIFICATION: Reviewed input & method

REVISIONS

NO.	REASON FOR CHANGE	PREP'D BY	DATE	CKD. BY	DATE	APVD. BY	DATE

COOK NUCLEAR PLANT
NED RECORD-NED COPY
SECTION HEP&T
ENGINEER JJ Rifak
DATE 10-31-90
☑ PLANT LIFETIME
DATE TO PLANT N/A
☐ NON PERMANENT
MINIMUM RETENTION ___ YRS.

METHOD OF VERIFICATION: ___

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RHR PUMP NPSH AT SATURATED CONDITIONS

Purpose

Westinghouse Owners Group (WOG) letter OG-90-44 dated August 2, 1990, identified a concern with regard to the operation of the residual heat removal (RHR) pumps while the plant is at half loop.

The letter states that, typically, a maximum reactor coolant system (RCS) temperature of 160°F is used to calculate the available NPSH for the RHR pump. While reviewing Generic Letters 87-12, "Loss of RHR while the RCS is partially filled," and 88-17, "Loss of decay heat removal," it became clear to the WOG that under these conditions, the RHR pump could be operating in the RHR mode taking suction from the RCS hot leg at saturated rather than subcooled conditions.

This calculation will determine if adequate NPSH is available to operate the RHR pump under saturated conditions, which could occur as a result of a loss of RHR event at mid-loop.

Conclusion

As shown on the attached graph (Attachment 1), there is adequate NPSH available for the RHR pumps to operate when they are taking suction from the RCS at saturated conditions (212°F when vented to atmospheric pressure).

Inputs

1. Westinghouse Owners Group (WOG) Letter OG-90-44 dated August 2, 1990, (Attachment 4)

2. RCS level at half-loop, 614"-0" per procedure 2-OHP-4021.002.005

3. RHR pump suction elevation 575'-0" per Drawing No. 1-5415-16

4. Hydraulic friction loss calculation program HFLC5 available in the HEP&T Section file 13.22.2.1

5. Ingersoll-Rand curve N-315 typical for the RHR pumps at Cook Nuclear Plant (Attachment 5)

6. The computer print-out attached is output from the HFLC5 program (Attachment 2). The input for the program (flow, pipe length, fittings and valves) is tabulated on the attached pipe friction data sheet (Attachment 3). The data sheet was generated from the drawings listed below:

1-5421	1-RH-28
1-5415	1-SI-4
1-RH-29	1-SI-2

7. Net positive suction head (NPSH) formula taken from Cameron Hydraulic Data, 16th edition Pg 1-10

For positive (flooded) suction

$NPSH = h_a - h_{vpa} + h_{st} - h_{fs}$

where: h_a = absolute pressure (in feet) on surface of the liquid supply level

h_{vpa} = vapor pressure of the liquid at the temperature being pumped (in feet)

h_{st} = static height (in feet) that liquid supply level is above or below the pump centerline

h_{fs} = all suction line losses (in feet)

Calculation

Net Positive Suction Head available

$NPSH_a = h_a - h_{vpa} + h_{st} - h_{fs}$

where: fluid = water at 212^{o}F

h_a = 14.696 psi (33.96 feet) - 1 atmosphere

h_{vpa} = 14.696 psi (33.96 feet)

(Standard Handbook for Mechanical Engineers 7th edition - Marks, Table 28, page 4-38)

h_{st} = 614 - 575 = 39 feet

half loop elevation = 614 feet

pump centerline = 575 feet

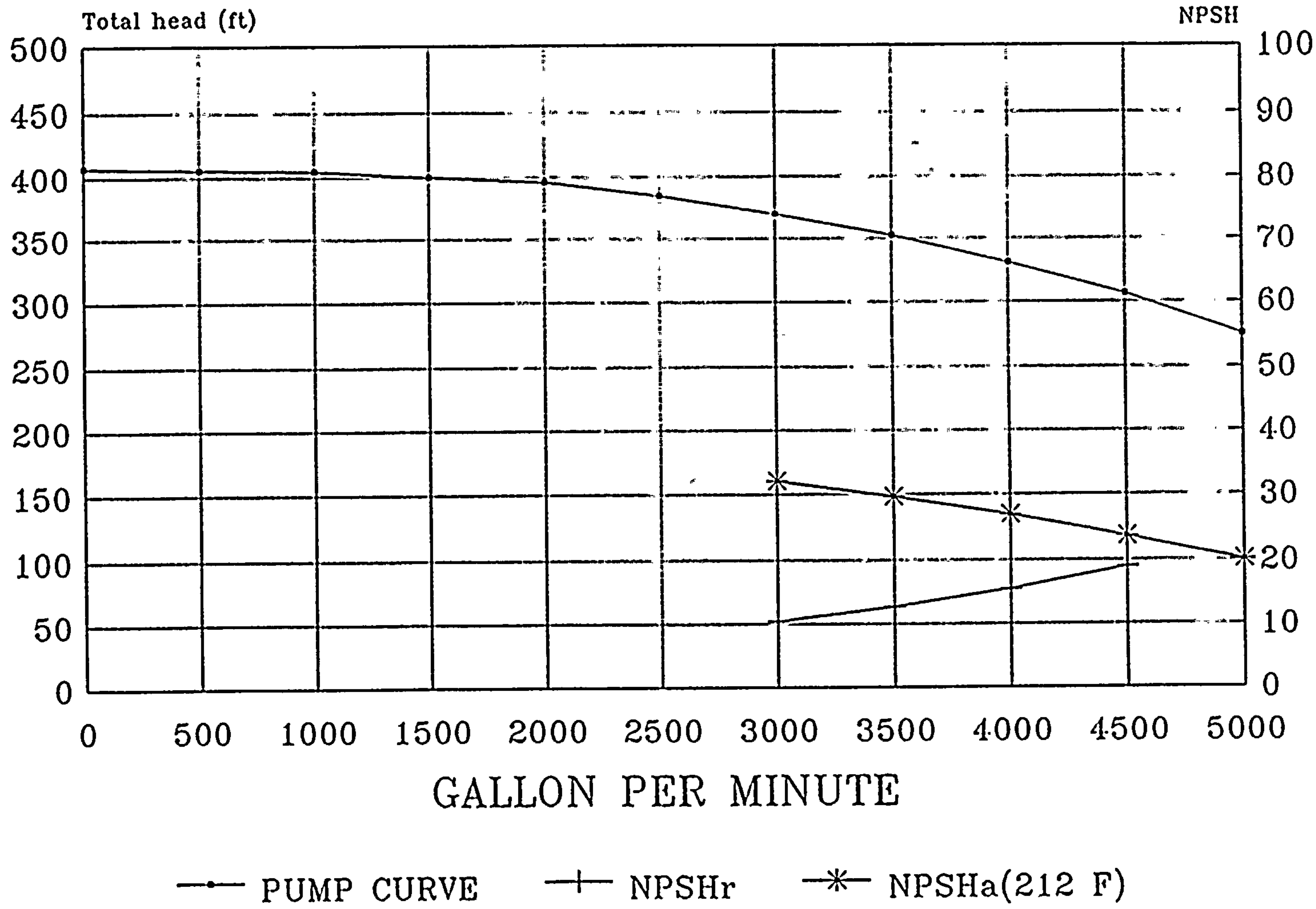
h_{fs} = 6.93 feet with fluid flow of 3000 gpm (ref. Attachment 2)

$NPSH_a$ = 33.96 - 33.96 + 39 - 6.93
= 32.07 feet

Similarly $NPSH_a$ was calculated for the following flows:

Flow (gpm)	NPSHa (feet)
3000	32.07
3500	29.62
4000	26.83
4500	23.65
5000	20.1

Residual Heat Removal Pump



Attachment 1
HXP90043EW

JEW 10/26/90

a:rhrnpsh

. PIPE FRICTION CALC - INPUT FILE IS-a:rhrnpsha

[illegible] INPUT DATA FOR THE HFLC5 SYS. RES. CALC.
CONSISTS OF THE FOLLOWING DATA:
T - TEMPERTURE DEG F
E - PIPE ABSOLUTE ROUGHNESS (FT.)
N - FIRST PIPE SEGMENT NUMBER
N1 - LAST PIPE SEGMENT NUMBER
QDES - DESIGN FLOW THRU PIPE SEGMENT (GPM)
QMIN - MINIMUM FLOW THRU PIPE SEGMENT (GPM)
QMAX - MAXIMUM FLOW THRU PIPE SEGMENT (GPM)
QDELT - FLOW INCREMENT THRU PIPE SEGMENT (GPM)
D - PIPE SEGMENT INTERNAL DIA. (IN.)
L - PIPE SEGMENT LENGTH (FT.)
K - PIPE SEGMENT K FACTORS
L/D - PIPE SEGMENT L/D FACTORS

FOLLOWING IS YOUR INPUT DATA

T	E	N	N1
212.00	.00015	1	1

QDES	QMIN	QMAX	QDELT	D	L	K	L/D
3000.00	3000.00	5000.00	500.00	13.124	170.35	.50	465.00

FOLLOWING IS HFLC5 RESULTS

WATER TEMP.(F) = 212.00
DENSITY(LBM/CUFT) = 59.74
ABS VISCOSITY(LBM/SEC/FT) = .190201E-03
PIPE ABS ROUGHNESS(FT) = .150000E-03

PIPE SEG NO 1 PIPE DIA(ID-IN) = 13.124

FLOW-GPM	VEL(FPS)	LHD(FT)	KHD(FT)	LDHD(FT)	TOT HD(FT)
3000.0	7.12	1.64	.39	4.90	6.93
3500.0	8.30	2.22	.54	6.63	9.38
4000.0	9.49	2.88	.70	8.59	12.17
4500.0	10.67	3.63	.89	10.84	15.35
5000.0	11.86	4.47	1.09	13.34	18.90

REYNOLDS NUMBER FRICTION FACTOR TABLE

PIPE SEG	DES. FLOW	RE.NO.	F-FACTOR	HEAD LOSS
1	3000.0	2444029.0	.0134	6.93

SHEET 1 OF 1
PLANT Cook Nuclear
BY Jew DATE
HXP900904JEW

PIPE FRICTION CALCULATION DATA SHEET

RHR System

SYSTEM From 29" Line (Half Loop) to RHR Pump Suction

G. REF. 1-5421, 1-5415, 1-RH-29, 1-RH-28, 1-SI-4, 1-SI-2

FLUID TEMP. (°F) 212 PIPE ABS. ROUGHNESS (FT) .00015 PIPE SEGMENT NUMBER 1

①FLUID FLOW (GPM) 3000 ①PIPE I.D. (IN) 13.124 PIPE EL. 614'-0" TO EL. 575'-0'

STRAIGHT PIPE LENGTHS (Feet)	FITTINGS	NUMBER	*K OR L/D	ΣK	ΣL/D
2.34	GATE VALVE	III	13		39
1.75	GLOBE VALVE		340		
1.75	BUTTERFLY VALVE		40		
10.61	SWING CHECK		135		
21.38	90° STD. ELBOW		30		
5.33	90° S.R. ELBOW	III	50		150
7.75	90° L.R. ELBOW	~~IIII~~ ~~IIII~~	20		200
4.42	45° STD. ELBOW	①	16		16
6.75	45° S.R. ELBOW		26		
4.92	180° CLOSE RETURN		50		
7.0	STD. TEE RUN	III	20		60
29.25	STD. TEE BRANCH		60		
.5	* MITRE BENDS		1.2(1-COS θ)		
21.75	* LATERAL ◁ OUTLET		1.0		
15.0	* LATERAL ◁ INLET		0.5		
2.583	* STRAIGHT RUN LATERAL		0.15		
10.499	* PIPE ENTR PROJ. INWD.		0.78		
10.67	* " " SHARP EDGE	1	0.50	.50	
2.5	* " " WELL ROUND		0.04		
.92	* PIPE EXIT SHARP EDGED		1.0		
1.83	* ORIFICE (C_D = .61)		2.69 RF/β^4		
.85	* SUDDEN CONTRACTION †		$.5(1-\beta^2)$		
	* SUDDEN INCREASE †		$(1-\beta^2)^2$		
	* VALVE, MISCELLANEOUS		$891.4\, d^4/C_v^2$		
	MISC				
TOTALS ① 170.352				① 0.50	① 465

* ITEMS ARE "K" VALUES ONLY † BASED ON SMALLER PIPE DIAMETER
β = d/D RF = RECOVERY FACTOR

FK-9-1-72

RECEIVED
AUG 8 1990
MANAGERIAL DEPARTMENT

Attachment 4
HXP900904JEW

A DECADE OF SERVICE WOG 10TH ANNIVERSARY 1979-1989

Westinghouse Owners Group

OG-90-44

August 2, 1990

To: Westinghouse Owners Group Primary Representatives
Operations Subcommittee Representatives
Analysis Subcommittee Representatives

Subject: Westinghouse Owners Group
<u>RHR Pump NPSH At Saturated Conditions</u>

This letter is to notify all WOG utilities of a concern associated with operation of the RHR pump at mid-loop conditions that may apply at some plants.

When the plant is operating in the Residual Heat Removal (RHR) mode, the net positive suction head (NPSH) for the RHR pump is calculated based on subcooled conditions in the Reactor Coolant System (RCS). Typically, a maximum RCS temperature of 160^{o}F is used to calculate the available NPSH for the RHR pump. Since the Reactor Coolant Pump (RCP) is assumed to be operating above this temperature, the RCS will be pressurized to approximately 400 psig to ensure proper RCP operating conditions and NPSH for the RHR pump is not a concern.

Over the past several years, a significant amount of effort has been expended by the utilities and Westinghouse to address NRC Generic Letters 87-12, "Loss of Residual Heat Removal (RHR) While the Reactor Coolant System (RCS) is Partially Filled" and 88-17, "Loss of Decay Heat Removal". In responding to the generic letters, it has become clear that under these conditions the RHR pump could be operating in the RHR mode taking suction from the RCS hot leg at saturated rather than subcooled conditions. In addition, the Westinghouse Owners Group has recently issued the Abnormal Response Guideline, ARG-1, "Loss of Residual Heat Removal While Operating at Mid-Loop Conditions", which directs the operator to run the RHR pump at saturated conditions if the RCS has heated up as a result of losing RHR while at mid-loop.

The available NPSH for the RHR pump will be much less at saturated RCS conditions than subcooled conditions. A preliminary investigation of this situation indicates that for some plants adequate NPSH may not be available at saturated conditions in the RCS, especially at higher RHR pump flowrates. A typical range of RHR pump flowrates is 500 gpm to 3,000 gpm. Based upon the results of this preliminary review, each plant should perform an evaluation to determine if adequate NPSH is available to operate the RHR pump under saturated conditions in the RCS, which could occur as a result of a loss of RHR event at mid-loop.

Should you have any questions concerning the above information, please contact Russ Oft at Westinghouse, 412-374-4465 or myself, 603-474-9574, X3347.

Very truly yours,

L.A. Walsh, Chairman
Operations Subcommittee
Westinghouse Owners Group

LAW/RROft

cc: Steering Committee
J.B. George, TU Electric
C.K. McCoy, Georgia Power
K.J. Voytell

1248G

G-1226 5M 4-69

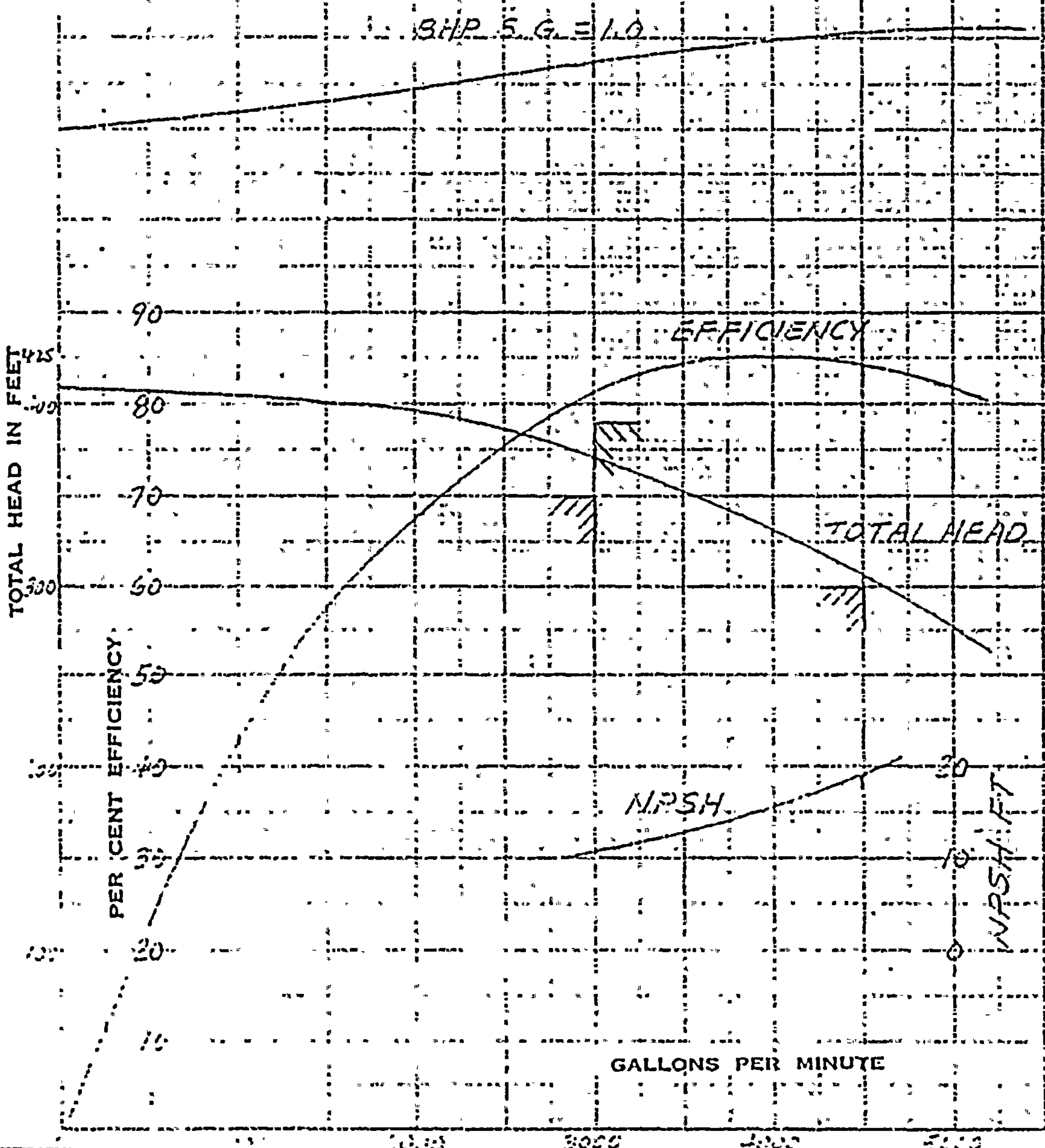
PHR "E" PP

CURVE NO. 11-3
DATE 6-18-71

CURVES ARE APPROXIMATE. PUMP 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° F. AND NOT OVER 15 FOOT SUCTION LIFT.

IMPELLER PATT. NO. 8X20A3B DIA. 17 1/8"

DIFFUSOR PATT. NO.



THIS CERTIFIES THAT THIS CURVE IS BASED ON ACTUAL TEST PERFORMANCE

Will Albert

W. D. Albert 6/18/71

WESTINGHOUSE SPIN NO AEP-ACAPRH-010

CHARACTERISTIC CURVE

NO. 8X20 TYPE W PUMP

1780 R. P. M.

PUMP NO. A6929 ORDER NO. 316-33294 ITEM 29

INGERSOLL-RAND COMPANY

CAMERON PUMP DIVISION

DATE 6-18-71 CURVE F-315

K & E 99 1101 82937 N.Y.

NEF-6.4B
(9/90)

NED CALCULATION VERIFICATION CHECKLIST

Calculation I.D. No.: HXP 900904 JEW

Title: NPSH Calculation

Authorized Verifier: John J. Ripak Date: 10/30/90

Calculation Preparer: John E. Wagner Date: 10/30/90

The Authorized Verifier shall use this checklist to evaluate the calculation against the following questions. A basis for the response to all questions (reference to a section of the calculation or other document) shall be noted in the "Remarks" column as well as resolution of verifier's comments.

	Checked*	Remarks
1. Was an appropriate method used?	X	Use of the friction calc program, HFLC5 to calculate NPSH available is appropriate
2. Are the results reasonable compared to the input?	X	Operation at the design runout flow of 4500 GPM without cavitation is reasonable
3. Are the results numerically correct?	X	The application of the HFLC5 output to the basic NPSH equation and curve was checked.
4. Are the equations used correct and the reference documented?	X	The calculation was based on the proper application of commonly used NPSH equation / methodology
5. Were the correct inputs used and their sources documented?	X	The correct inputs were used and were documented on pages 2 + 3
6. Are the assumption(s) reasonable?	NA	No assumptions were made.
7. Does the calculation include the necessary documentation as described in NEP 6.4, Sections 5.0 and 6.0?	X	The calculation was properly documented.
8. Is the calculation deemed acceptable?	X	The review has determined that this calculation correctly determines the NPSH conditions of the described system

* Legend X = Yes NA = Not Applicable

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Pipe Length and Fittings | 42 ECCW Print 2-CCW-39

14" PIPE

TEE BRANCH

3.5 ft

90° SR

2.97 ft

45°

TEE RUN

9.35 ft

45°

20.89 ft

90°

6.58 ft

90°

15.25 ft

90°

4.60 ft

45°

68.5 ft

45°

3.29 ft

45°

14.16 ft

90°

2.83 ft

TOTAL > 152.32

1 90° EL SR
4 90° EL LR
5 45° EL
1 TEE RUN
1 TEE BRANCH

18" PIPE

TEE BRANCH
14"x18" DIFFUSER

21.5 ft

90°

9.91 ft

2.16 ft

TEE BRANCH

2.25 ft

BUTTER FLY VALVE

90° EL SR

~~4.33 ft~~
2.66 ft

TEE BRANCH

TOTAL = 42.81 ft

1 90° EL SR
1 90° EL LR
3 TEE BRANCH
1 BUTTERFLY VALVE
1 14x18 DIFFUSER

Walter E. McElroy
10/10/97