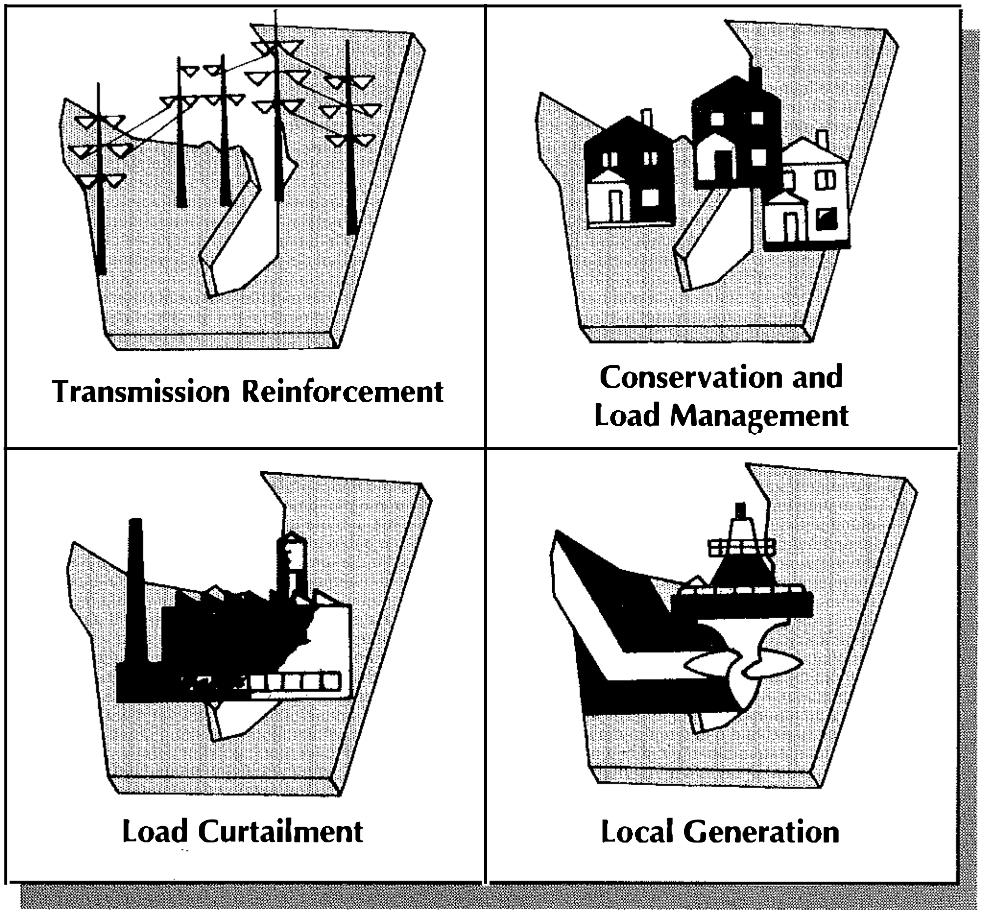
File Copy

Puget Sound Area Electric Reliability Plan

Transmission Reinforcement Analysis
Appendix E



Transmission Reinforcement

Conservation and Load Management

Load Curtailment

Local Generation

Bonneville
POWER ADMINISTRATION

April 1992

DRAFT ENVIRONMENTAL IMPACT STATEMENT

PUGET SOUND AREA ELECTRIC RELIABILITY PLAN

Appendix E
Transmission Reinforcement Analysis

Bonneville Power Administration
U.S. Department of Energy

Prepared as part of a coordinated plan to address a power system problem in the Puget Sound Area. Utilities participating in planning include: Bonneville Power Administration, Puget Sound Power and Light, Seattle City Light, Snohomish County Public Utility District No. 1, and Tacoma City Light.

April 1992

PSAERP Transmission System Reinforcement Options Engineering Report

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PSAERP Transmission System Reinforcement Options 3-9-92
by Marv Landauer - BPA

The purpose of this report is to provide an update of the latest study work done on transmission system options. Much of the development work for these options is included in the attachments of this report. Also included in the attachments are 2 reports analyzing the voltage stability of the Puget Sound transmission system (one by BPA and one by General Electric) and a review by Power Technologies, Inc. of the BPA voltage stability analysis and reactive options.

Five transmission line options and several reactive options are presently being considered as possible solutions to the PSAERP by the Transmission Team. The first two line options would be built on new rights-of way adjacent (as much as possible) to existing corridors. The reactive options would optimize the existing transmission system capability by adding new stations for series capacitors and/or switchgear. The other three line options are rebuilds or upgrades of existing cross mountain transmission lines. These options are listed below and include a preliminary assessment of the additional transmission system reinforcement required to integrate the new facilities into the existing transmission system. Plans were designed to provide at least 500 MVAR reactive margin.

The transmission line options were derived from earlier study work that was summarized in "Puget Sound Reinforcement Transmission Options" and "New Cross Mountain Transmission Line Alternative: The Crosstie", which are attached. The initial Transmission Options study report recognized the value to system performance of adding an entirely new circuit rather than rebuilding an existing one. However, siting realities require that rebuild options be considered. Typically, the most attractive rebuild options would be the lowest capacity (lowest voltage) circuits. But because of corridor location, length and terminal proximity, the rebuild options listed below appear to be the most promising. Diagrams of each option are also attached.

ASSUMED SYSTEM ADDITIONS

The following equipment is assumed to be in service: Echo Lake substation (which is referred to as Snoqualmie in the studies); 300 MVAR SVC's at Maple Valley and Keeler; LDC's at Coulee, Centralia, John Day, The Dalles and Bonneville; and new 230-kv capacitor banks at Tacoma, Olympia and Snoking and the Option 14 reactive plan (two 500-kV capacitor groups at Raver, Echo Lake and Monroe). These additions will meet the winter 1995-96 load level as shown in QV Curve-0. No local generation additions beyond 1993 or accelerated conservation programs have been added to these studies.

OPTION 1: New Chief Joseph-Monroe/Echo Lake 500-kV double circuit line

A new double-circuit 500-kV line would be built on new right-of way from Chief Joseph substation west toward Monroe following the existing Stevens Pass corridor. In the vicinity of Skykomish the double circuit line would split, with one circuit continuing on to Monroe following the existing corridor. The other circuit would head southwest on a new corridor toward Echo Lake substation. A new 500/230-kV transformer would be needed at the existing Snoking substation. The existing 230-kV line that feeds this substation from Monroe was designed for 500-kV operation and would need to be converted at that time. A second Bothell-Snoking 230-kV line would also be needed and this line could be obtained by reconnecting existing lines in the area and/or constructing new lines. A second Chief Joseph 500/230-kV transformer will also be needed and this can be added in the existing substation. This plan is analyzed in detail in "Puget Sound Reinforcement Transmission Options" in Attachment 1.

OPTION 2: New Chief Joseph-Echo Lake 500-kV double circuit line

A new double-circuit line would be built on new right-of way from Chief Joseph substation southwest by Sickler substation to Echo Lake substation following the existing Snoqualmie Pass corridor. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1. This plan is also analyzed in detail in "Puget Sound Reinforcement Transmission Options" in Attachment 1.

OPTION 3: Reactive additions (Voltage Support-2)

This plan involves building a new substation in the vicinity of Naneum, tying all the 500-kV lines together. Series compensation would be added west of this new station on the old Coulee-Raver lines (19 ohms and 3150 amps). In the early 2000's, additional series compensation would be needed on the other two lines west of Naneum, (20 ohms and 2200 amps on the old Sickler-Raver line and 23 ohms and 2000 amps on the old Vantage-Raver line). Also an upgrade of the Columbia series capacitors to 2700 amps will be needed at this time. An alternative to the latter two capacitor banks would be to increase the 19 ohm series capacitor banks on the Coulee-Raver lines to 26 ohms and 4200 amps. With this cross mountain reinforcement, a new transformer will be needed at Snoking in 2000 (as discussed in Option 1). Also, a second Raver-Echo Lake 500-kV line or the Chief Joe-Monroe series compensation, as discussed in Attachment 3, will be needed in about 2001. A third shunt capacitor group is also needed in the vicinity of Raver in about 2001. (These later additions may not be needed until after 2003 in the PSAERP preferred option because the accelerated conservation and expected resources will reduce flows into the Puget Sound area.)

Many other options and variations were also studied. Refer to Attachment 3 for the development of these options. It should be noted that substation names of Naneum, Kittitas and Schultz are interchangeable in the Reactive Options analysis.

OPTION 4: Chief Joseph-Snohomish 345-kV upgrade with Crosstie

The existing Chief Joseph-Snohomish 345-kV double circuit line (through the Stevens Pass corridor) would be upgraded to a single-circuit 500-kV line in this option (using the existing right-of-way). This upgrade would be accomplished by replacing the top of the existing double circuit towers with new single circuit ones and adding three new conductors. The feasibility of this transmission line upgrade is still being investigated. A new single circuit line would also be needed between Columbia, Sickler and a new substation on the Stevens Pass corridor, tentatively called Mad River (near Chumstick). The rebuilt Chief Joe-Snohomish line would be connected to Monroe substation and a new 500/230-kV transformer would be added at Snohomish to replace the 345/230-kV transformers that will be removed. A third Bothell-Snohomish 230-kV line would be needed with this transformer and could be obtaind by connecting one of SCL's Skagit River lines into Snohomish or by building a new circuit. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1. An additional 30% series compensation would be needed at a new site near Naneum on the existing Coulee-Raver lines. Eventually a second Raver-Echo Lake 500-kV line (adjacent to the existing line) will also be needed. This plan is analyzed in detail in the report entitled "New Cross Mountain Transmission Line Alternative: The Crosstie" in Attachment 2.

OPTION 5: Chief Joseph-Snohomish 345-kV rebuild

The existing Chief Joseph-Snohomish 345-kV line (through the Stevens Pass corridor) would be replaced by a new double-circuit 500-kV line in this option (using existing right-of-way). This new line would be connected to Monroe substation and a new 500/230-kV transformer would be added at Snohomish to replace the 345/230-kV transformers that will be removed. A second Bothell-Snohomish 230-kV line would be needed with this transformer and could be obtaind by connecting one of SCL's Skagit River lines into Snohomish or by building a new circuit. One of the circuits between Monroe and Snohomish would operate at 500-kV to supply the new transformer, the other would operate at 230-kV. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1.

OPTION 6: Rocky Reach-Maple Valley 345-kV rebuild with Crosstie

The existing Rocky Reach-Maple Valley 345-kV line (through the Snoqualmie corridor) would be replaced by a new double-circuit 500-kV line in this option (using existing right-of-way). This new line would be connected to Echo Lake substation and a new 500/230-kV transformer would be added at Maple Valley to replace the 345/230-kV transformer that was removed. Since Sickler substation is not a strong enough source for a new double circuit line, it will have to be reinforced. Many options exist to do this (as discussed in Attachment 4), but the following option has some desirable traits. A double circuit line would be added between a new Columbia switching station (adjacent to the existing series capacitor yard and 230/115-kV substation) and this new line following the Columbia-Rocky Reach 230-kV line. These additions would create a Sickler-Echo Lake line, a Columbia-Echo Lake line and a Columbia-Sickler line. A new single-circuit line would also be needed between Columbia and the Coulee-Hanford line, following the 115-kV right-of-way east toward the old Rocky Ford substation site. A small switching station would be required there. A second Sickler 500/230-kV transformer will also probably be needed. Eventually a Snoking 500/230-kV transformer would be needed as described in Option 1.

SUMMARY

The performance of these options is summarized in Table 1. All of these options will solve the voltage stability problems in the Puget Sound Basin beyond the 2003 study period. The two new line options (Options 1 and 2) are somewhat stronger than the other plans for outage conditions since they contain more transmission lines. The upgrade of the Chief Joseph-Snohomish line to single circuit 500-kV (option 4) is the weakest of the transmission options being investigated, however it should be the least expensive. This option would be slightly better than the Reactive Options for solving the voltage stability problems.

All of the transmission line options save a substantial amount of transmission system losses. Option 5, the rebuild of the Chief Joseph-Snohomish 345-kV to 500-kV double-circuit would save the most. The next best loss-saver is Option 1. Options 2, 4 and 6 have similar loss saving that are somewhat lower. The Reactive option saves the least amount of losses.

TABLE 1: COMPARISON OF TRANSMISSION REINFORCEMENT PLANS FOR PSAERP

OPTION	PEAK SYSTEM LOSS SAVINGS		REACTIVE MARGIN
	MW - 2004		MVARS - 2004
	BPA	PNW	2-line/1-line/Trojan(3) margins include unused MSC QV curves are attached
1. New Chief Joe-Monroe/Echo Lake 500-kV double circuit	86	108	1100/900/900
2. New Chief Joe-Echo Lake 500-kV double circuit line	72	90	1000/900/900
3. Voltage Support 2 Switchyard and series caps 19/19/20/23 ohms	18 (1)	27 (1)	700/400/550 (2)
4. Chief Joe-Snohomish 345-kV upgrade to 500-kV single circuit	75	97	500/800/600
5. Chief Joe-Snohomish 345-kV rebuild to 500-kV double circuit	93	112	800/700/700
6. Rocky Reach-Maple Valley 345-kV rebuild to 500-kV double circuit	73	83	1200/700/800

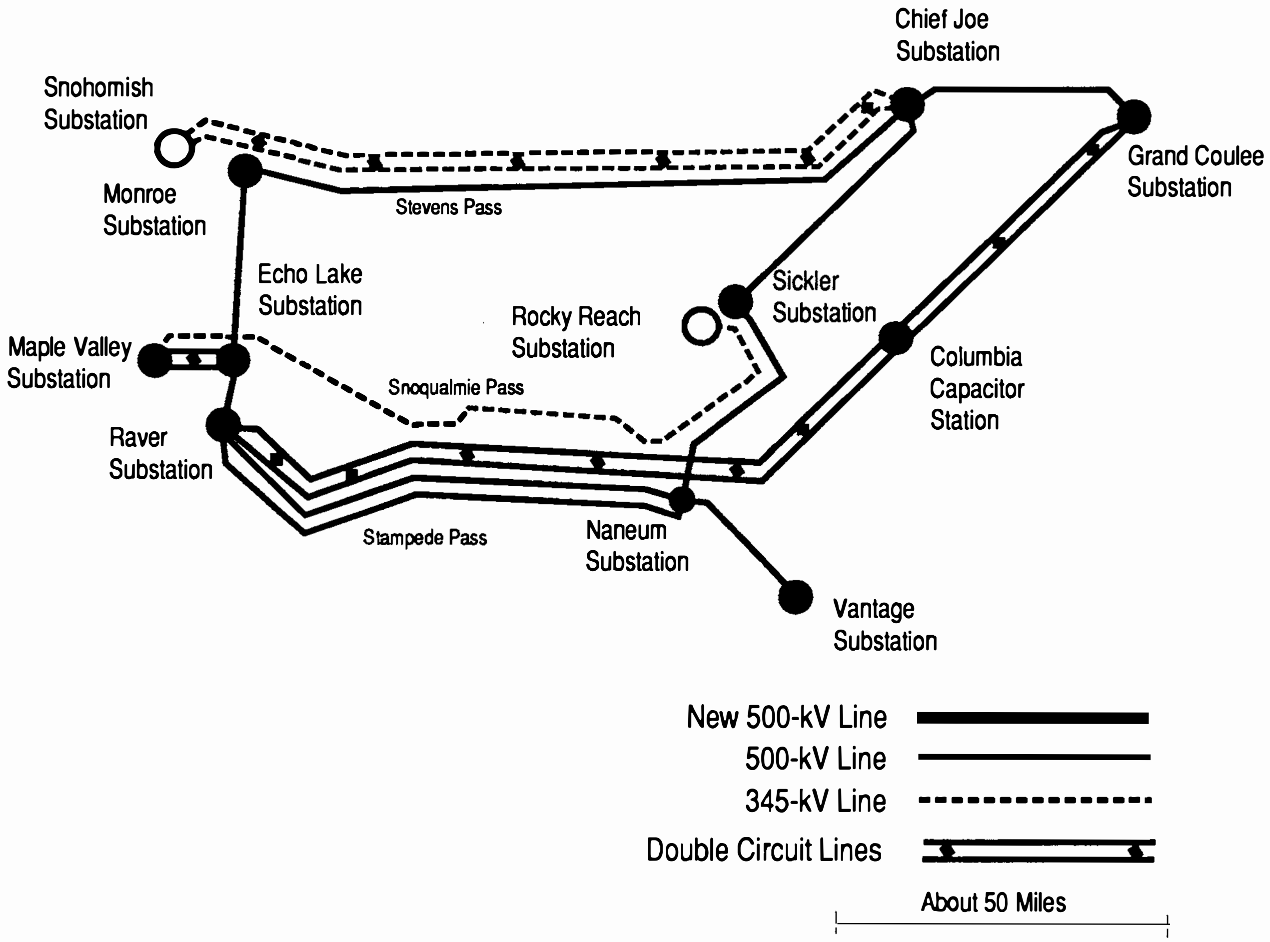
(1) 10 MW of the BPA loss savings and 13 MW of the PNW loss savings is due to the addition of the Raver-Echo Lake #2 and Maple Valley Transformer #2 needed in early 2000's.

(2) This plan includes replacement of the third (PCB) capacitor group at Raver. Another option to this Raver group could be an MSC at Naneum.

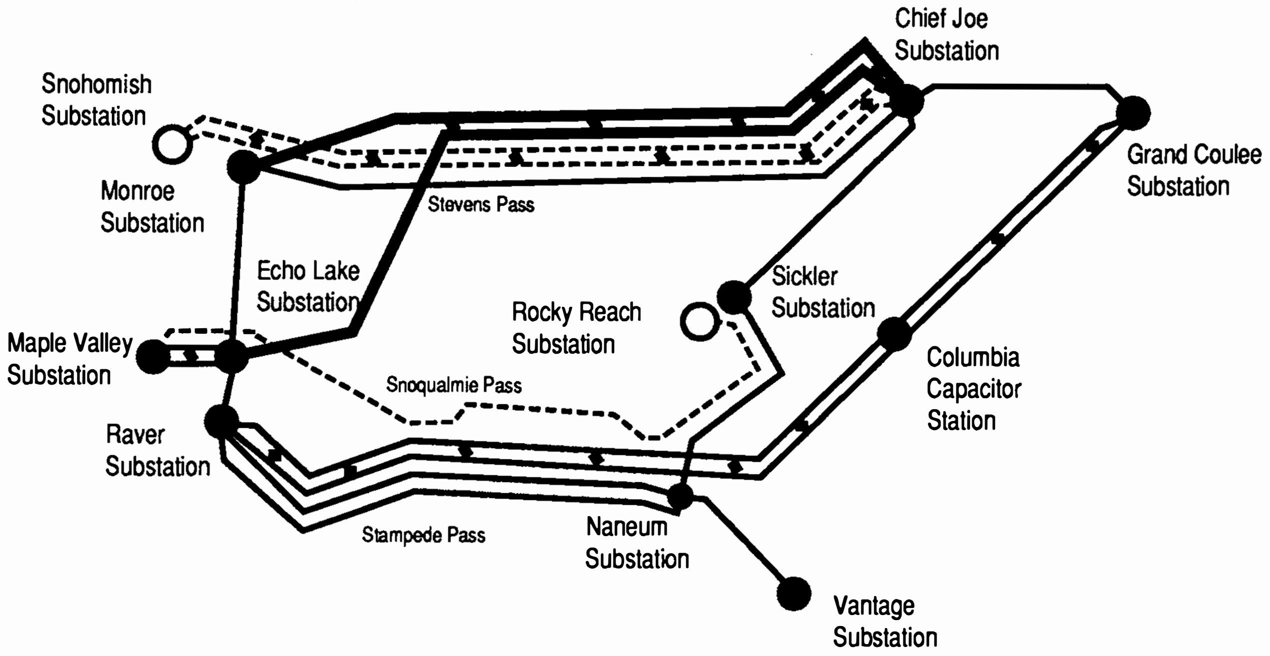
(3) The Portland area will need to be supported in the early to mid 2000's. Cursory studies indicate that one MSC will provide this support; a 300 MVAR MSC at Marion substation near Salem. All options include this MSC.

Diagrams

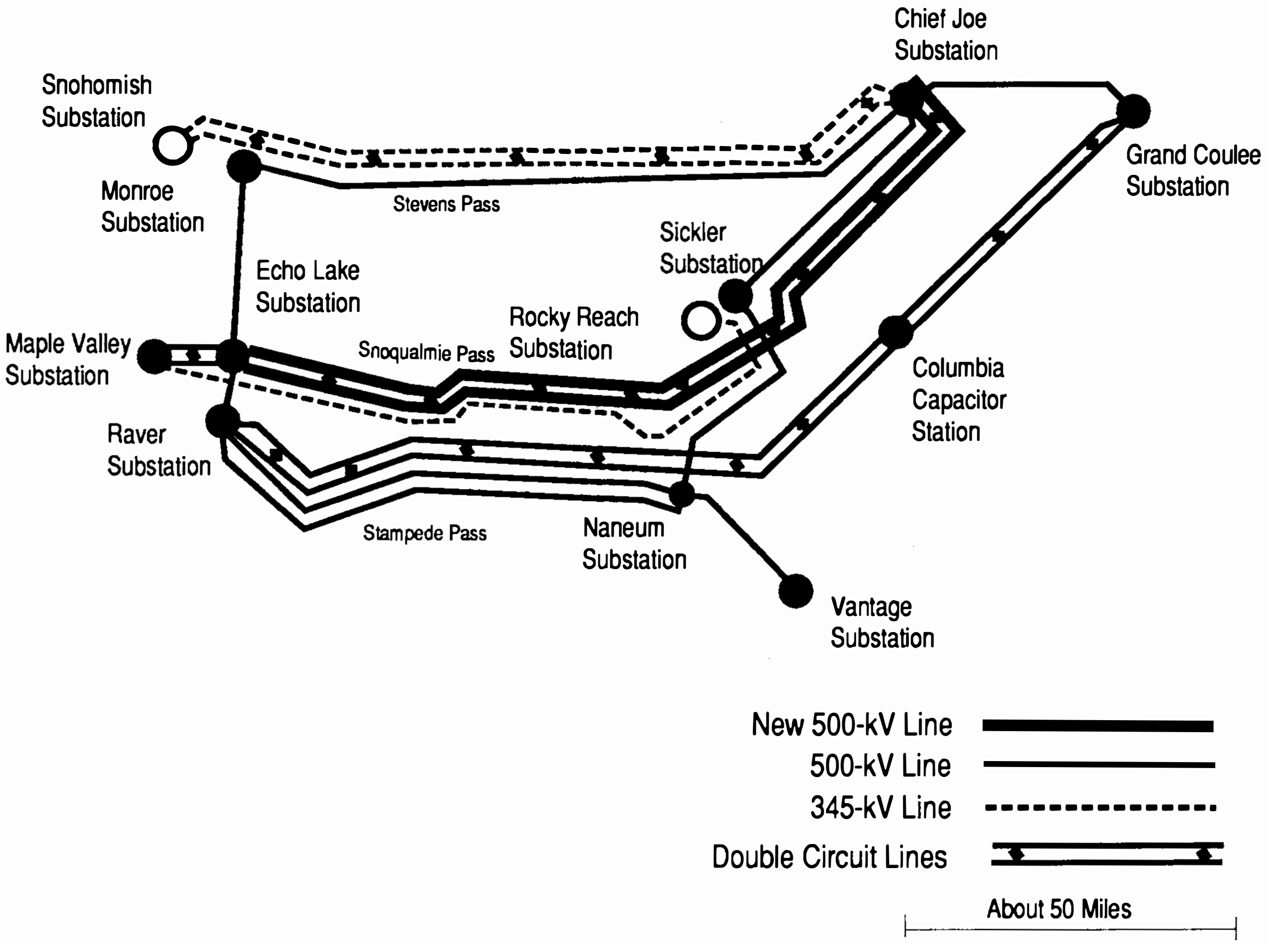
PRE-PSAERP SYSTEM
(Existing System plus Echo Lake Substation)



OPTION 1



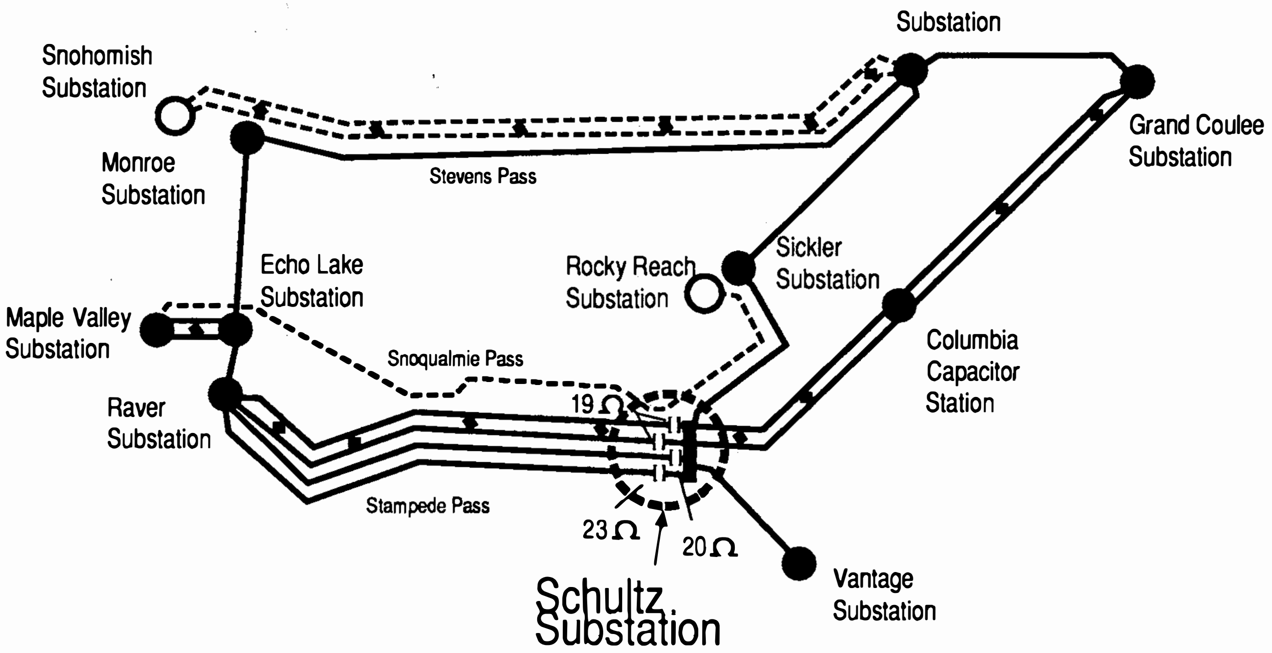
OPTION 2



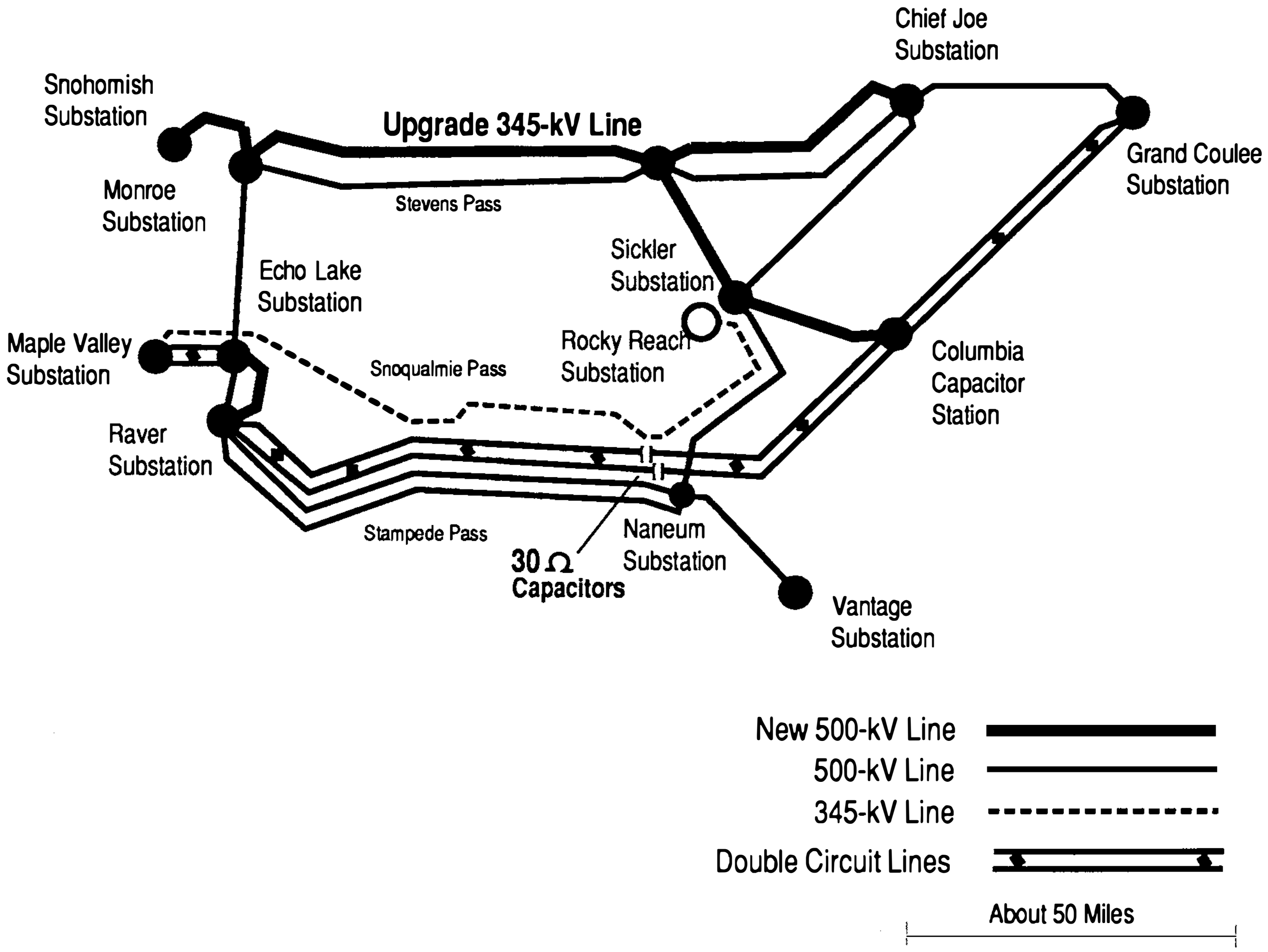
OPTION 3 (in circle)

Two 19Ω capacitor banks needed initially

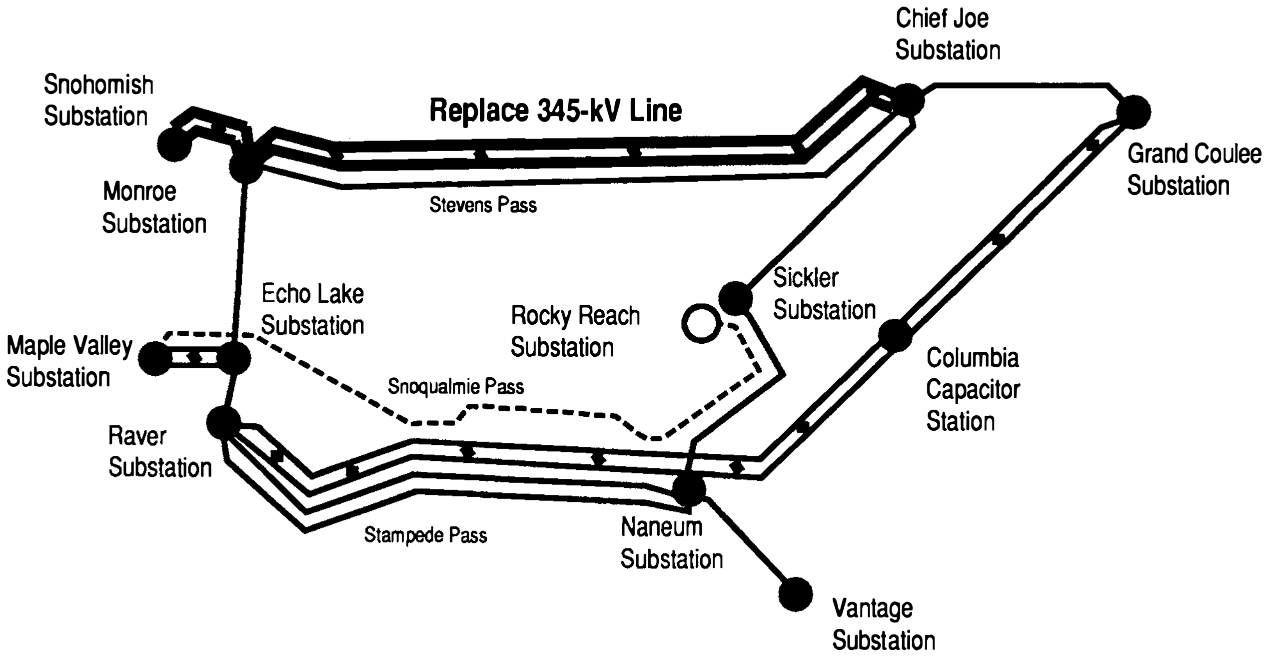
20 and 23Ω capacitor banks needed in early 2000's



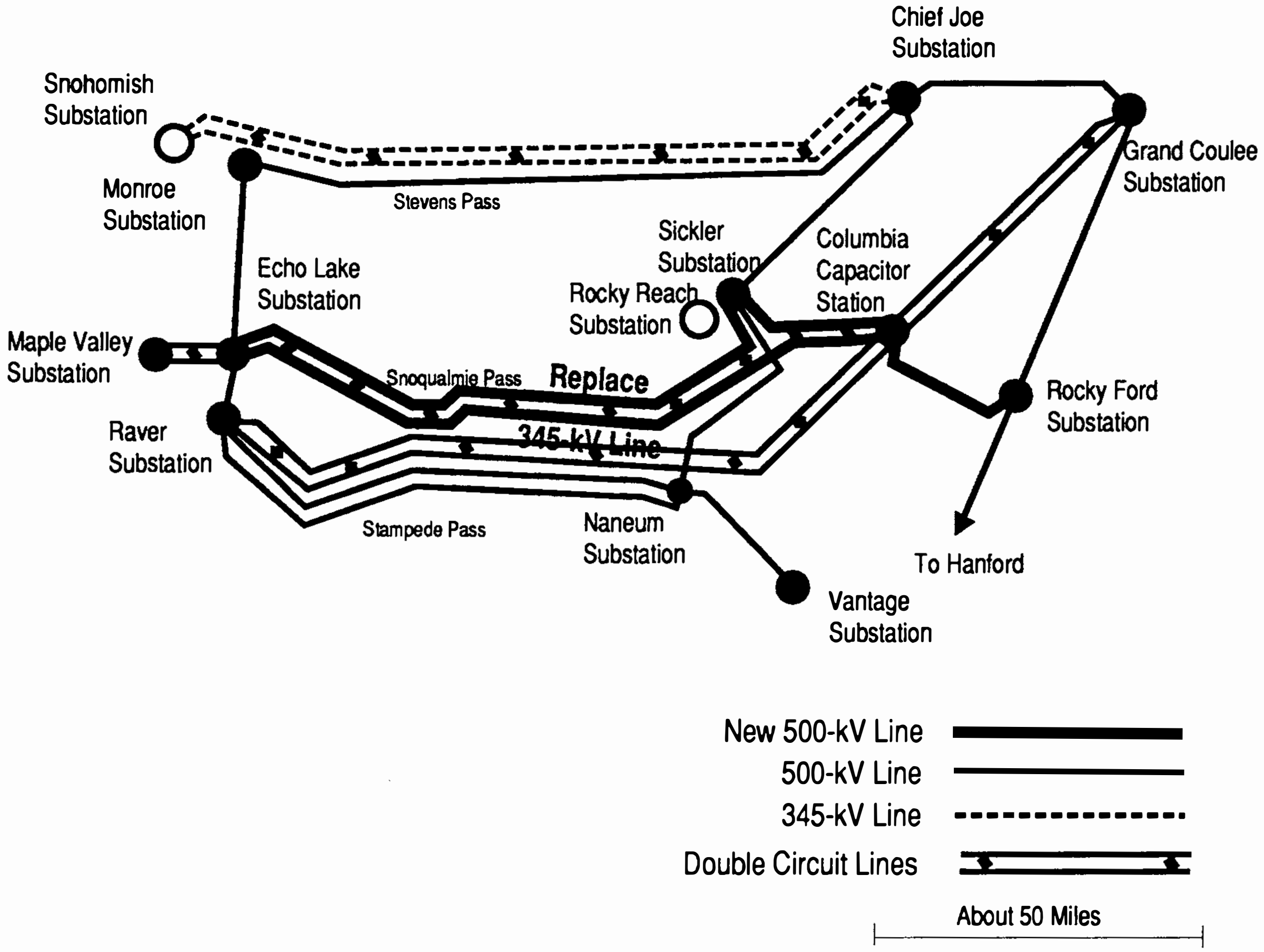
OPTION 4



OPTION 5



OPTION 6

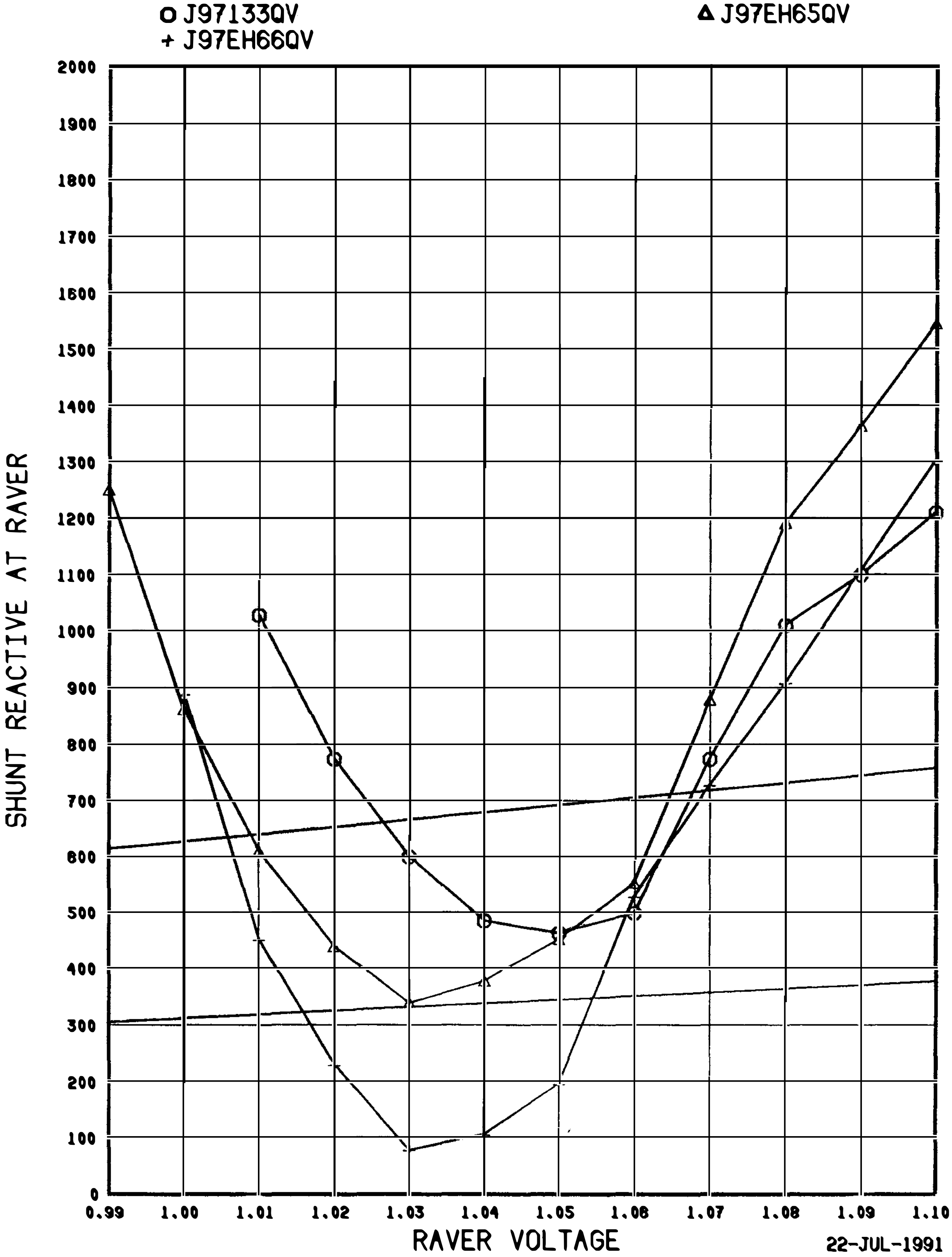

Chief Joe Substation
Snohomish Substation
Grand Coulee Substation
Monroe Substation
Stevens Pass
Sickler Substation
Columbia Capacitor Station
Echo Lake Substation
Rocky Reach Substation
Maple Valley Substation
Snoqualmie Pass
Replace
345-kV Line
Rocky Ford Substation
Raver Substation
Stampede Pass
Naneum Substation
To Hanford
Vantage Substation
New 500-kV Line
500-kV Line
345-kV Line
Double Circuit Lines
About 50 Miles

QV-Curves

QV Curve - 0

PERFORMANCE OF SYSTEM WITH REACTIVE-1 INSTALLED

J97133:2C-R OUT(J9782)MSC @SNOQ(2),MON(1),TAC,OLY
J97EH65:CJ-MON OUT (J97EH63) MSC @ MON(1), OLY
J97EH66:TROJAN SCRAM (J97EH64) MSC @ MON(1), OLY
ALL MSC'S USED

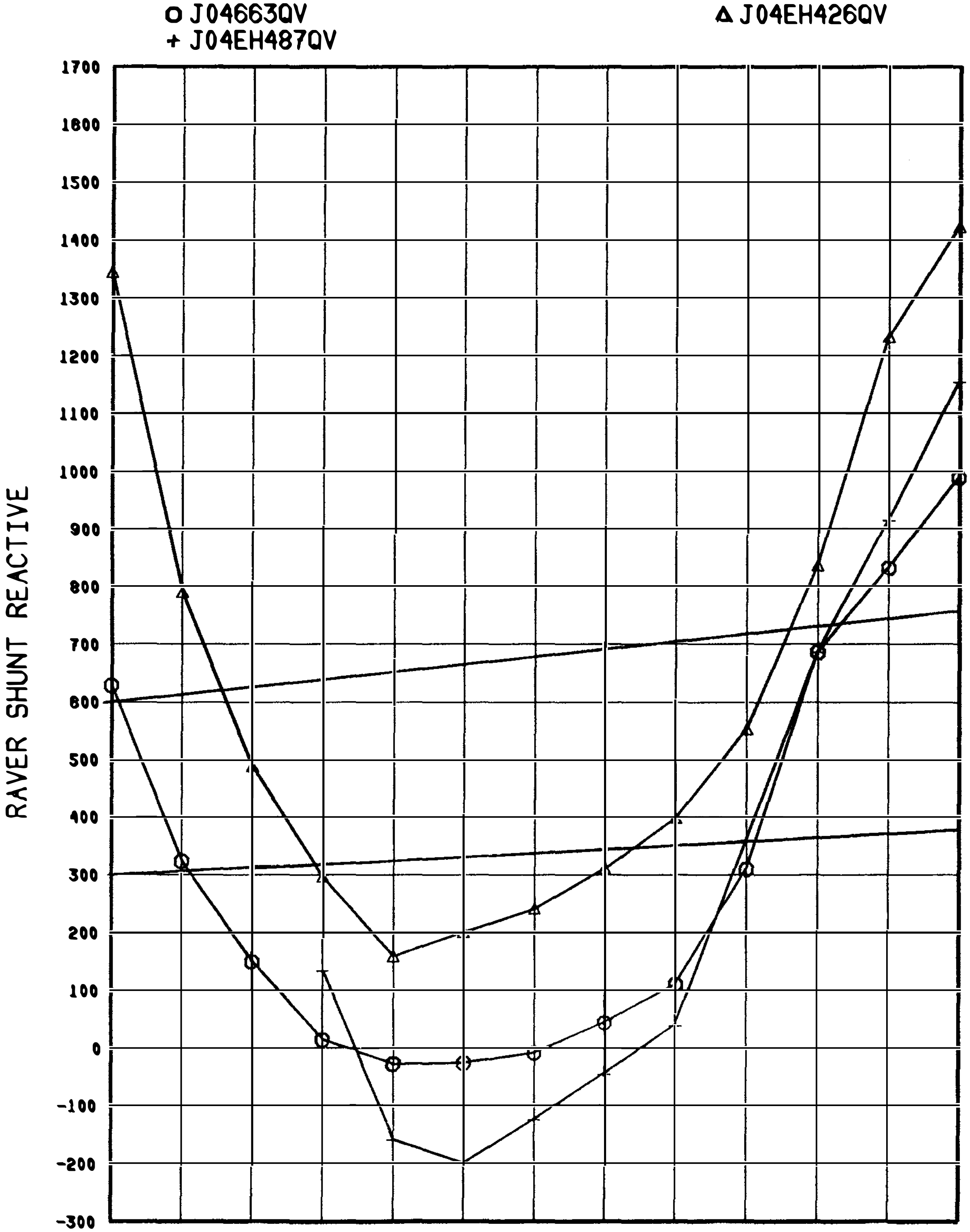


22-JUL-1991
REACTIVE1.SETUP

PLAN 1: CHIEF JO-MONROE/SNOQUALMIE 500 ADDED

J04663:COUL-RAV 1&2 OUT(J04662)MSC SNOQ(2),RAV(1)
J04EH426:COULEE-RAVER 500 OUT (J04EH422) NO MSC
J04EH487:TROJAN SCRAM(J04EH423)MSC MON(1),OLY,MAR

MSC AVAILABLE
MON, OLY
MON, OLY
None

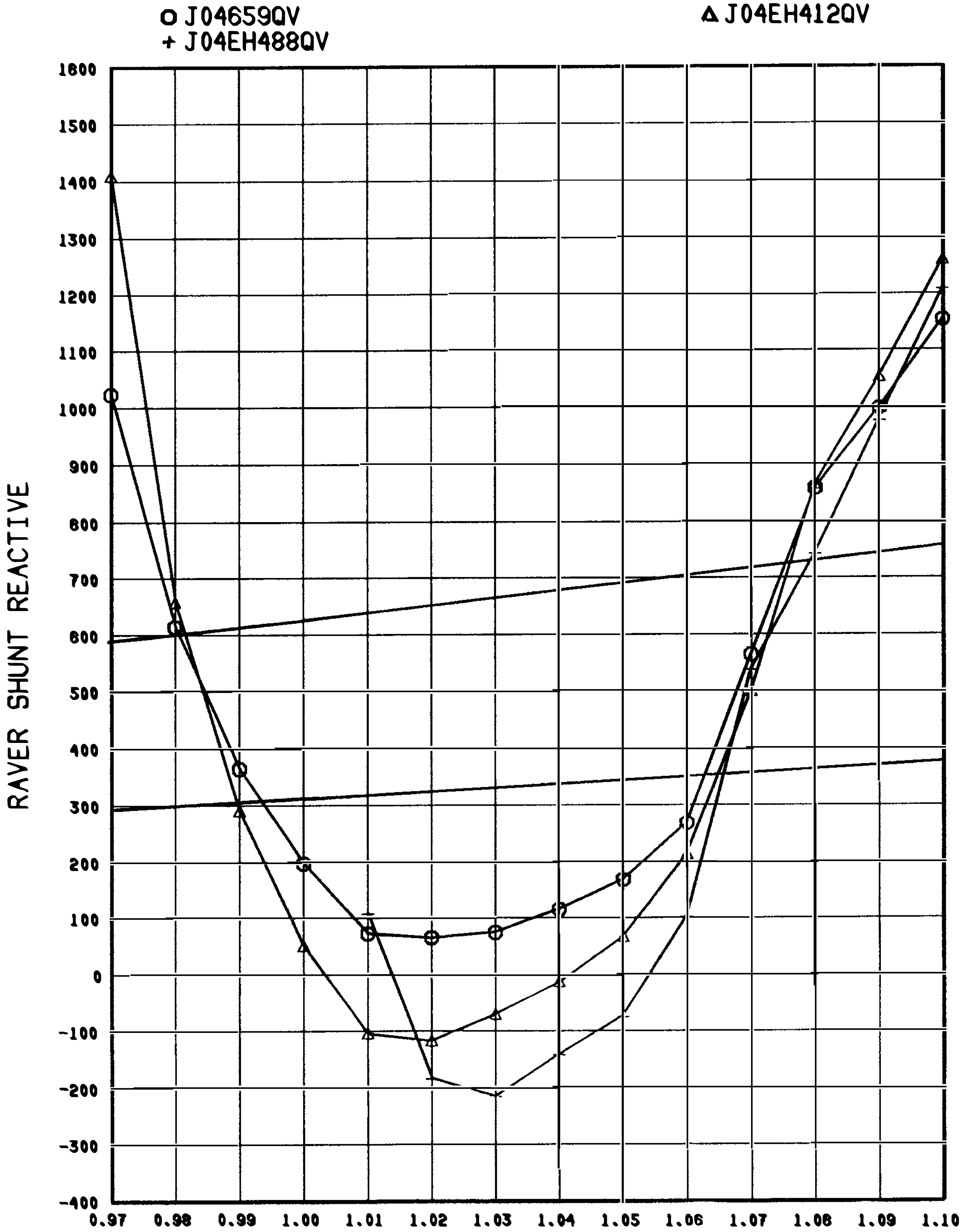


22-JUL-1991
PLAN1M.SETUP

PLAN 2: CHIEF JOE-SNOQUALMIE 500 ADDED

o J04659:COULEE-RAVER 1&2 OUT(J04656)
MSC AT MON(1), SNOQ(1), RAV(1)
△ J04EH412:COULEE-RAVER 1 OUT(J04EH408)MSC AT MON(1)
+ J04EH413:TROJAN SCRAM (J04EH409)
MSC AT MON(1), OLY(1), MARION(1)

MSC AVAILABLE
SNOQ, OLY
OLY
None

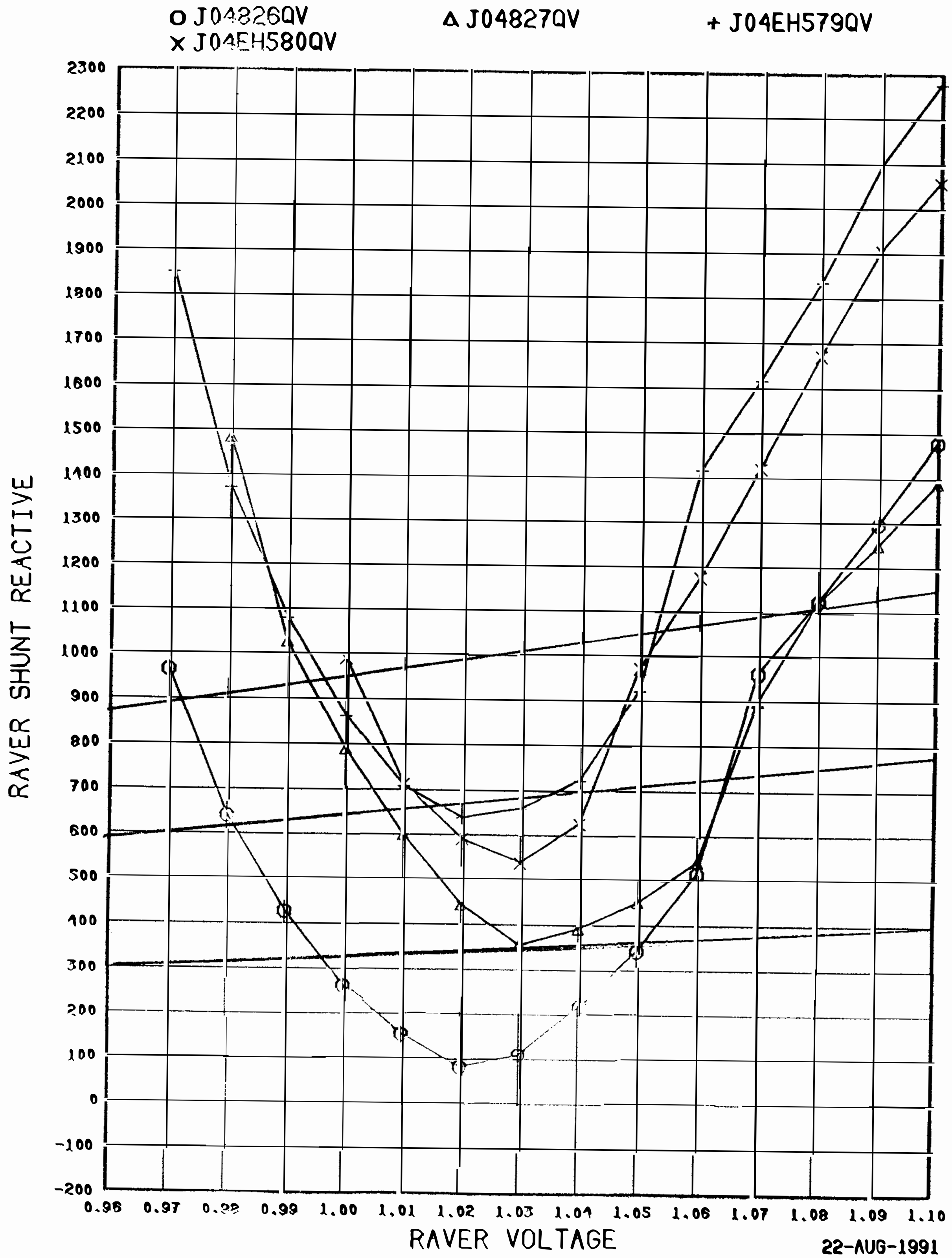


22-JUL-1991
PLAN2M.SETUP

ALL MSC's USED

PLAN 3: NANEUM SWYD

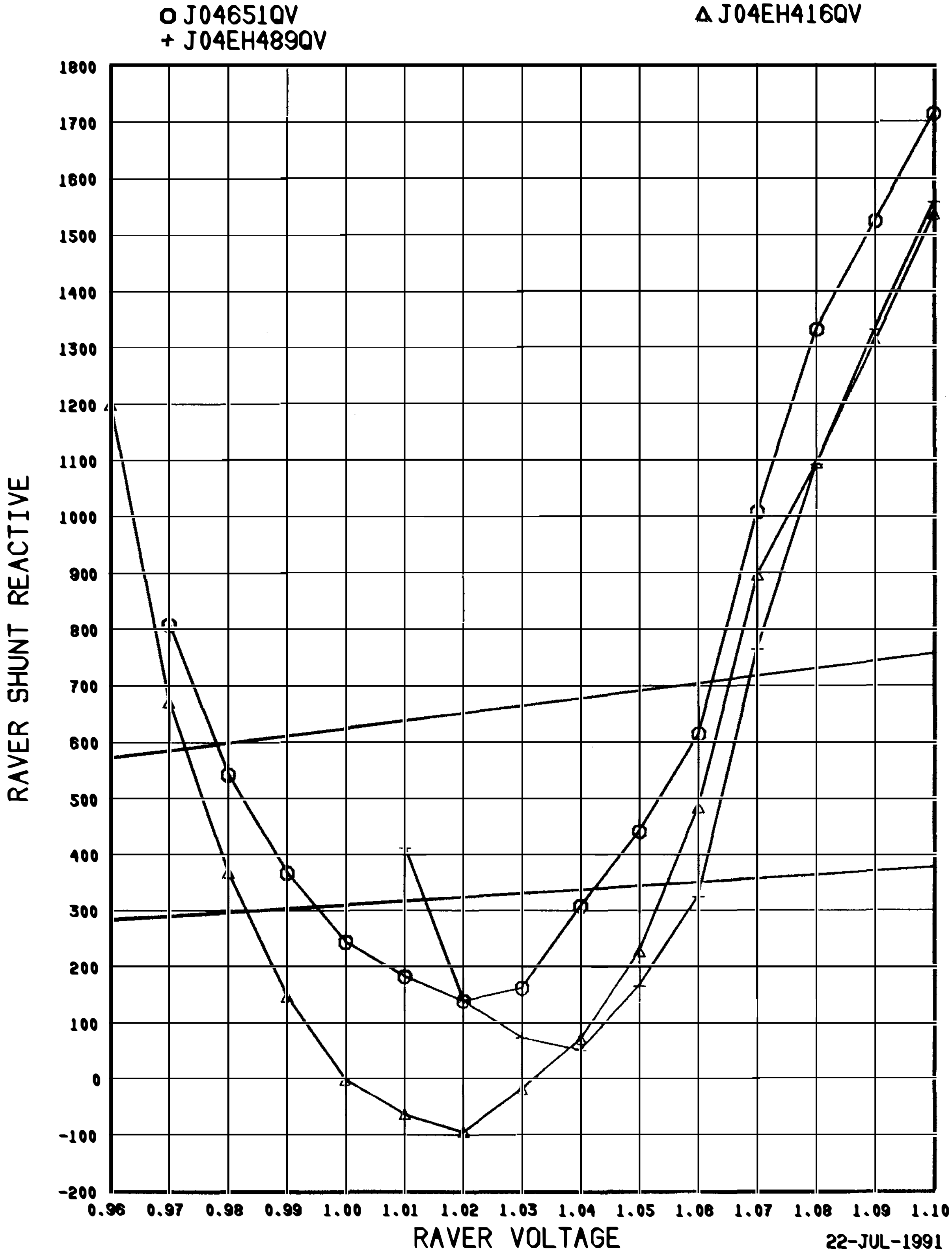
20% ON COULE-RAV,30% ON SICK-RAV, 39% ON VANT-RAV
o J04826:NAN-RAV 3&4 OUT,MSC @OL,SNQ,MON,RAV(J04825)
Δ J04827:GC-NAN 1&2 OUT,MSC @OL,SNQ,MON,RAV(J04825)
+J04EH579:CJ-MON, MSC @ OLY (J04EH577) MSC RAV
x J04EH580:TROJAN SCRAM, MSC @ OLY,MARION (J04EH578) MSC RAV



22-AUG-1991
J04PLAN3-4.SETUP

PLAN 4: UPGRADE CJ-SNOHOMISH 345 TO 500 SSC

ADD CROSSTIE: COLUMBIA-SICKLER-MAD RIVER 500 SSC
J04651:MADRVR-MONROE 1&2(J04650)MSC @MON1,SQ2,OLY1
J04EH416:COLUMB-RAVER 1 OUT(J04EH406)MSC @ MON(1)
J04EH489:TROJAN SCRAM (J04EH407) MSC @ OLY, MARION

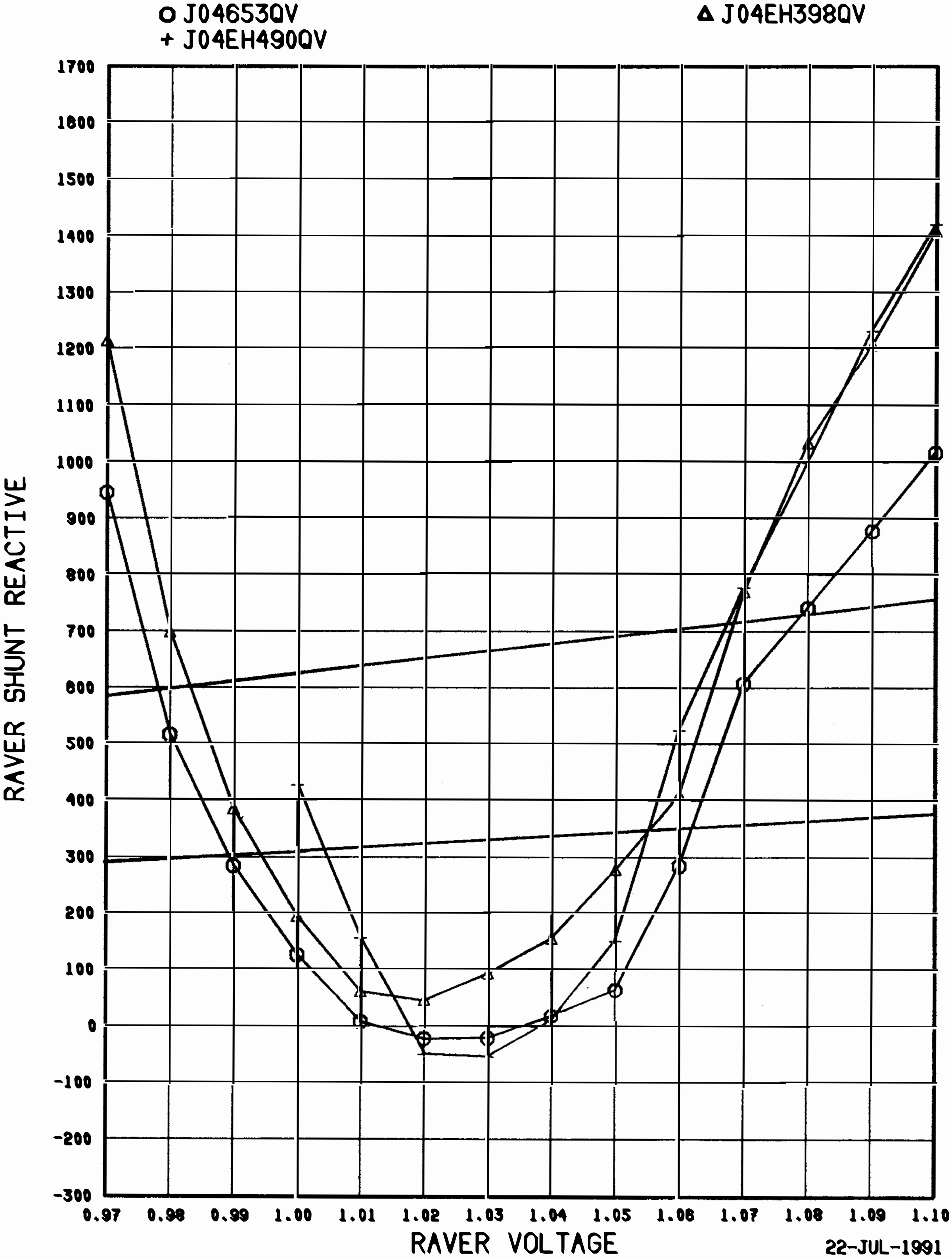


22-JUL-1991
PLAN4M.SETUP

PLAN 5: CHIEF JOE-SNOHOMISH REBUILT TO 500 SDC

J04653:COULE-RVR 1&2 OUT(J04652)MSC SNQ(2),MON,RAV
J04EH398:COULE-RVR 1 OUT(J04EH396)MSC @ MON(1)
J04EH490:TROJAN SCRAM (J04EH397)MSC @ OLY,MON,MAR

MSC AVAIL
OLY
OLY
None

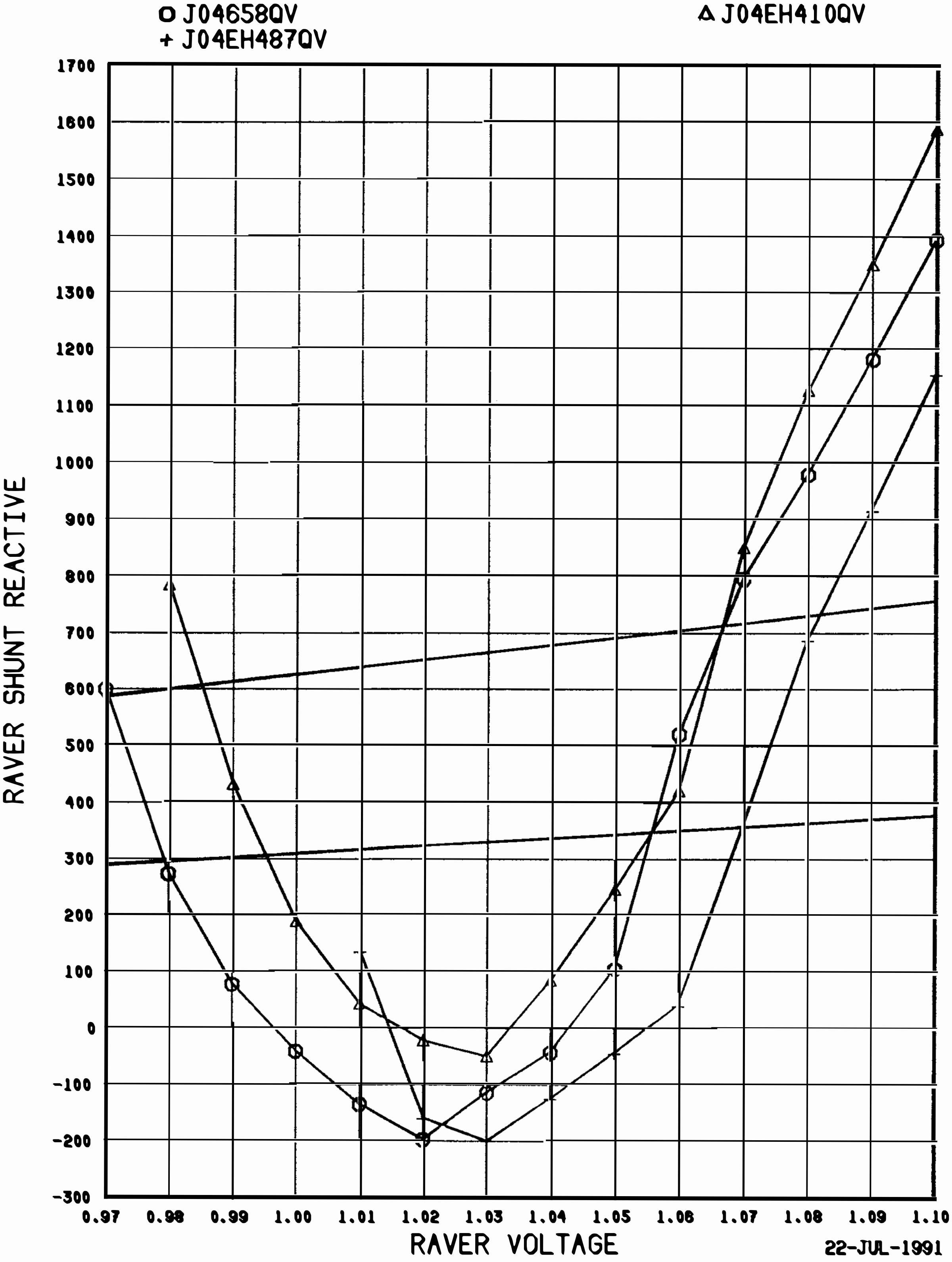


22-JUL-1991
PLANSM.SETUP

PLAN 6: ROCKY RH-MAPLE VL 345 REBUILD TO 500 SDC

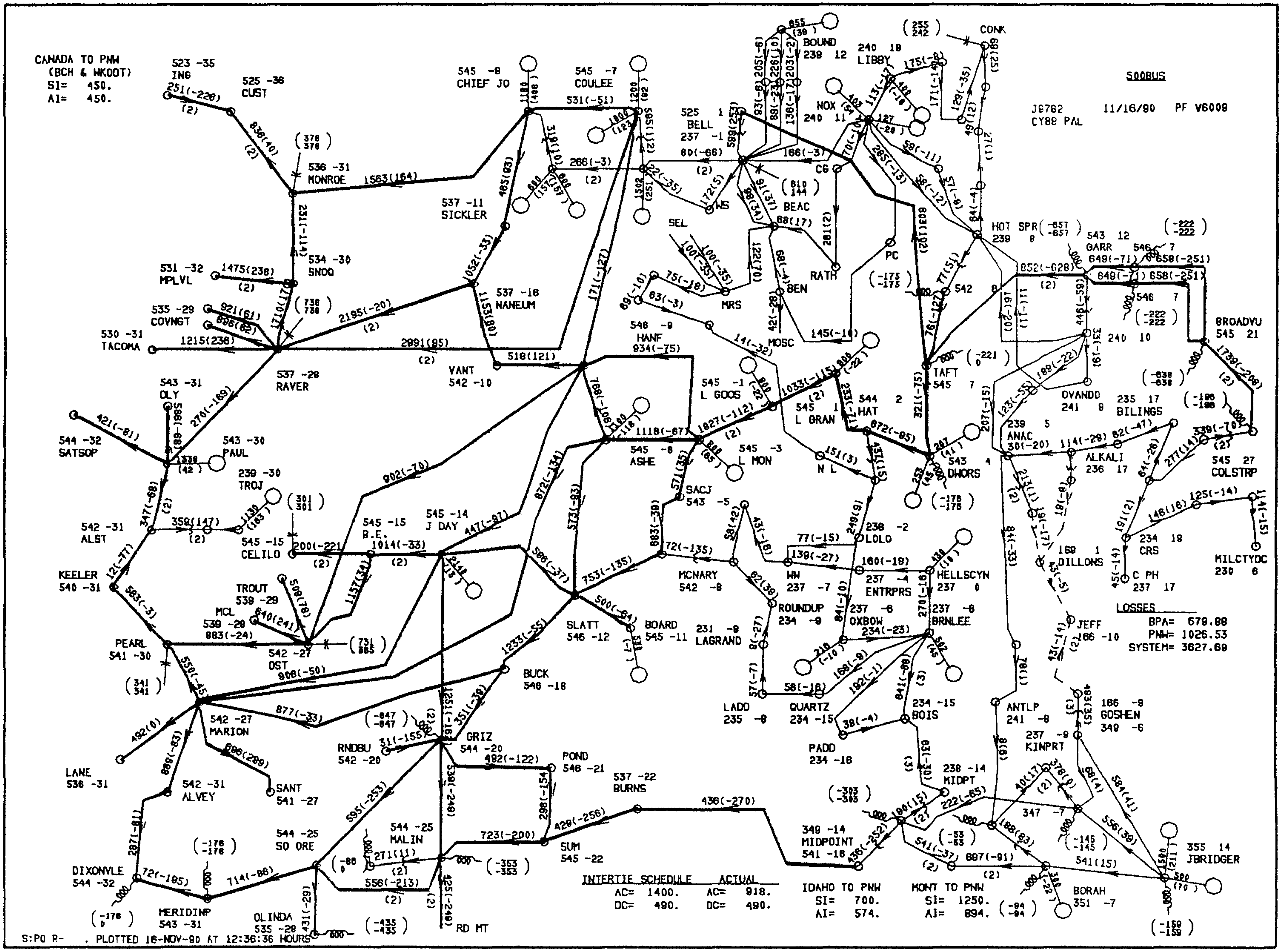
CROSSTIE ADDED: SICKLER-COLUMBIA-ROCKY FORD
J04658:COL/SICK-SNOQ OUT(J04655)MSC @ SNOQ(2),RAV
J04EH410:CJ-MON OUT (J04EH404) MSC @ OLY
J04EH487:TROJAN SCRAM(J04EH423)MSC @ MARION & OLY

MSC AVAILABLE
MON, OLY
None
None



22-JUL-1991
PLAN6M.SETUP

Base Cases


CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.
500BUS
J9762 11/16/90 PF V6009
CY89 PAL
523 -35 ING
525 -36 CUST
536 -31 MONROE
534 -30 SNOQ
531 -32 MPLVL
535 -29 COVNGT
530 -31 TACOMA
537 -28 RAVER
543 -31 OLY
544 -32 SATSOP
543 -30 PAUL
239 -30 TROJ
542 -31 ALST
545 -15 CELILO
540 -31 KEELER
539 -29 TROUT
539 -28 MCL
541 -30 PEARL
542 -27 OST
542 -27 MARION
536 -31 LANE
542 -31 ALVEY
541 -27 SANT
544 -32 DIXONVLE
543 -31 MERIDINP
535 -29 OLINDA
544 -25 SO ORE
544 -25 MALIN
RD MT
542 -20 RNDBU
544 -20 GRIZ
546 -21 POND
545 -22 SUM
537 -22 BURNS
546 -18 BUCK
546 -12 SLATT
545 -11 BOARD
545 -15 B.E.
545 -14 J DAY
545 -9 CHIEF JO
545 -7 COULEE
537 -11 SICKLER
537 -16 NANEUM
542 -10 VANT
546 -9 HANF
545 -8 ASHE
545 -1 L GOOS
545 1 L GRAN
545 -3 L MON
543 -5 SACJ
542 -8 MCNARY
231 -8 LAGRAND
234 -9 ROUNDUP
235 -8 LADD
234 -15 QUARTZ
234 -16 PADD
234 -15 BOIS
238 -14 MIDPT
349 -14 MIDPOINT
541 -16
237 -7 WW
237 -8 OXBOW
237 -4 ENTRPRS
237 0 HELLSCYN
237 -8 BRNLEE
238 -2 LOLO
N L
544 2 HAT
543 4 DWORS
545 7 TAFT
542
525 1 BELL
237 -1
238 12 BOUND
240 10 LIBBY
240 11 NOX
CG
WS
BEAC
SEL
MRS
BEN
RATH
MOSC
PC
CONK
239 8 HOT SPR
543 12 GARR
546 7
545 21 BROADVU
240 10
241 9 OVANDO
239 5 ANAC
236 17 ALKALI
235 17 BILINGS
545 27 COLSTRP
234 19 CRS
237 17 C PH
230 6 MILCTYDC
169 1 DILLONS
166 -10 JEFF
241 -8 ANTLP
237 -9 KINPRT
166 -9 GOSHEN
349 -6
347 -7
351 -7 BORAH
355 14 JBRIDGER
LOSSES
BPA= 679.88
PNW= 1026.53
SYSTEM= 3627.69
INTERTIE SCHEDULE ACTUAL
AC= 1400. AC= 918.
DC= 490. DC= 490.
IDAHO TO PNW
SI= 700.
AI= 574.
MONT TO PNW
SI= 1250.
AI= 894.
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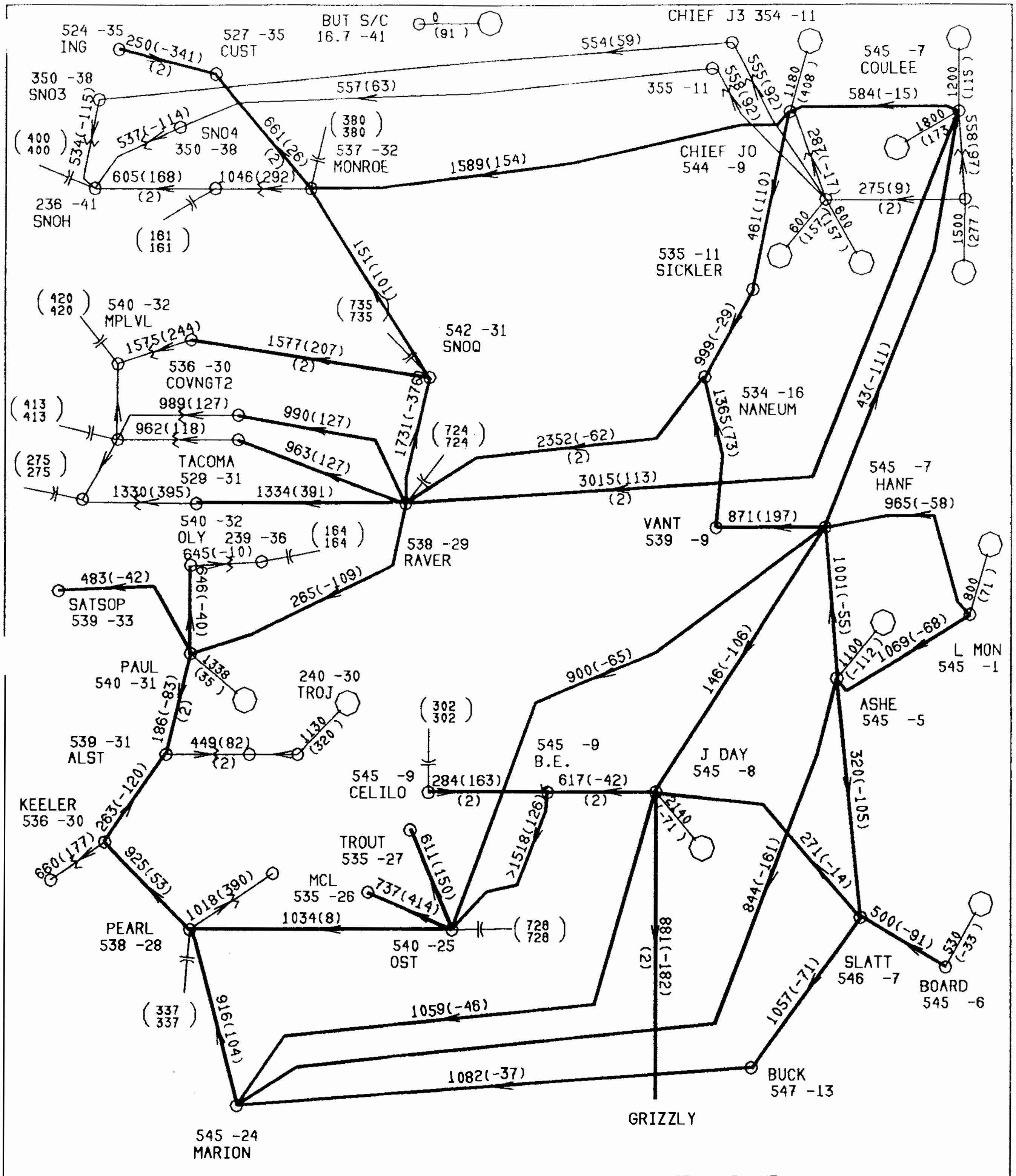
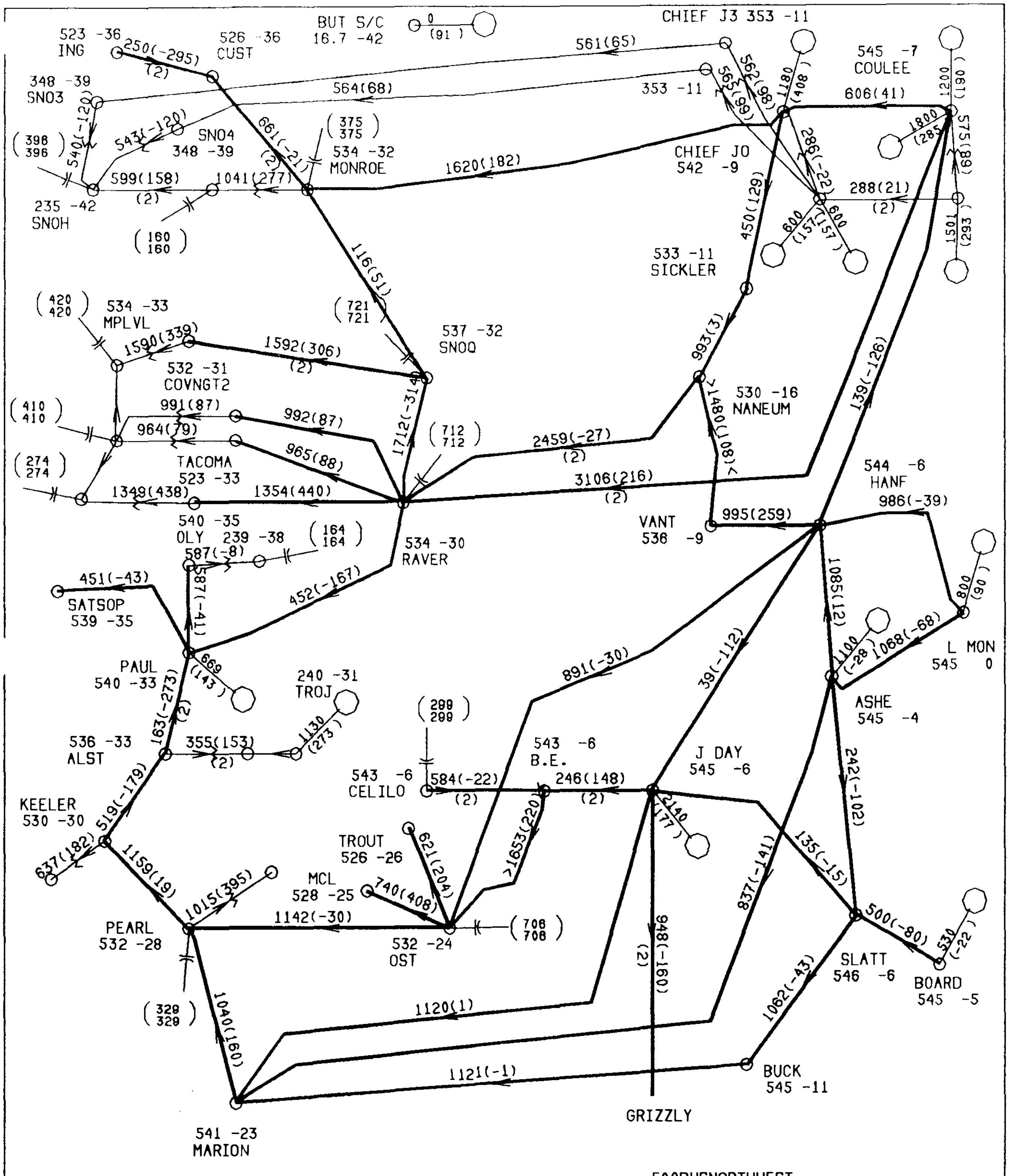


500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -346.	BPA= 782.19
DC= -710.	DC= -710.	PNW= 1187.69
		SYSTEM= 3822.42

J97EH63 6/ 5/91 PF V6010
CY89 MJL
BASED ON J97EH05
REACTIVE 1 ADDED

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1310.	SI= 700.
AI= 450.	AI= 1016.	AI= 648.



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= -1460.

ACTUAL
AC= -363.
DC= -1460.

LOSSES
BPA= 888.71
PNW= 1299.20
SYSTEM= 3966.91

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

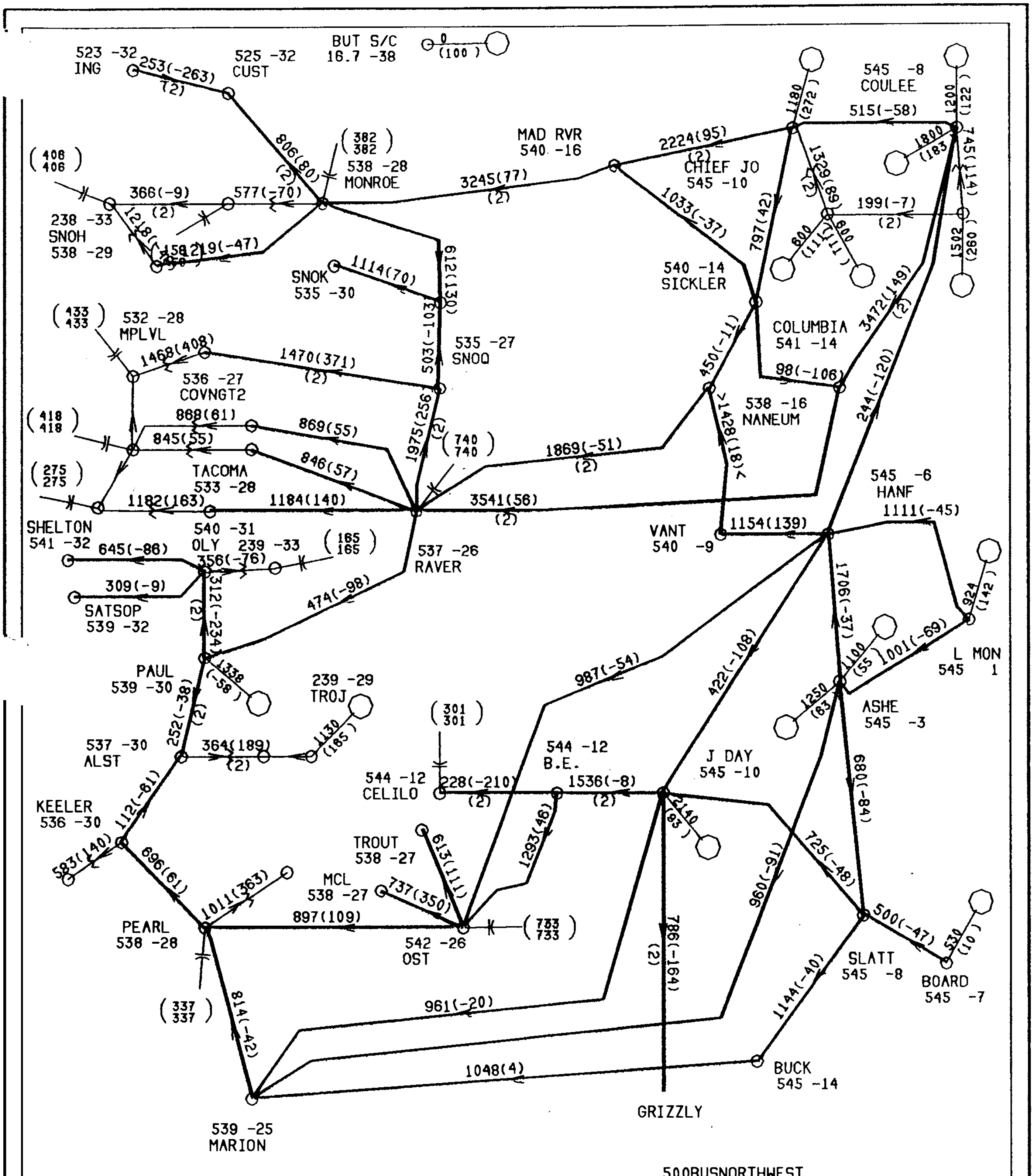
MONT TO PNW
SI= 1310.
AI= 1019.

IDAHO TO PNW
SI= 700.
AI= 629.

J97EH64 6/ 5/91 PF V6010
CY89 MJL
BASED ON J97EH06
REACTIVE 1 ADDED
Cent unit down

S:PQ R- , PLOTTED 5-JUN-91 AT 08:57:54 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -277.	BPA= 679.99
DC= 557.	DC= 557.	PNW= 1051.47
		SYSTEM= 3779.53

ANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 994.	AI= 678.

J04650 2/22/91 PF V6010
CY89 MJL-ALH
BASED ON J04632
PLAN 4

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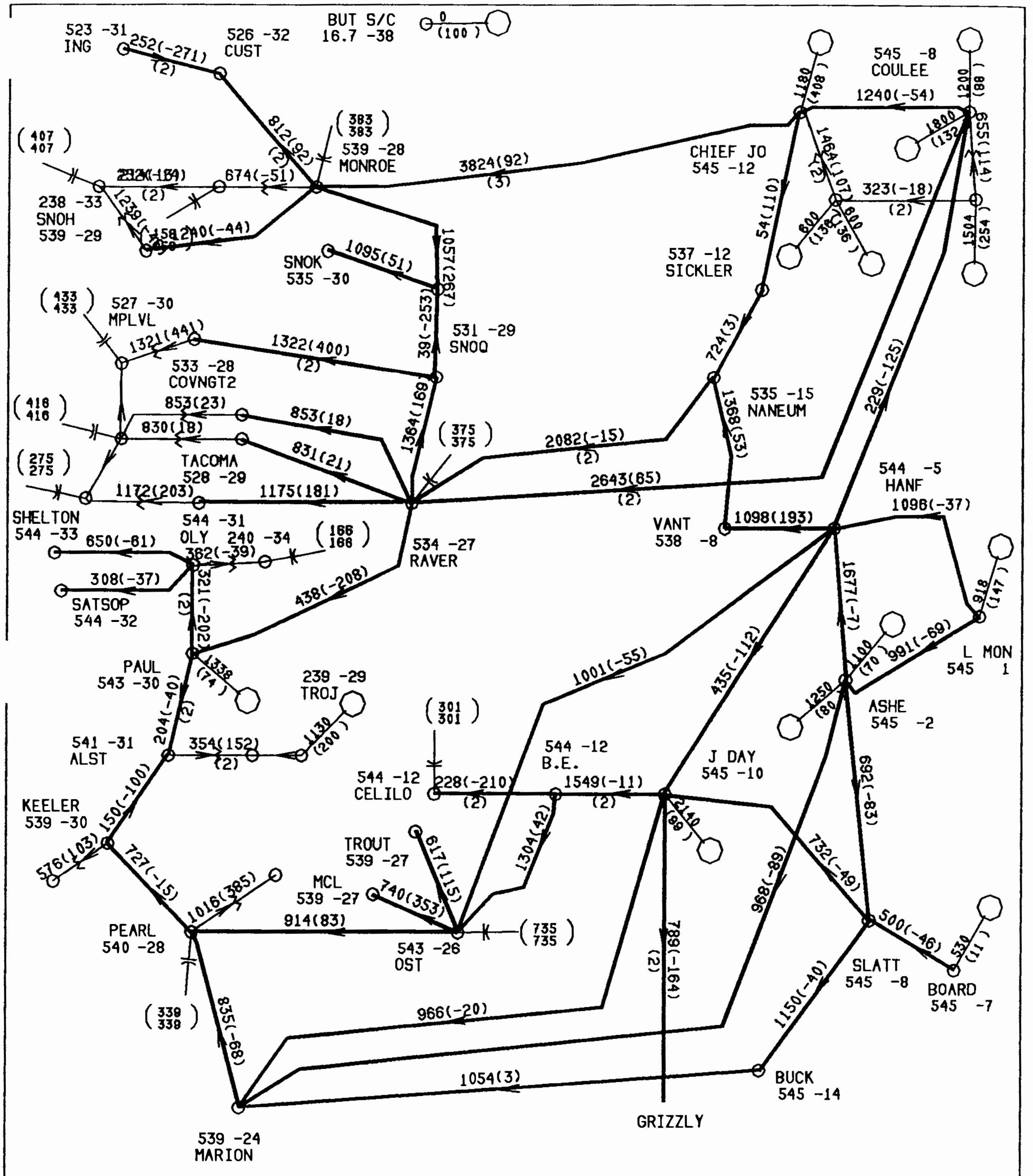
PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

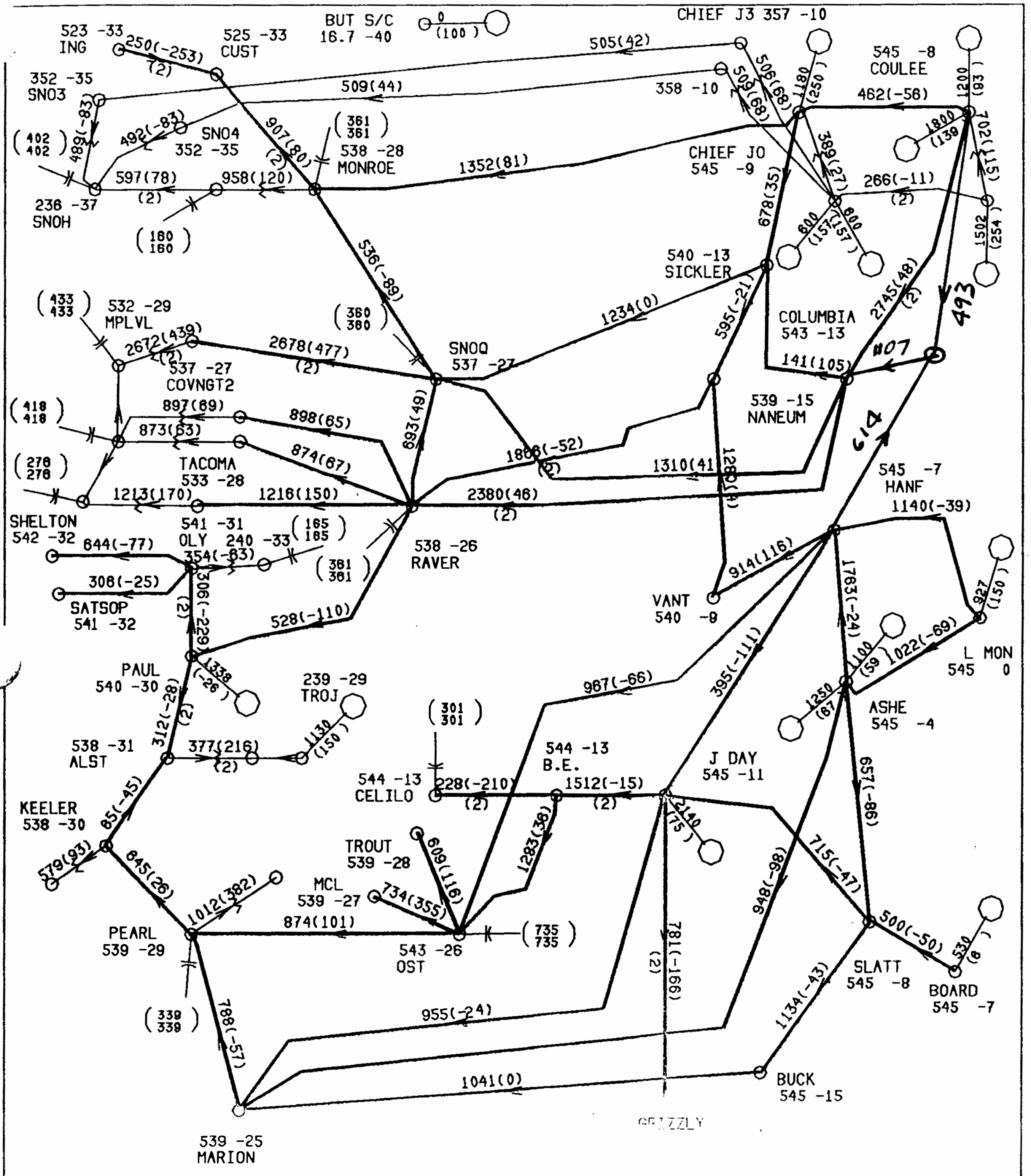
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -278.	BPA= 662.31
DC= 557.	DC= 557.	PNW= 1036.35
		SYSTEM= 3764.05

J04652 6/ 4/91 PF V6010
CY89 MJL-ALH
BASED ON J04632
PLAN 5

:ANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 994.	AI= 678.

S:PQ R- , PLOTTED 4-JUN-91 AT 13:50:39 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE

AC= 0.

DC= 557.

ACTUAL

AC= -279.

DC= 557.

LOSSES

BPA= 679.21

PNW= 1060.20

SYSTEM= 3789.27

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

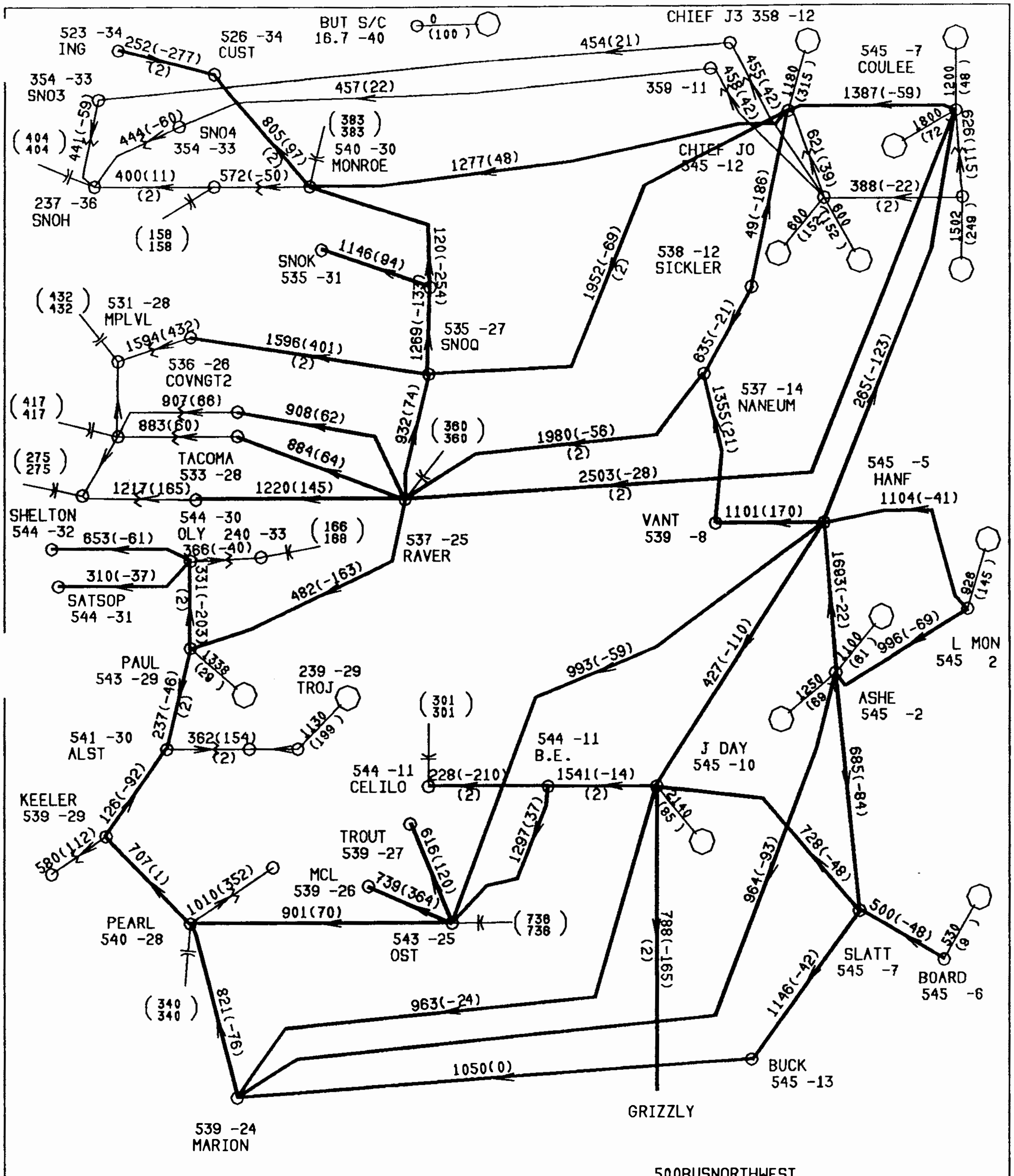
MONT TO PNW
SI= 1250.
AI= 992.

IDAHO TO PNW
SI= 700.
AI= 680.

J04655 9/ 9/91 PF V6010
CY89 MJL-ALH
BASED ON J04632
PLAN 6D

S:PQ R- , PLOTTED 9-SEP-91 AT 17:02:38 HOURS

PFPLOT PFP334 : REVISED 10/11/90

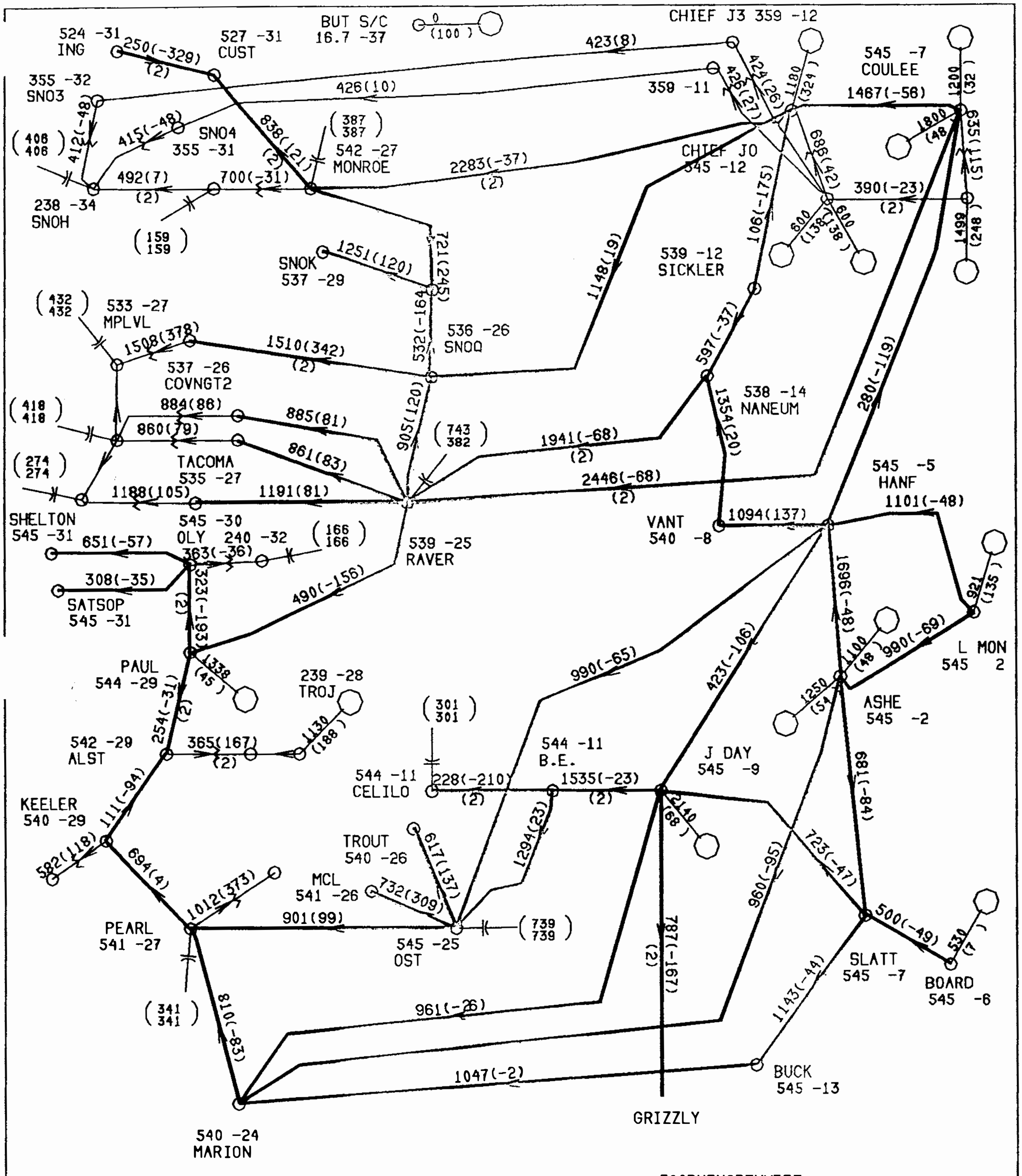


500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -277.	BPA= 683.08
DC= 557.	DC= 557.	PNW= 1057.85
		SYSTEM= 3787.64

NADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 995.	AI= 678.

J04656 6/ 4/91 PF V6010
CY89 MJL-ALH
BASED ON J04632
PLAN 2 1' CAP ON AT RAVER



INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -276.	BPA= 668.86
DC= 557.	DC= 557.	PNW= 1040.14
		SYSTEM= 3767.43

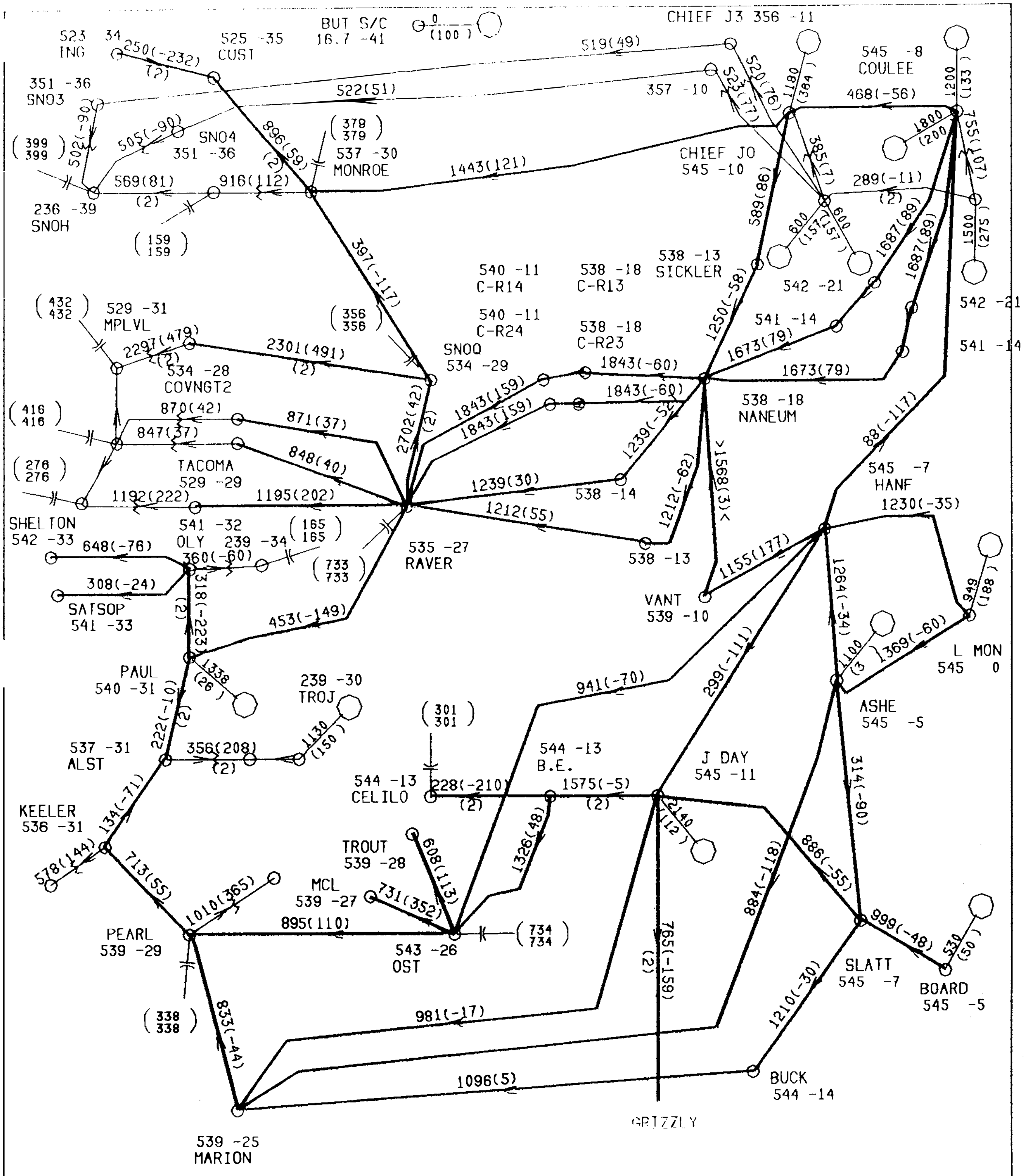
.NADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 996.	AI= 677.

500BUSNORTHWEST

J04662 3/22/91 PF V6010
CY89 ALH-MJL
BASED ON J04632
PLAN 1

S:PQ R- , PLOTTED 22-MAR-91 AT 11:52:24 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

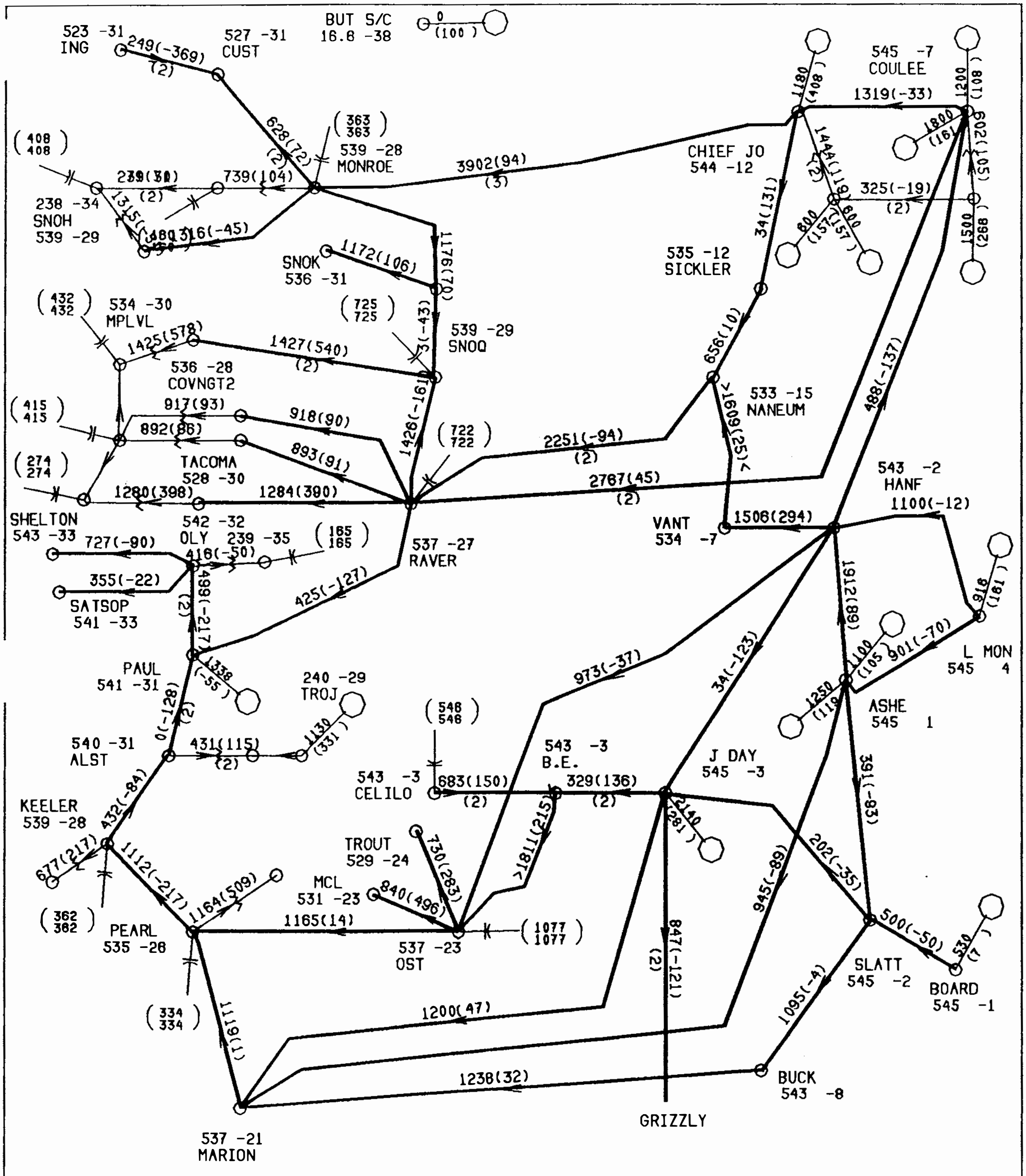
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -288.	BPA= 744.37
DC= 557.	DC= 557.	PNW= 1134.45
		SYSTEM= 3869.11

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 971.	AI= 691.

J04825 8/22/91 PF V6010
CY89 ALH-MJL
BASED ON J04632
NANEUM SWITCHYARD
30% COMP ON SICKLER-RAVER
20% COMP ON COULEE-RAVER
39% COMP ON VANTAGE-RAVER

S:PQ R- , PLOTTED 22-AUG-91 AT 13:45:36 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

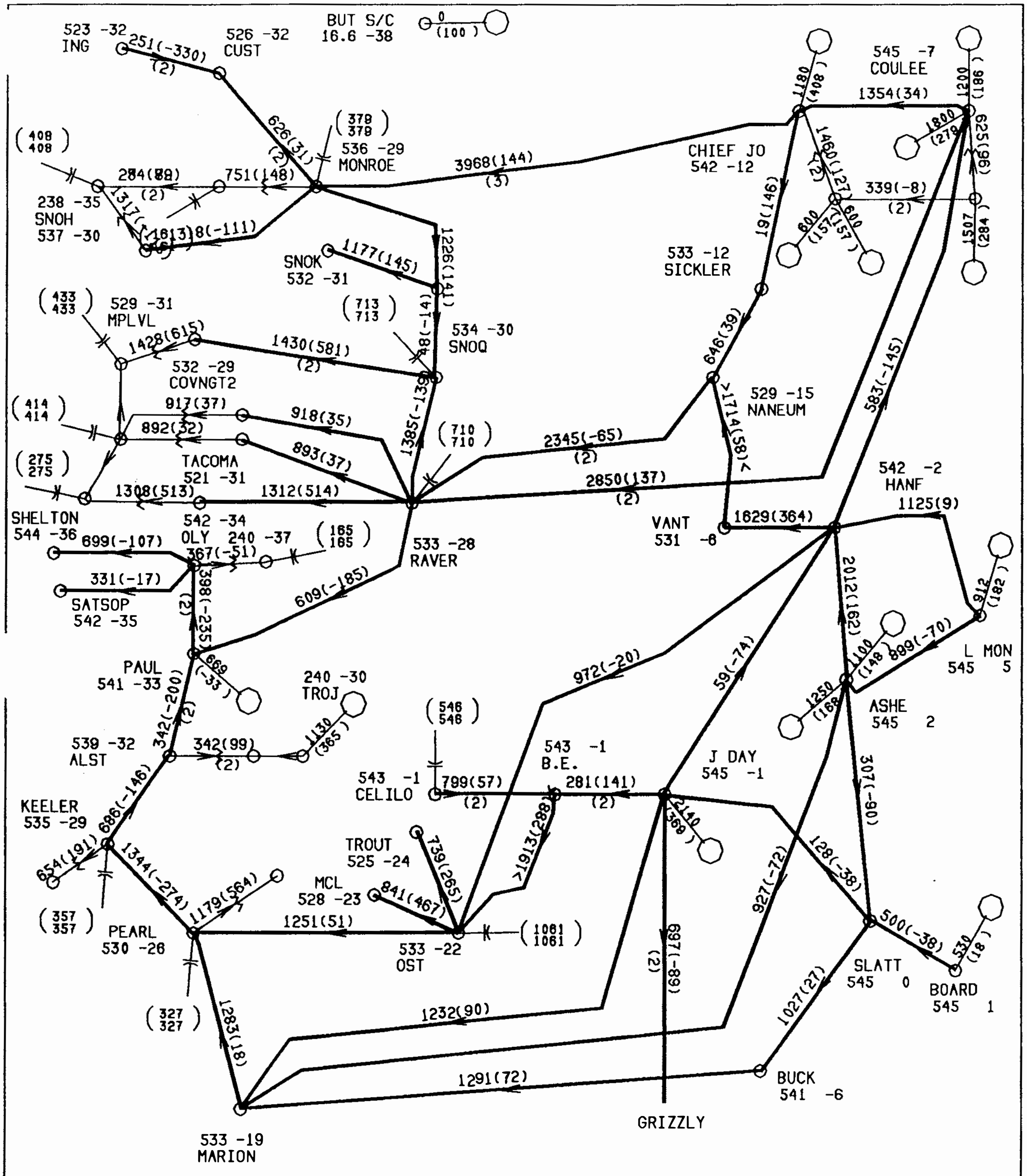
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -949.	BPA= 898.53
DC= -1710.	DC= -1710.	PNW= 1336.88
		SYSTEM= 4169.97

NADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1029.	AI= 532.

J04EH396 3/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH333
PLAN 5

S:PQ R- , PLOTTED 7-MAR-91 AT 10:28:21 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -1175.
DC= -2000.

ACTUAL
AC= -1369.
DC= -2000.

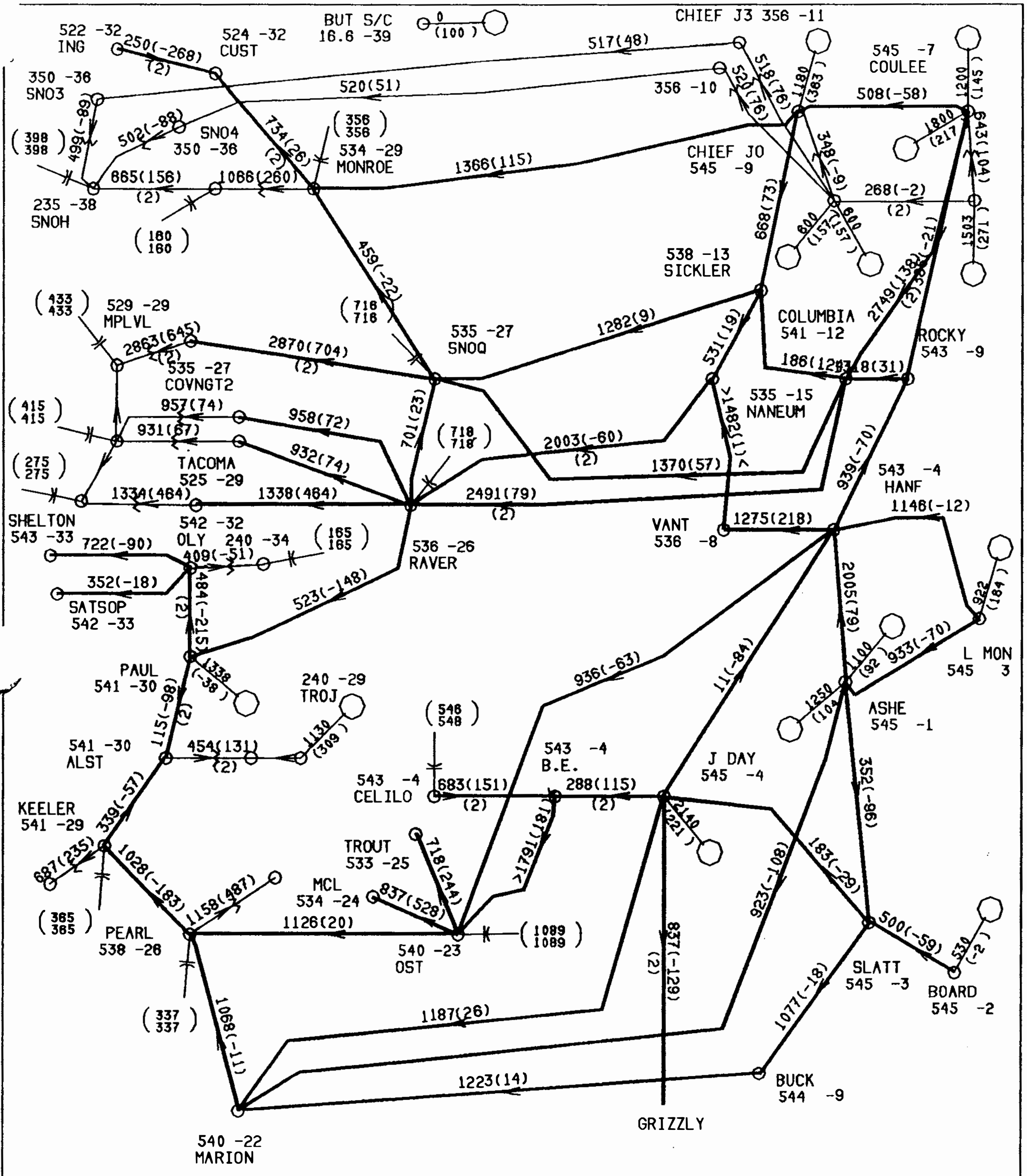
LOSSES
BPA= 977.23
PNW= 1426.94
SYSTEM= 4269.91

ADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1044.

IDAHO TO PNW
SI= 480.
AI= 543.

J04EH397 6/ 4/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH337
PLAN 5



500BUSNORTHWEST

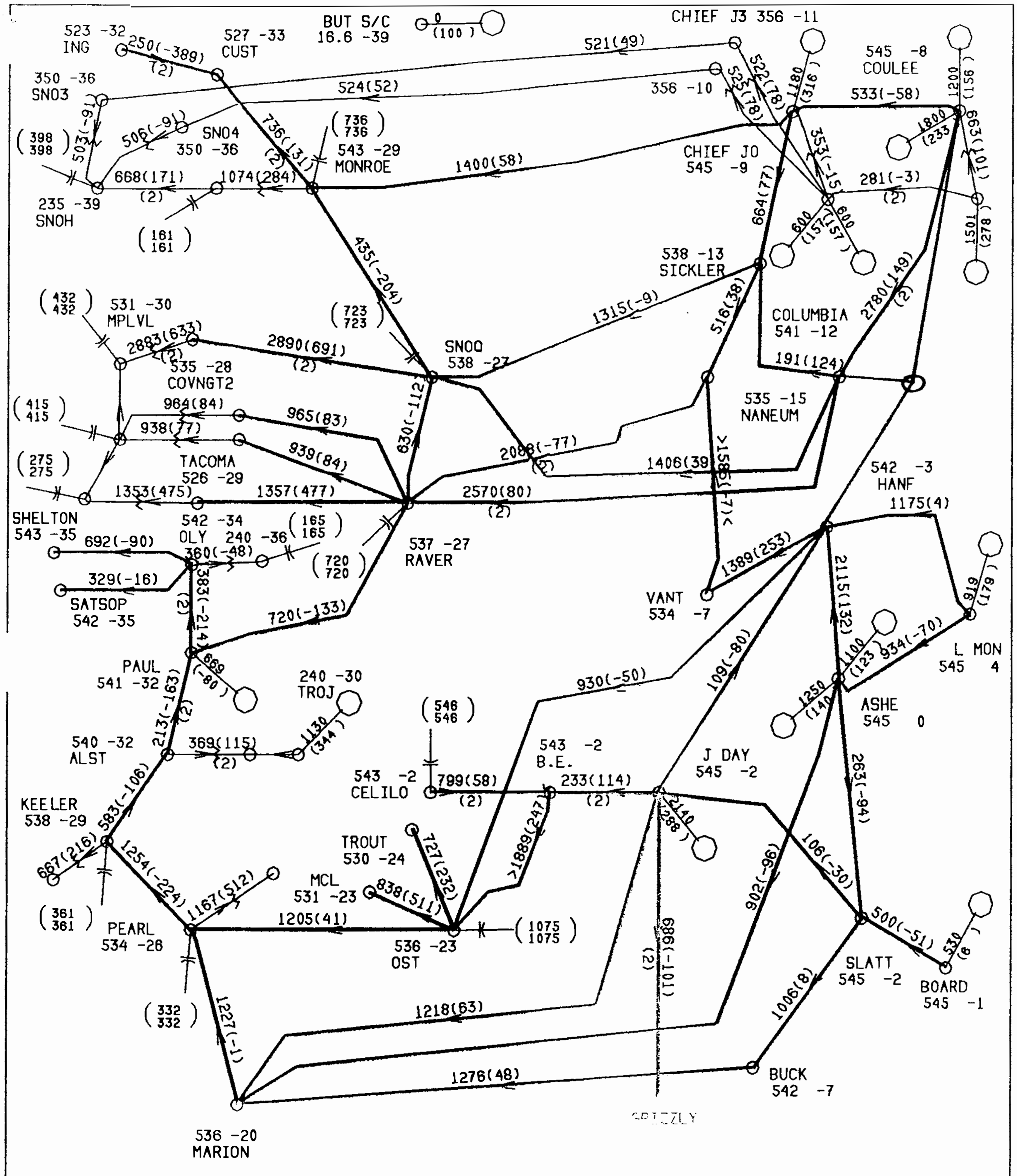
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -949.	BPA= 912.10
DC= -1710.	DC= -1710.	PNW= 1357.33
		SYSTEM= 4191.76

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1027.	AI= 534.

J04EH404 6/12/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH333
PLAN 6

S:PQ R- , PLOTTED 12-JUN-91 AT 16:12:38 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

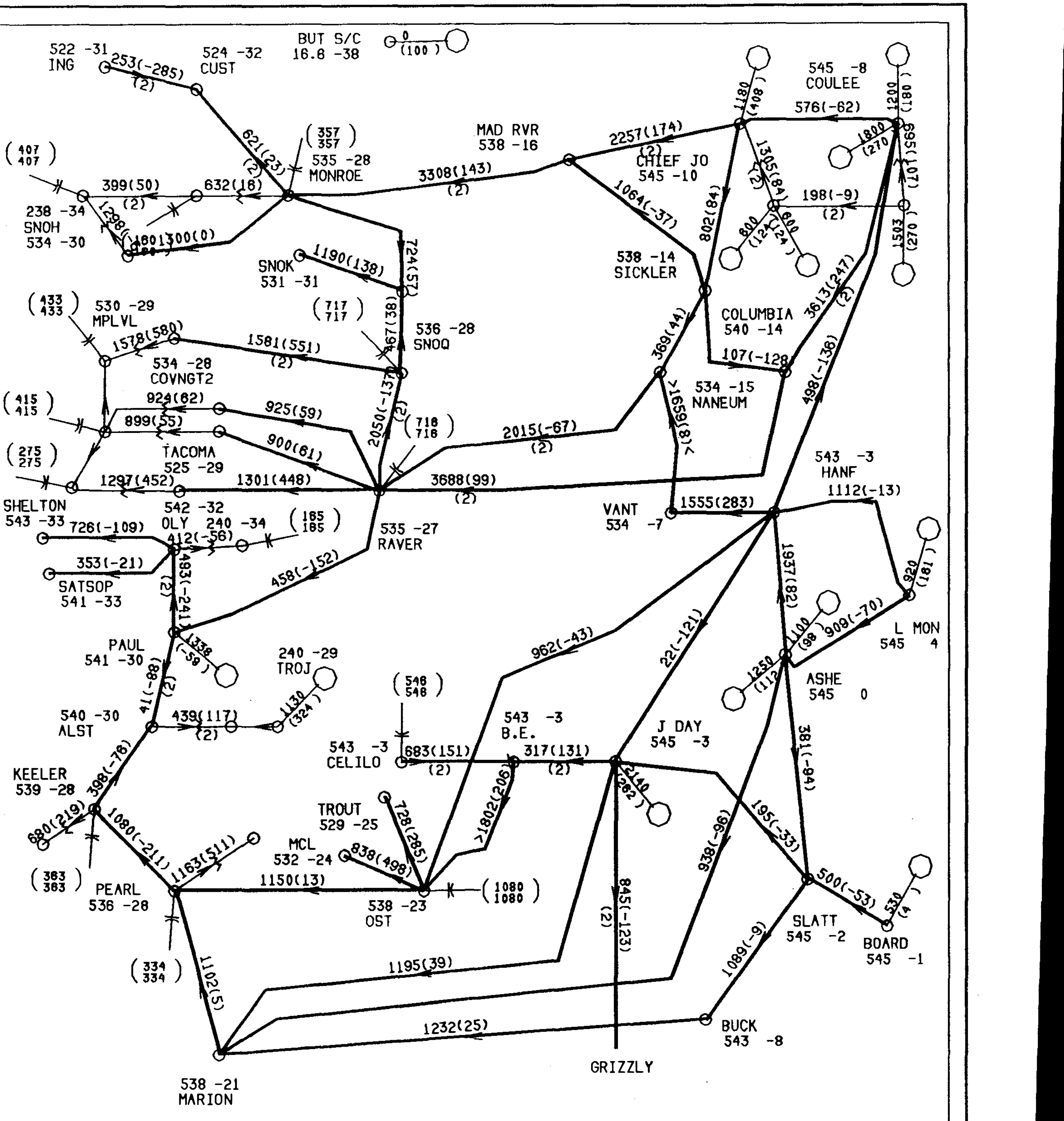
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -1175.	AC= -1370.	BPA= 986.84
DC= -2000.	DC= -2000.	PNW= 1441.61
		SYSTEM= 4285.54

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1039.	AI= 546.

J04EH105 9/ 9/91 PF V6010
CY89 HJL-ALH
BASED ON J04EH337
PLAN 6D

S:PQ R- , PLOTTED 9-SEP-91 AT 16:31:15 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

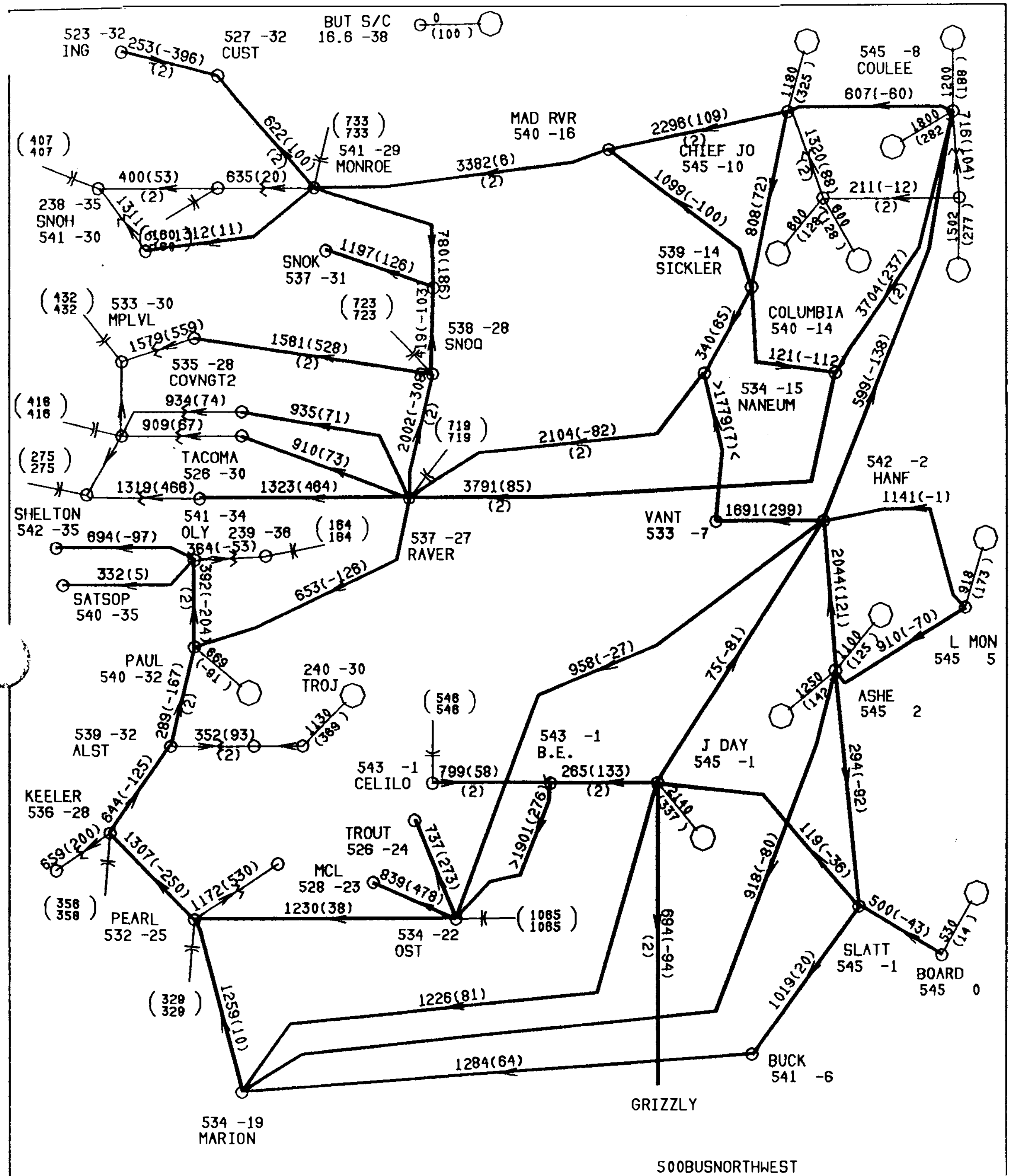
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -947.	BPA= 916.42
DC= -1710.	DC= -1710.	PNW= 1351.50
		SYSTEM= 4185.13

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1032.	AI= 531.

J04EH406 3/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH333
PLAN 4

S:PQ R- , PLOTTED 7-MAR-91 AT 10:21:31 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

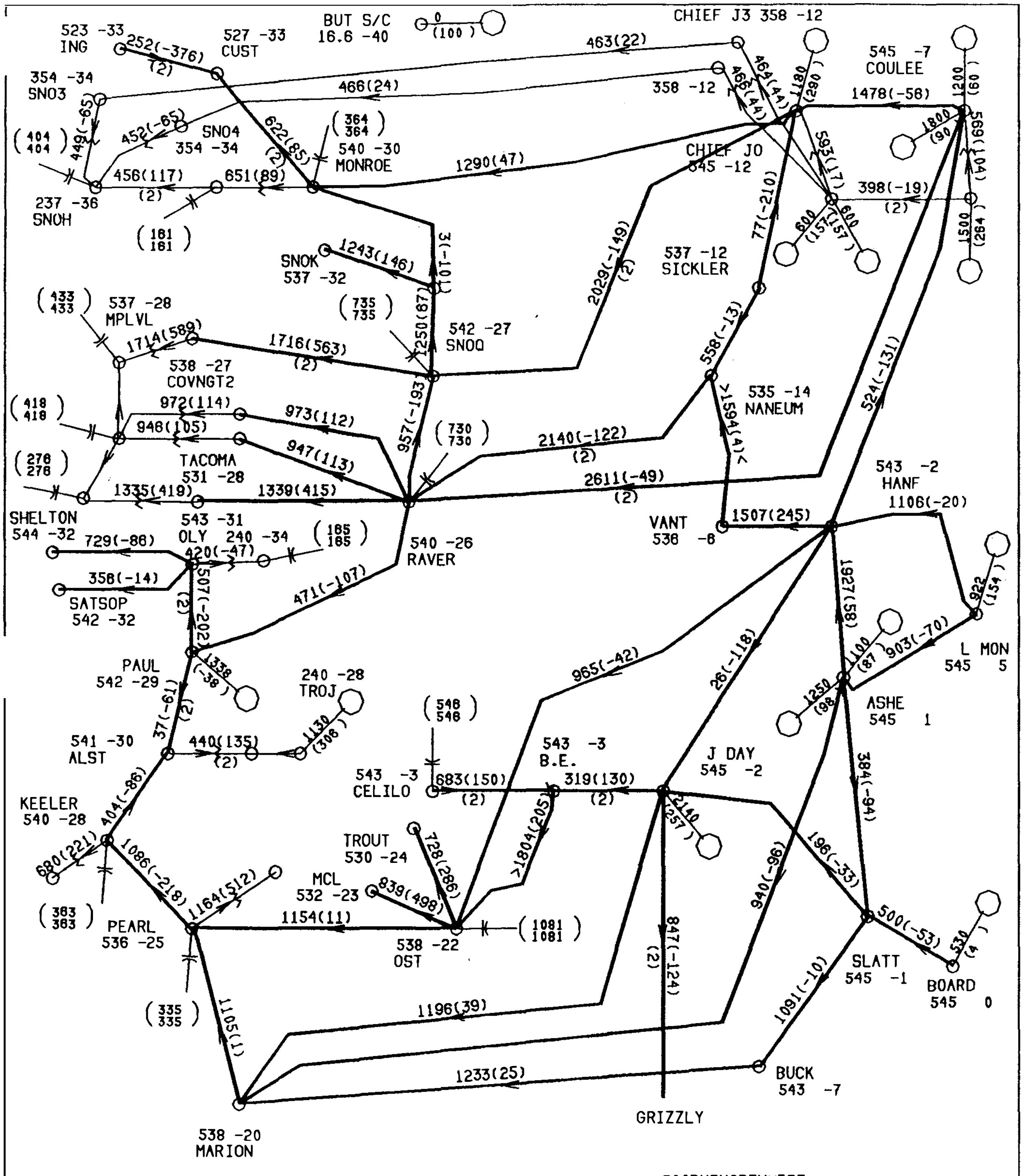
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -1175.	AC= -1368.	BPA= 994.18
DC= -2000.	DC= -2000.	PNW= 1439.73
		SYSTEM= 4282.74

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1044.	AI= 543.

J04EH407 3/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH337
PLAN 4

S:PQ R- , PLOTTED 7-MAR-91 AT 10:25:12 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -730.
DC= -1710.

ACTUAL
AC= -946.
DC= -1710.

LOSSES
BPA= 916.86
PNW= 1354.53
SYSTEM= 4188.31

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

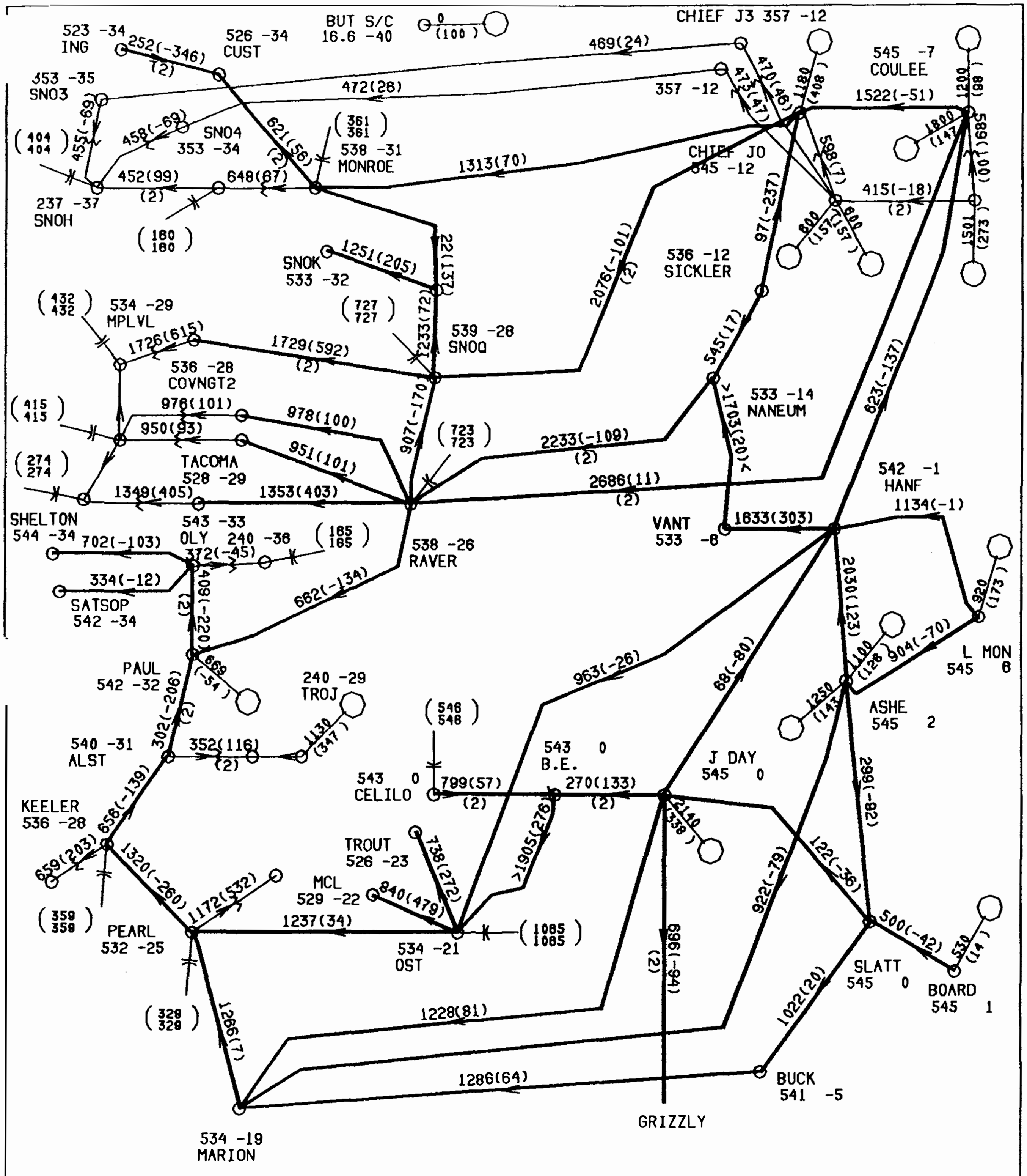
MONT TO PNW
SI= 1300.
AI= 1034.

IDAHO TO PNW
SI= 480.
AI= 530.

J04EH408 3/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH333
PLAN 2

S:PQ R- , PLOTTED 7-MAR-91 AT 09:58:16 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

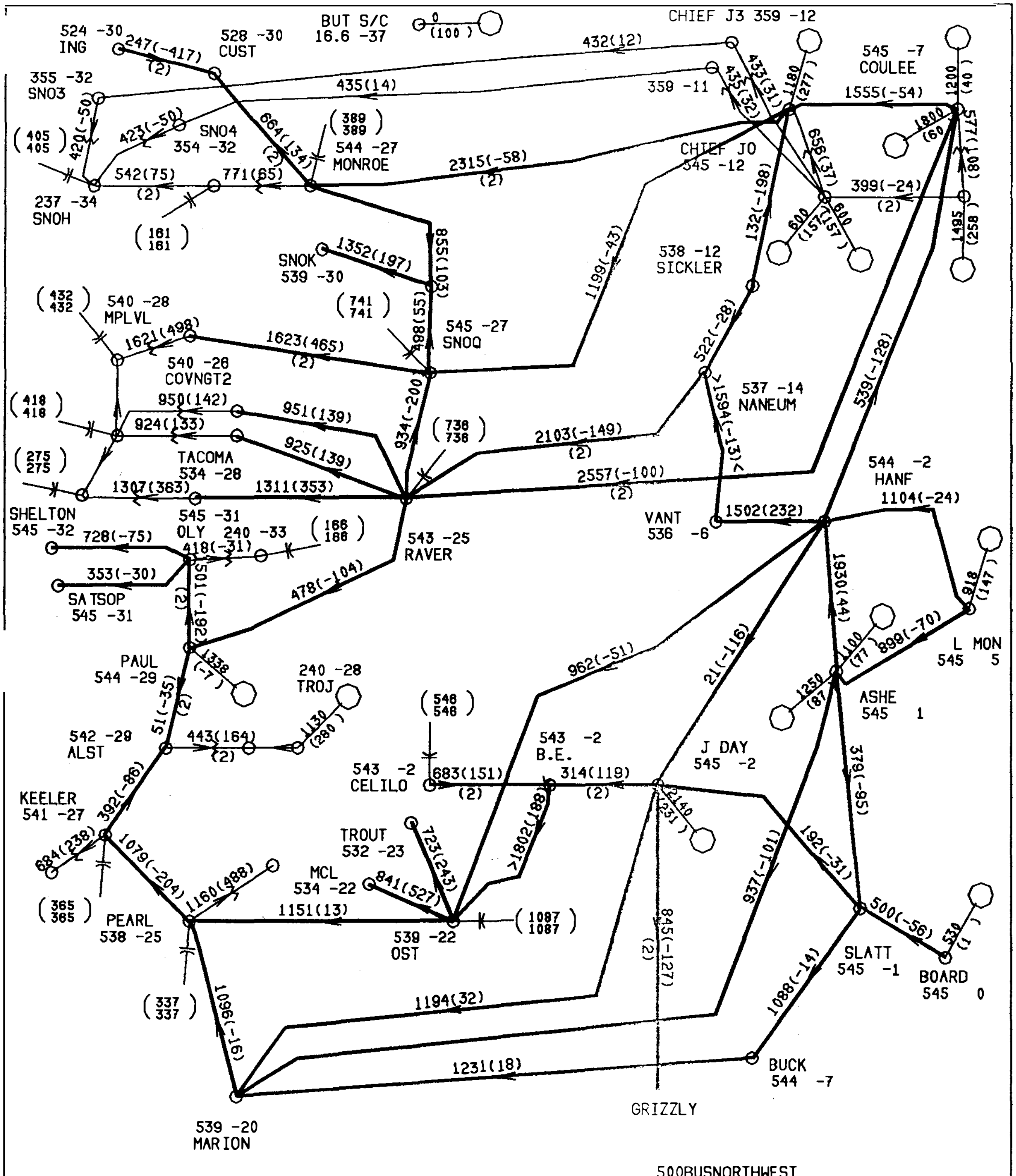
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -1175.	AC= -1367.	BPA= 995.54
DC= -2000.	DC= -2000.	PNW= 1444.46
		SYSTEM= 4288.85

J04EH409 3/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH337
PLAN 2

IADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1046.	AI= 542.

S:PQ R- , PLOTTED 7-MAR-91 AT 10:12:44 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

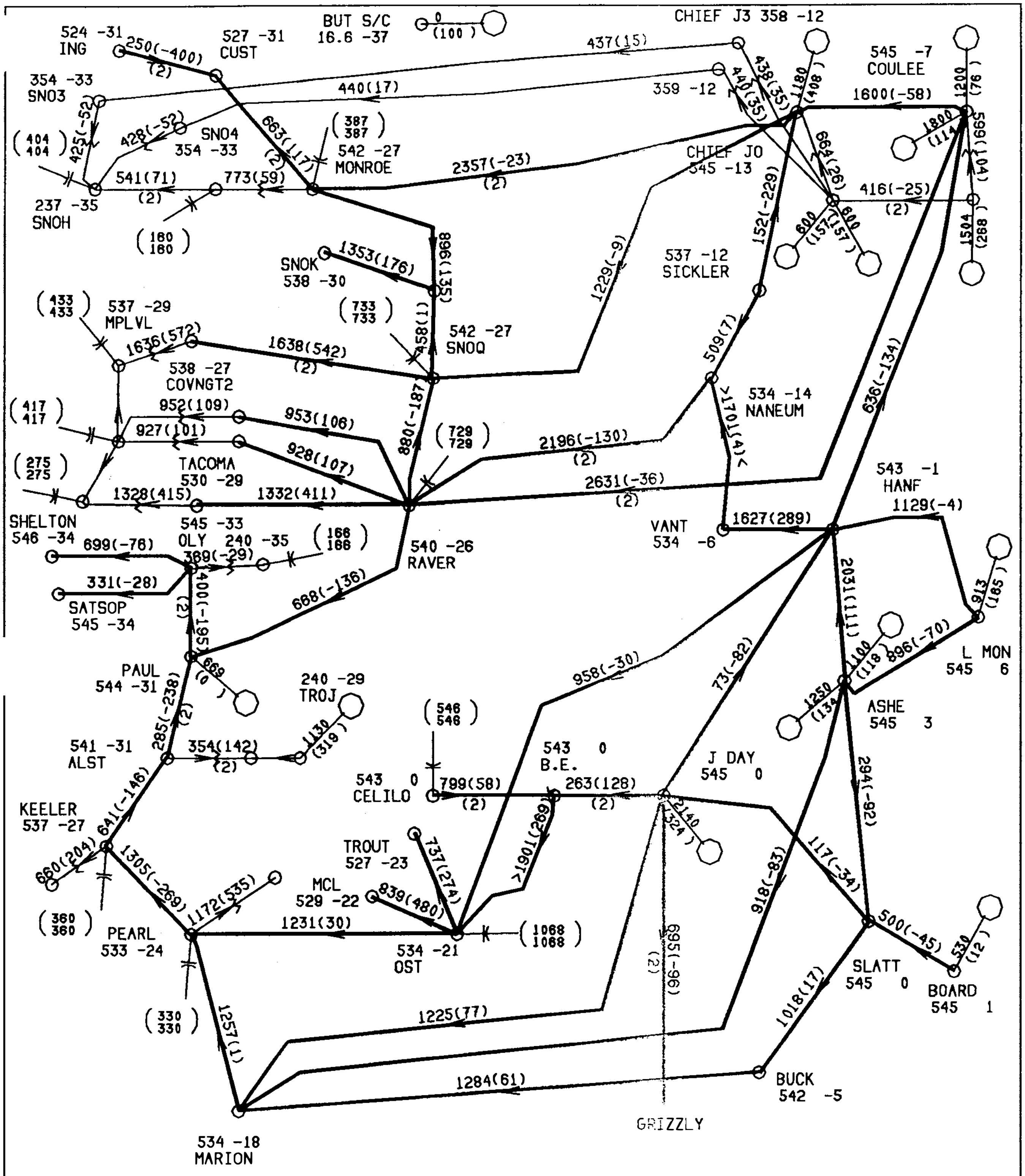
J04EH422 3/25/91 PF V6010
CY89 ALH-MJL
BASED ON J04EH333
PLAN 1

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -947.	BPA= 903.54
DC= -1710.	DC= -1710.	PNW= 1338.27
		SYSTEM= 4169.85

ANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1032.	AI= 531.

S:PQ R- , PLOTTED 25-MAR-91 AT 14:52:14 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -1175.
DC= -2000.

ACTUAL
AC= -1368.
DC= -2000.

LOSSES
BPA= 981.38
PNW= 1426.88
SYSTEM= 4269.45

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

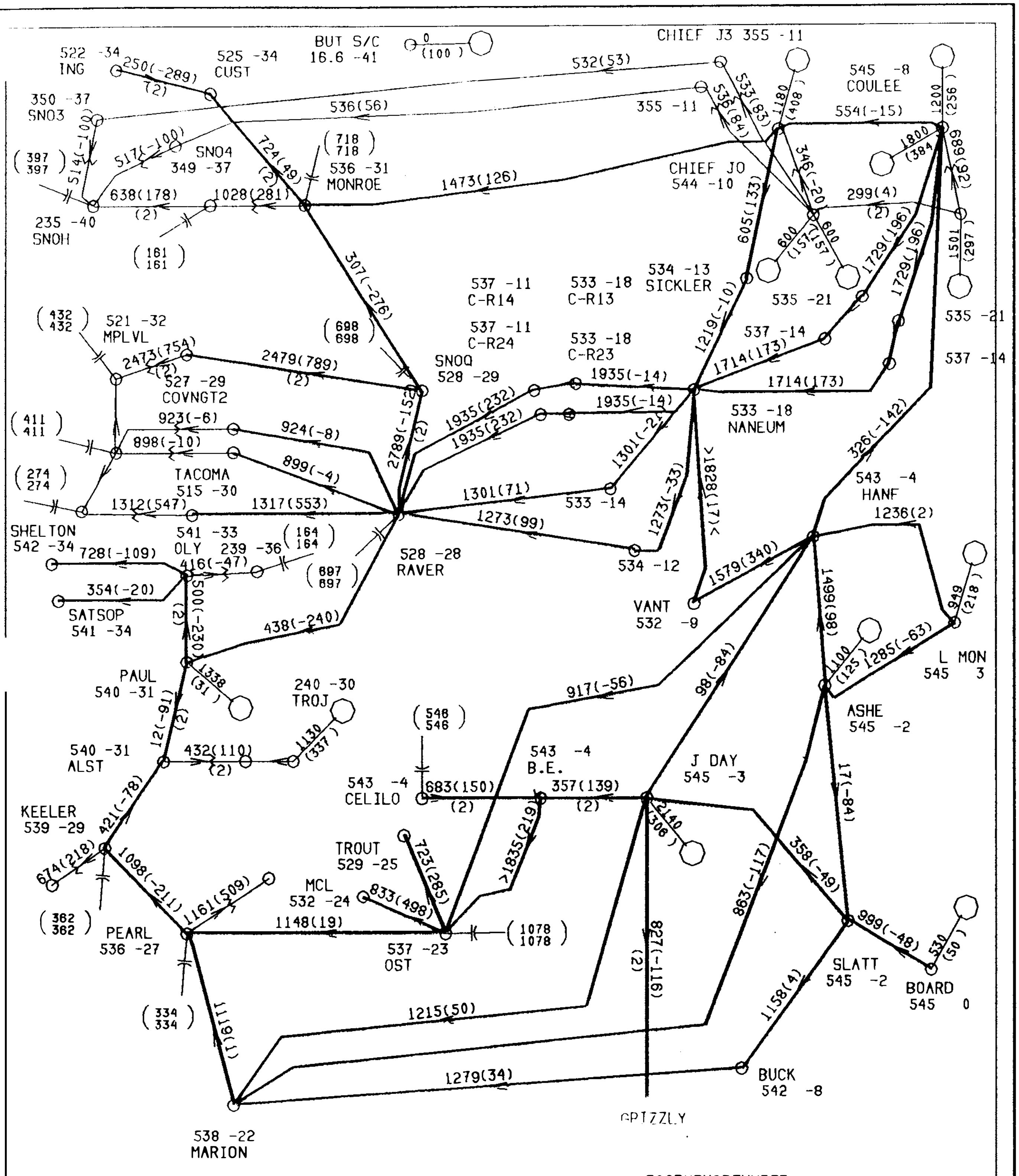
MONT TO PNW
SI= 1300.
AI= 1044.

IDAHO TO PNW
SI= 480.
AI= 543.

J04EH423 3/25/91 PF V6010
CY89 ALH-MJL
BASED ON J04EH337
PLAN 1

S:PQ R- , PLOTTED 25-MAR-91 AT 14:55:38 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

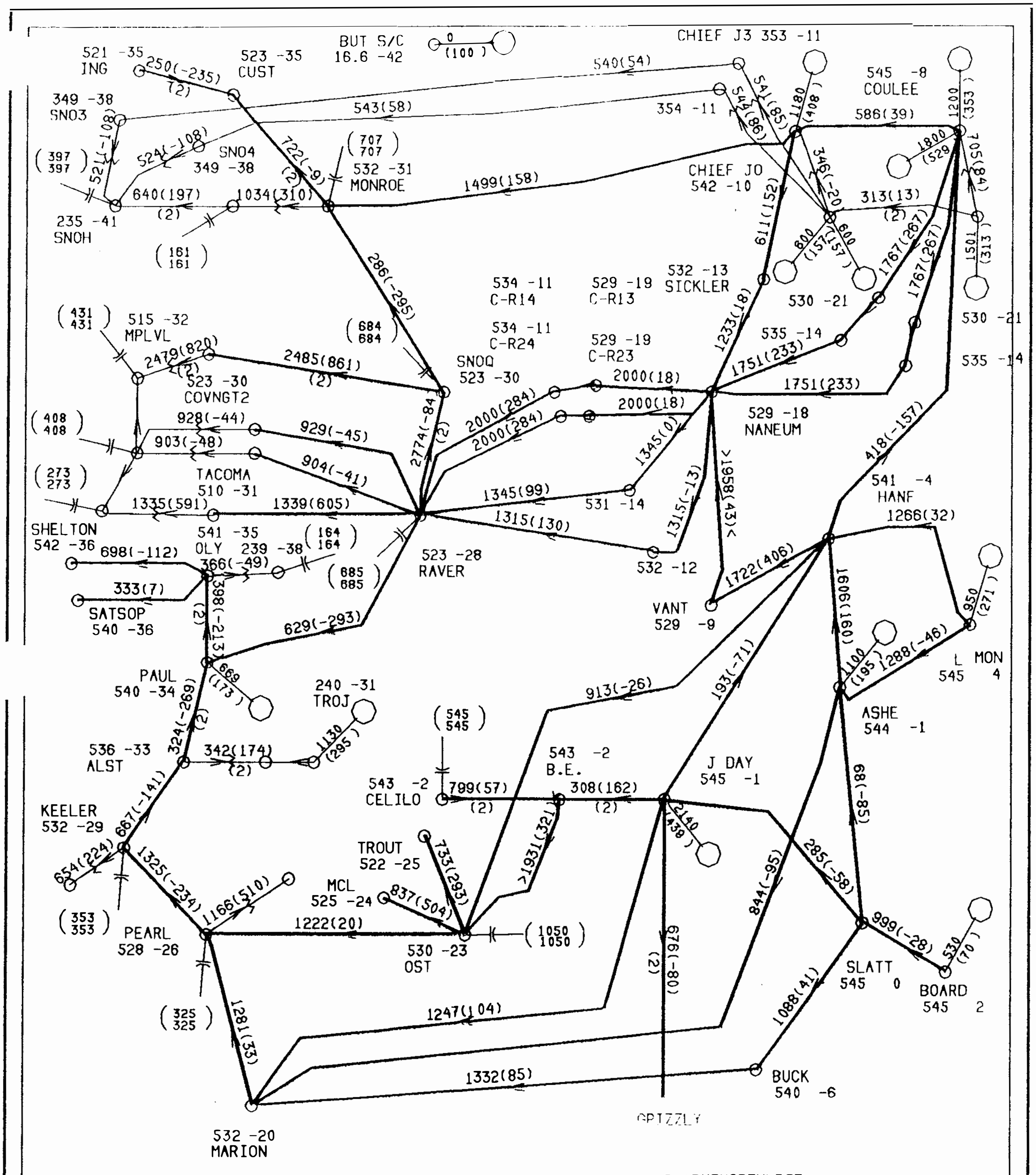
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -955.	BPA= 990.42
DC= -1710.	DC= -1710.	PNW= 1446.55
		SYSTEM= 4284.97

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1016.	AI= 539.

J04EH577 8/22/91 PF V6010
CY89 ALH-MJL
BASED ON J04EH333
NANEUM SWITCHYARD
30% COMP ON SICKLER-RAVER
20% COMP ON COULEE-RAVER
39% COMP ON VANTAGE-RAVER

S:PQ R- , PLOTTED 22-AUG-91 AT 13:49:02 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -1175.
DC= -2000.

ACTUAL
AC= -1376.
DC= -2000.

LOSSES
BPA= 1077.31
PNW= 1544.85
SYSTEM= 4394.52

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1028.

IDAHO TO PNW
SI= 480.
AI= 551.

J04EH578 8/22/91 PF V6010
CY89 ALH-MJL
BASED ON J04EH337
NANEUM SWITCHYARD
30% COMP ON SICKLER-RAVER
20% COMP ON COULEE-RAVER
39% COMP ON VANTAGE-RAVER

Attachment 1

ATTACHMENT 1

PUGET SOUND REINFORCEMENT TRANSMISSION ALTERNATIVES

by Marv Landauer and Gordon Comegys - BPA
9-19-90

There is a minor omission in this document. Reinforcement is needed in the Lake Sammamish area within the study period. A Lakeside 230/115-kV transformer addition is assumed in the powerflow models after 2001 to correct these local problems. This project was inadvertently left out of Table 150, however, it is included in all options studied in this report. Projects such as this are needed in the powerflow to get accurate results from the analysis of the cross Cascade transmission capacity. The performance of the alternatives studied in this report are not dependent on the Lakeside project. This project will be studied independently by the utilities involved to determine whether this or some other option is most favorable.

PUGET SOUND REINFORCEMENT TRANSMISSION ALTERNATIVES

ASSUMPTIONS

This report uses the the same assumptions as contained in the 1-12-90 memo from Porter to Perry (Table 150).

The line ratings used in this report are included in Table 151. The assumptions include Skagit generation levels prior to and after January 6 of each year. For calculation of loss savings noted in this report, it is assumed that the high and low generation levels will each exist for half the winter peak load period and the loss savings will be the average of these two conditions.

At the time this study was started, there was some concern about the high number of unexplained outages experienced by the new 1.7 pu line designs. Therefore, a 2.0 p.u. line design was used in these studies for calculation of line parameters. Sensitivity of this assumption is tested in Table 310. Due to audible noise constraints, a 4-bittern conductor bundle is assumed.

If an SVC is used in any study, its ouput is assumed to be zero until a contingency occurs. From that point on, the SVC attempts to maintain the pre-contingency voltage of the bus it is connected to.

NOTE

The January 2004 cases (except Plan 5 and 6) have an error in the compensation level of the Coulee-Raver lines (45% instead of 22.5%). This error improved the performance of the EH winter outages by about 150 MVARs. It was, however, detrimental to the normal winter double line outages of the Coulee-Raver lines, since the system had to withstand the loss of this additional compensation with fewer shunt capacitors energized prior to the outage. This error will be corrected in future cases. It should not have a great effect on the comparison of these alternatives. Refer to Table 310 for more detail.

PROBLEMS

The potential for voltage instability exists in the Puget Sound area for several cross mountain line outages or loss of Trojan generation. This report will analyze the reinforcement of the Cross Mountain (CM) transmission system to relieve these problems. Modifications to the transmission system could cause increased flow in certain areas of the system and require additional facilities. Major areas with transmission problems that are affected by the CM reinforcement are the north Seattle area, Trojan area, Okanogan area and Coulee-Chief Joe area. These will be analyzed individually for each alternative studied.

Reactive support for the maingrid transmission system was studied through 2004. Not all plans are necessarily equal, since additions beyond this time (some of them may be significant) were not considered. Thermal problems in the bulk transmissions system in the Puget Sound area were studied through 2010 to ensure that the plans were equivalent. The other problems were only studied around the 1996 timeframe to measure the impact of the Cross Mountain reinforcement.

Solving the voltage stability problem in the Puget Sound area is a two-tiered problem. The voltages on the 230-kV system need to be supported to preserve the output of the large amount of shunt compensation on the lower voltage system and the reactive losses of the Cross Mountain (CM) transmission needs to be reduced.

There are also three problems that exist prior to the assumed energization of the CM reinforcement (10-96) and will not necessarily be solved by this project. They are: a breaker failure at Raver, the integration of the new PSPL line into Lake Tradition and the Massachusetts-Broadstreet 115-kV line overload.

The breaker failure at Raver could cause loss of the Raver-Snoqualmie and Raver-Tacoma lines, which, prior to the CM additions, would cause the Covington transformers to overload as shown in J96254. Reinforcement of the CM transmission would reduce the severity of this problem. It is assumed that this problem is corrected by rearranging the bus layout at Raver (somehow) and this fix will eliminate the problem in later years. However, the effect of each plan on the existing bus layout is analyzed in Table 170.

There are many line overload problems in the Lake Tradition area that are the result of poor integration of Puget's new 230-kV cross mountain circuit. The heavy loading of the 115-kV lines in this area is further aggravated by external outages. The Massachussetts-Broadstreet overload is caused by throughflow which occurs during maingrid equipment outages. Nothing is assumed to be added to correct these problems, however the effect of each CM reinforcement plan is analyzed with respect to these problems in Table 170.

ALTERNATIVES CONSIDERED

Thirty nine new line options were studied in an attempt to solve the Puget Sound Voltage Stability problem. Five of these are considered technically and economically feasible. Also discussed below are a Reactive Option (no line construction) and two rebuild options. Options that were studied and rejected are included in Tables 302 and 303. The options listed in Table 302 are considered technically feasible, but are too costly. Those options listed in Table 303 are not considered technically feasible or are technically inferior.

The performances of the 500-kV transmission line alternatives are fairly similar. Generic development of these alternatives is included in Table 310. Differences are noted with each plan.

A. Chief Joseph-Monroe 500-kV Double-Circuit Line: Plan 1

1. Puget Sound Area Voltage Stability Performance

This plan assumes a new double circuit Chief Joe-Monroe 500-kV line is built parallel to the existing circuit on new right-of-way (ROW). This new line and the 300 MVAR Static VAR Compensator (SVC) at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs is later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004, respectively. For more detail on these additions, refer to Table 310.

The voltage stability performance of Plan 1 is shown in QV-110 for 1996 and in QV-111 for 2004 for the 3 critical outages. Since this plan does not have the reactive margins for the double line outage in 2004, an additional 300 MVAR SVC is needed at Covington prior to the 2003-4 winter.

2. Puget Sound Area Thermal Overload Requirements

If the Chief Joe-Monroe 500-kV double-circuit line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These include:

a. Loss of the Monroe-Sedro-Snohomish 230-kV three terminal line causes the Monroe-Snoking Tap 230-kV line to overload during low Skagit generation (J96M218). This overload will not occur with normal Skagit generation (J96M227).

b. Loss of the Monroe-Snoking-Sammamish 230-kV three terminal line causes the Monroe-Sedro Tap 230-kV line to overload during low Skagit generation (J96M217). This overload will also not occur with normal Skagit generation (J96M226).

c. Loss of the Maple Valley 500/230-kV transformer overloads the Monroe transformer beyond its emergency loading and loads the Monroe-Sedro tap line heavily (J96EH554).

d. Loss of the double-circuit Chief Joe-Snohomish 345-kV lines during normal winter causes the Monroe-Sedro Tap 230-kV line to overload (J96235).

e. Loss of the Monroe-Snoqualmie 500-kV line also overloads the Monroe 500/230-kV transformer (J96EH555).

f. The Monroe transformer and the Monroe-Snohomish 230-kV line will overload during cold weather without any outages in 2001 as shown in J00EH32.

This is a difficult set of problems to solve. Since Monroe is strengthened considerably by the addition of the double-circuit CM line, the 230-kV system out of Monroe is stressed heavily as indicated by the fact that there are overloads in the base system without any outages in 2001. To correct these problems, additional 500/230-kV transformation is needed and the 230-kV system into Snohomish needs backup. Since the base system is so heavily stressed, a single reinforcement project will not be able to solve the problems through the study period (2010).

Adding a new Monroe-Snohomish 500-kV line to feed a 500/230-kV transformer at Snohomish would relieve these problems best initially. Case J96EH568 shows that a third Bothell-Snohomish 230-kV line is needed with this plan for the outage of one of the existing lines. This can be accomplished by looping-in or tapping one of SCL's Skagit lines. The worst outage for this plan appears to be the loss of the new transformer and/or the new Monroe-Snohomish 500-kV line (J00EH32) which will cause the Monroe transformer to overload in 2001.

To relieve these later problems, a transformer addition is needed in the Snoking/Snohomish area. Reinforcing Snoking with a 500/230-kV transformer looks attractive at this time since the Monroe-Snoqualmie 500-kV line can be tapped and the existing Snoking Tap 230-kV line can be converted to its design voltage of 500-kV (no new 500-kV line construction is needed). A second Bothell-Snoking 230-kV line is also needed with this transformer (case J00EH113). These additions should solve the area problems well beyond 2010.

If the Snoking transformer were added first, it would require a new circuit to Monroe and not just a tap on the Monroe-Snoqualmie line in order to correct problem 5 above. This line construction (9 miles) can be eliminated by adding the Snohomish transformer first, even though the Snoking project saves about 4

MW more losses than Snohomish.

If the Snoking 500/230-kV transformer is added first, the transmission between Monroe and Snohomish will overload in 1998 for the loss of the new Snoking transformer (J96EH565 and J00EH28). This plan is not as good as Snohomish since the conversion of the existing 230 tap line into Snoking to its design voltage of 500-kV just replaces the existing circuit with one of higher capacity. But since the new line is 500-kV, the system must serve abnormally cold weather loads during that outage instead of moderate loads as was the case prior to the change.

Additional transformation could be added at Monroe with an additional 230-kV circuit added to the Snohomish area. Loss savings would favor the addition of the transformation closer to the load, however, this could aggravate through-flow problems.

Tapping an existing Custer-Monroe 500-kV line to feed a 500/230-kV transformer at Snohomish is another possibility to relieve these problems and would save some line construction. However, loss of the Custer-Monroe line with the new transformer aggravates the overloads that would occur if only the transformer were lost. Additional support would be needed in about 1999 to eliminate the overloads of the Monroe transformer and Monroe-Snohomish line for loss of this new transformer as shown in case J00EH30. As shown above, this overload can be delayed about 2 years if an entirely new line is built from Monroe to Snohomish to supply the new transformer.

The loss savings due to the addition of the recommended Snohomish transformer project is about 13.5 MW on the BPA system and 14.9 MW total for the Northwest in 1996 (compare cases J96248, J96252, J96261 and J96262). These loss savings increase to 21.5 MW on the BPA system and 26.0 MW for the Northwest in 2000 (compare cases J0035, J0036, J0037 and J0038). Note that the 2000 cases have both the Snohomish and the Snoking transformers in service.

A 300 MVAR shunt reactor is required at Monroe to provide voltage control on the 500-kV system during lighter load periods.

Summer and spring conditions were studied (Tables 202-212). The assumed summer conditions include 2000 MW Ingledow to Custer powerflow and 8000 MW total PNW to PSW interchange schedules. The assumed spring conditions include 2000 MW Ingledow to Custer powerflow and 1800 MW Custer to Ingledow powerflow. Eleven transmission lines need upgrading to higher conductor operating temperatures (Table 201).

The Ingledow to Custer powerflow cannot exceed 1000 MW with the Monroe-Snoqualmie 500-kV line permanently out of service during summer. This applies only to Plan 1. The other plans can accomodate 2000 MW Ingledow to Custer during outages.

3. Portland Area Voltage Stability Performance

The critical outage for the Portland area is loss of the Trojan Nuclear plant with one Centralia generating unit previously out of service during abnormally cold weather loads. The addition of the new line into the Puget Sound area, with 300 MVAR SVC's at Maple Valley and Keeler will provide the necessary reactive margins in the Portland area. The Keeler SVC will need to be increased to 500 MVARs in later years to keep up with the load growth. Also, additional 500-kV shunt capacitors will be needed at Ostrander, Keeler and Pearl substations between 1998 and 2004. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-112. For more detail on this plan, refer to Table 310.

4. Portland Area Thermal Overload Requirements

Prior to Puget Sound Reinforcement, the PGE Trojan-Rivergate 230-kV and Trojan-St. Marys 230-kV lines overload following an Allston-Keeler 500-kV line outage during summer conditions (A93194). The severity of the overload increases during off peak Seattle summer loads, very high PNW to PSW schedules over the DC and AC interties (following 3rd AC), and high BCH to PNW schedules (A93160). Adding a cross mountain line increases the severity of the overload by about 4% (A96174, A96175). However, the overload is more sensitive to high area interchange schedules during off peak summer loads than it is to the addition of a new cross mountain line. The overloads slightly decreases in future years as the Seattle summer loads increase.

5. Okanogan Valley Performance/Effects

The new cross mountain line increases loading by about 7%. The Okanogan-Brewster 115-kV line needs upgrading to a higher conductor operating temperature before and after addition of a cross mountain line to prevent overloads following an outage of either Douglas-Wells 230-kV line or Sickler 500/230-kV transformer during summer (A96170, A96176). Refer to Table 201.

6. Coulee/Chief Joseph Area Performance/Effects

Loading increases on the 500/230-kV transformers with a new CM line. A second Chief Joe 500/230-kV transformer is needed to prevent overloading the Coulee 500/230kv transformer following an outage of the existing Chief Joe 500/230-kV transformer during spring with 1800 MW Custer to Ingledow powerflow (SPG94116). Refer to Table 201.

7. Plan 1 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus; Add 300 MVAR SVC on Keeler 230-kV bus; Add 500-kV shunt capacitor bank at Ostrander.
1996	Add Chief Joseph-Monroe 500-kV double circuit line; Add 1300 MVA Snohomish 500/230-kV transformer fed from new 11 mile 500-kV line from Monroe; Loop-in one SCL Bothell-Diable line into Snohomish; Add Monroe 500-kV shunt reactor; Upgrade 12 transmission lines to higher operating temperatures; Add second Chief Joe 500/230-kV transformer.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR; Add Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking; Add Snoking-Bothell 230-kV #2; Add MSC to one existing Raver shunt capacitor group; Add second 500-kV shunt capacitor bank at Ostrander.
2001	Upgrade Maple Valley SVC to 500 MVAR.

2002	Add 500-kV shunt capacitor bank at Snoqualmie; Add second 500-kV shunt capacitor bank at Pearl;
2003	Add 300 MVAR SVC on Covington 230-kV bus.
2004	Add 500-kV shunt capacitor bank at Monroe: Add third 500-kV shunt capacitor bank at Ostrander.

8. Loss savings of Plan 1

The loss savings of various options is summarized in Table 100. Plan 1 will save 58.0 MW on the BPA system and 70.2 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 67.9 MW on the BPA system and 82.0 MW in the Northwest in 2004 (compared to the Reactive Plan). This plan has some of the highest loss savings of the 500-kV options studied.

B. Chief Joseph-Snoqualmie 500-kV Double-Circuit Line: Plan 2

1. Puget Sound Area Voltage Stability Performance

This plan assumes a new Chief Joseph-Snoqualmie 500-kV double circuit line is built on new ROW paralleling the existing Chief Joe-Sickler line, on new ROW from Sickler toward the Cascades summit, then paralleling the Rocky Reach-Maple Valley 345-kV line into Snoqualmie. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs is later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on this and the additions needed through 2004, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 2 in service is shown in QV-120 for 1996 and in QV-121 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These include:

a. Loss of the double-circuit Chief Joe-Snohomish 345-kV lines during normal winter will cause the Monroe-Sedro Tap 230-kV line to overload in 1997 (J96234).

b. Loss of the Monroe 500/230-kV transformer causes the Maple Valley-Snoking 230-kV line to load beyond the 1275 amp limit (J96EH553).

c. Loss of the Maple Valley 500/230-kV transformer will cause the Monroe transformer to overload in 2001 (J00EH25).

The 230-kV three-terminal line outages out of Monroe are not serious with this CM plan (J96M219 and J96M220).

Although transformation is not required until 2001, it is advantageous to add a Snoking transformer with the new CM line. This transformer addition solves both line overloads (problems a and b above) and the eventual 500/230-kV transformer overload (problem c above). It also has loss saving benefits. The Monroe-Snoqualmie line can be tapped and the existing Snoking Tap-Snoking 230-kV line converted to its design voltage of 500-kV to supply the new Snoking transformer. A second Snoking-Bothell 230-kV line is needed with this transformer to prevent overloads during Monroe transformer outages (J00EH26).

When the Lakeside transformer is added (assumed in 2001), the unused 230-kV circuit that is parallel to the existing Bothell-Snoking-Maple Valley 230-kV line will need to be put into service at 230-kV. With the new Chief Joe-Snoqualmie 500-kV line plan, the Maple Valley-Lakeside section of this line will need to be rebuilt to about 1800 amps at -15 degrees Celcius.

The Maple Valley 500/230-kV transformer will overload in about 2007 for loss of the Snoking transformer and Monroe-Snoqulamie line (J04EH97 and 2% load growth). A parallel Maple Valley 500/230-kV transformer will be needed at this time. With these additions, this plan should provide for future load growth beyond 2010.

If a second Maple Valley-Snoking 230-kV line (25 miles) is added to correct problem #2 above instead of the Snoking transformer, it would also delay the Monroe-Snohomish overload in problem #1 until about 1999 (J96236 and J0017). If a second Maple Valley 500/230-kV transformer is then added in 1999, it would delay this overload further until about 2002 (2% load growth applied to case J0018). Additional support would then be needed into the Snohomish area. The Snoking project would be needed at this time.

If the second Maple Valley-Snoking 230-kV line is added in 10-96, followed by a Snoking transformer in 1999, the 230-kV line addition would have limited usefulness until the Lakeside transformer is added (J00EH27). The Snoking transformer addition provides substantial loss savings over the 230-kV line addition (9 MW vs 1.2 MW). If the Snoking 500/230-kV transformer is added in 1996, it would solve all the problems listed above through the year 2007 without the addition of a second Maple Valley-Snoking 230-kV line. This line would not be needed until the Lakeside transformer is added. Therefore, the Snoking transformer is the preferred option.

The loss savings due to the addition of the Snoking project is about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Snoqualmie line addition on the Portland system performance is is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-122. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)

6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)

7. Plan 2 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus; Add 300 MVAR SVC on Keeler 230-kV bus; Add 500-kV shunt capacitor bank at Ostrander.
1996	Add Chief Joseph-Snoqualmie 500-kV double circuit line; Add 1300 MVA Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking; Add Snoking-Bothell 230-kV line #2; Add Snoqualmie 500-kV shunt reactor; Eight transmission line upgrades to higher operating temperatures Add second Chief Joe 500/230-kV transformer.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR; Add MSC to one existing Raver shunt capacitor group; Add second 500-kV shunt capacitor bank at Ostrander.
2001	Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition).
2002	Upgrade Maple Valley SVC to 500 MVAR; Add 500-kV shunt capacitor bank at Snoqualmie; Add second 500-kV shunt capacitor bank at Pearl.
2004	Add second 500-kV shunt capacitor bank at Monroe; Add third 500-kV shunt capacitor bank at Ostrander.
2006	Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 2

The loss savings of various options is summarized in Table 100. Plan 2 will save 53.6 MW on the BPA system and 66.9 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 53.8 MW on the BPA system and 65.1 MW in the Northwest in 2004 (compared to the Reactive Plan).

C. Chief Joseph-Snoqualmie/Monroe 500-kV Double-Circuit Line: Plan 3

1. Puget Sound Area Voltage Stability Performance

This plan includes a double circuit 500-kV line from Chief Joe west towards Puget Sound using the existing northern corridor to Monroe. At 29 miles outside Monroe, the line will split into two single circuits with one circuit extending southwest to the new Snoqualmie switchyard site and the other circuit line continuing northwest to Monroe. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs is later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004. For more detail on this and the additions needed through 2004, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 3 in service is shown in QV-132 for 1996 and in QV-133 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, the following problems will occur:

a. The Maple Valley 500/230-kV transformer outage will cause the Monroe 500/230-kV transformer to overload by January 1997 (J96EH328).

b. The new line addition aggravates the loadings experienced during outages of either 230-kV three-terminal line out of Monroe (J96M147 and J96M148). These lines will overload one or two years after the Cross Mountain line is added.

c. The loss of the double-circuit Chief Joe-Snohomish 345-kV lines will cause the Monroe-Sedro Tap 230 line to overload (J96260).

The addition of a 500/230-kV transformer at Snoking will solve all the problems listed above. The existing 500-kV constructed tap line presently feeding Snoking should be used to tap the newly formed Snoqualmie-Monroe 500-kV line. A second Bothell-Snoking section is also needed for either the Maple Valley or Monroe 500/230-kV transformer outages as shown in J96EH251 and J96EH252.

The existing Monroe-Snohomish 230-kV line will overload in about 2001 for loss of the new Snoking transformer (J00EH39). A second Snoking-Maple Valley 230-kV line would delay this line overload until about 2006 (case J04EH42 and 2% load growth). This line is assumed to be added in the early 2000's with the Lakeside 230/115-kV transformer. Therefore, if Lakeside is added by 2001, no reinforcement is needed in the Monroe-Snohomish area until 2006.

At this time, additional support will be needed for Snohomish. If a Monroe-Snohomish line is added in 2006, the Monroe 500/230-kV transformer will overload in 2010 for loss of the new Snoking transformer (case J04EH110 and 2% load growth). Since additional 500/230-kV transformation is also needed, this plan will include construction of the Monroe-Snohomish line at 500-kV (operated at 230-kV initially) in 2006 and conversion of this line to 500-kV and a Snohomish 500/230-kV transformer in 2010. As shown with Plan 1, a loop-into Snohomish of one Skagit line is needed with this transformer. This reinforcement will relieve the overload problems in the area beyond 2010.

If the Lakeside transformer is delayed beyond 2001, the Monroe-Snohomish construction will have to be done earlier.

Another solution to these problems would be to reverse the order of the 500/230-kV transformers. If the Snohomish transformer is added first, additional support would be needed to relieve the Monroe transformer and Monroe-Snohomish 230-kV line loadings at about the same time as the Snoking transformer plan (case J00EH35).

Both plans would perform similarly. However, line constuction between Monroe and Snohomish can be delayed with the Snoking plan, especially if Lakeside is added as planned. The BPA loss savings for both plans are almost identical, while the Northwest loss savings favors Snoking by 2.1 MW. Therefore, the Snoking Reinforcement is preferred.

The loss savings due to the addition of the Snoking project (using the existing parallel Bothell-Snoking circuit) is about 10.6 MW on the BPA system and 15.1 MW total for the Northwest in 1996 (compare cases J96241, J96242, J96250, and J96251). The loss savings increases to 12.6 MW for BPA and 17.6 for the Northwest in 2000 (compare cases J0023, J0024, J0027 and J0028).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Snoqualmie/Monroe line addition on the Portland system performance is is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-134. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)

6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)

7. Plan 3 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus; Add 300 MVAR SVC on Keeler 230-kV bus; Add 500-kV shunt capacitor bank at Ostrander.
1996	Add Chief Joseph-Snoqualmie/Monroe 500-kV double circuit line; Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking; Add Snoking-Bothell 230-kV line #2; Add Snoqualmie 500-kV shunt reactor; Add second Chief Joe 500/230-kV transformer. Eight line upgrades.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR; Add MSC to one existing Raver shunt capacitor group; Add second 500-kV shunt capacitor bank at Ostrander.
2001	Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition).
2002	Upgrade Maple Valley SVC to 500 MVAR; Add 500-kV shunt capacitor bank at Snoqualmie; Add second 500-kV shunt capacitor bank at Pearl;
2004	Add second 500-kV shunt capacitor bank at Monroe;

Add third 500-kV shunt capacitor bank at Ostrander.

2005 Add Monroe-Snohomish 500-kV line, operate at 230-kV initiallly.

2010 Add Snohomish 500/230-kV 1800 MVA transformer;
Loop Bothell-Diablo 230-kV line into Snohomish;
Convert Monroe-Snohomish line to 500-kV operation.

8. Loss savings of Plan 3

The loss savings of various options is summarized in Table 100. Plan 3 will save 59.1 MW on the BPA system and 73.9 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 63.6 MW on the BPA system and 77.1 MW in the Northwest in 2004 (compared to the Reactive Plan). This plan has the highest loss savings of the 500-kV options studied.

D. Hanford-Snoqualmie 500-kV Double-Circuit Line: Plan 4

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built from Hanford to Naneum paralleling the existing 500-kV line. From Naneum to Snoqualmie, the new line will parallel the existing Rocky Reach-Maple Valley 345-kV line. The reason for including this plan is the possibility that future resources (eg. the mothballed nuclear plant at Ashe, WNP-1) may be energized in the Hanford area.

This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs is later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on the need for these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 4 in service is shown in QV-140 for 1996 and in QV-141 for 2004 for the 3 critical outages. To meet the reactive requirements for the double line outage in 2004, an additional 300 MVAR SVC is needed at Covington in 2004.

2. Puget Sound Area Thermal Overload Requirements

The thermal requirements of this plan are the same as Plan 2 above. The Snoking and Maple Valley transformer addition projects are similarly proposed to correct these problems. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Hanford-Snoqualmie line addition on the Portland system performance is is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-142. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: No impact

6. Coulee/Chief Joseph Area Performance/Effects: No impact

7. Plan 4 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus; Add 300 MVAR SVC on Keeler 230-kV bus; Add 500-kV shunt capacitor bank at Ostrander.
1996	Add Hanford-Snoqualmie 500-kV double circuit line; Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking; Add Snoking-Bothell 230-kV line #2; Add Snoqualmie 500-kV shunt reactor; Eight line upgrades.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR; Add MSC to one existing Raver shunt capacitor group; Add second 500-kV shunt capacitor bank at Ostrander.
2001	Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition); Upgrade Maple Valley SVC to 500 MVAR.
2002	Add 500-kV shunt capacitor bank at Snoqualmie; Add second 500-kV shunt capacitor bank at Pearl.
2004	Add second 500-kV shunt capacitor bank at Monroe; Add third 500-kV shunt capacitor bank at Ostrander; Add 300 MVAR SVC on Covington 230-kV bus.
2006	Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 4

The loss savings of various options is summarized in Table 100. Plan 4 will save 39.9 MW on the BPA system and 51.0 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 57.4 MW on the BPA system and 74.2 MW in the Northwest in 2004 (compared to the Reactive Plan). The increase in loss savings in 2004 is largely due to the assumption of WNP-1 operating.

E. Sickler-Snoqualmie Double-Circuit Line & Naneum Switchyard: Plan 5

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built on new ROW from Sickler to Snoqualmie. Mileage for the northern corridor was assumed in the studies, however, the southern corridor is not much longer. Also included in this plan is the development of a major Naneum switchyard (the Coulee-Raver lines will be tied into the existing station with the Sickler-Raver and Vantage-Raver lines). This switchyard development strengthens Sickler as a source for the new line and reduces the severity of the double-line Coulee-Raver outage.

With this new line added, the three critical outages for the Puget Sound area are 1) loss of the Chief Joe-Monroe 500-kV line during abnormally cold weather, 2) loss of the Trojan nuclear plant with one Centralia unit previously out-of-service, also during abnormally cold weather and 3) simultaneous loss of both Coulee-Naneum 500-kV lines (the compensated section of the old Coulee-Raver lines) during normal winter peak loads.

These new additions and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs is later years to keep up with the expected load growth. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on these additions, refer to Table 310.

The voltage stability performance of Plan 5 is shown in QV-150 for 1996 and in QV-151 for 2004 for the 3 critical outages. To meet the reactive requirements for the single line outage in 2004, an additional 300 MVAR SVC is needed at Covington in 2004. Performance of this plan with the Covington SVC is shown in QV-152.

A Chief Joseph-Sickler 500-kV single circuit and a 300 MVAR SVC at Sickler was investigated as alternatives to the Covington SVC to provide the required reactive margins. Neither performed as well as the Covington SVC during post-transient conditions. However, the transmission between Chief Joe and Sickler will eventually need to be reinforced.

It should be noted that in Plans 1 and 4, a Covington SVC was also proposed, but to correct the double line outage. In Plan 5 this SVC is needed for the cold weather single line outage. The development of the Naneum switchyard in Plan 5 improves the performance of the double line outages. The MSC at Raver is not needed with this plan.

2. Puget Sound Area Thermal Overload Requirements

The thermal requirements of this plan are the same as Plan 2 above. The Snoking and Maple Valley transformer addition projects are similarly proposed to correct these problems. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Sickler-Snoqualmie line and Naneum Switchyard additions on the Portland area performance is is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-153. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: No impact

6. Coulee/Chief Joseph Area Performance/Effects: No impact

Although there is no impact in the Coulee/Chief Joseph area, there may be some impact on the Sickler/Douglas transformer. This needs further study.

7. Plan 5 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus and Add 300 MVAR SVC on Keeler 230-kV bus. Add 500-kV shunt capacitor bank at Ostrander.
1996	Add Sickler-Snoqualmie 500-kV double circuit line; Expand Naneum 500-kV switchyard; Add 300 MVAR 230-kV shunt capacitors at Wells; Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking; Add Snoking-Bothell 230-kV line #2; Add Snoqualmie 500-kV shunt reactor; Eight line upgrades.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR; Add second 500-kV shunt capacitor bank at Ostrander.
2001	Rebuild Maple Valley-Lakeside 230-kV line; Upgrade Maple Valley SVC to 500 MVAR.
2002	Add second 500-kV shunt capacitor bank at Pearl; Add 500-kV shunt capacitor bank at Snoqualmie.
2003	Add 300 MVAR SVC on Covington (or Snohomish) 230-kV bus.
2004	Add second 500-kV shunt capacitor bank at Monroe; Add third 500-kV shunt capacitor bank at Ostrander.
2006	Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 5

The loss savings of various options is summarized in Table 100. Plan 5 will save 49.6MW on the BPA system and 65.1 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 56.1 MW on the BPA system and 68.7 MW in the Northwest in 2004 (compared to the Reactive Plan).

F. Reactive Alternative Plan 6

1. Puget Sound Area Voltage Stability Performance

The assumed voltage stability criteria can be achieved in 1996 with the addition of three 300 MVAR SVC's and two series capacitor stations on the Coulee-Raver lines (J96EH573QV4, J96EH575QV4, J96275QV4). A possible plan to add five series capacitor stations (one on the Chief Jo-Monroe, one on each Naneum-Raver circuit, and one on each Coulee-Raver line) to reduce the number of SVC's does not meet voltage stability criteria for the Chief Jo-Monroe outage (J96EH581QV). Therefore, reducing the number of SVC's by increasing series compensation is not an alternative.

Distributing the SVC's among different locations provides about 40MVARS of benefits in Q-V performance for the double generator outage during abnormal or double line outage during normal (J96EH573QV4, J96EH573QV5, J96275QV4, J96275QV5). The single line outage during abnormal shows a 40MVAR disadvantage to distributing SVC's (J96EH575QV4, J96EH575QV5).

The series capacitor stations perform better when located halfway between Columbia and Raver on the Coulee-Raver lines (20% compensation, 2600A continuous). Q-V performance improves by about 30MVARS (J96EH575QV4, J96EH576QV). Voltages are about 4kv less at the stations so criteria levels are not violated when sending end voltages are held high.

System planning assumes that the SVC's can be made equally reliable to transmission lines. If assumptions change and system design assumes the failure of one SVC following the contingency, then one more 300MVAR SVC is needed (assumed at Snohomish J96275QV2, J96275QV3).

In 2000, load growth and system design for the simultaneous loss of both Coulee-Raver 500-kV lines cause the need for three additional series capacitor stations on the other three existing cross Cascades 500-kV lines (25% 3200A midline on Chief Joe-Monroe 500, 35% 2300A on each Naneum-Raver 500 line). These will be switched in service following the double Coulee-Raver line loss during normal winter or double generator loss during abnormal winter. Another 324MVAR 500-kV shunt capacitor bank is needed at Monroe. The plan for 2000 was not studied. It was estimated from 1996 and 2004 studies.

By 2004, load growth causes the need for series compensation to be in service on the Chief Jo-Monroe line (25%) and Naneum-Raver line sections (35%) with no outage during abnormal cold weather (J04EH34). More series compensation on the Chief Jo-Monroe line (25% more for 50% total) and the Naneum-Raver lines (35% more for 70% total) need to be added for the double Coulee-Raver line loss during normal winter. Two 500-kV 324MVAR shunt capacitor banks are needed at Snoqualmie (J0482QV). The assumed voltage stability criteria is achieved for the single line loss (J04EH148QV) and double generator outage (J04EH149QV) with the added series and shunt compensation.

The amounts of series compensation were calculated by considering these factors:

> series compensation keeps the amount of needed dynamic and switched shunt compensation from dramatically increasing every year with assumed load growth. For example, about 3MVARS of dynamic shunt (SVC's) would be needed for 1MW of load growth without series compensation (3:1 ratio). With the planned series compensation, only about .5-1MVARS per MW of less expensive switched shunt compensation needs to be added. Therefore, adding the series compensation is estimated to be more cost effective than adding more dynamic shunt compensation.

> series compensation reduces voltage sensitivity to load level (reduces the slope on a Q-V curve). This allows more shunt capacitors to be on line prior to an outage.

> distributing series compensation along the line improves Q-V performance because reactive power cannot be transmitted over long distances on heavily loaded lines.

> the amount of series compensation at any specific site is limited by the voltage drop (or rise) that may cause the voltage at the station to exceed 550kv steady state.

\> transmission system energy efficiency is best with Coulee-Raver series compensation at about 40-50% (J96279, J96280, J96273).

\> the ratio of series compensation between the Chief Jo-Monroe line and the Naneum-Raver lines was sized to keep the powerflow on the lines roughly proportional to the thermal rating of each circuit during the double Coulee-Raver outage.

\> voltage stability criteria cannot be met with only series compensation and switched shunt compensation. SVC's are needed too. This is caused by the very high critical voltage (520kv, J96EH577QV). SVC'S provide voltage control in the vicinity of the critical voltage. Also, SVC's lower the critical voltage in this case and the series compensation becomes more effective in Q-V performance. Theoretically, voltage stability could be accomplished with very large amounts of SVC's and no series compensation, regardless of the critical voltage level on a constant power Q-V curve. However, the cost would be much higher with no apparent benefits.

Based on these factors, the maximum compensation is about 50% on Chief Jo-Monroe, 42% on Coulee-Raver #1 & #2, and 70% on Naneum-Raver #1 & #2.

2. Puget Sound Area Thermal Overload Requirements

The loss of both Chief Joe-Snohomish 345-kV lines overloads the Monroe-Sedro Tap 230-kV line section during a 2000 normal winter (J0049). Adding another Monroe-Sedro Tap circuit solves this.

The loss of the Maple Valley 500/230-kV transformer overloads the Covington 500/230-kV transformers during abnormal cold in 2004 (J04EH22). Adding a second Maple Valley transformer solves this.

The loss of the Snoqualmie-Raver 500-kV line overloads the PSP Christopher-Obrien and Covington-Creston 230-kV lines with abnormal cold loads in 2004 (J04EH25). A second Snoqualmie-Raver 500-kV line solves this.

3. Portland Area Voltage Stability Performance

A 300 MVAR SVC is needed at Keeler in 1996 (J96EH573QV3,QV4) and one additional 300 MVAR SVC is needed at Ostrander in 2004 to satisfy voltage stability criteria for the Trojan outage during abnormal cold with one Centralia unit down (J04EH149QV2).

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: see Table 201 (no cross mtn line)

6. Coulee/Chief Joseph Area Performance/Effects: none

7. Reactive Plan 6 Summary

1994 300 MVAR SVC on Maple Valley 230-kV bus and
300 MVAR SVC on Keeler 230-kV bus.
8 line upgrades

1996 300 MVAR SVC at Snohomish
300 MVAR SVC at Covington

	20% more series comp on Coulee-Raver #1 and #2 between Columbia and Raver
2000	25% series comp on Chief Joe-Monroe 500 midline 35% series comp on Naneum-Raver #1 and #2 between Naneum and Raver 3rd parallel circuit from Monroe Tap to Sedro Tap Add 500-kV shunt capacitor bank at Monroe Add 500-kV shunt capacitor bank at Pearl Add 500-kV shunt capacitor bank at Ostrander
2004	Add 2-500-kV shunt capacitor banks at Snoqualmie Add 500-kV shunt capacitor bank at Ostrander 25% more series comp on Chief Joe-Monroe 500 35% more series comp on Naneum-Raver #1 and #2 2nd Maple Valley 500/230 transformer 2nd Raver-Snoqualmie 500 line 300 MVAR SVC at Ostrander

8. Loss savings of Reactive Plan 6

The loss savings of all feasible options are summarized in Table 100. The Reactive Plan will save 2.4 MW in the Northwest in 1996. In the 2004 loss savings case, the reactive plan is used as the base since the powerflow will not solve with just the base system in service.

G. Coulee-Snoqualmie/Olympia 500-kV Double-Circuit Line Rebuild: Plan 7

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built, replacing existing 230-KV and 287-KV lines between Grand Coulee and the Puget Sound area. The Coulee-Columbia 230-kV line, the Columbia-Covington 230-kV line and the Columbia-Olympia portion of the Coulee-Olympia 287-kV line would need to be removed. The remaining section of 287-kV line from Coulee to Olympia would be converted to 230-kV to replace the parallel circuit that was removed. Nothing will be added at Columbia to replace the circuit to Covington, since it is a load line. The Olympia and Covington 230-kV busses will be investigated in the Puget Sound thermal overload section to determine if any reinforcement is needed at these busses to replace the facilities that were removed.

This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs is later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004. A 300 MVAR SVC is needed at Snohomish in 2004 to strengthen this plan for double line outage. For more detail on these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 7 in service is shown in QV-171 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

The problem areas in the North Seattle area for Plan 7 would be very similar to

Plan 2. Since the Shelton 500/230-kV transformer has been added by this time, additional support is not needed at Olympia to replace the 287-kV circuit. However, at some future time, additional facilities will be needed in this area earlier as compared to the other plans considered (J04EH162). Although a source line was removed from Covington, the addition of the new 500-kV CM lines redistributes the powerflow so that Covington capacity is not a problem. There are no transformer overloads in the Puget Sound area for several years.

As in Plan 2, it is advantageous to add a Snoking transformer with the new CM line since this transformer addition will also alleviate the double 345-kV line outage. The Monroe-Snoqualmie line can be tapped and the existing Snoking Tap-Snoking 230-kV line converted to its design voltage of 500-kV to supply the new transformer. A second Snoking-Bothell 230-kV line is needed with this transformer to prevent overloads during Monroe transformer outages (J00EH26, from Plan 2). With the Snoking Transformer addition, the Covington transformer loadings actually decrease from the pre-CM conditions even though a 230-kV circuit was removed (compare J96EH158 and J96EH582).

When the Lakeside transformer is added (assumed in 2001), the unused 230-kV circuit that is parallel to the existing Bothell-Snoking-Maple Valley 230-kV line will need to be put into service at 230-kV. With a new Chief Joe-Snoqualmie 500-kV line in service, the Maple Valley-Lakeside section of this line will need to be rebuilt to about 1800 amps at -15 degrees Celcius.

This plan has extremely well balanced 500/230-kV transformer loading. The Covington 500/230-kV transformer will overload in about 2011 for loss of the Tacoma transformer (J04EH183 and 2% load growth) and in 2012 for loss of the parallel bank (J04EH165). The Maple Valley 500/230-kV transformer will overload in about 2012 for loss of the Snoking transformer and Monroe-Snoqulamie line (J04EH166). The Tacoma 500/230-kV transformer will overload in 2015 for loss of the Maple Valley transformer (J04EH163). A parallel Maple Valley 500/230-kV transformer will therefore be needed by 10-2010. As can be seen in these outages, the new Snoking transformer is loading in excess of 1600 MVA in these cases. This transformer will need to be a 1800 MVA bank when it is installed in 1996.

The loss savings due to the addition of the Snoking project will be similar to that of Plan 2. The loss savings for Plan 2 are about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201). The effect of the new line terminated at Olympia on intertie schedules has not been studied yet.

3. Portland Area Voltage Stability Performance

The effect of the Coulee-Snoqualmie/Olympia 500-kV line addition on the Portland system performance is similar to the other plans. Identical facilities are required in the Portland area. Refer to Table 310 for further information.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: None

6. Coulee/Chief Joseph Area Performance/Effects: Not studied yet.

7. Plan 7 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus and Add 300 MVAR SVC on Keeler 230-kV bus. Add 500-kV shunt capacitor bank at Ostrander.
1996	Replace the existing Coulee-Columbia 230-kV line, Columbia-Covington 230-kV line and Columbia-Olympia portion of the Coulee-Olympia 287-kV line to a new 500-kV double circuit line; Convert remaining section of Coulee-Olympia 287-kV line to a 230-kV Coulee-Columbia line. Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking; Add Snoking-Bothell 230-kV line #2; Add Snoqualmie 500-kV shunt reactor; Eight transmission line upgrades to higher operating temperatures; Add second Chief Joe 500/230-kV transformer.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR; Add MSC to one existing Raver shunt capacitor group; Add second 500-kV shunt capacitor bank at Ostrander.
2001	Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition); Upgrade Maple Valley SVC to 500 MVAR.
2002	Add 500-kV shunt capacitor bank at Snoqualmie; Add second 500-kV shunt capacitor bank at Pearl.
2004	Add second 500-kV shunt capacitor bank at Monroe; Add third 500-kV shunt capacitor bank at Ostrander; Add 300 MVAR SVC on Snohomish 230-kV bus.
2012	Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 7

The loss savings of various options is summarized in Table 100. Plan 7 will save 58.2 MW on the BPA system and 69.4 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 54.6 MW on the BPA system and 63.9 MW in the Northwest in 2004 (compared to the Reactive Plan).

H. Chief Joseph-Sickler-Snoqualmie Double-Circuit Line Rebuild: Plan 8

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new Chief Joseph-Sickler-Snoqualmie 500-kV double circuit line is built replacing the existing Chief Joseph-Sickler 500-kV and Rocky Reach-Maple Valley 345-kV lines. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs is later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe in 2002 and 2004. A 300 MVAR SVC is needed at Snohomish in 2002 to strengthen this plan for the double line outage. For more detail on these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 8 in service is shown in QV-180 for 2004 for the 3 critical outages (without the Snohomish SVC).

The exact timing of the need for the Chief Joe-Sickler portion of this plan has not been determined. The 2004 base case with one Centraila unit down would not solve without this reinforcement. A QV curve of this system showed that the 3 shunt capacitor groups at Raver were required to just touch the knee of the QV curve without any outage. It was therfore assumed that this line would be needed immediately.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These are very similar but slightly worse than the problems in Plan 2 since the Maple Valley 345/230-kV transformer is removed. If the Snoking transformer is added as in Plan 2, these initial problems are relieved. This transformer will need to be an 1800 MVA bank instead of 1300 MVA as in Plan 2 to make up for the loss of the Maple Valley 345/230-kV transformer (compare cases J04EH163 and J04EH168).

The Maple Valley 500/230-kV transformer will overload in about 2006 for loss of the Snoking transformer and Monroe-Snoqulamie line (J04EH167). A parallel Maple Valley 500/230-kV transformer will be needed at this time. With these additions, this plan should provide for future load growth beyond 2010.

The loss savings due to the addition of the Snoking project will be similar to that of Plan 2. The loss savings for Plan 2 are about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Sickler-Snoqualmie line rebuild on the Portland system performance is similar to all the other transmission line options. Identical facilities are required in the Portland area. Refer to Table 310 for further information.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)

6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)

7. Plan 8 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus and Add 300 MVAR SVC on Keeler 230-kV bus. Add 500-kV shunt capacitor bank at Ostrander.
1996	Rebuild the existing Chief Joseph-Sickler 500-kV and Rocky Reach-Maple Valley 345-kV lines to form a Chief Joseph-Sickler-Snoqualmie 500-kV double circuit line; Add 1800 MVA Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking; Add Snoking-Bothell 230-kV line #2; Add Snoqualmie 500-kV shunt reactor; Eight transmission line upgrades to higher operating temperatures; Add second Chief Joe 500/230-kV transformer.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR; Upgrade Maple Valley SVC to 500 MVAR; Add MSC to one existing Raver shunt capacitor group; Add second 500-kV shunt capacitor bank at Ostrander.
2001	Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition).
2002	Add 500-kV shunt capacitor bank at Snoqualmie; Add second 500-kV shunt capacitor bank at Pearl; Add 300 MVAR SVC on Snohomish 230-kV bus.
2004	Add second 500-kV shunt capacitor bank at Monroe; Add third 500-kV shunt capacitor bank at Ostrander.
2006	Add Maple Valley 500/230-kV 1800 MVA transformer #2.

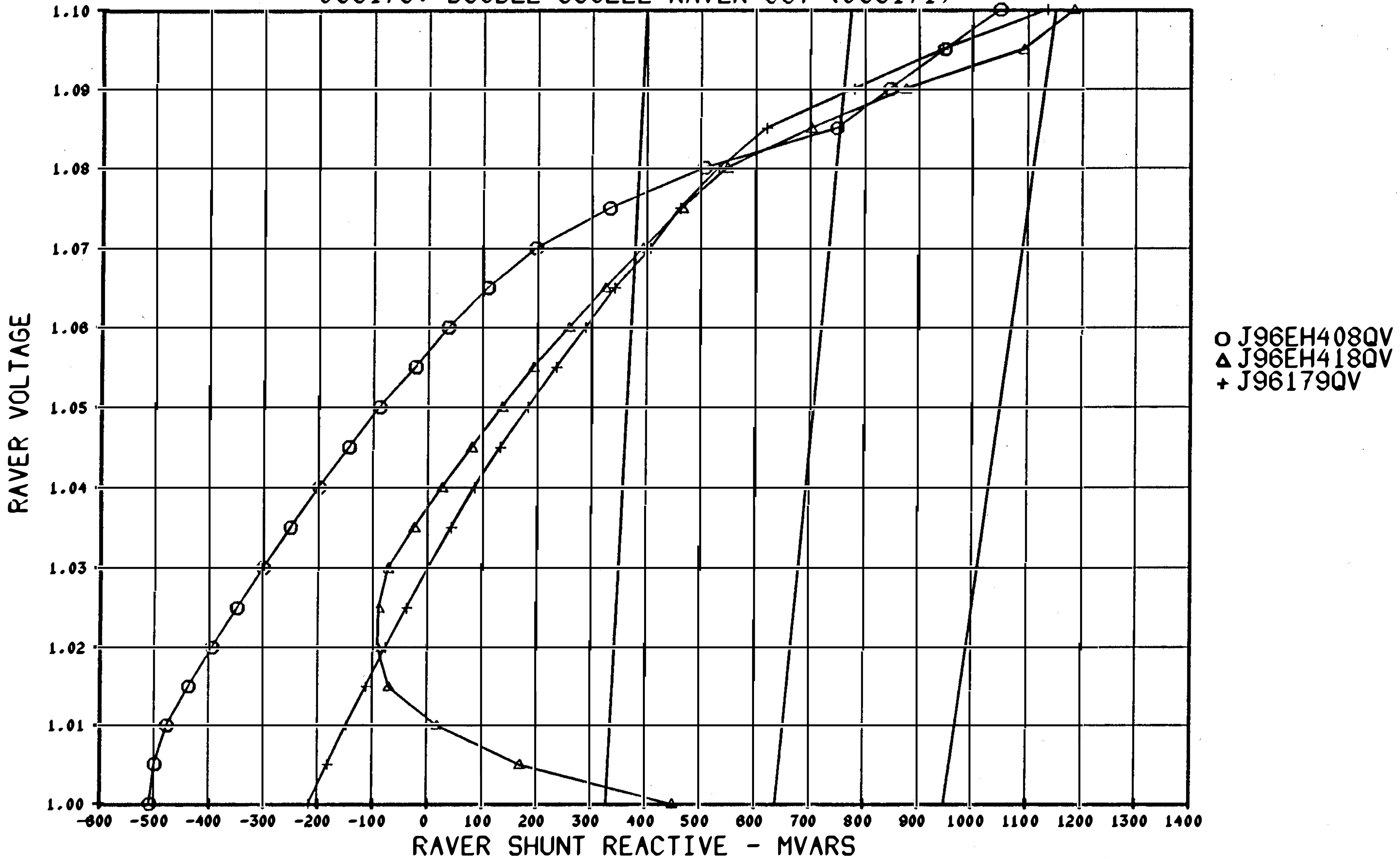
8. Loss savings of Plan 8

The loss savings of various options is summarized in Table 100. Plan 8 will save 50.0 MW on the BPA system and 60.1 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 49.7 MW on the BPA system and 58.2 MW in the Northwest in 2004 (compared to the Reactive Plan).

19-SEPT-1990

QV CURVES

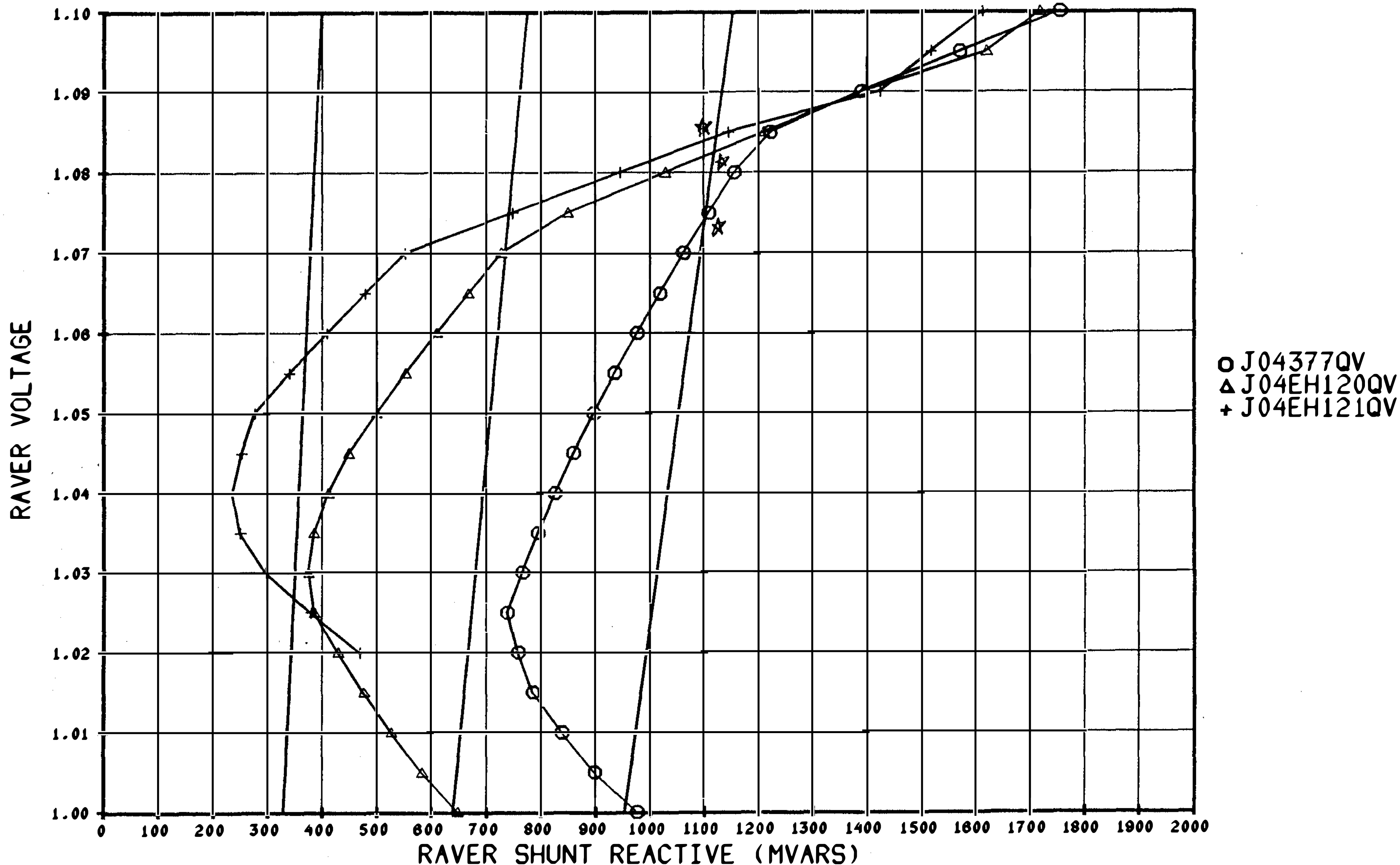
PLAN 1: CJ - MON 2&3, SNOKING, LDC,
COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER,
300MVAR SVC AT MAPLE VL
○ J96EH408: COULEE-RAVER OUT (J96EH390)
△ J96EH418: TROJAN SCRAM (J96EH394)
+ J96179: DOUBLE COULEE-RAVER OUT (J96171)



30-APR-1990

QV-110

PLAN 1: CHIEF JO-MONROE,SNOK & SNOHOMSH TX,LDC
500 MVAR SVCS AT MAPLE VALLEY & KEELER
J04377: DOUBLE COULEE-RAVER OUT (J04376)
J04EH120: COULEE-RAVER OUT (J04EH119)
J04EH121: TROJAN SCRAM (J04EH114)



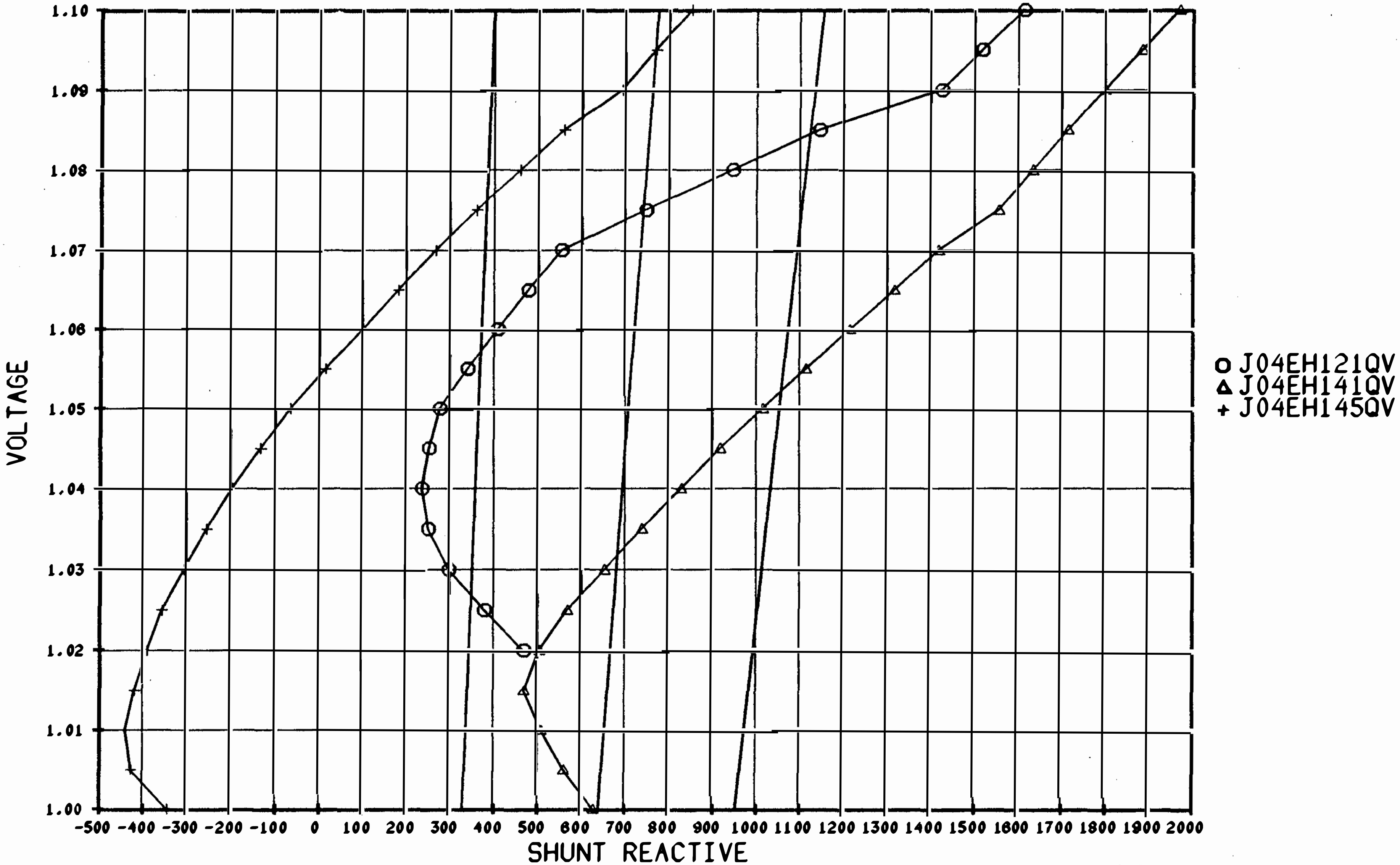
28-JUN-1990

GV-111

PLAN 1: CHIEF JOE-MONROE

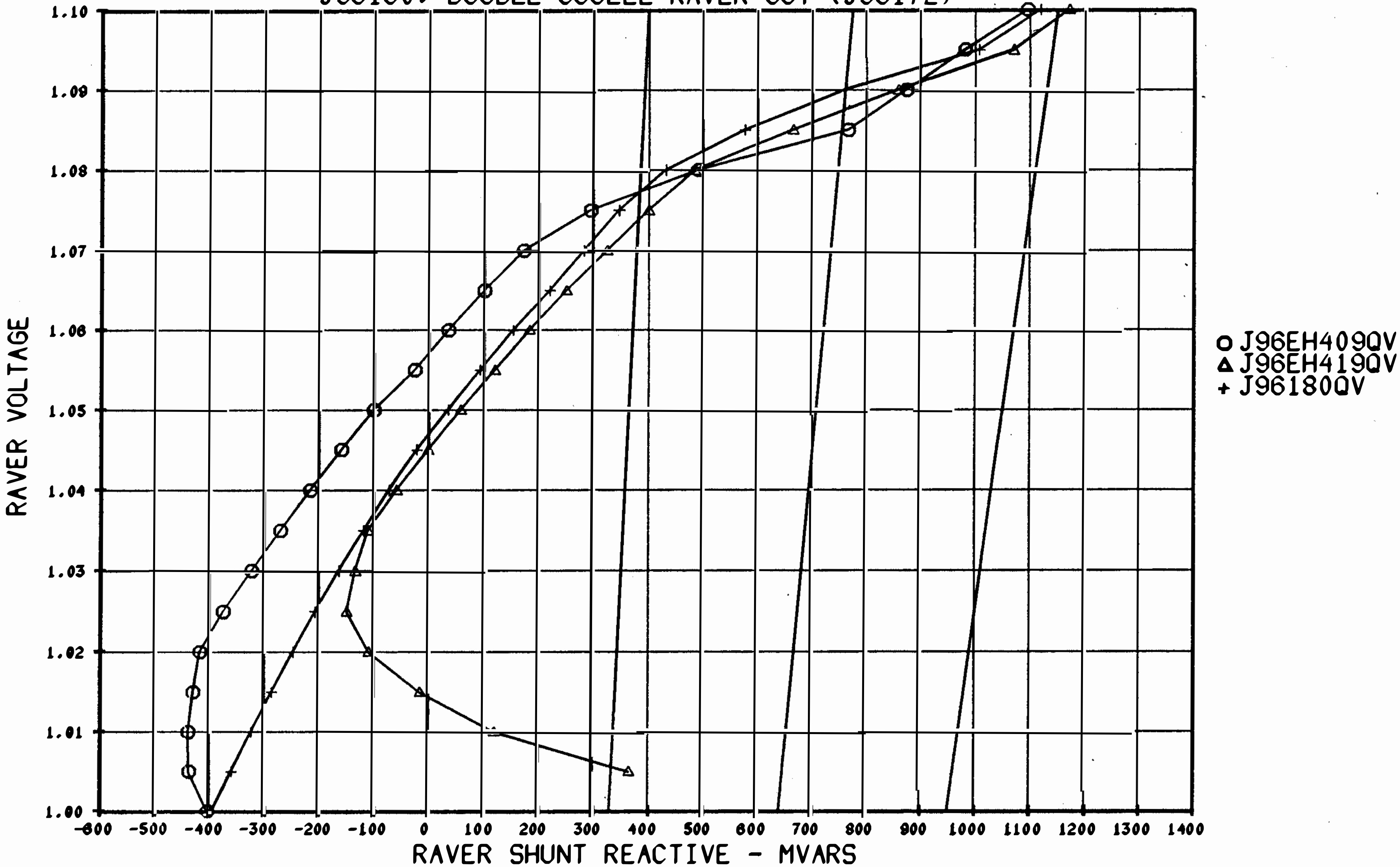
TROJAN SCRAM (BASECASE: J04EH114)

J04EH121: RAVER
J04EH141: OSTRANDER
J04EH145: MARION



27-JUN-1990

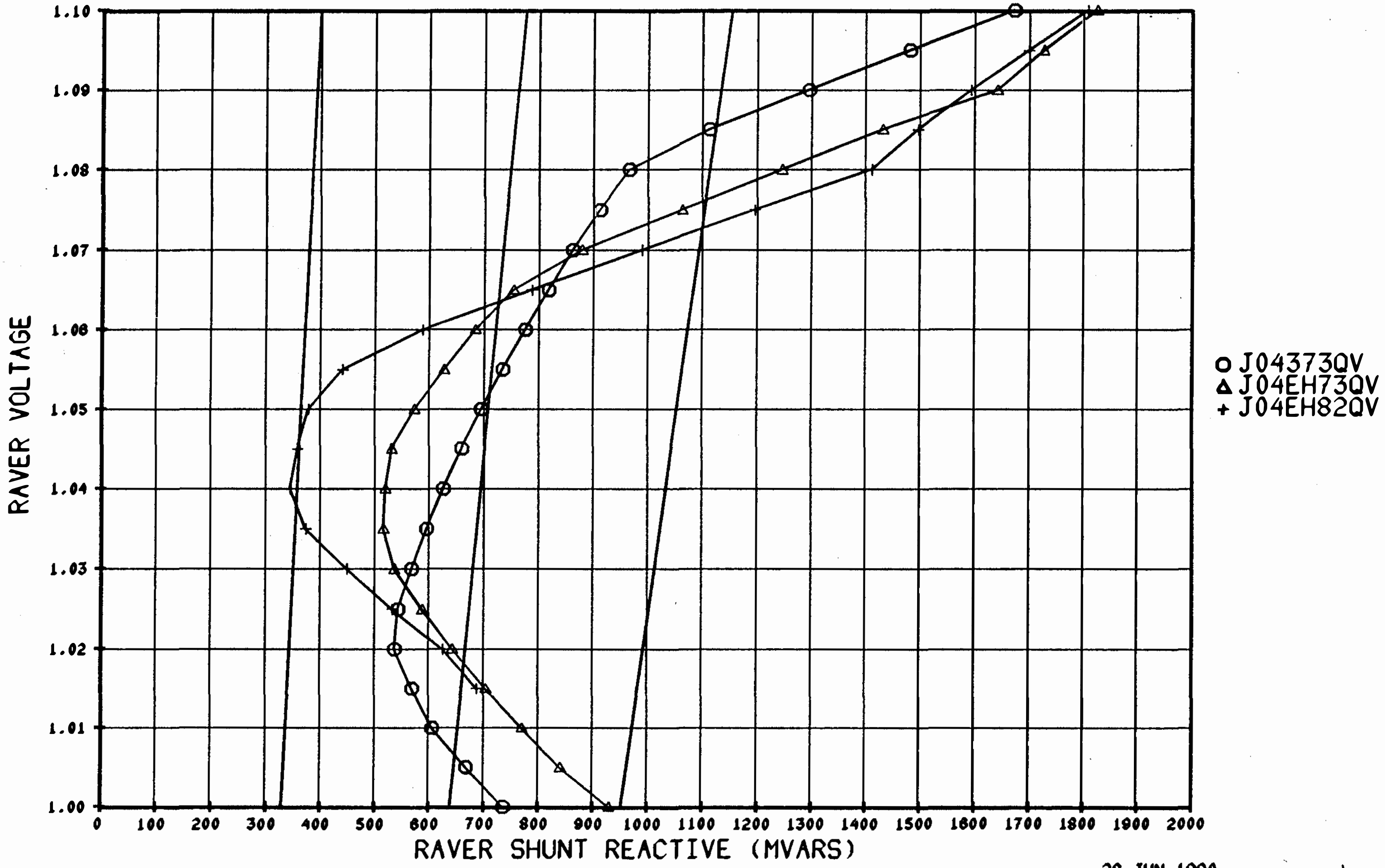
PLAN 2: CJ - SNOQ, SNOKING, LDC,
COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER
300MVAR SVC AT MAPLE VL
J96EH409: COULEE-RAVER OUT (J96EH391)
J96EH419: TROJAN SCRAM (J96EH395)
J96180: DOUBLE COULEE-RAVER OUT (J96172)



5-MAR-1990

QV-12(

PLAN 2: CHIEF JO-SNOQUALMIE, SNOKING, LDC
500 MVAR SVCS AT MAPLE VALLEY & KEELER
○ J04373: DOUBLE COULEE-RAVER OUT (J04372)
△ J04EH73 : COULEE-RAVER OUT (J04EH71)
+ J04EH82 : TROJAN SCRAM (J04EH81)

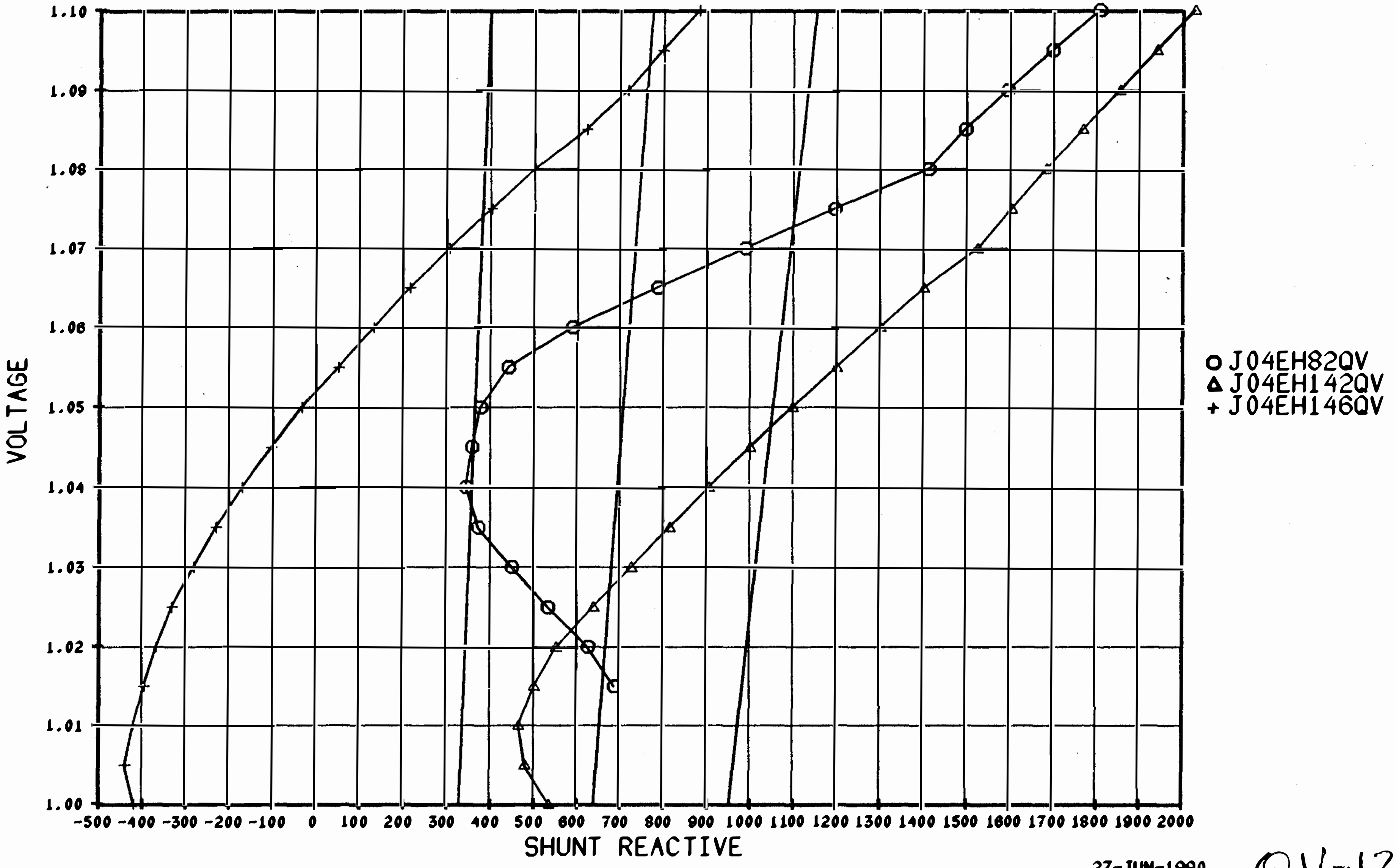


28-JUN-1990

QV-17

PLAN 2: CHIEF JOE-SNOQUALMIE

TROJAN SCRAM (BASECASE: J04EH81)
J04EH82 :   RAVER
J04EH142:   OSTRANDER
J04EH146:   MARION

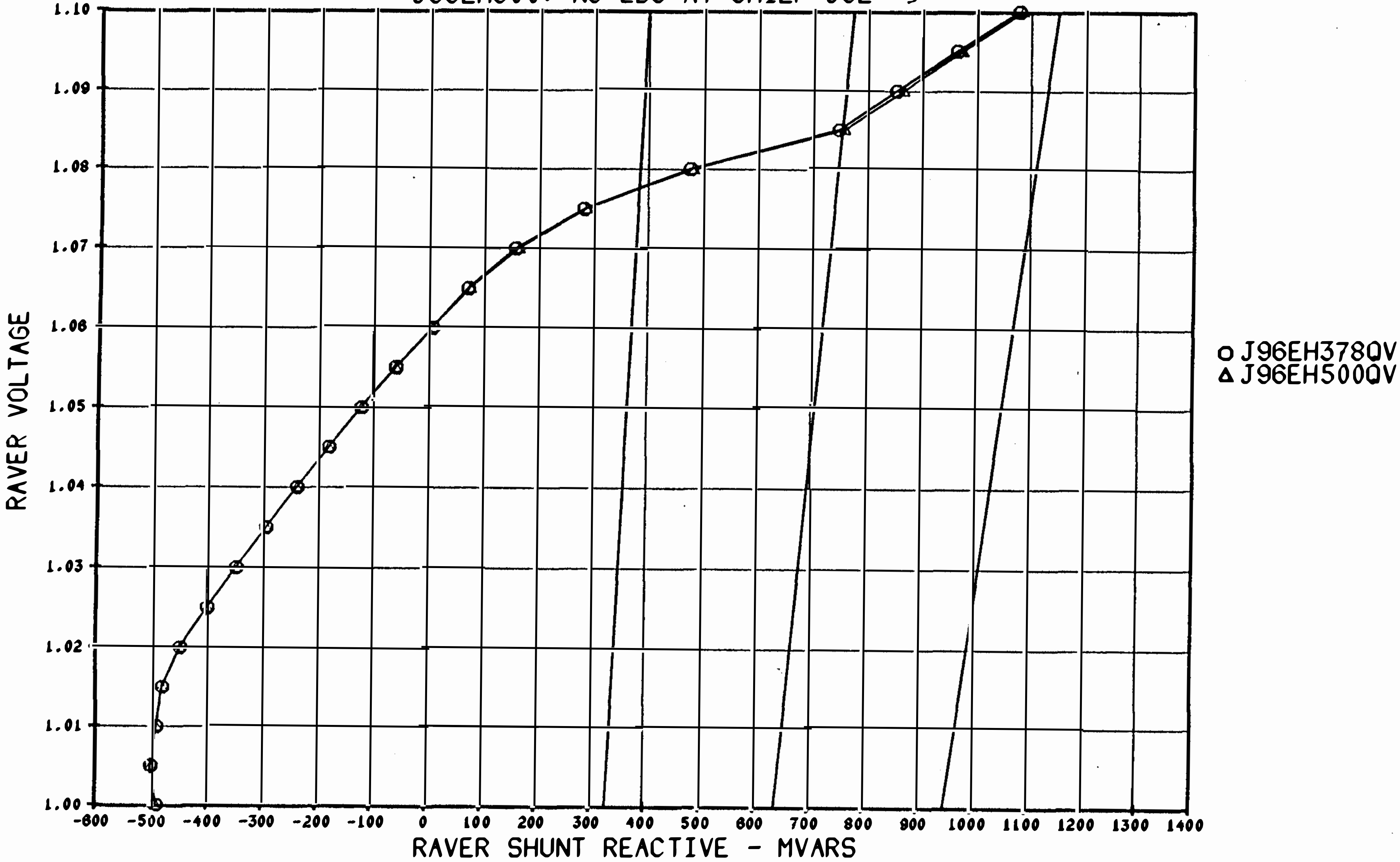


27-JUN-1990

QV-12.2

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE ADDED

300 MVAR SVC'S AT MAPLE VALLEY AND KEELER
LDC'S AT COULEE, CENTRALIA, JOHN DAY, DALLES, BONN
SNOKING 500/230 TRANSFORMERS
J96EH378: LDC ADDED AT CHIEF JOE } Based on J96EH332
J96EH500: NO LDC AT CHIEF JOE

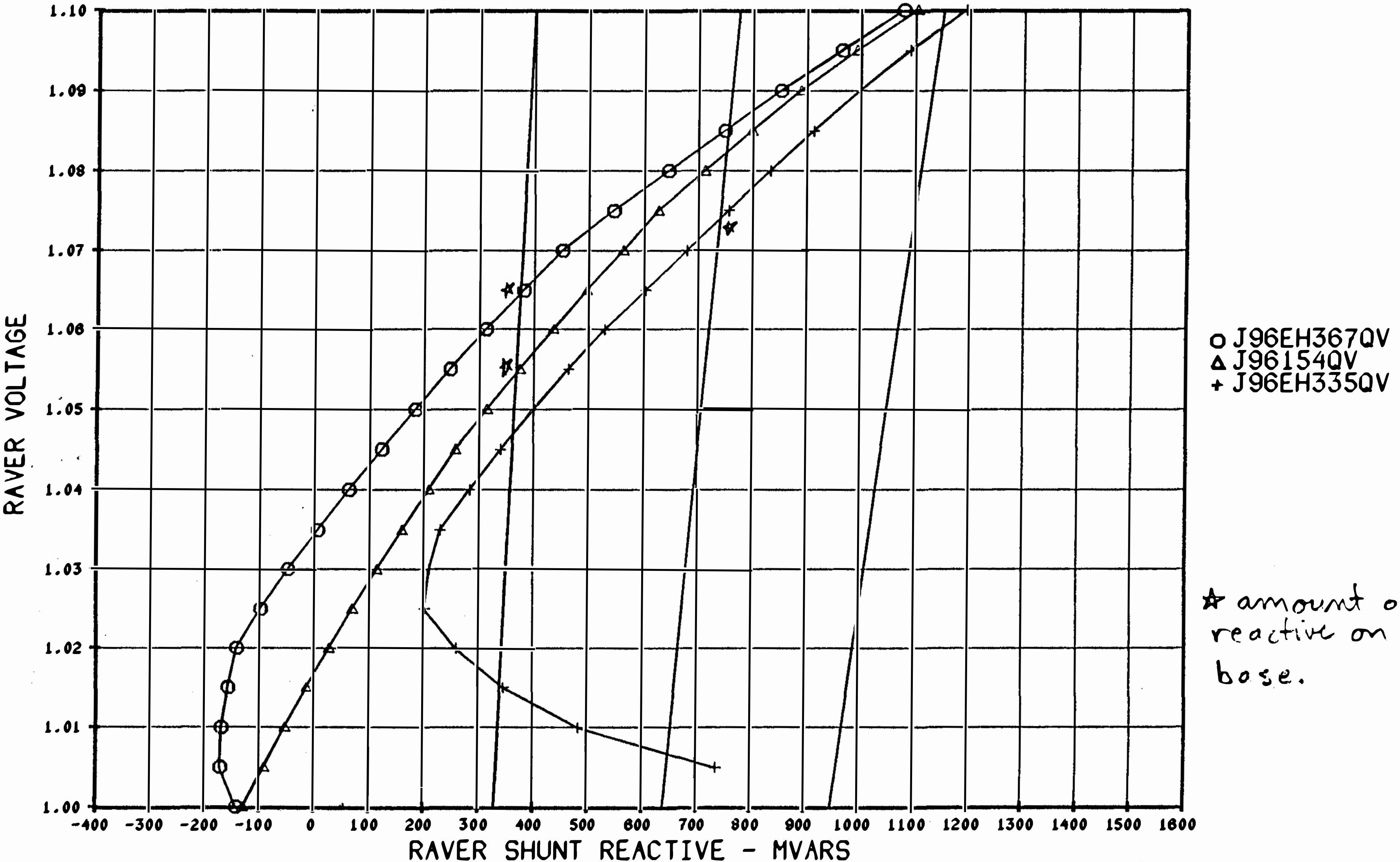


3-APR-1990

QV-130

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

300MVAR SVC AT KEELER, LDC, SNOKING TX
○ J96EH367:ONE COULEE-RAVER 500 LINE OUT (J96EH332)
△ J96154:DOUBLE COULEE-RAVER LINE OUT (J96144)
+J96EH335: TROJAN SCRAM (J96EH333)



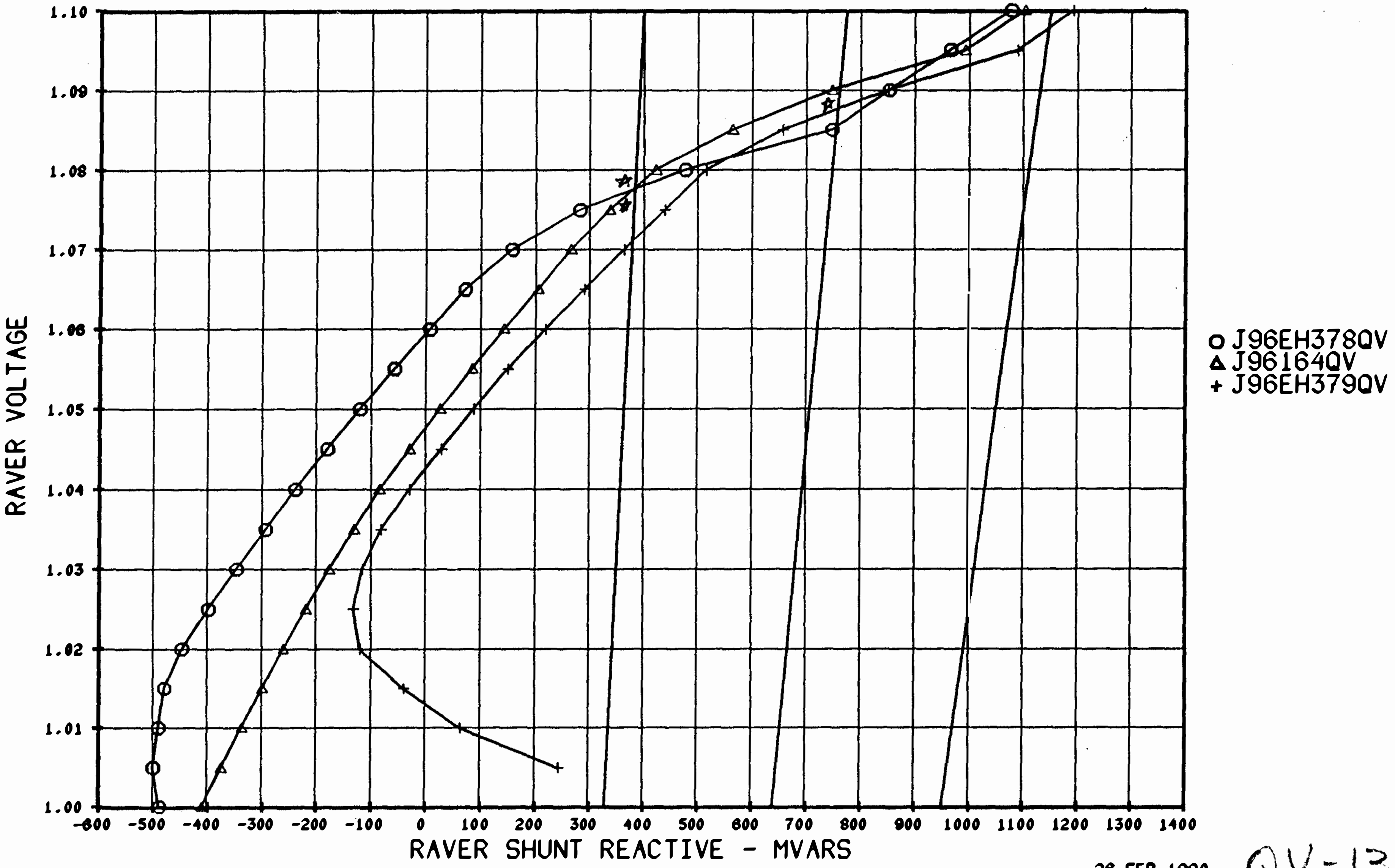
★ amount of reactive on in base.

21-FEB-1990

QV-131

PLAN 3: CHIEF JOE - SNOQUALMIE/MONROE

300MVAR SVC AT KEELER & AT MAPLE VL, LDC, SNOK TXF
oJ96EH378:ONE COULEE-RAVER 500 LINE OUT (J96EH332)
ΔJ96164:DOUBLE COULEE-RAVER LINE OUT(J961[redacted]44)
+J96EH379: TROJAN SCRAM (J96EH333)

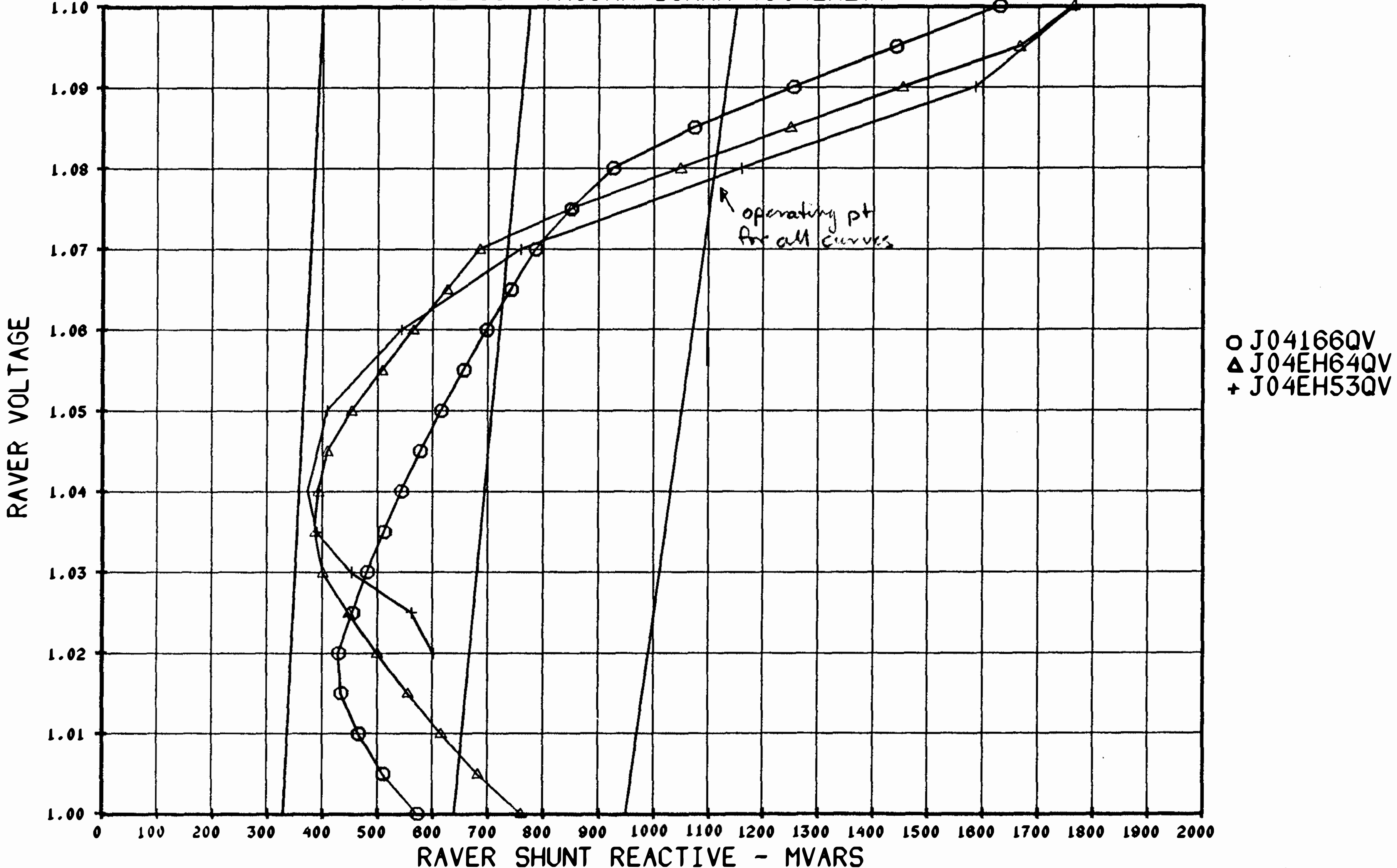


26-FEB-1990

QV-132

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

500 MVAR SVCS AT KEELER AND MAPLE VALLEY
LDC AND SNOKING TRANSFORMER
J04166: DOUBLE COULEE-RAVER LINE OUTAGE (J04165)
J04EH64: COULEE-RAVER #1 LINE OUT (J04EH26)
J04EH53: TROJAN SCRAM (J04EH27)



↖ operating pt for all curves

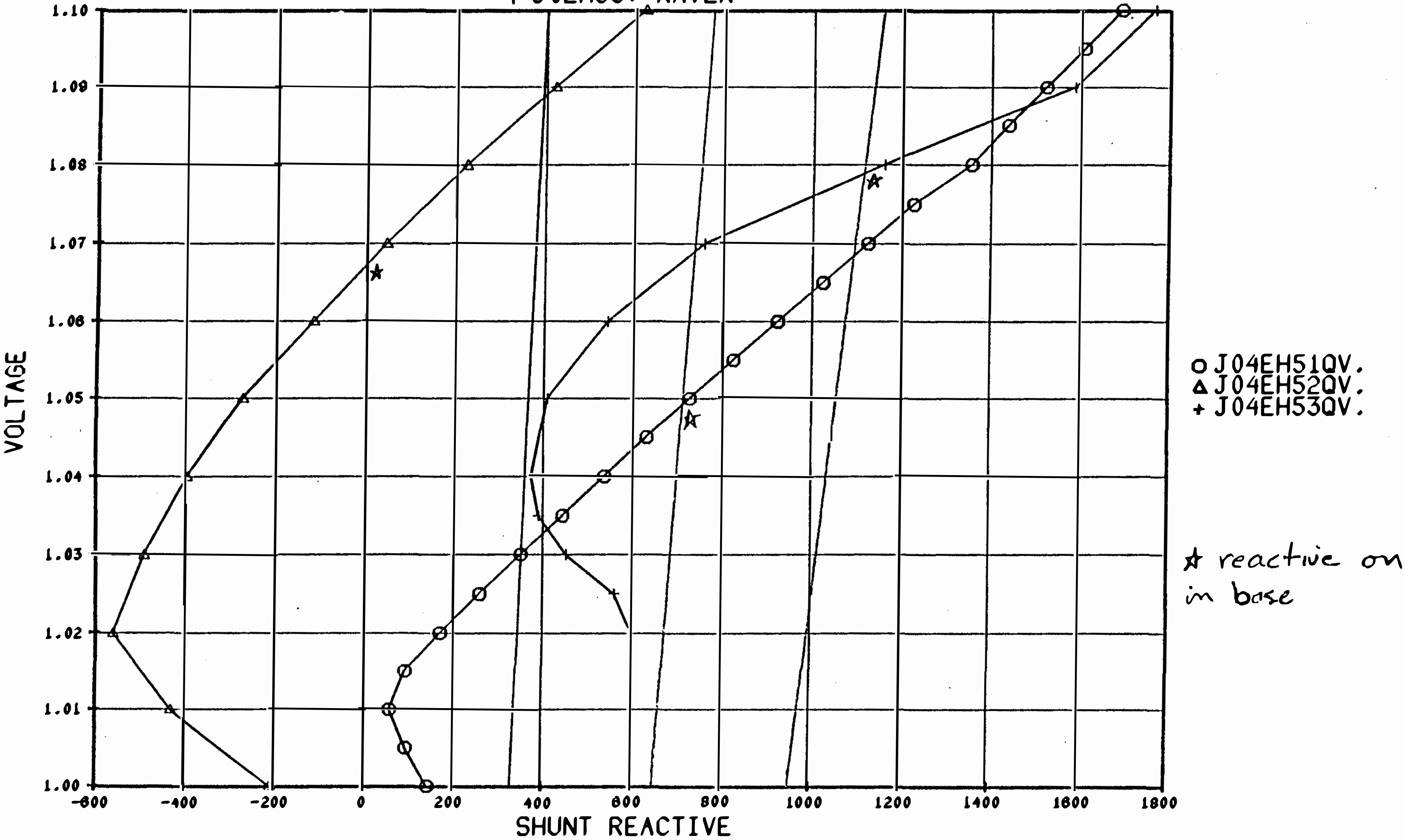
11-APR-1990

QV-133

TROJAN SCRAM ON BASE J04EH27

PLAN 3: CJ-S/M, LDC, SNOKING, 500MVAR SVC'S AT KEELER AND MAPLE VALLEY

○ J04EH51: OSTRANDER
△ J04EH52: MARION
+ J0EH53: RAVER

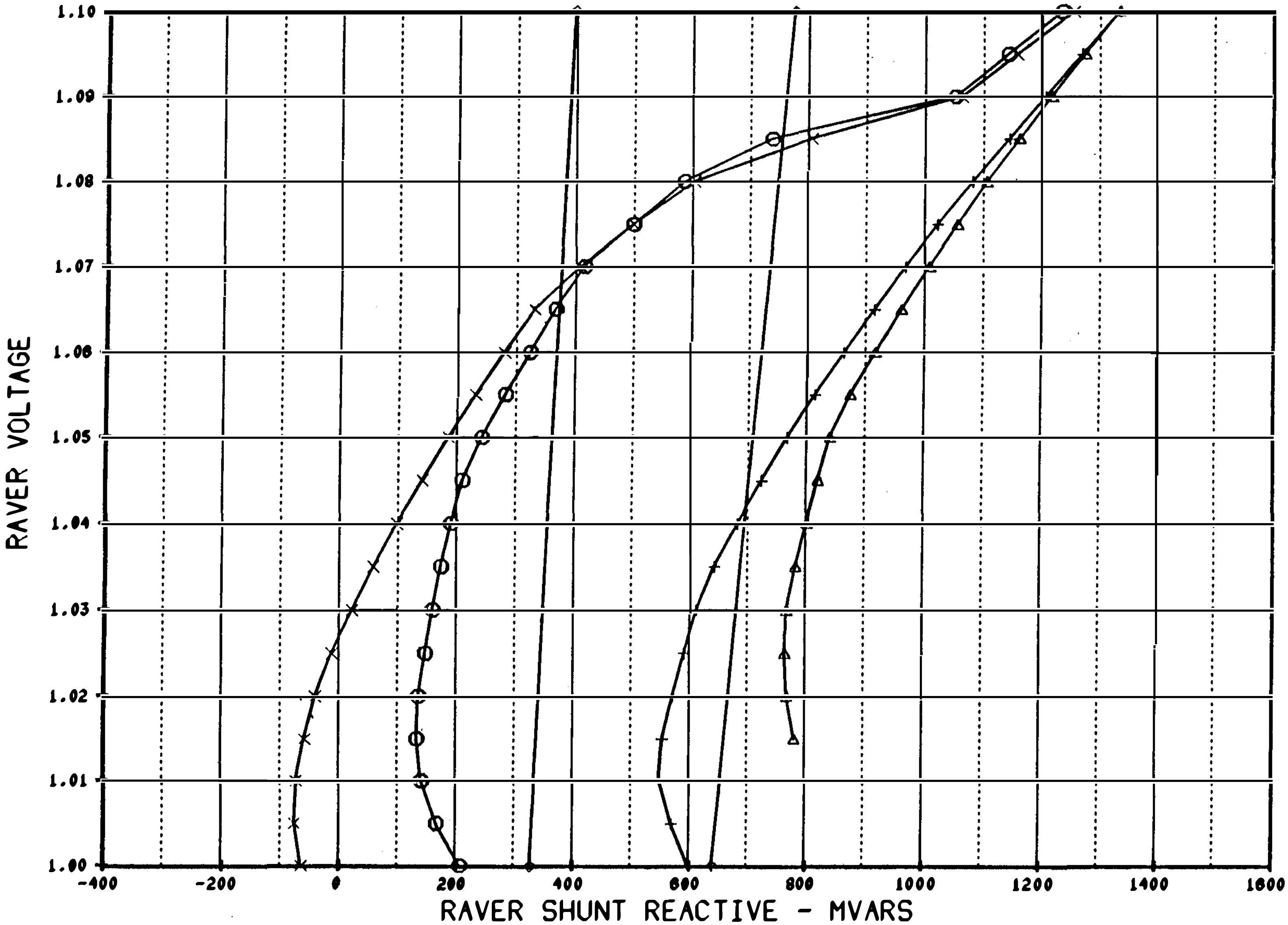


★ reactive on
in base

21-FEB-1990

DOUBLE COULEE-RAVER LINE OUT ON CJ-SNOQ/MON PLAN

△J9642: LINE ADDITION ONLY
○J9668: LINE AND 2X300 MVAR SVC ADDED
+J9663: LINE AND 35%/40% COMP ADDED
×J9662: LINE, 35%/40% COMP AND 2X300 MVAR SVC

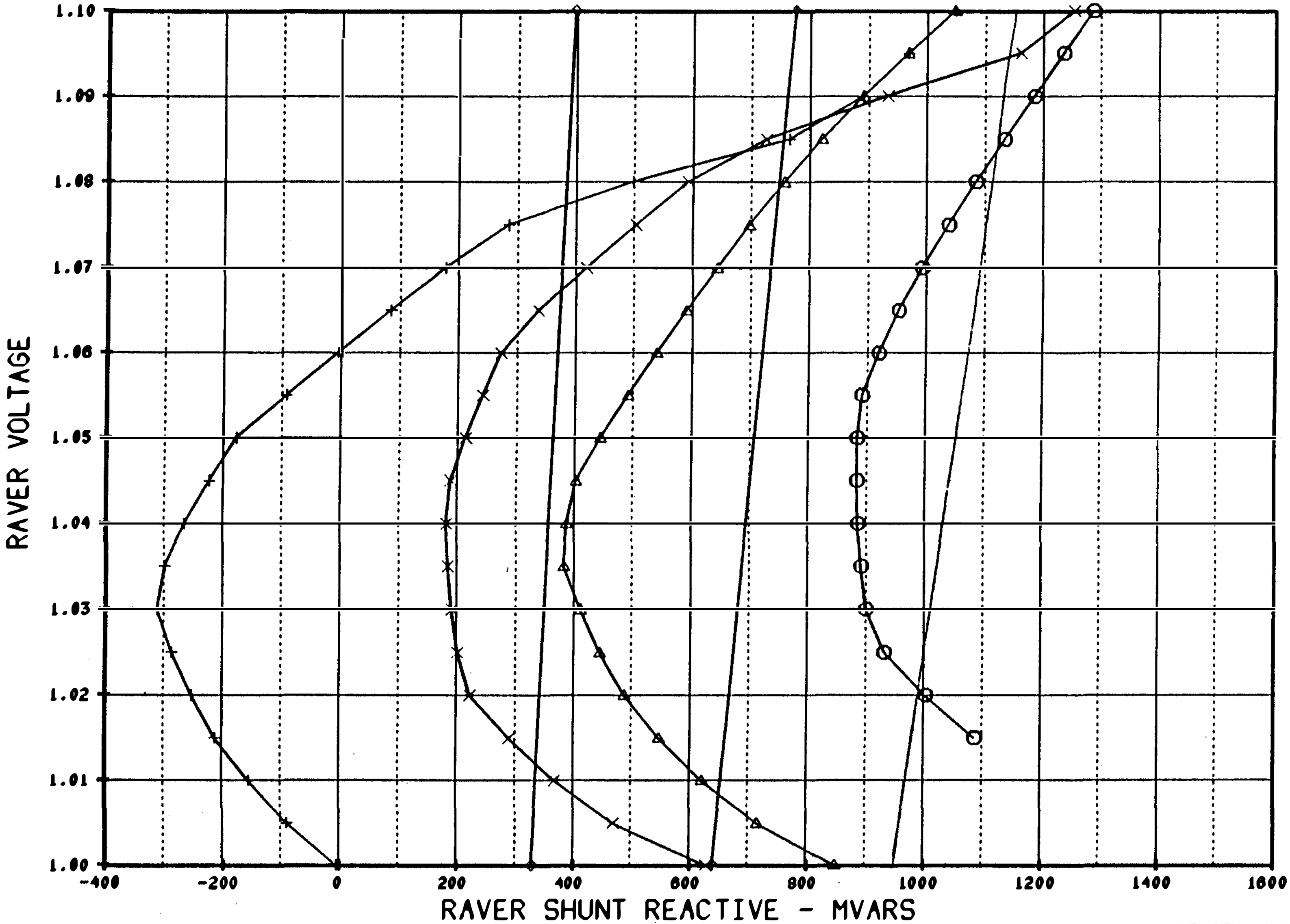


27-DEC-1989

QV-135

COULEE-RAVER LINE OUTAGE ON CJ-SNOQ/MON PLAN

○J96EH46: LINE ADDITION ONLY
×J96EH88: LINE AND 2X300 MVAR SVC ADDED
△J96EH63: LINE AND 35%/40% COMP ADDED
+J96EH62: LINE, 35%/40% COMP AND 2X300 MVAR SVC ADD



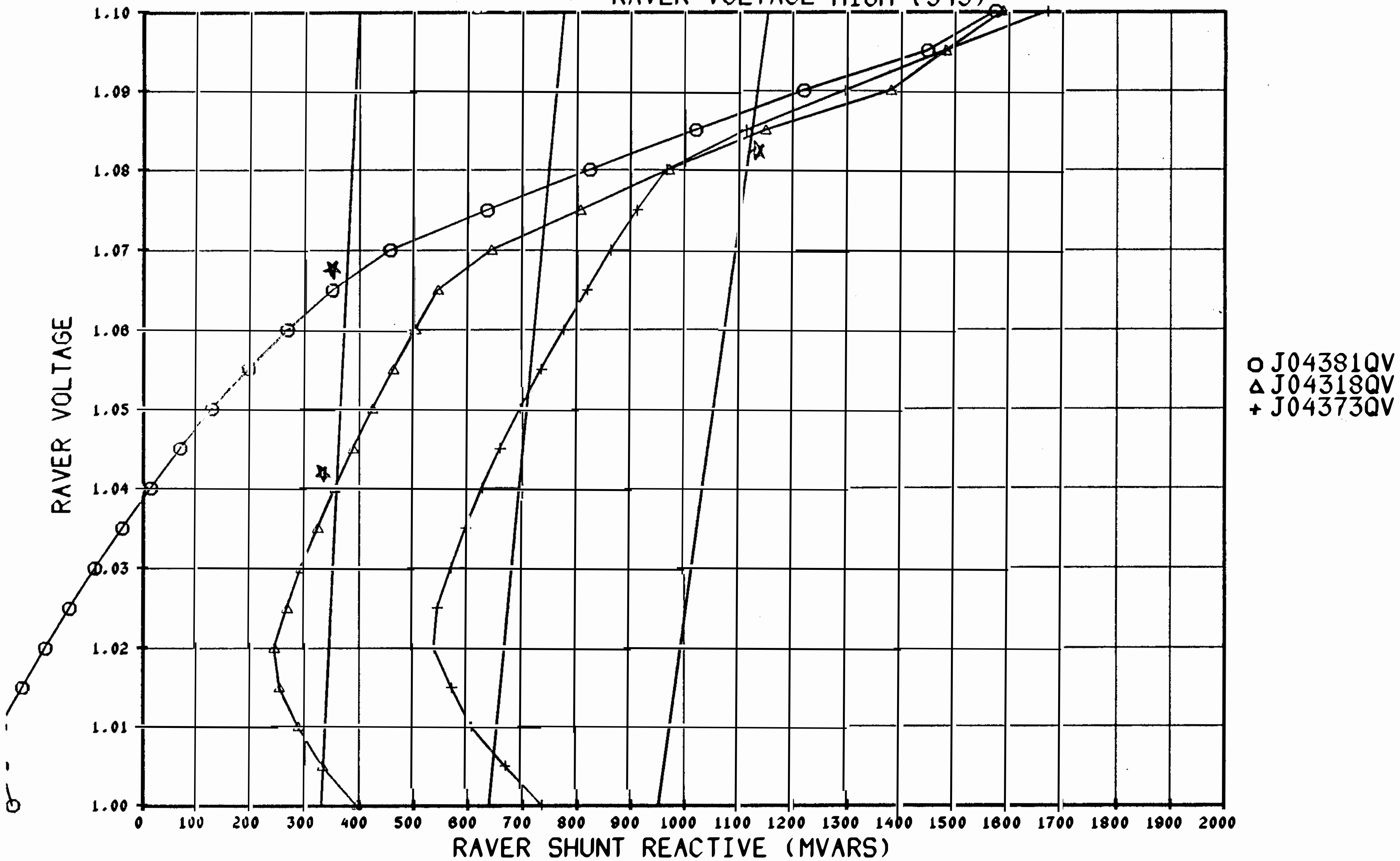
27-DEC-198

QV-136

PLAN 2: CJ-SNOQ, DOUBLE COULEE-RAVER OUTAGE

500 MVAR SVCS AT MAPLE VALLEY & KEELER

J04381QV: WITH SERIES COMP 35% (J04380)
J04318QV: NO SERIES COMP (J04308)
J04373: NO SERIES COMP (J04372)
RAVER VOLTAGE HIGH (549)

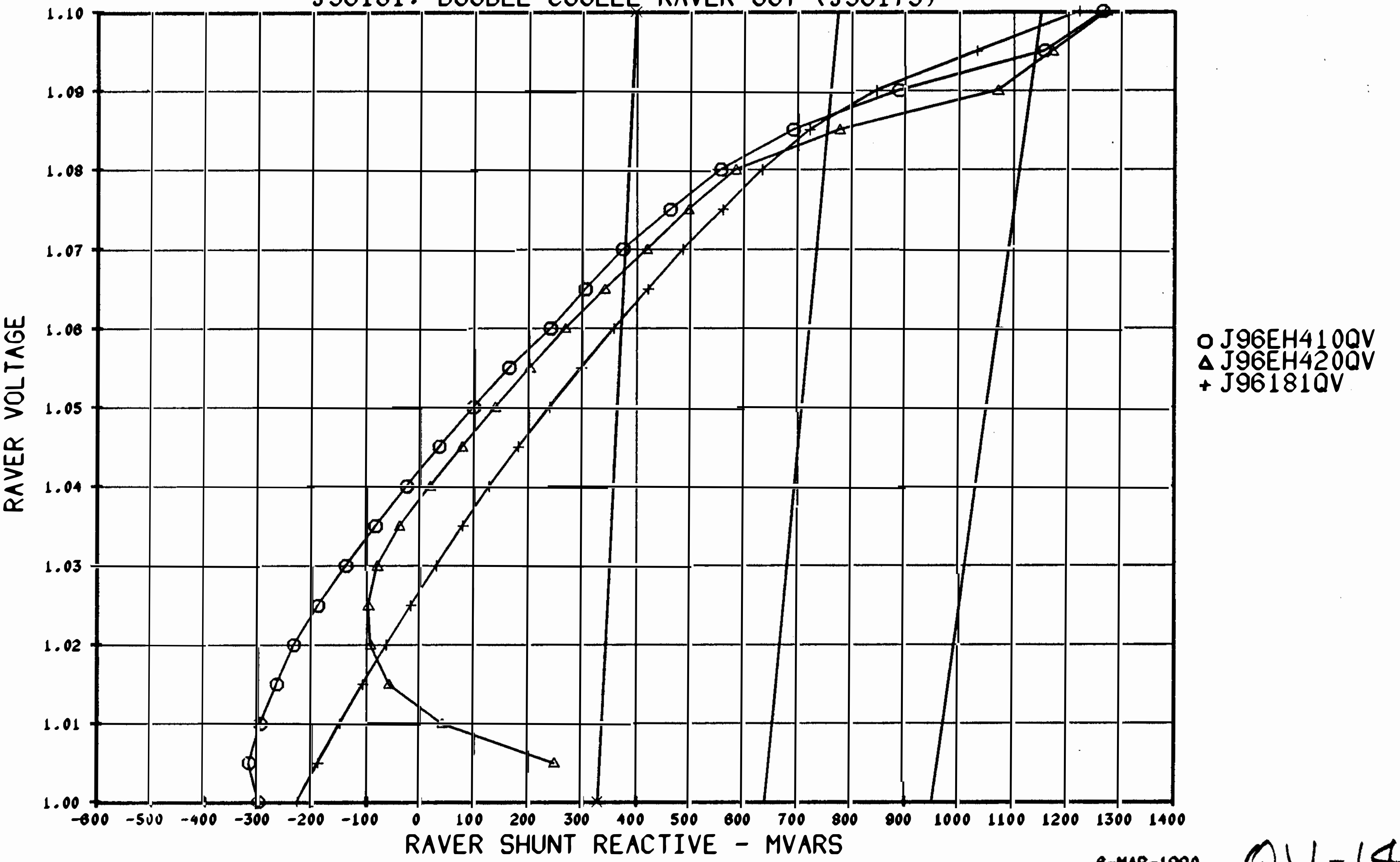


19-JUN-1990

QV-137

PLAN 4: HANFORD-SNOQ 1&2, SNOKING, LDC,
COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER,
300MVAR SVC AT MAPLE VL
J96EH410: COULEE-RAVER OUT (J96EH392)
△J96EH420: TROJAN SCRAM (J96EH396)
J96181: DOUBLE COULEE-RAVER OUT (J96173)

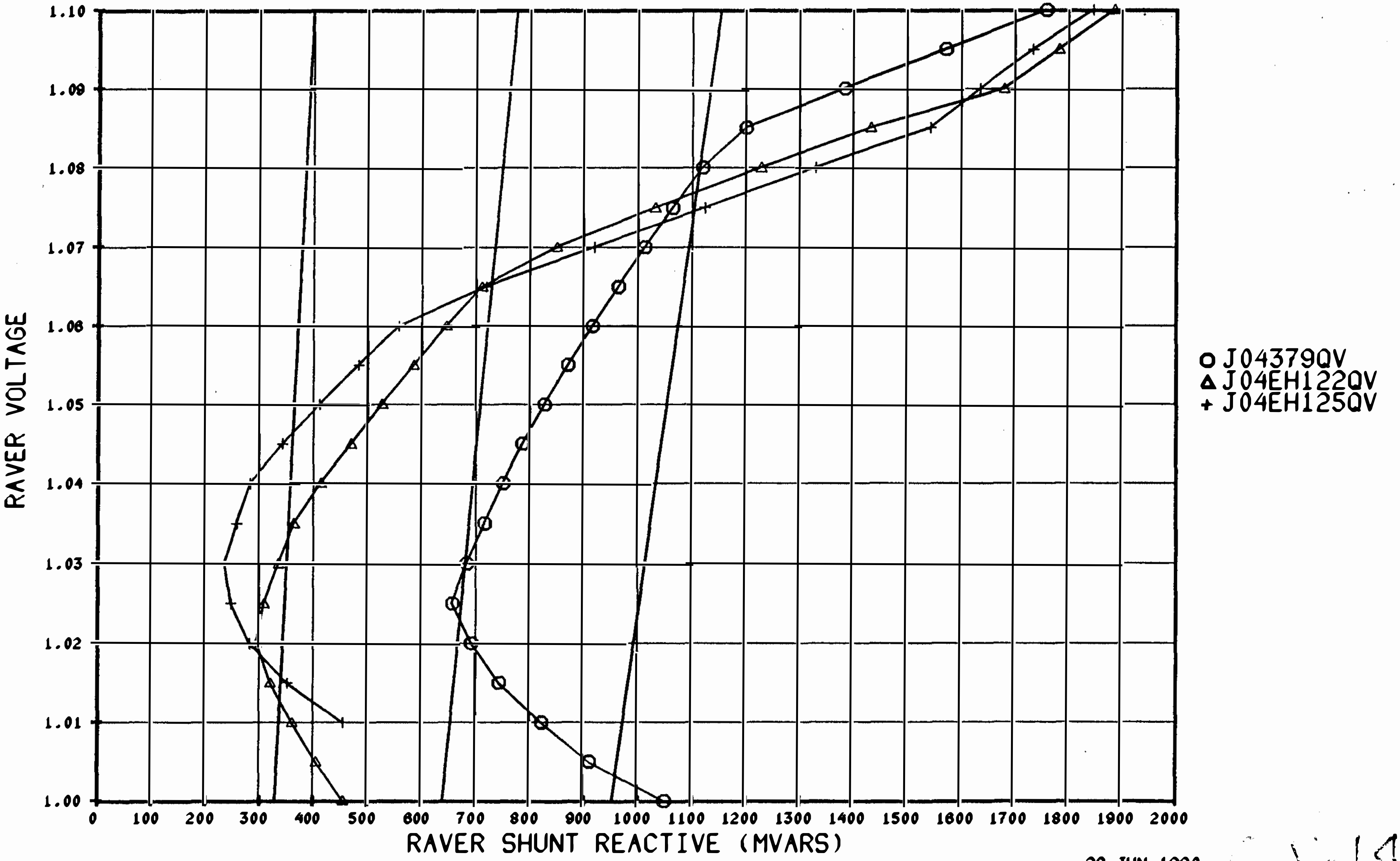
No Ashe LDC



6-MAR-1990

QV-140

PLAN 4: HANFORD-SNOQUALMIE, SNOKING, LDC
500 MVAR SVCS AT MAPLE VALLEY & KEELER
J04379: DOUBLE COULEE-RAVER OUT (J04378)
J04EH122: COULEE-RAVER OUT (J04EH115)
J04EH125: TROJAN SCRAM (J04EH116)

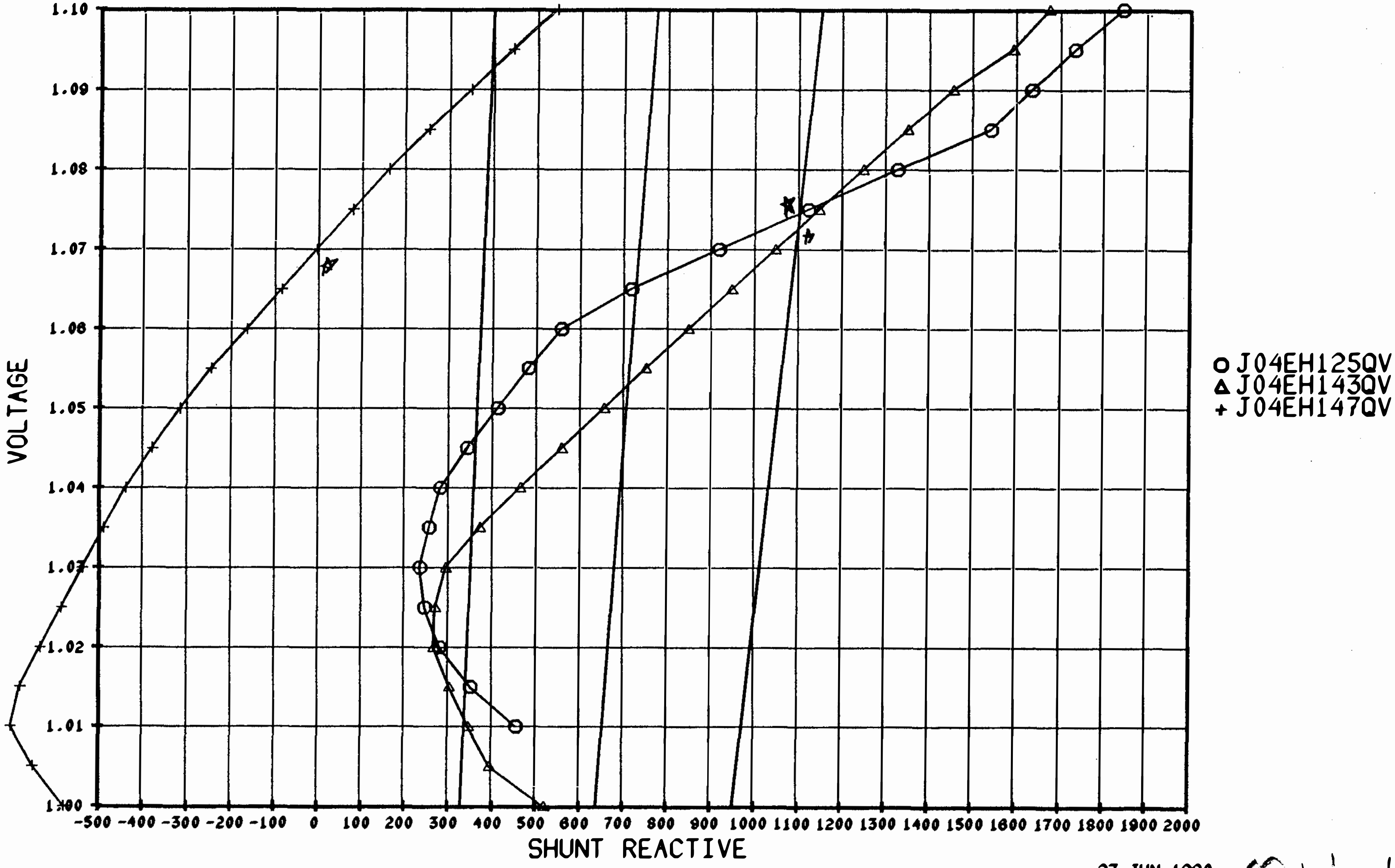


28-JUN-1990

V-141

PLAN 4: HANFORD-SNOQUALMIE

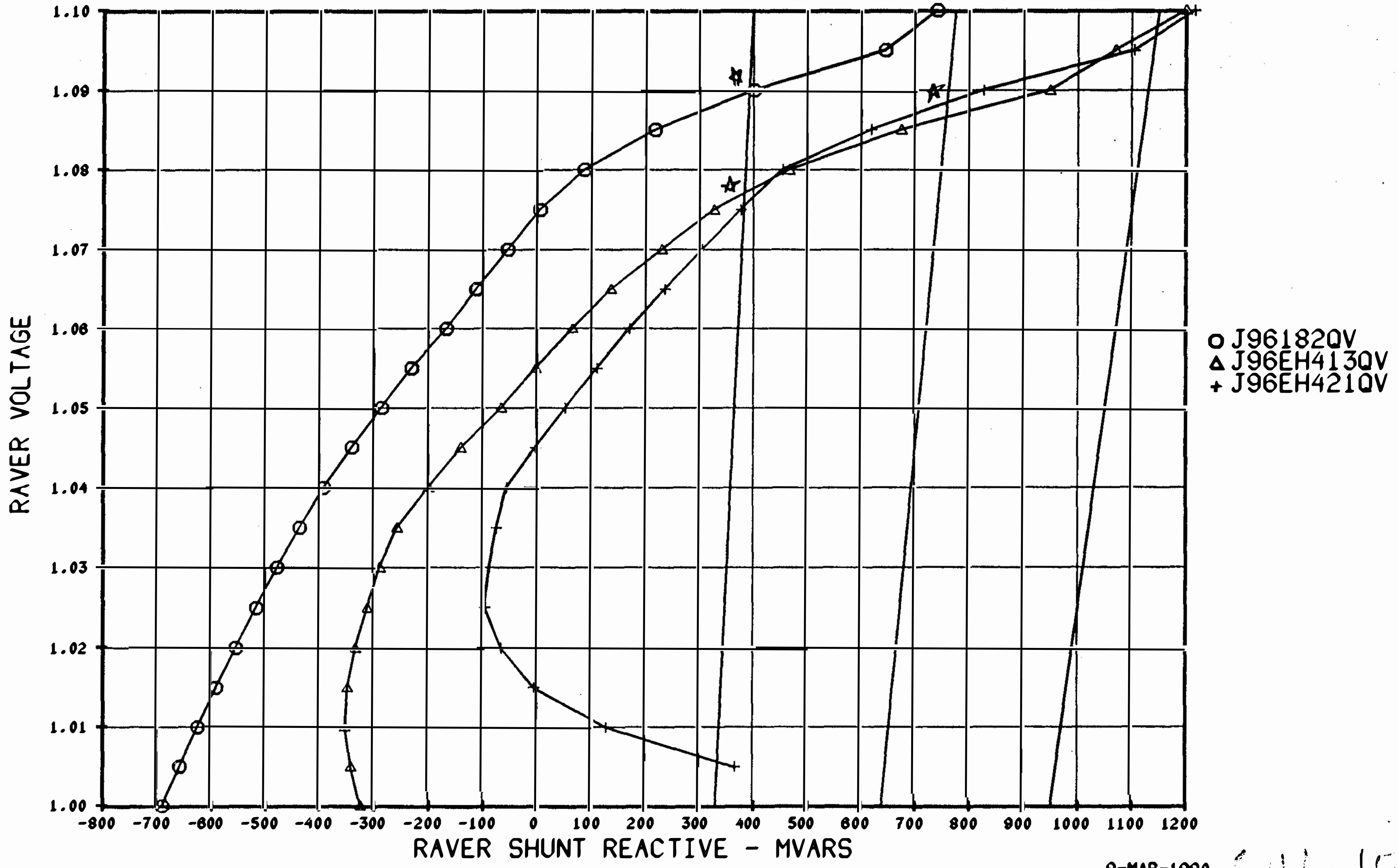
TROJAN SCRAM (BASECASE: J04EH116)
J04EH125: RAVER
J04EH143: OSTRANDER
J04EH147: MARION



27-JUN-1990

QV-142

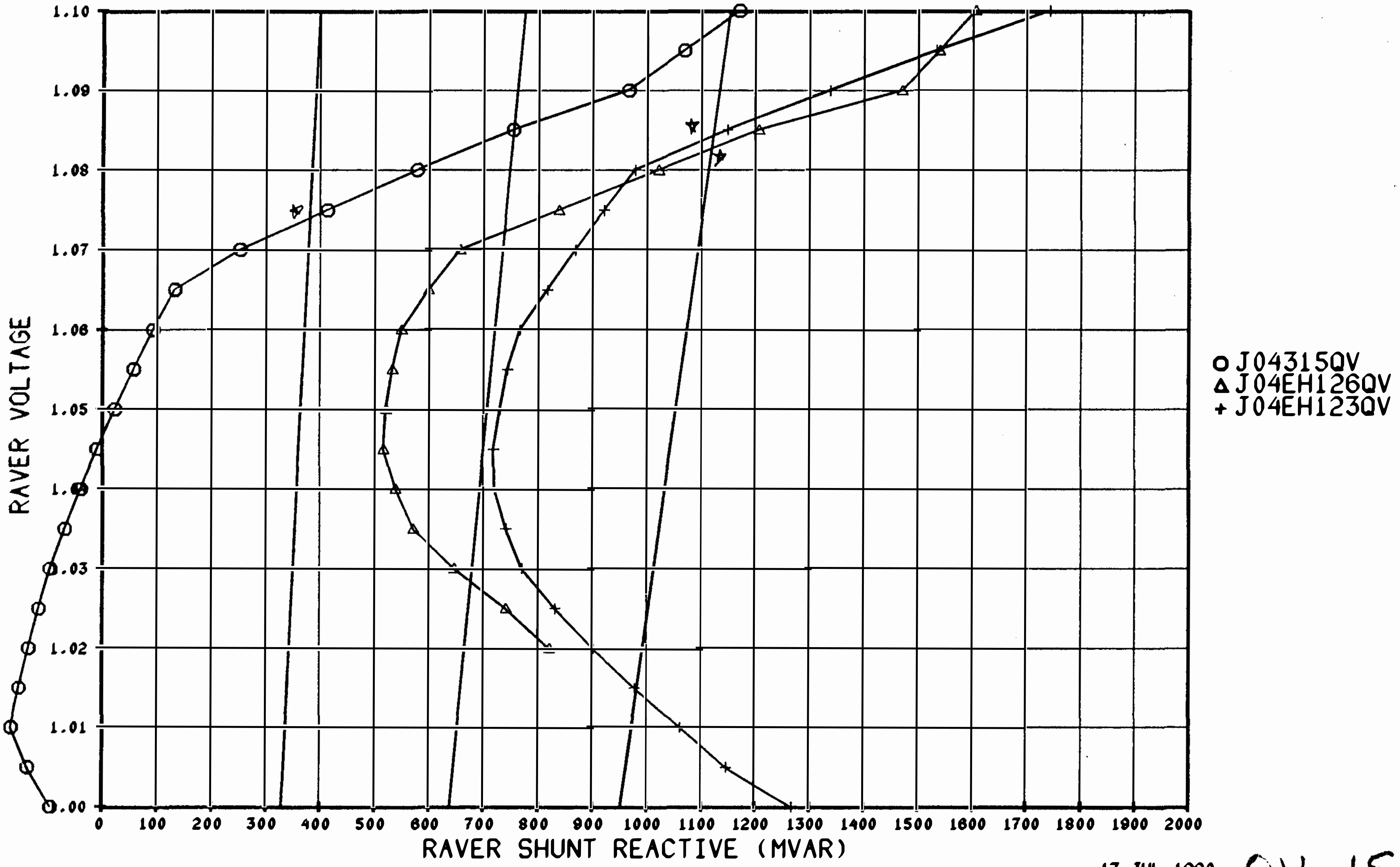
PLAN 5: SICKLER-SNOQ-NANEUM SY, SNOKING,
LDC, COV-BERYDL, 300MVAR SVC AT KEELER & MAPLE VL
○ J96182: DOUBLE COULEE-NANEUM OUT (J96174)
△ J96EH413: CHIEF JO-MONROE OUT (J96EH393)
+ J96EH421: TROJAN SCRAM (J96EH397)



9-MAR-1990 QV-150

PLAN 5: CHIEF JO-SICKLER-SNOQUALMIE,SNOKING,LDC

500 MVAR SVCS AT MAPLE VALLEY & KEELER
J04315QV: DOULBE COULEE-NANEUM OUT (J04310)
J04EH126QV: CHIEF JO-MONROE OUT (J04EH118)
J04EH123QV: TROJAN SCRAM (J04EH117)

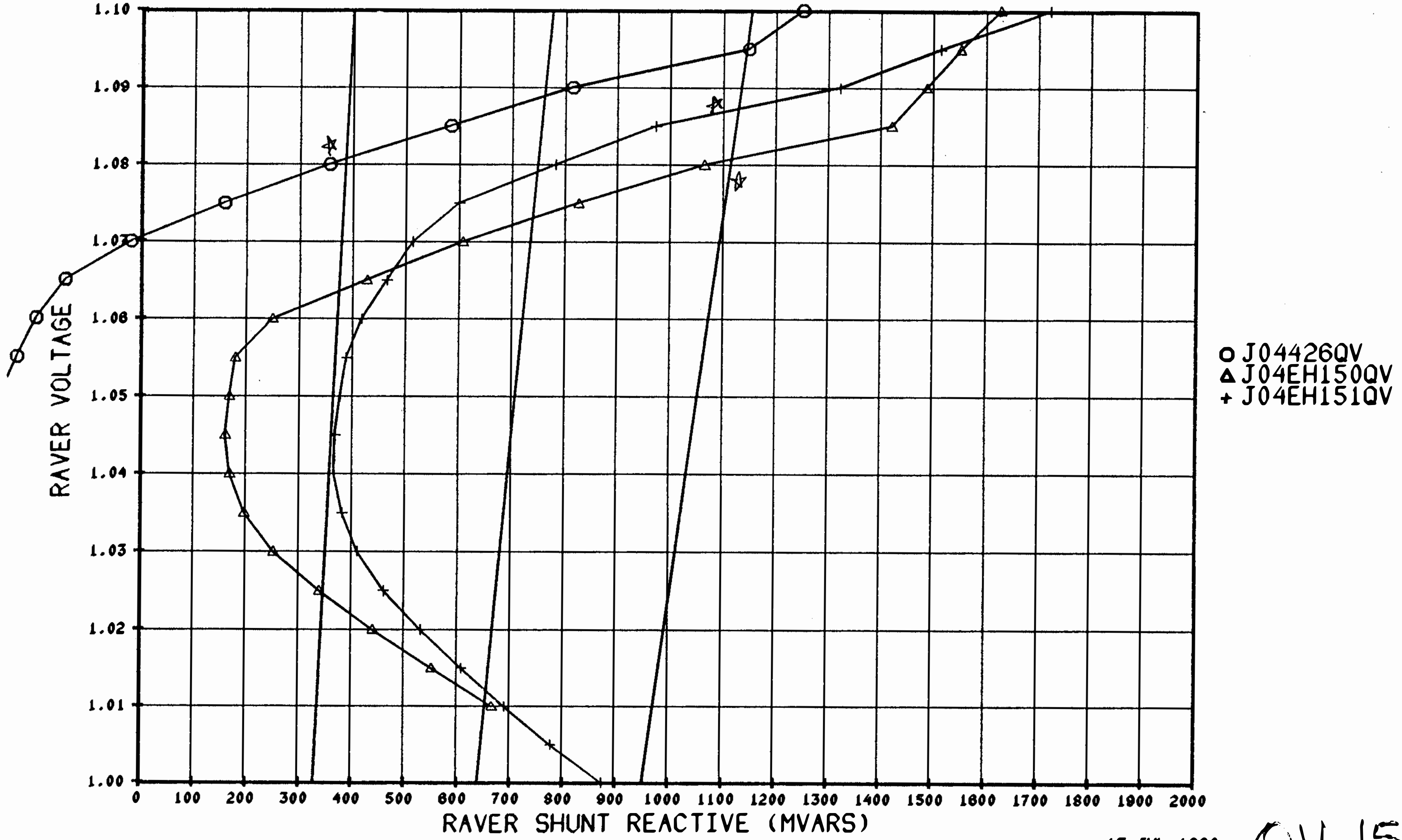


17-JUL-1990

QV-151

PLAN 5: SICKLER-SNOQUALMIE, SNOKING, LDC

500 MVAR SVCS AT MAPLE VL & KEELER, 300 MVAR AT COV
J04426: DOUBLE COULEE-NANEUM OUT (J04310)
J04EH150: CHIEF JO-MONROE OUT (J04EH118)
J04EH151: TROJAN SCRAM (J04EH117)

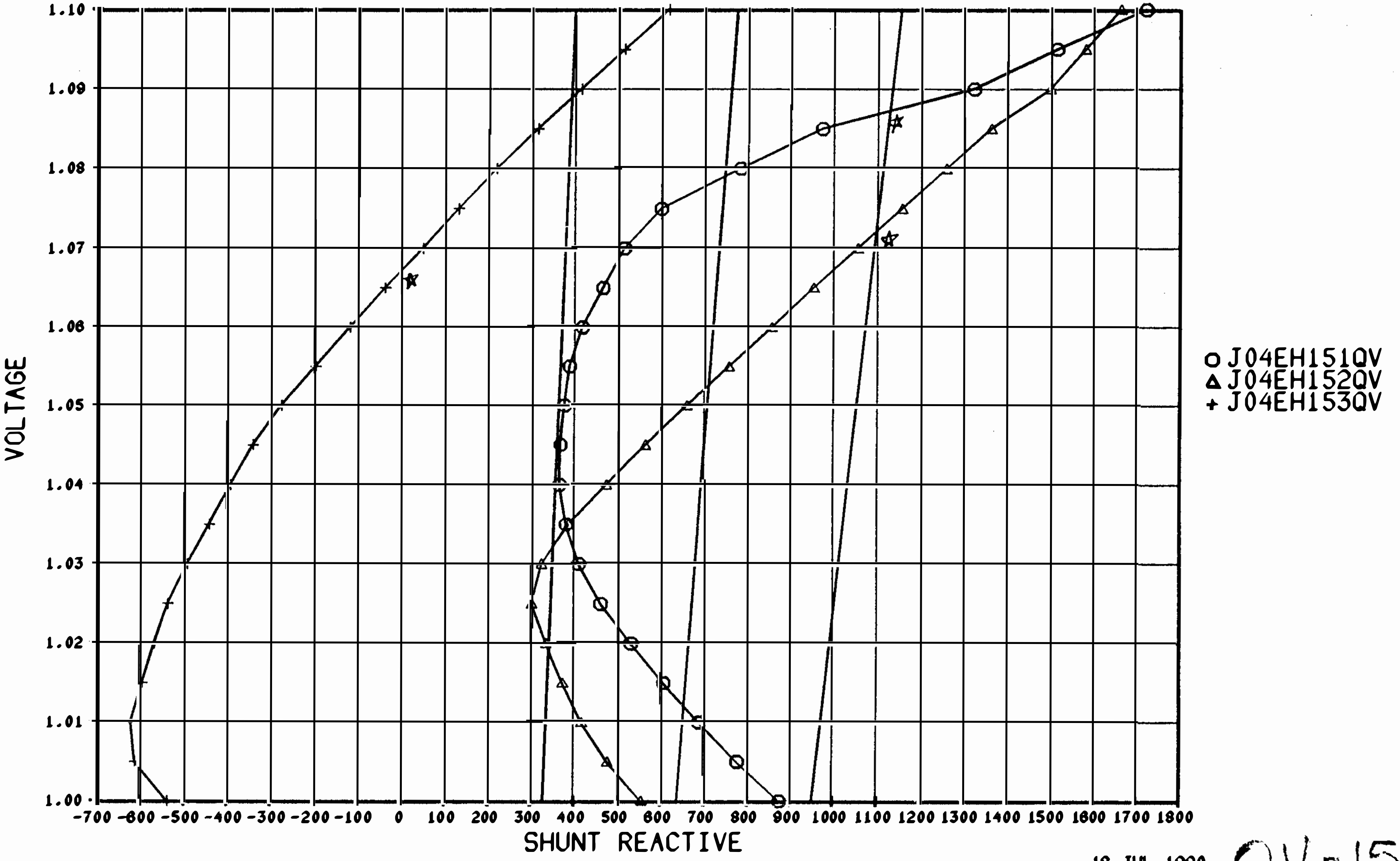


17-JUL-1990

QV-152

PLAN 5: SICKLER-SNOQUALMIE

TROJAN SCRAM (BASECASE J04EH117)
○ J04EH151:   RAVER
△ J04EH152: OSTRANDER
+ J04EH153:   MARION

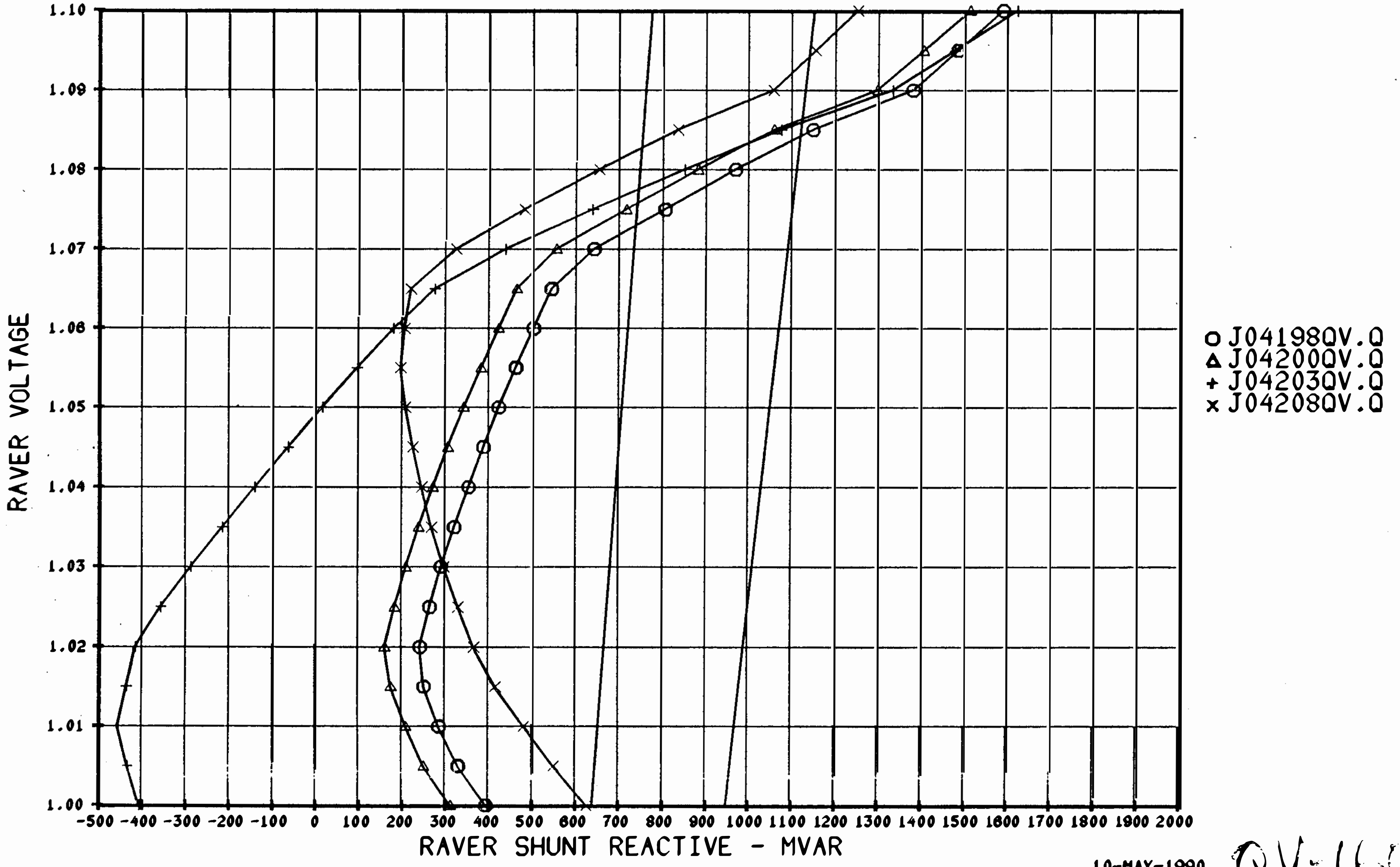


18-JUL-1990

QV-153

PLAN 2: CHIEF JO-SNOQUALAMIE, NORMAL WINTER

○ J04198: 500-KV LINE, COULEE-RAVER OUT (J04197)
△ J04200: 765-KV LINE, OP @ 500, C-R OUT (J04199)
+ J04203: 765-KV LINE, CHIEF JO-SNOQ OUT (J04202)} 2000 MW
× J04208: 765-KV LINE, COULEE-RAVER OUT (J04202)} PS setting



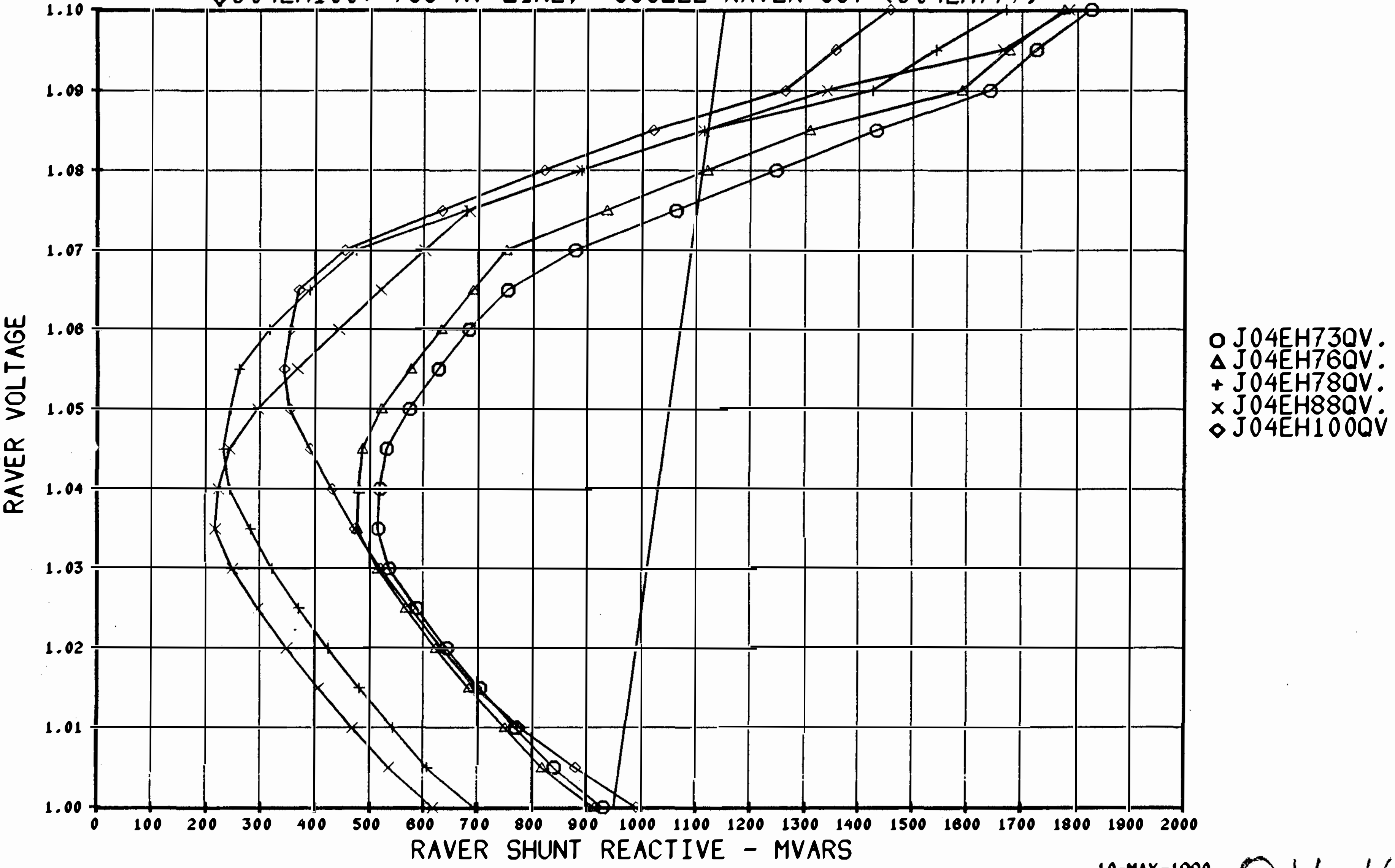
10-MAY-1990

QV-160

PLAN 2: CHIEF JO-SNOQUALAMIE

○J04EH73: 500-KV LINE, COULEE-RAVER OUT (J04EH71)
△J04EH76: 765-KV LINE, OP @ 500, C-R OUT (J04EH74)
+J04EH78: 765-KV LINE, CHIEF JO-SNOQ OUT (J04EH77)
×J04EH88: 765-KV LINE,PS Z=0,CH J-SNOQ OUT(J04EH87)
◇J04EH100: 765-KV LINE, COULEE-RAVER OUT (J04EH77)

2000 MW PS setting

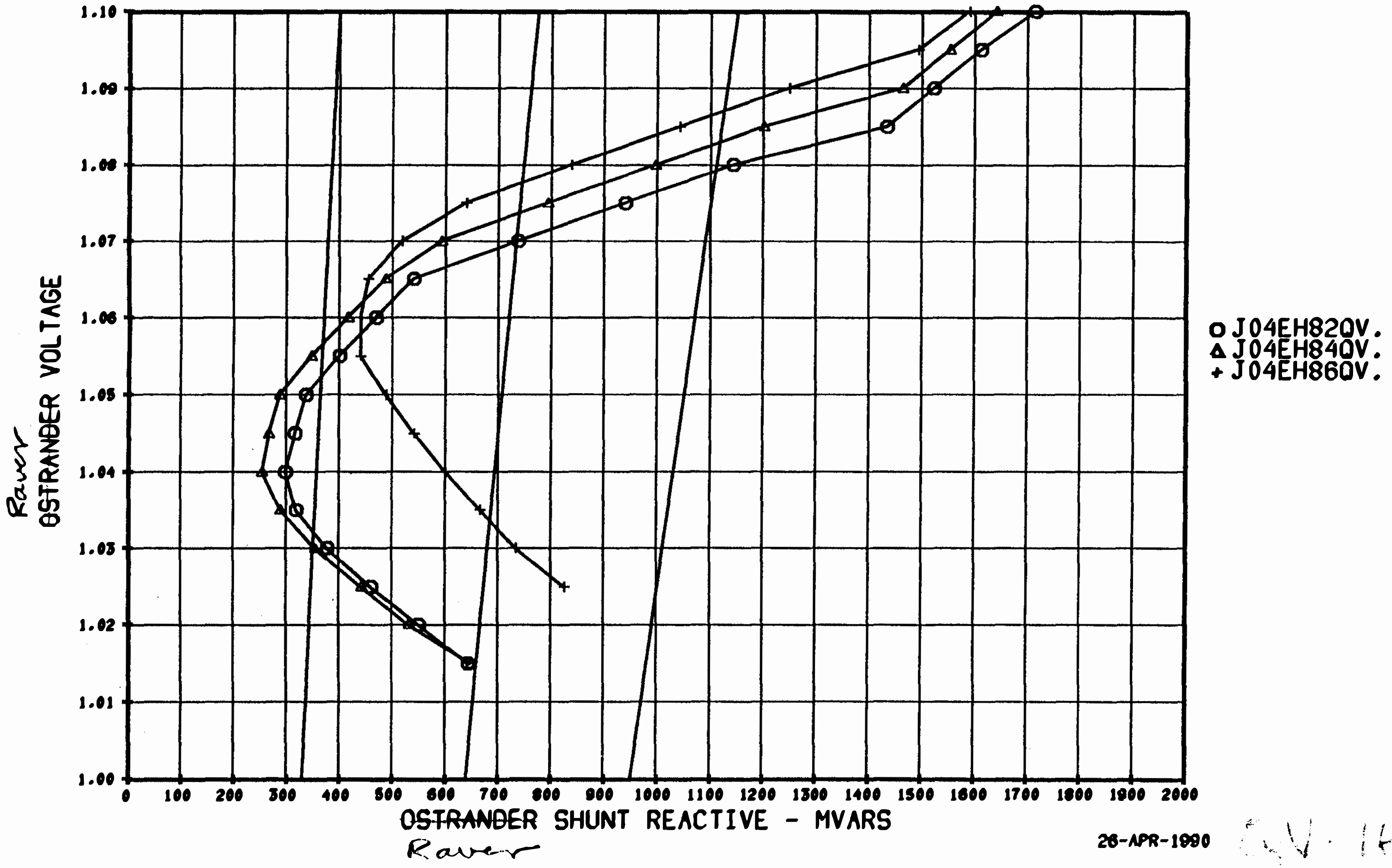


10-MAY-1990

QV-161

PLAN 2: TROJAN SCRAM

○ J04EH82: 500-KV LINE (J04EH81)
△ J04EH84: 765-KV LINE, OP AT 500, (J04EH83)
+ J04EH86: 765-KV LINE (J04EH85) - 2000 MW PS setting

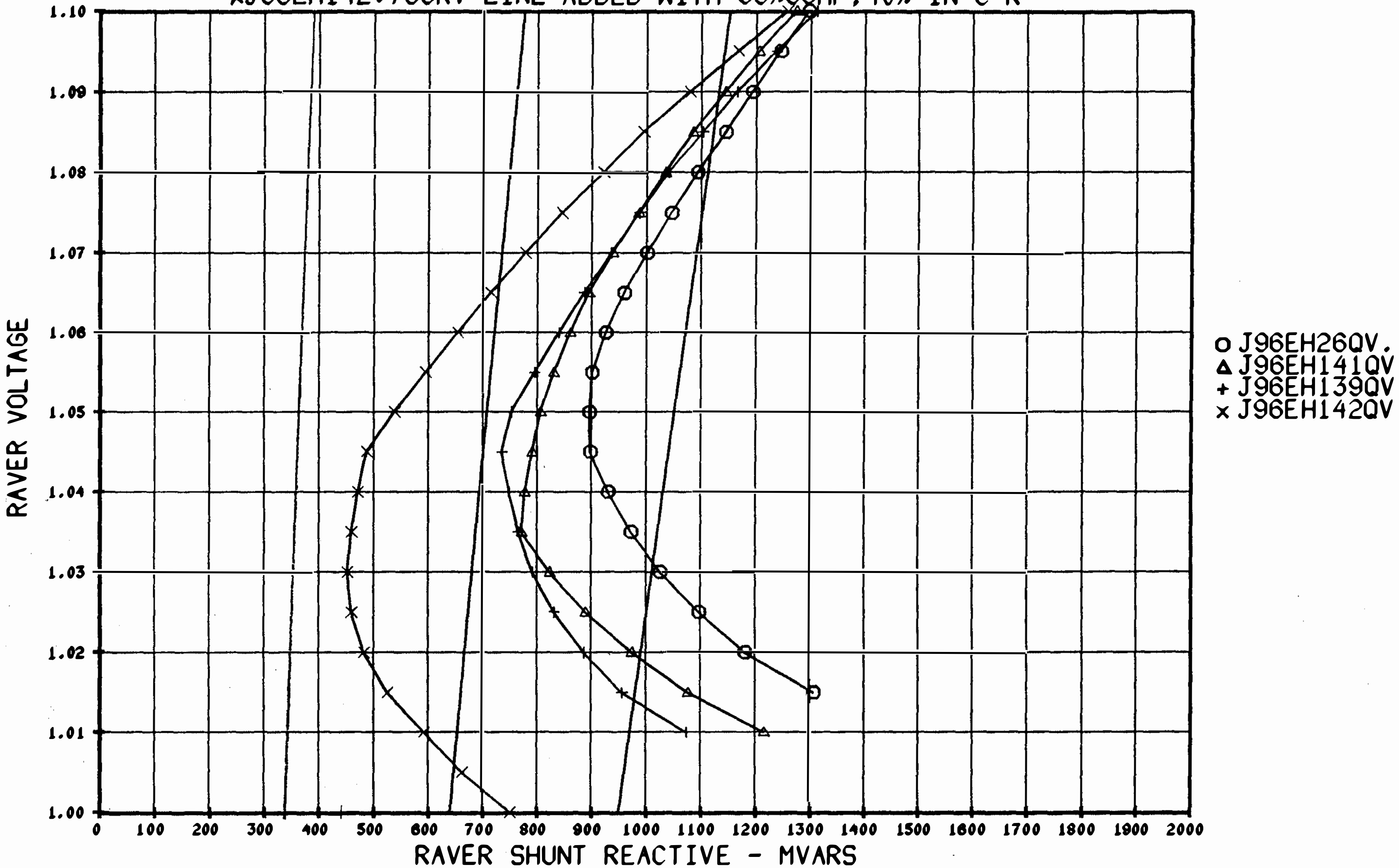


28-APR-1990

RV-167

CHIEF JOE - SNOQUALMIE PLAN

WORST SINGLE LINE OUTAGE
o J96EH26: 500KV LINE ADDED
△ J96EH141:765KV LINE ADDED OPERATED AT 500KV
+J96EH139: 765KV LINE ADDED
×J96EH142:765KV LINE ADDED WITH 35%COMP,40% IN C-R

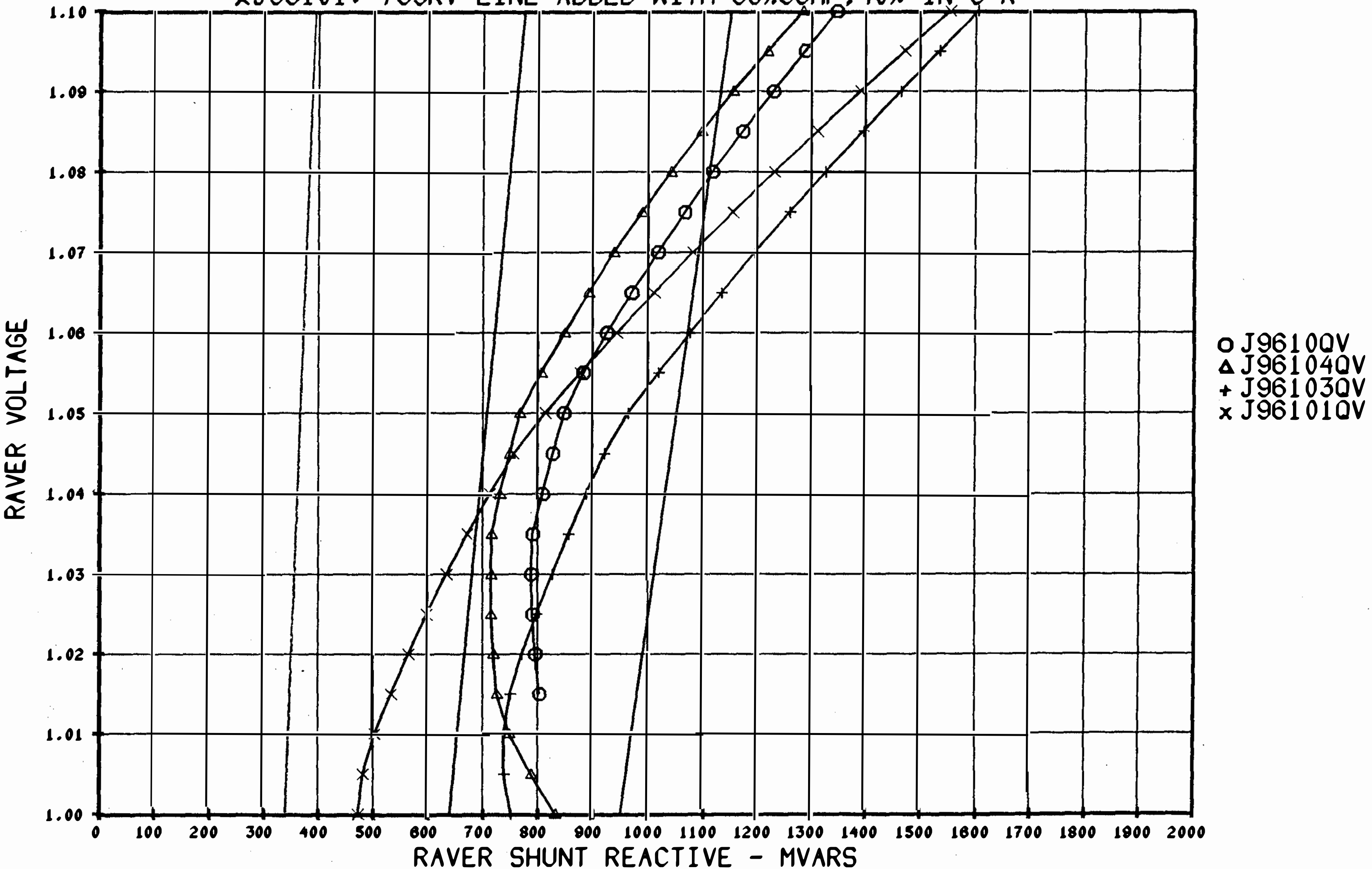


12-JAN-1990

QV-163

CHIEF JOE - SNOQUALMIE PLAN

WORST DOUBLE LINE OUTAGE
○J9610: 500KV LINE ADDED
△J96104: 765KV LINE ADDED OPERATED AT 500KV
+J96103: 765KV LINE ADDED
×J96101: 765KV LINE ADDED WITH 35%COMP,40% IN C-R

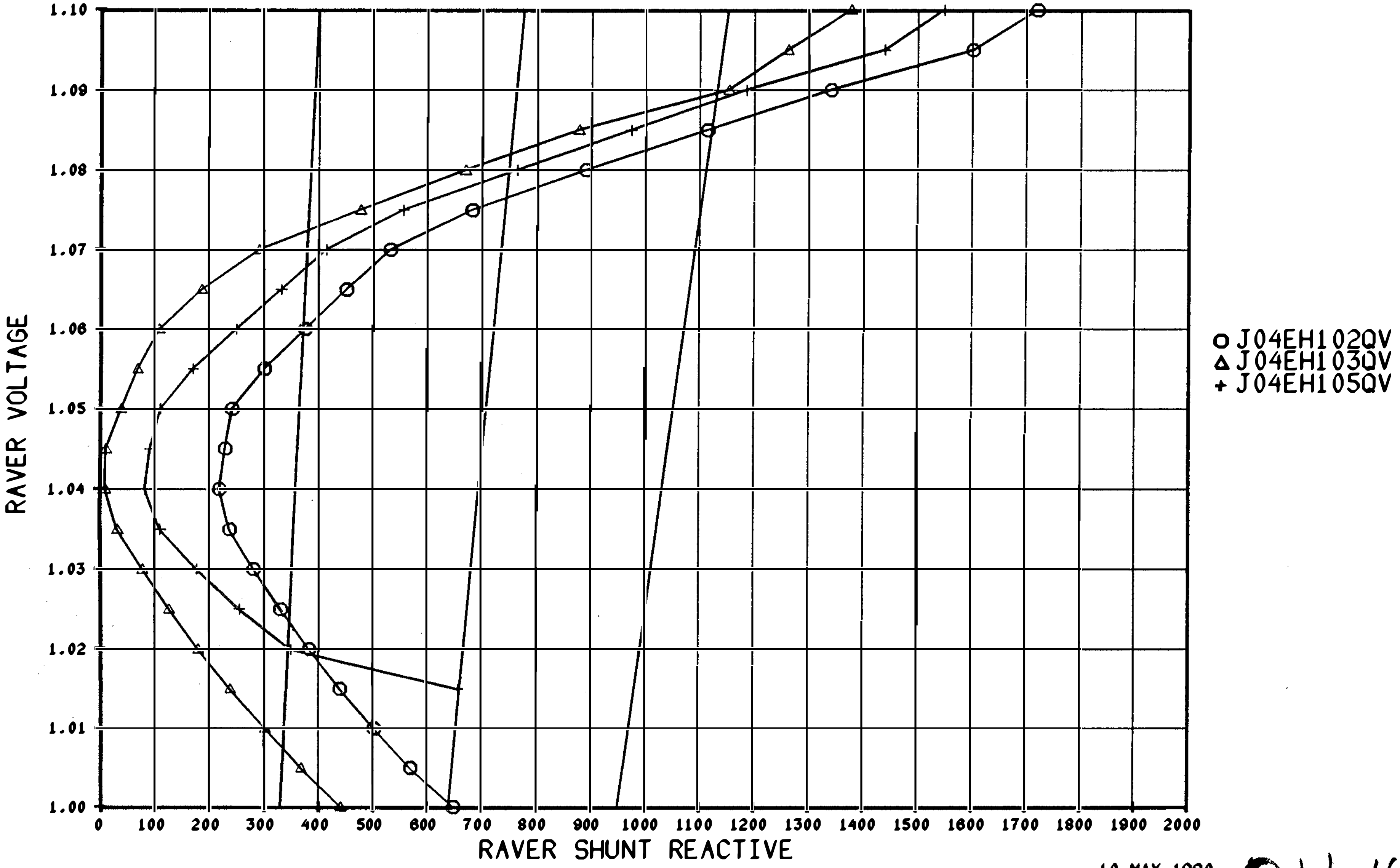


12-JAN-1990

QV-164

PLAN 2: CHIEF JOE/COULEE-SNOQUALMIE 765 DOUBLE CIR

○ J04EH102: COULEE-SNOQUALMIE 765 LINE OUT (J04EH101
△ J04EH103: COULEE-RAVER 500 LINE OUT (J04EH101)
+ J04EH105: TROJAN SCRAM (J04EH104)

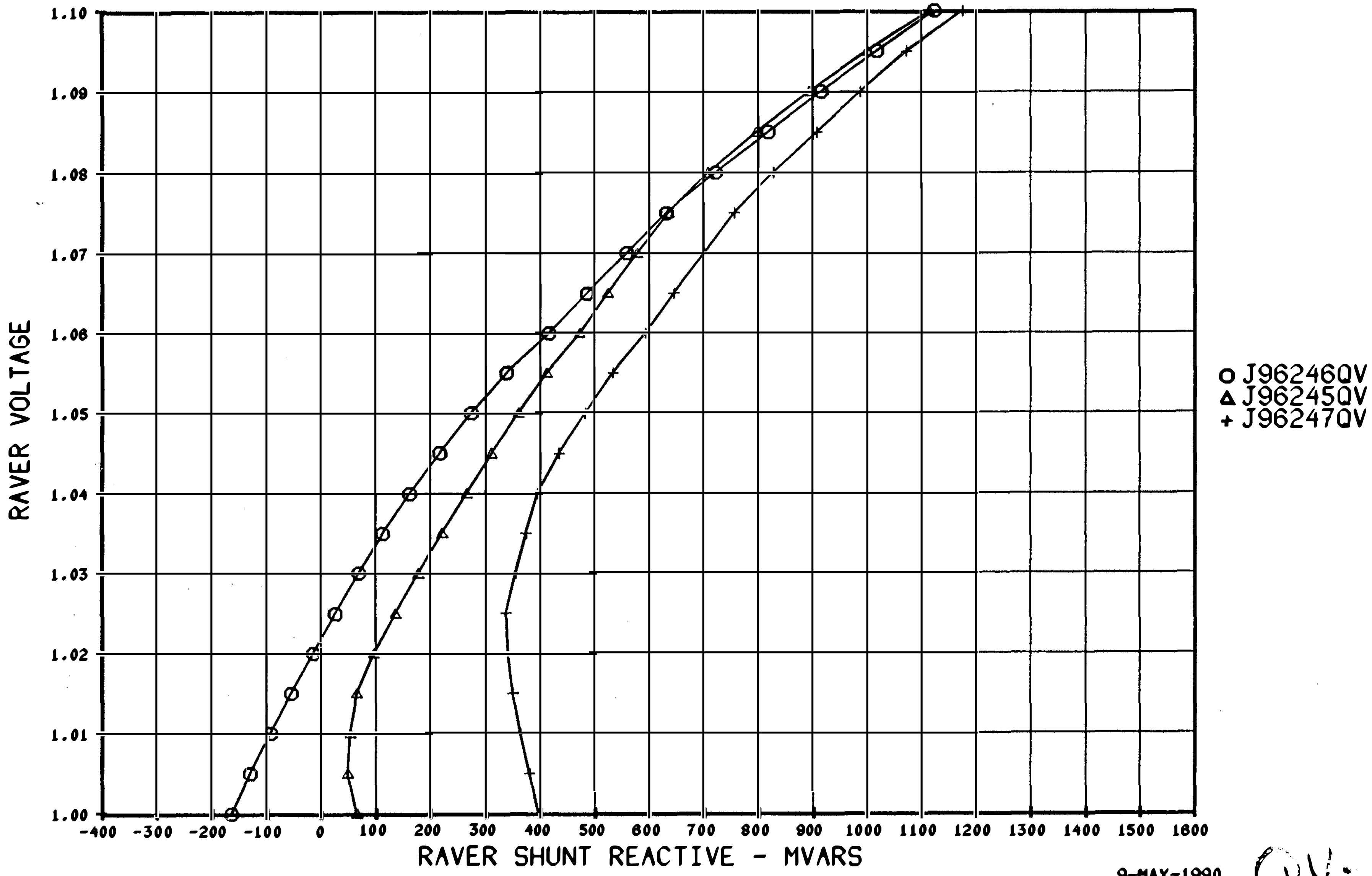


10-MAY-1990

QV-165

COULEE - RAVER NO 1&2 OUT

○ J96246: 1700MW (J96199)
△ J96245: 2000MW (J96191)
+ J96247: 2200MW (J96203)

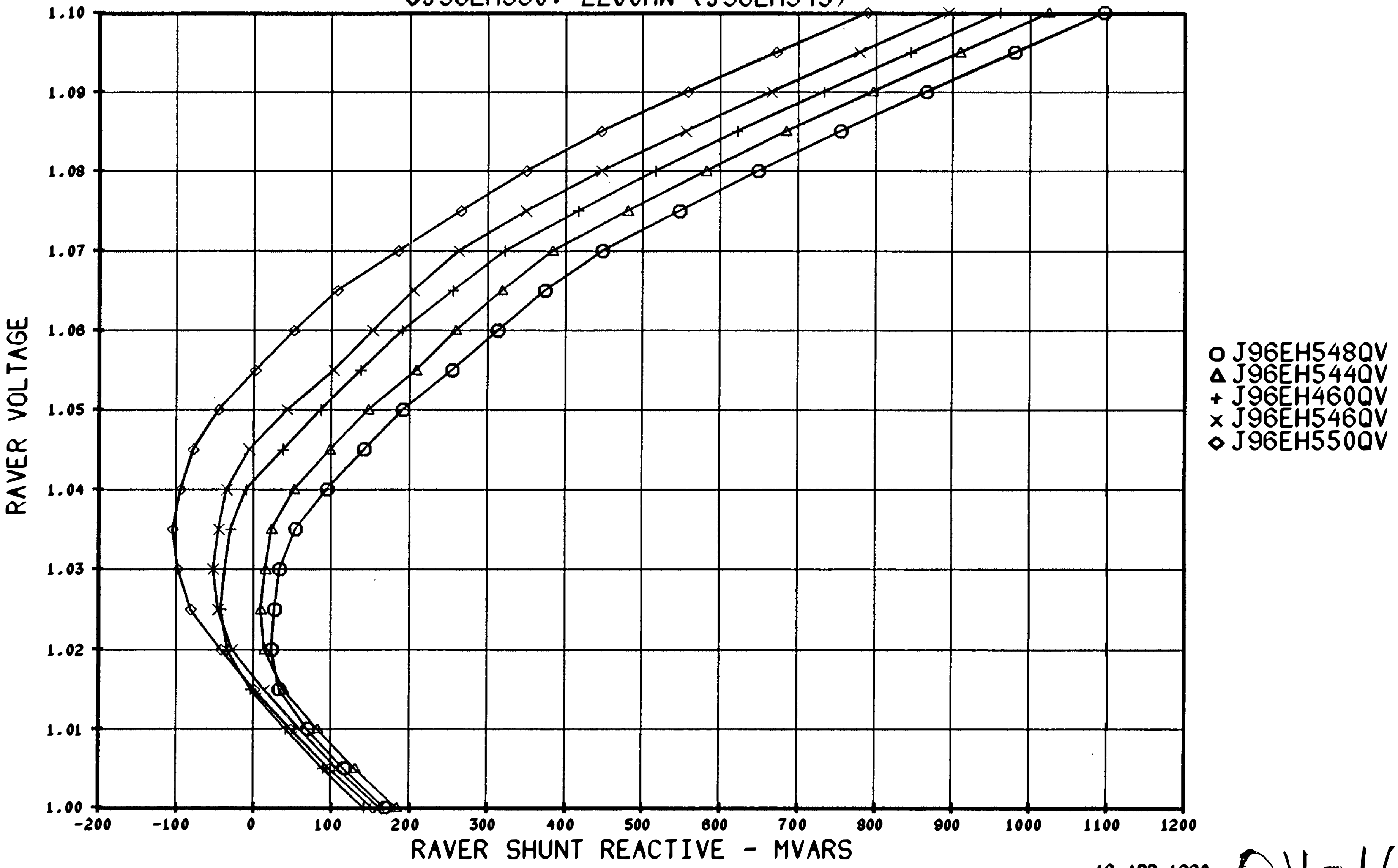


9-MAY-1990

QV-16

COULEE - RAVER NO 1 OUT

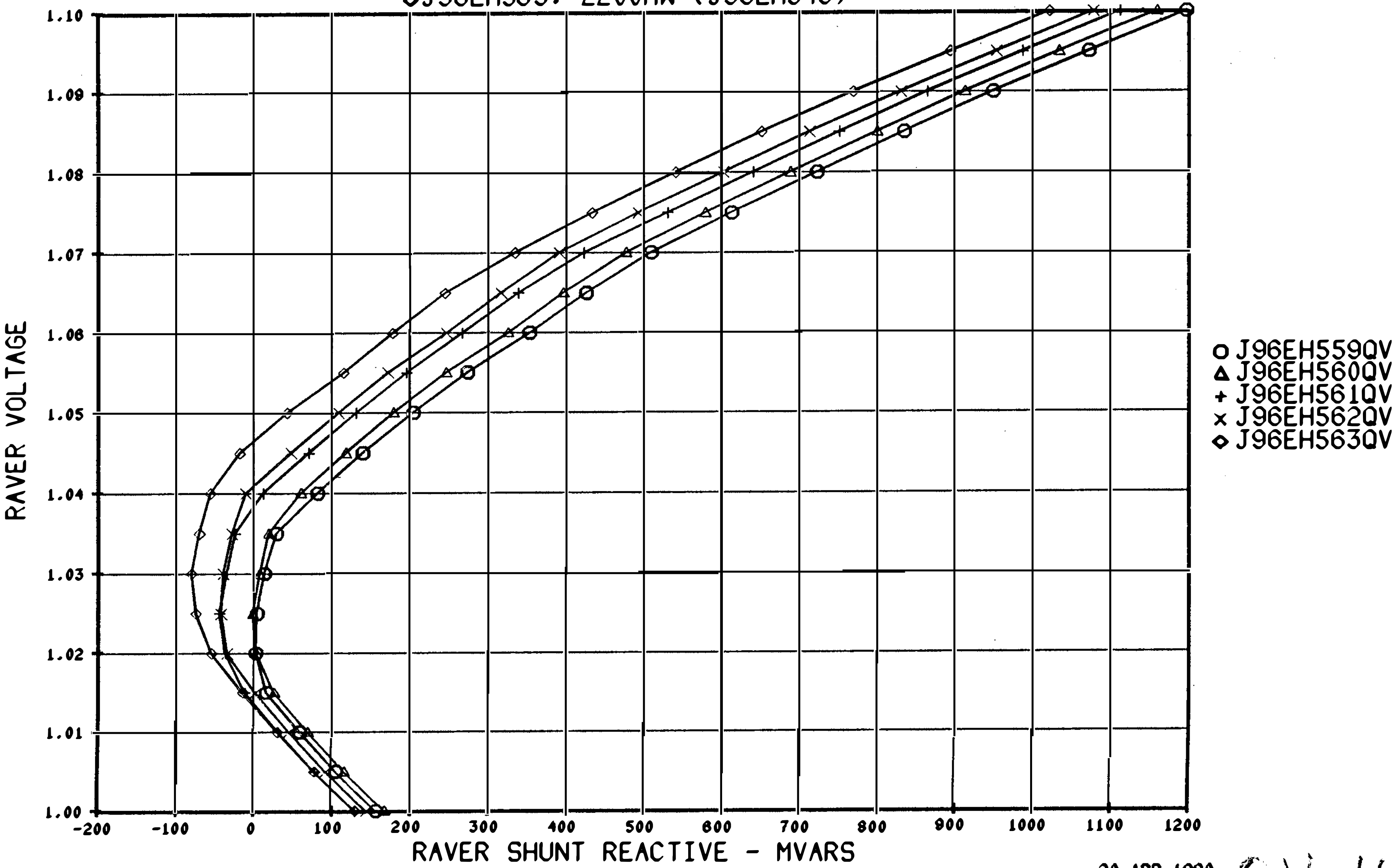
○J96EH548: 1800MW (J96EH547)
△J96EH544: 1900MW (J96EH543)
+J96EH460: 2000MW (J96EH458)
×J96EH546: 2100MW (J96EH545)
◇J96EH550: 2200MW (J96EH549)



16-APR-1990 QV-167

CHIEF JOE-SNOQUALMIE 765 LINE OUT

○J96EH559: 1800MW (J96EH547)
△J96EH560: 1900MW (J96EH543)
+J96EH561: 2000MW (J96EH458)
×J96EH562: 2100MW (J96EH545)
◇J96EH563: 2200MW (J96EH549)

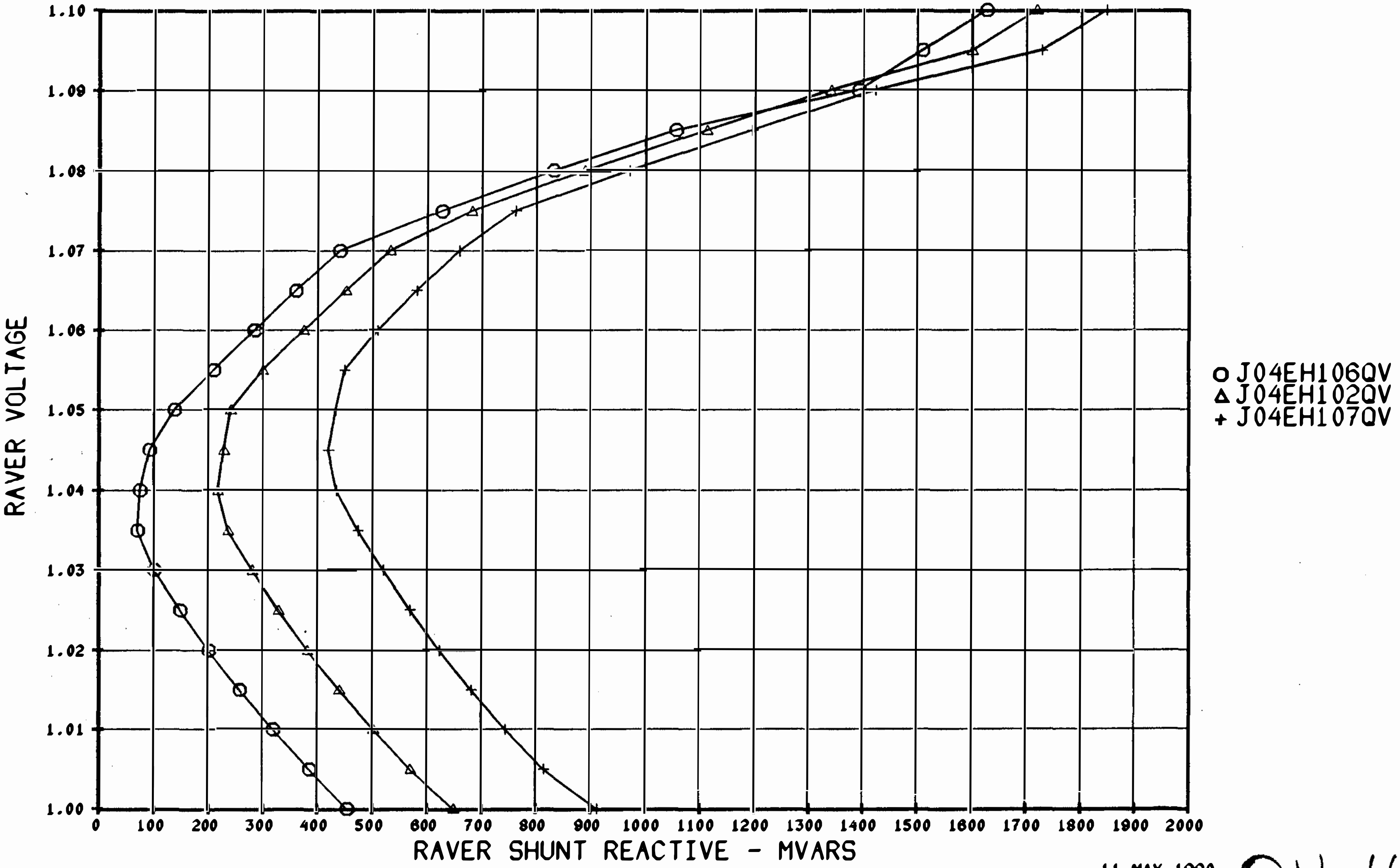


20-APR-1990

QV-168

CHIEF JOE/COULEE-SNOQ 765 DBL CKT PLAN

PHASE SHIFTED TO 2000MW IN BASE (J04EH101)
○J04EH106:PS ANGLE DECREASED 5° FROM PRE OUTAGE
△J04EH102:PS SET AT 2000MW PRE OUTAGE ANGLE
+J04EH107:PS ANGLE INCREASED 5° FROM PRE OUTAGE



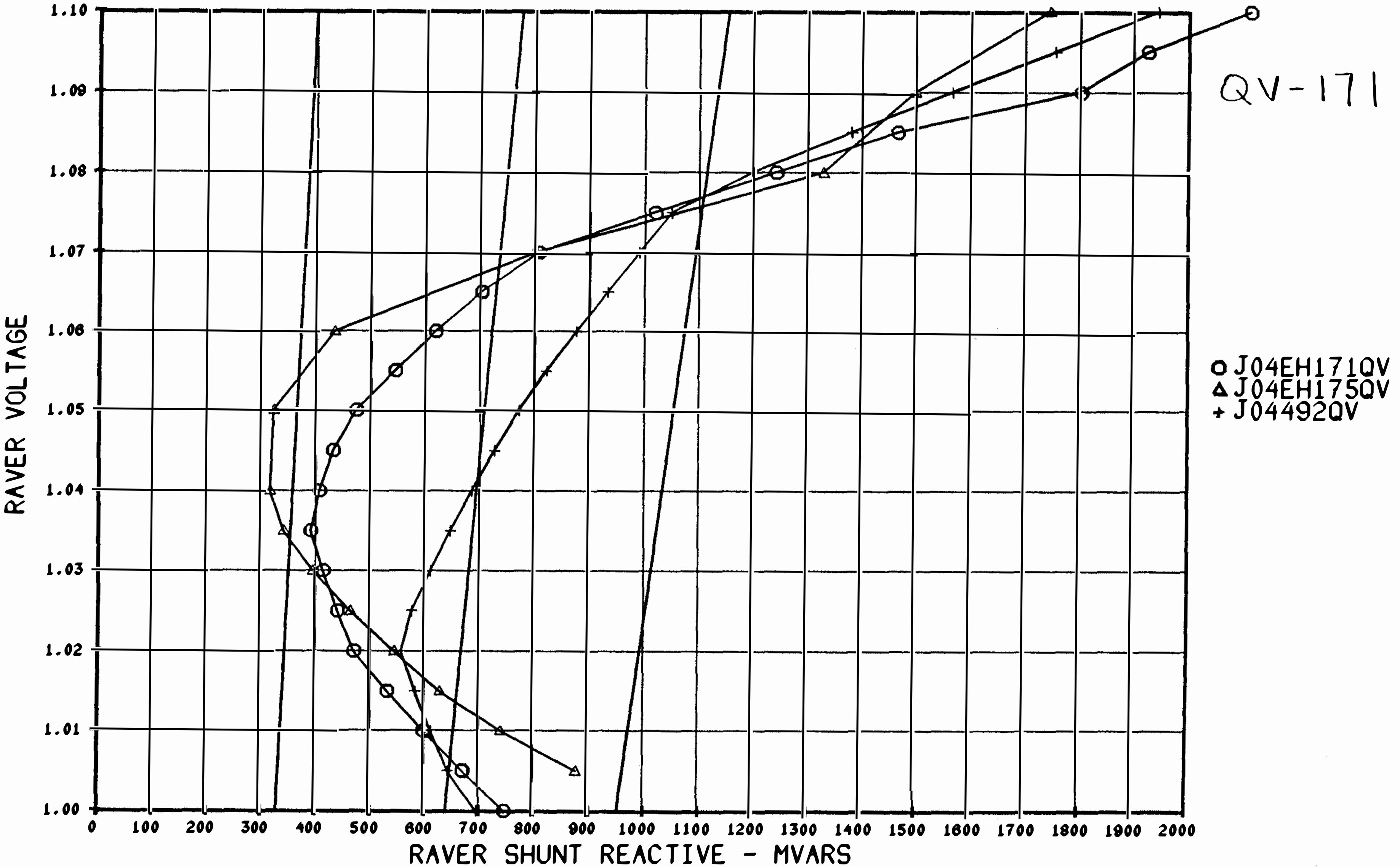
11-MAY-1990

QV-169

PLAN 7: GRAND COULEE-OLYMPIA/COVINGTON 500 (Rebuild of 230/287)

○J04EH171: CHIEF JO-MONROE 500 OUTAGE (J04EH154)
△J04EH175: TROJAN SCRAM (J04EH155)
+J04492: DOUBLE COULEE-RAVER OUTAGE (J04438)

Snoking, LDC
500 MVAR SVC @ Keel + [illegible]



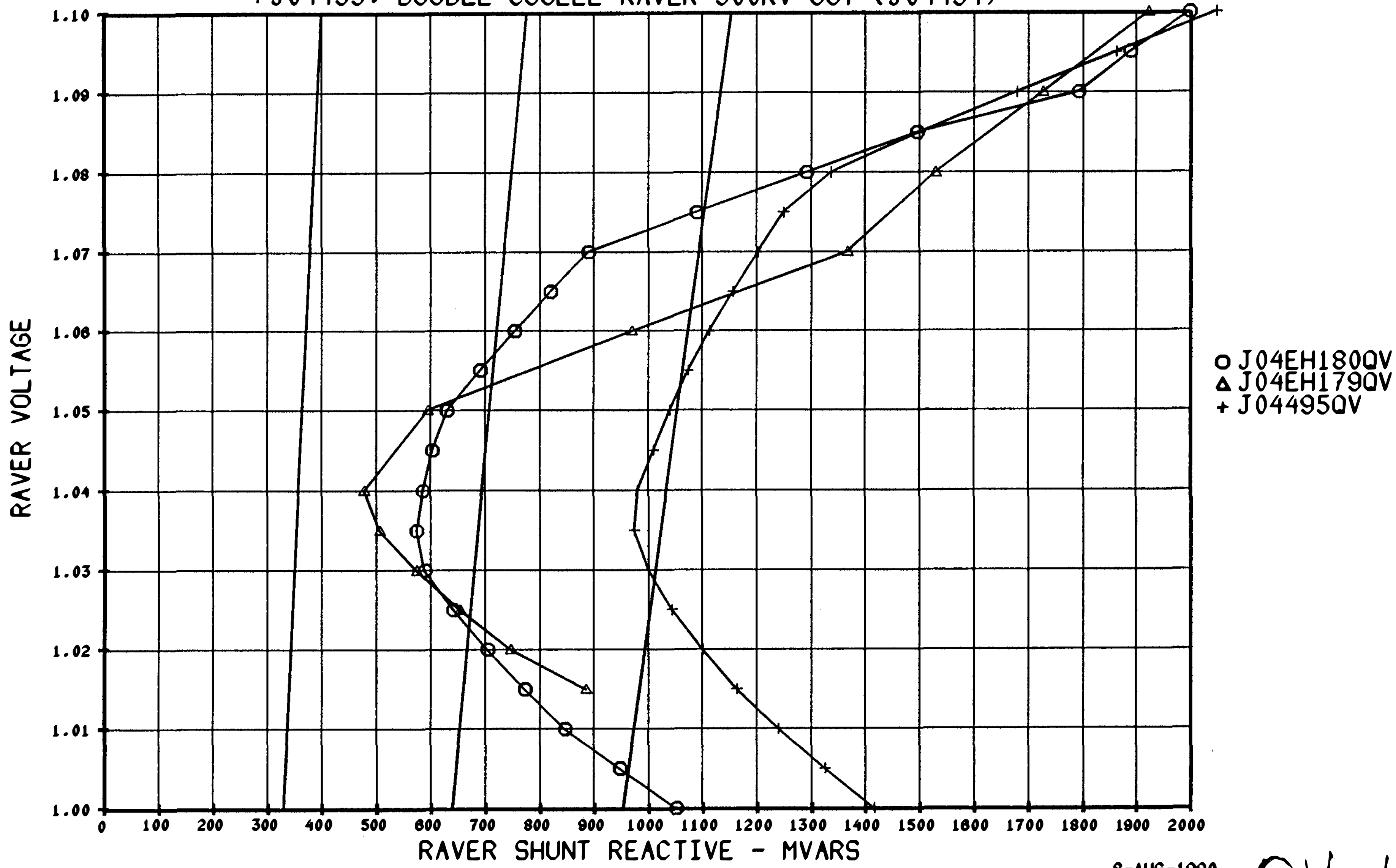
QV-171

8-AUG-1990

QV-171

PLAN 8: CHIEF JOE-SICKLER-SNOQUALMIE 500KV REBUILD

AND ROCKY R-MAPLE VL 345KV
500MVAR SVCS AT MAPLE VL & KEELER
○J04EH180: CHIEF JOE-MONROE 500 OUT (J04EH176)
△J04EH179: TROJAN SCRAM (J04EH177)
+J04495: DOUBLE COULEE-RAVER 500KV OUT (J04494)

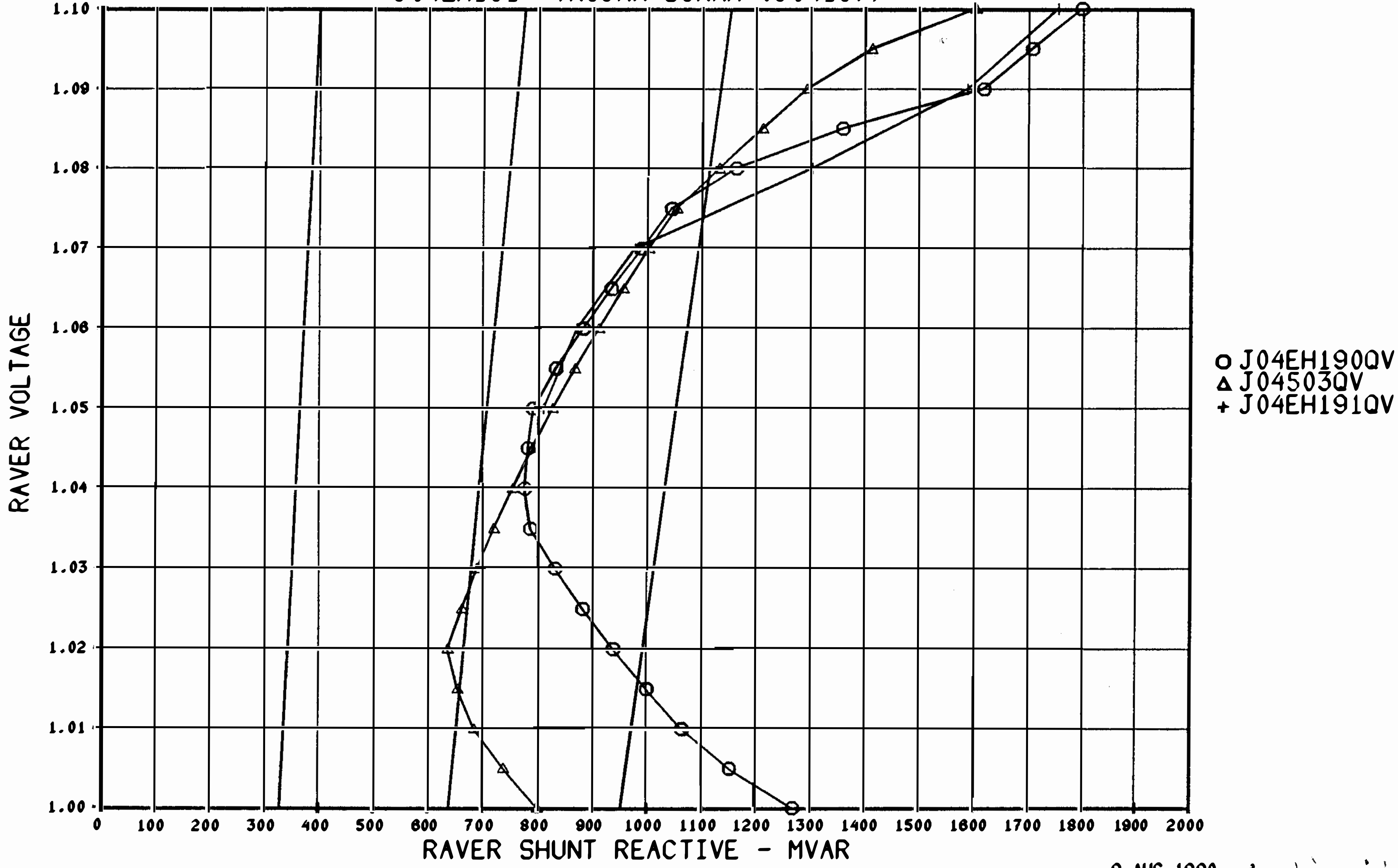


8-AUG-1990

QV-180

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

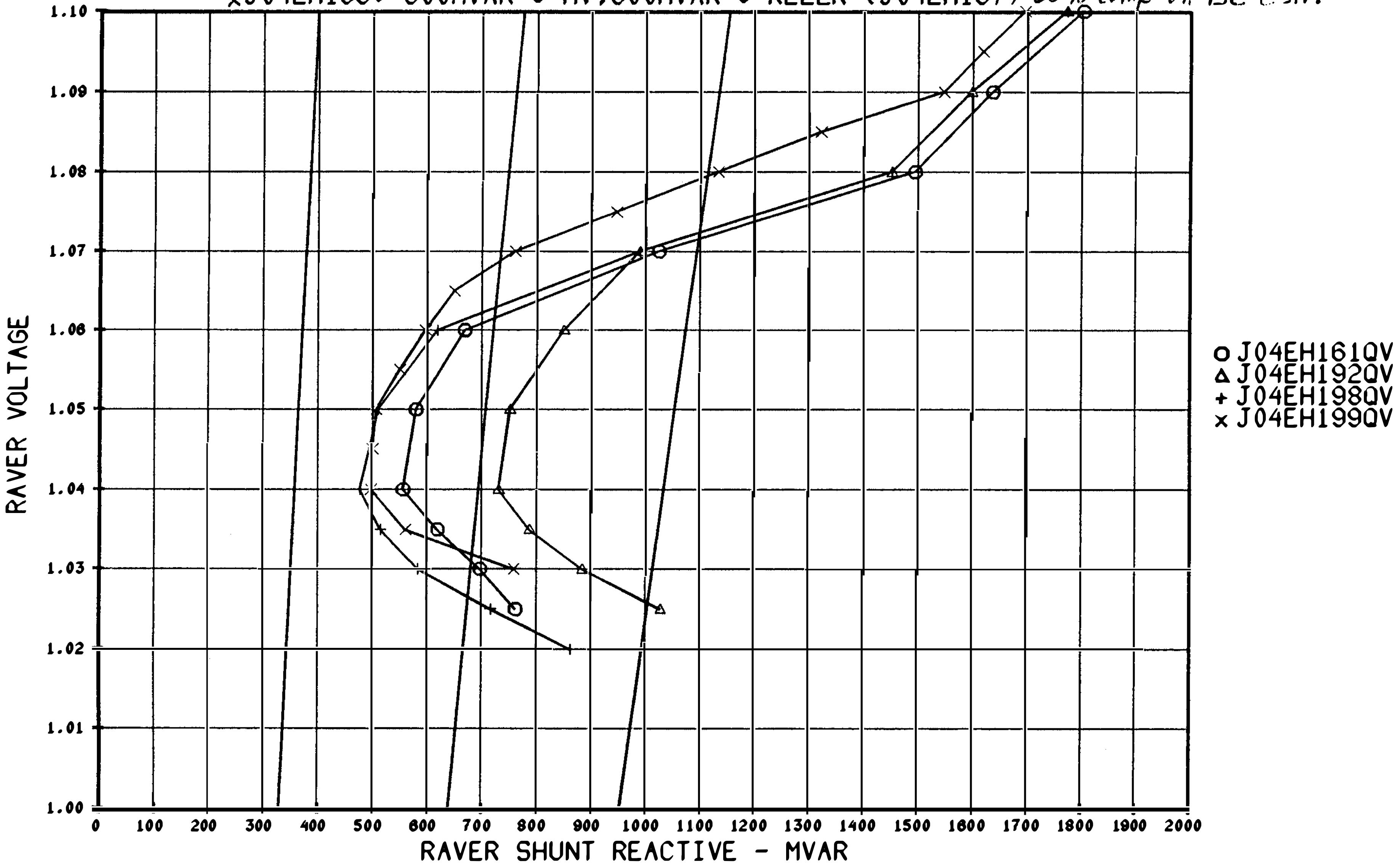
300MVAR SVC AT KEELER & MAPLE VALLEY
ADD 35% COMP ON ASHE-MARION
J04EH190: COULEE-RAVER 500 LINE OUT (J04EH186)
J04503: DOUBLE COULEE-RAVER 500 LINES OUT (J04500)
J04EH191: TROJAN SCRAM (J04187)



9-AUG-1990

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

TROJAN SCRAM -- BASED ON J04EH160
○J04EH161: 500 MVAR SVC AT KEELER & MAPLE VL
△J04EH192: 300 MVAR SVC AT KEELR, MV & OSTR
+J04EH198: 500 MVAR AT MV,300 MVAR AT KEELR & OSTR
×J04EH199: 500MVAR @ MV,300MVAR @ KEELR (J04EH197) 50% comp on BE-Ostr.

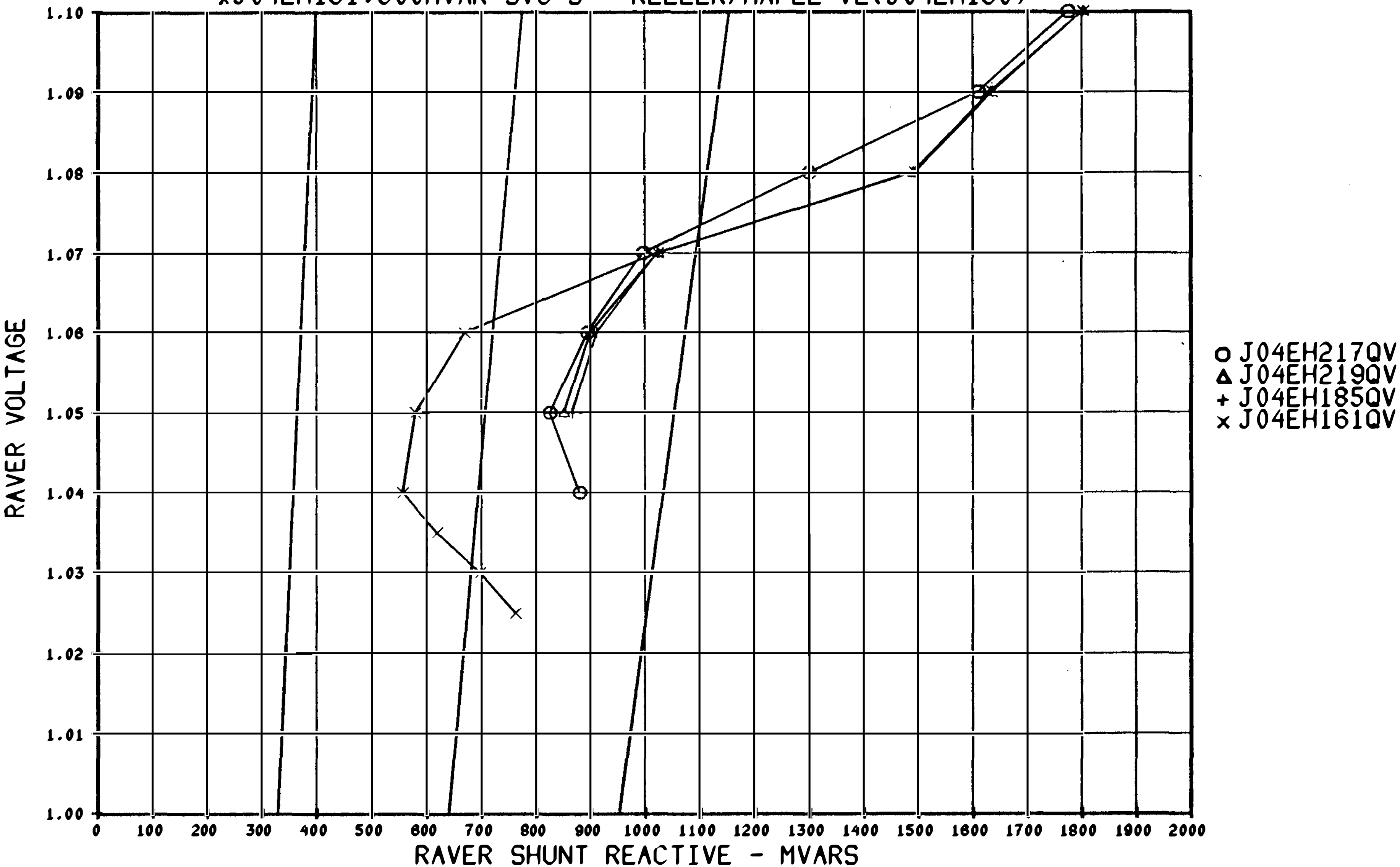


15-AUG-1990

PLAN 3: CHIEF JO-SNOQ/MONROE

TROJAN SCRAM

oJ04EH217:300/300 BE TAP TO HAN-OST(J04EH216)
ΔJ04EH219:300/300 BE TAP TO ASHE/MARION(J04EH218)
+J04EH185:300MVAR SVC'S - KEELER/MAPLE VL(J04EH160)
xJ04EH161:500MVAR SVC'S - KEELER/MAPLE VL(J04EH160)

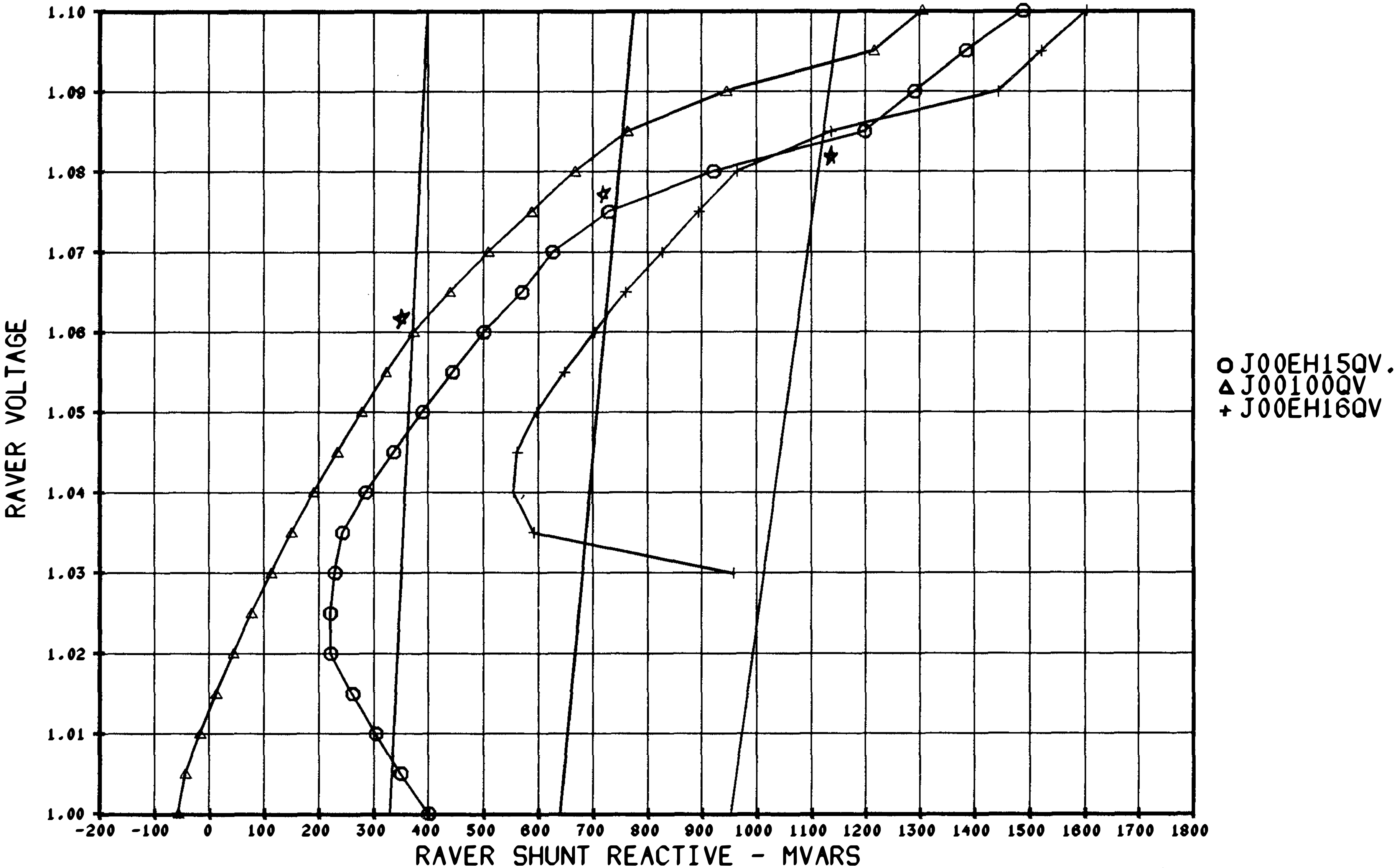


16-AUG-1990

QV-212

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

300MVAR SVC AT KEELER & MAPLE VL, LDC, SNOK TXF
○ J00EH15: ONE COULEE-RAVER 500 LINE OUT (J00EH12)
△ J00100: DOUBLE COULEE-RAVER LINE OUT (J0010)
+ J00EH16: TROJAN SCRAM (J00EH17)

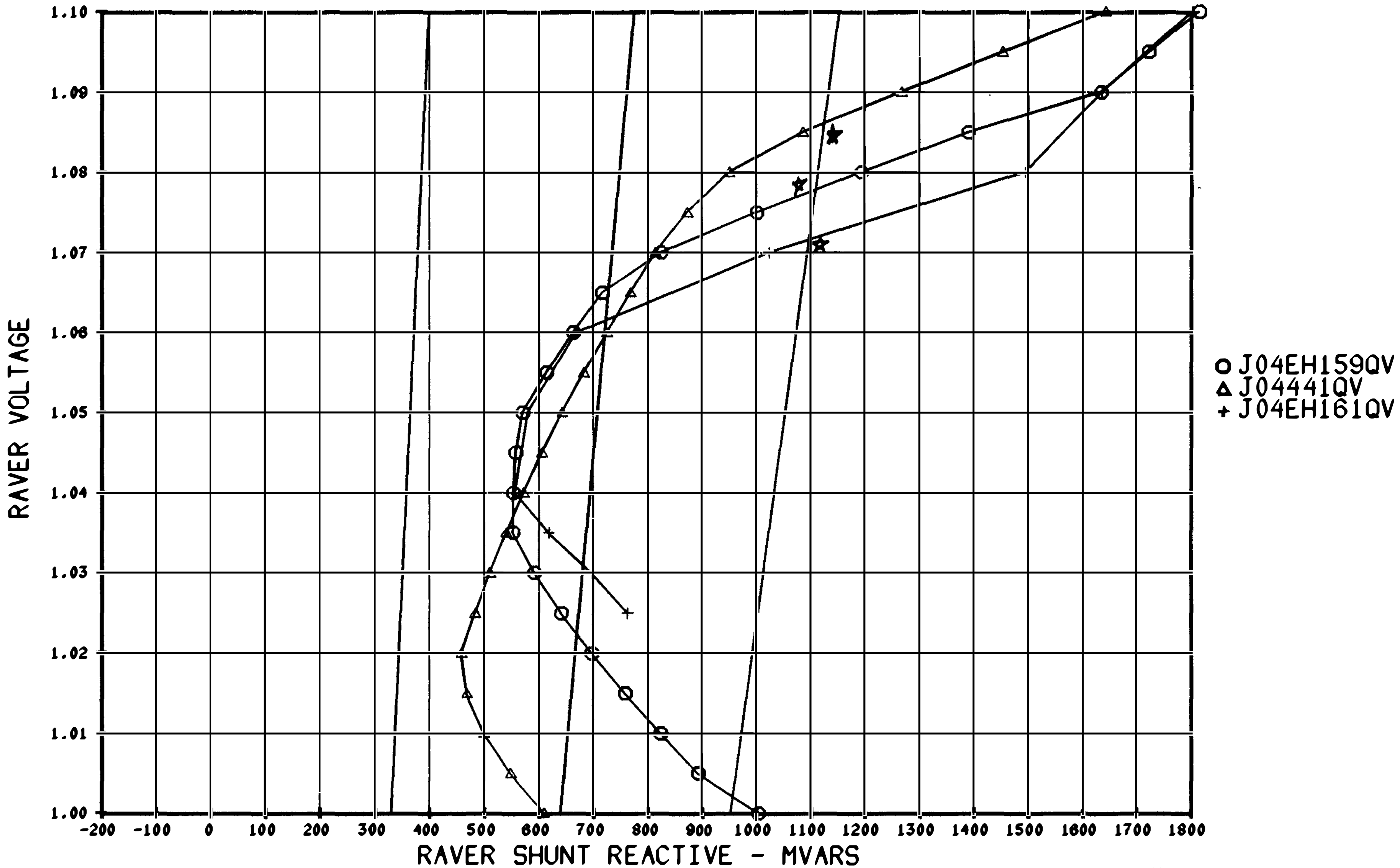


8-AUG-1990

QV-220

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

5~~6~~00MVAR SVC AT KEELER & MAPLE VL, LDC, SNOK TXF
○ J04EH159: ONE COULEE-RAVER 500 LINE OUT (J04EH158)
△ J04441: DOUBLE COULEE-RAVER LINE OUT (J04440)
+ J04EH161: TROJAN SCRAM (J04EH160)

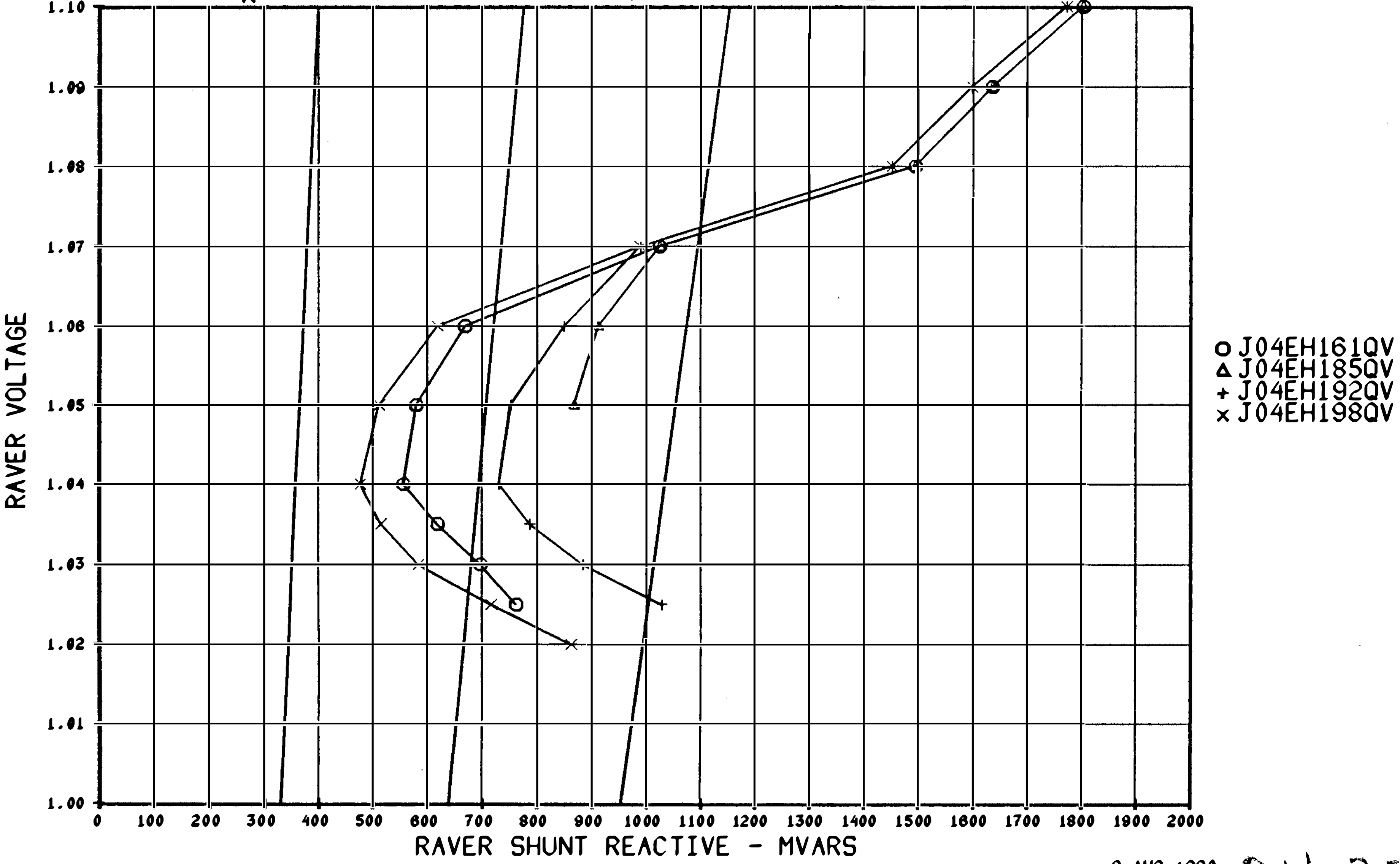


8-AUG-1990

QV-221

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

TROJAN SCRAM -- BASED ON J04EH160
o J04EH161: 500MVAR SVC AT KEELER & MAPLE VL
Δ J04EH185: 300MVAR SVC AT KEELER & MAPLE VL
+ J04EH192: 300MVAR SVC AT KEELR, MV & OSTRNDER
x J04EH198: 500MVAR AT MV;300MVAR AT KEELR & OSTR

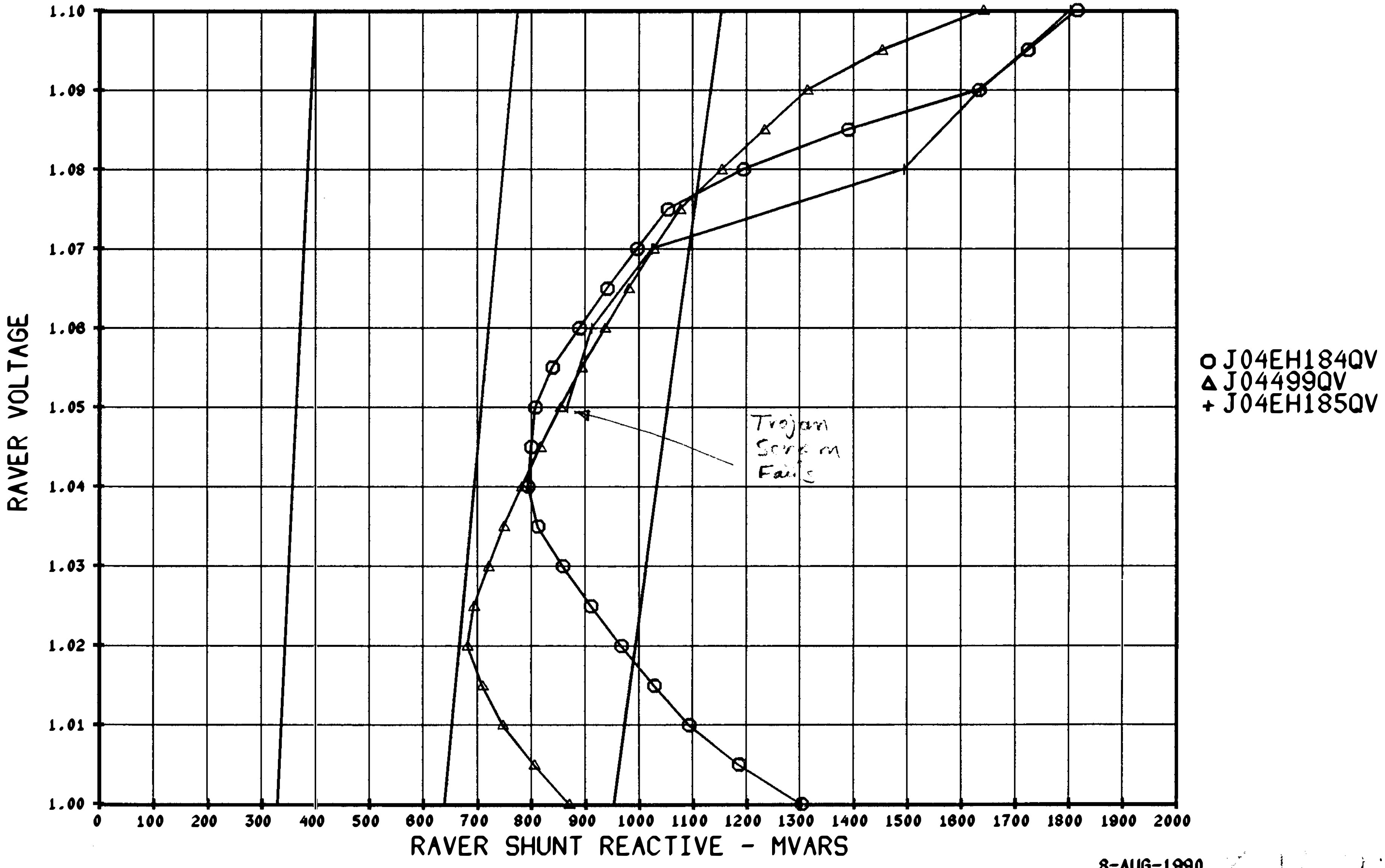


9-AUG-1990

QV-222

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

300MVAR SVC AT KEELER & MAPLE VL
○ J04EH184: ONE COULEE-RAVER 500 LINE OUT (J04EH158)
∆ J04499: DOUBLE COULEE-RAVER LINE OUT (J04441)
+ J04EH185: TROJAN SCRAM (J04EH160)



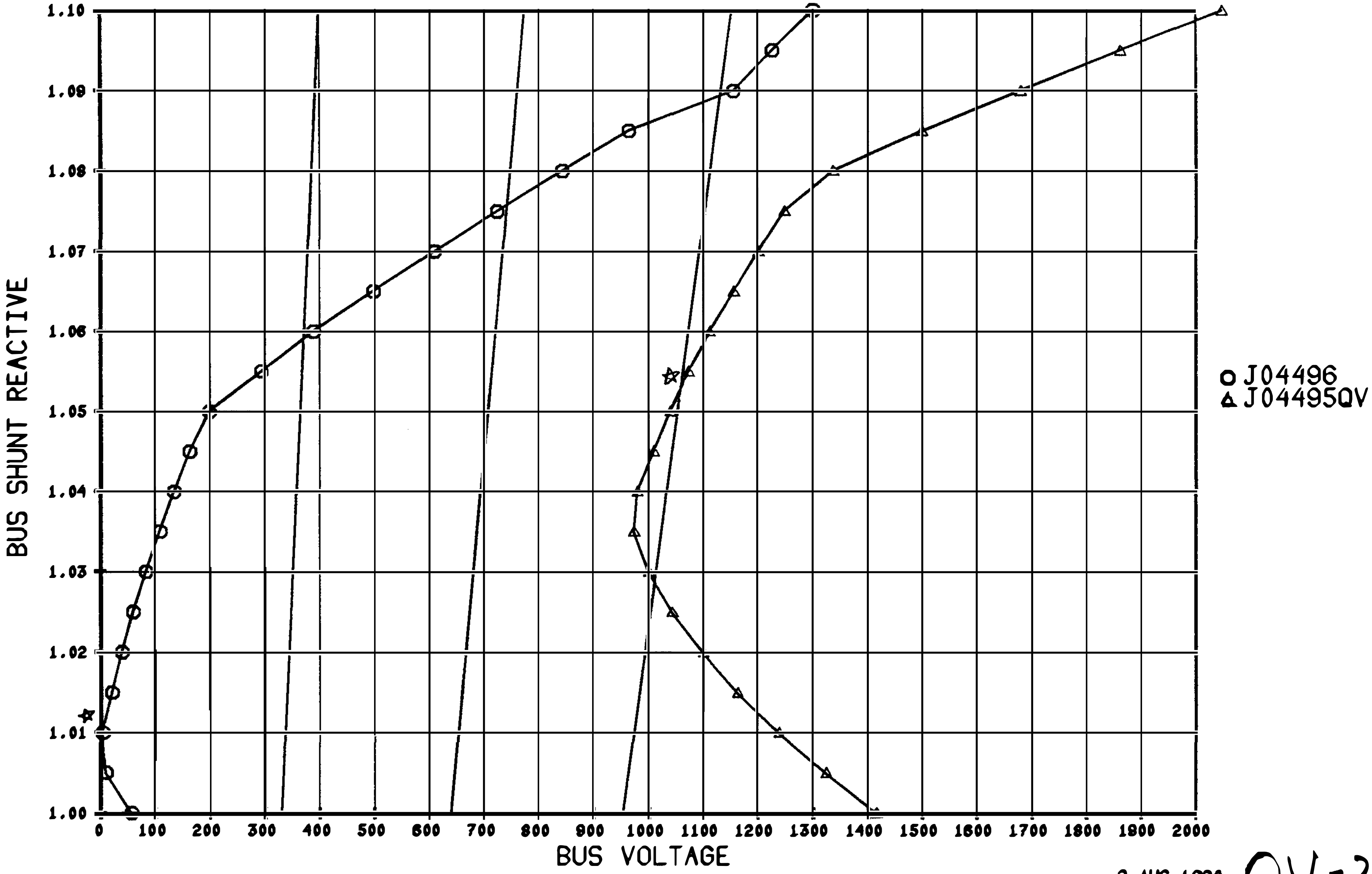
Trojan Scram Fails

8-AUG-1990

QV-223

PLAN 8: CJ-SNOQ REPLACING EXISTING LINES

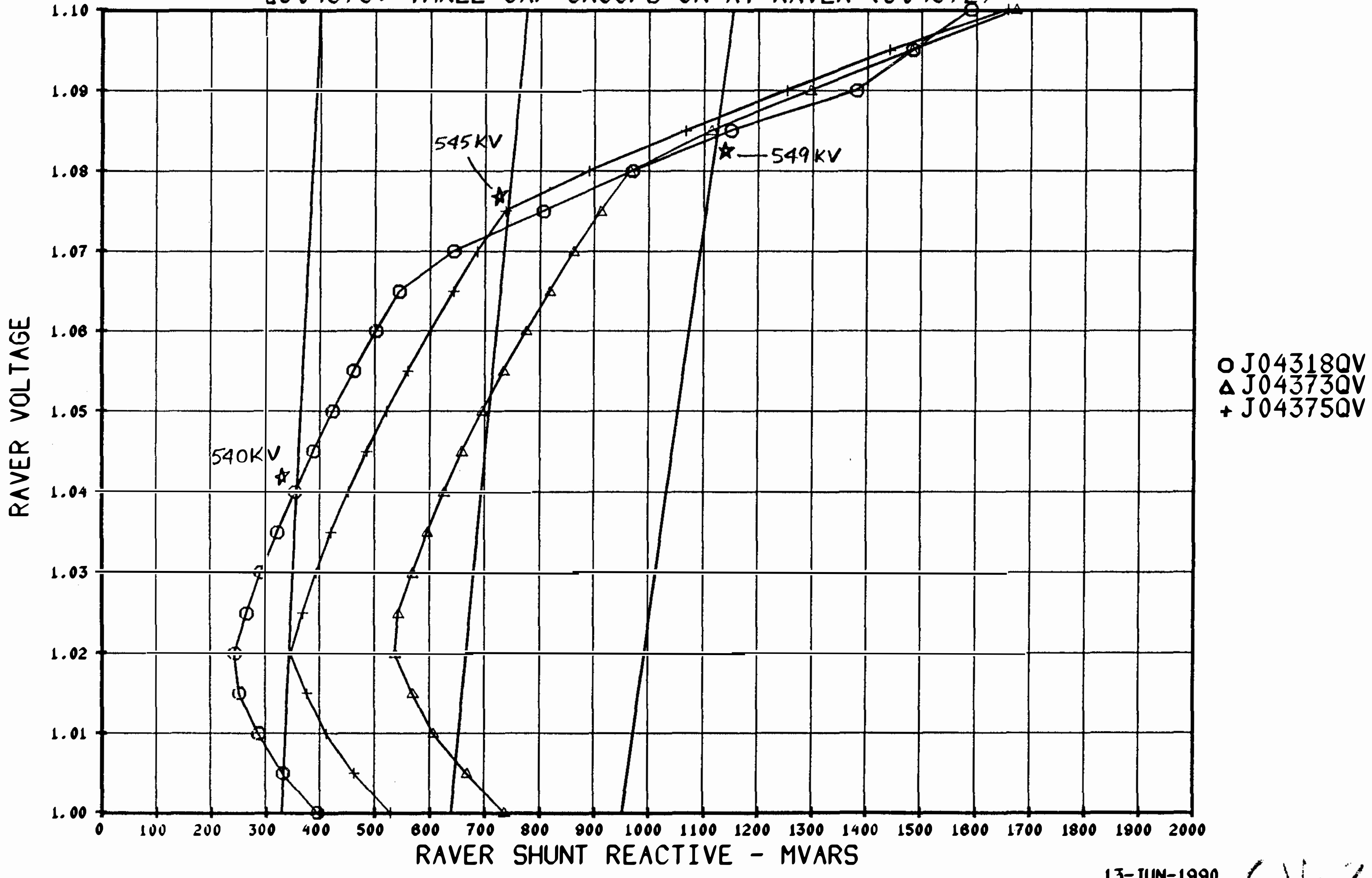
DOUBLE COULEE-RAVER 500 OUTAGE
J04495: RAVER CHARACTERISTICS
J04496; MONROE CHARACTERISTICS
BOTH BASED ON J04494



2-AUG-1990 QV-225

PLAN 2: CHIEF JO-SNOQUALMIE

DOUBLE COULEE-RAVER LINE OUTAGE
500 MVAR SVC'S AT MAPLE VALLEY AND KEELER
○J04318: ONE CAP GROUP ON AT RAVER (J04308)
+J04375: TWO CAP GROUPS ON AT RAVER (J04374)
△J04373: THREE CAP GROUPS ON AT RAVER (J04372)



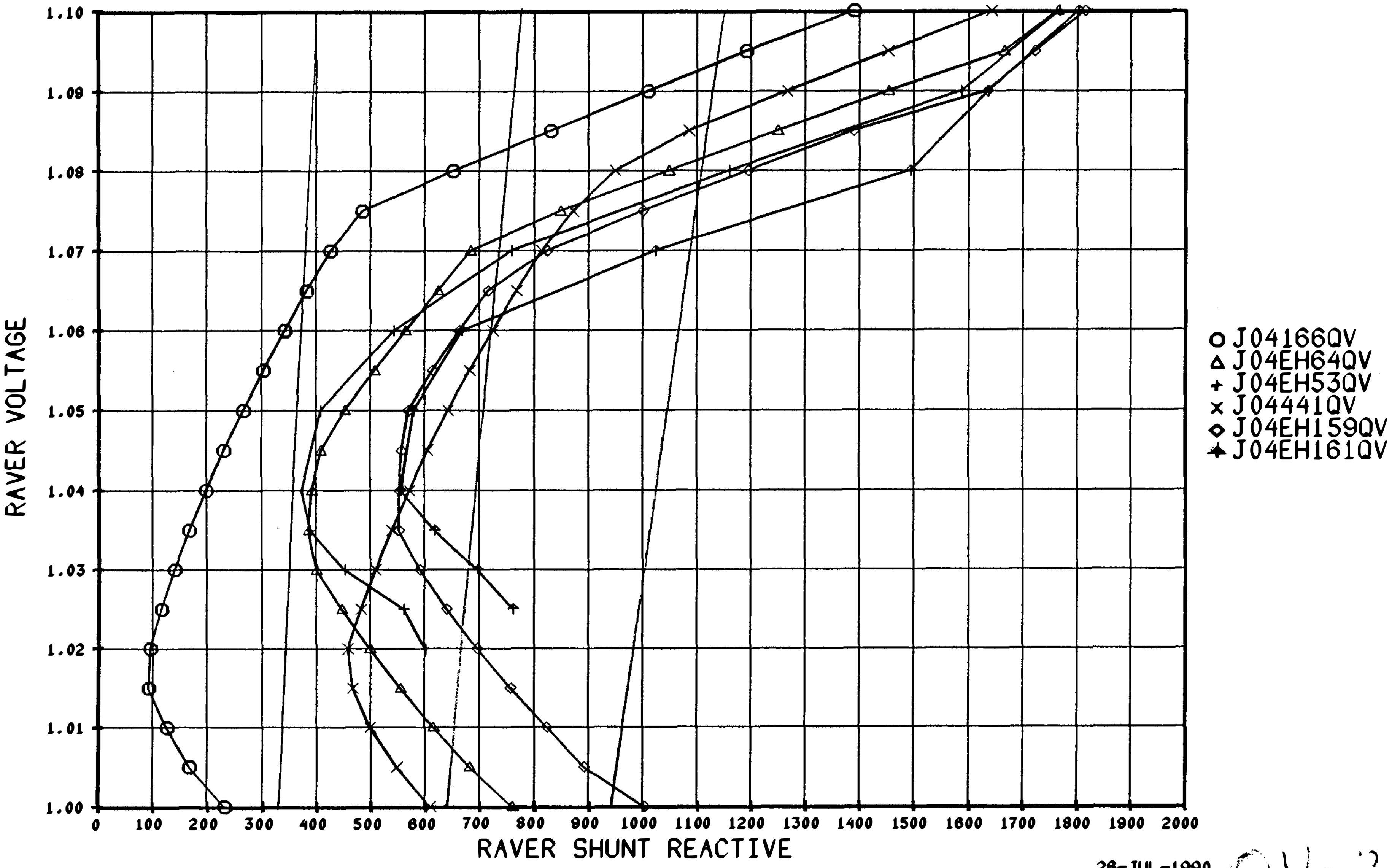
13-JUN-1990

QV-72C

[illegible]

CORRECTION OF C-R SERIES COMP LEVEL

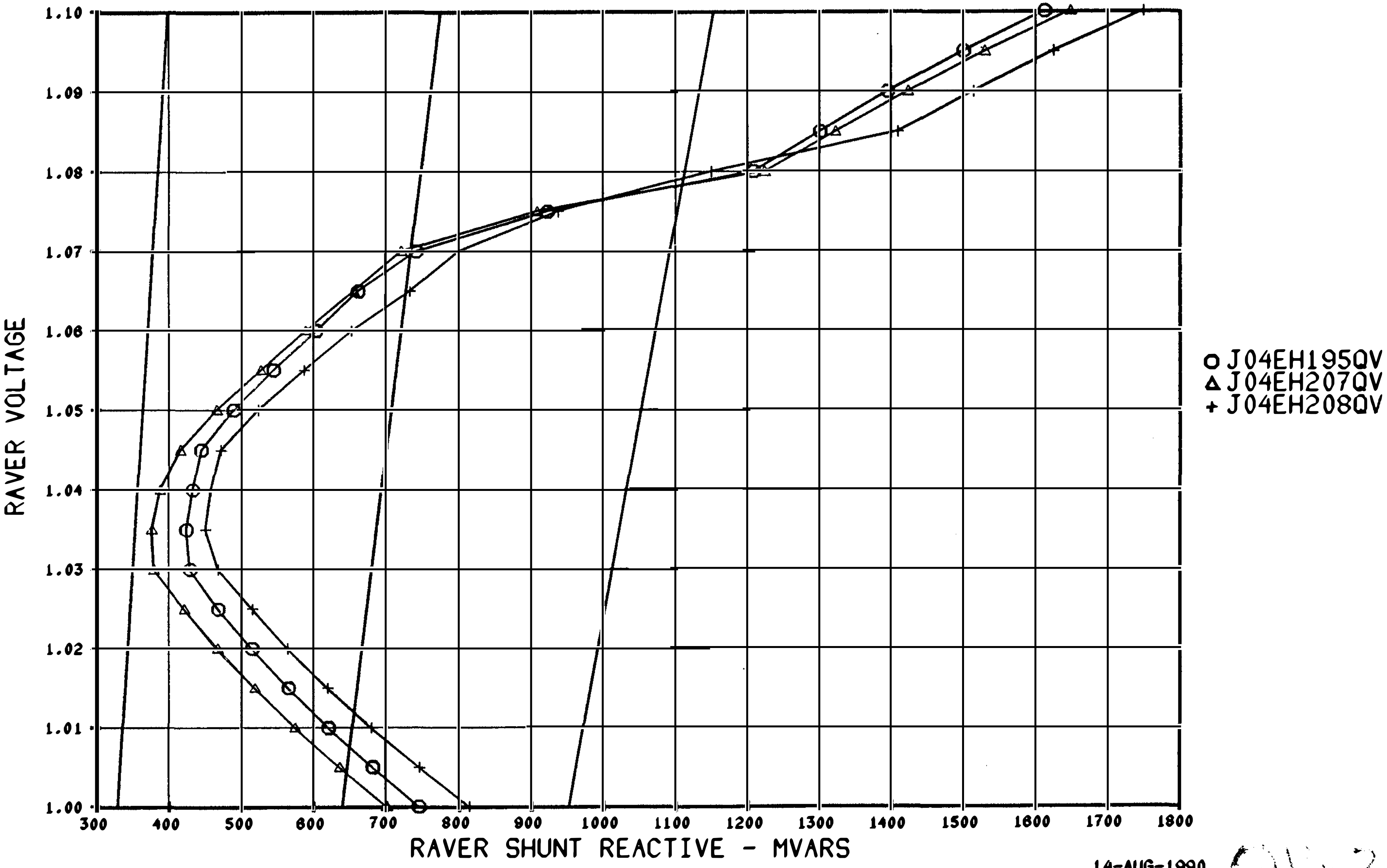
○ △ + J04166, J04EH64 AND J04EH53 - 45% COMP
× ◇ ✦ J04441, J04EH159 AND J04EH161 - 22% COMP
△ — 2-C-R — 1-C-R — TROJAN



28-JUL-1990 QV-230

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.

BASED ON J04EH193
○J04EH195:COULEE-RAVER 500KV LINE 1 OUT
△J04EH207:CHIEF JO-SNOQ 500KV LINE OUT
+J04EH208:CHIEF JO-MONROE 500KV LINE OUT

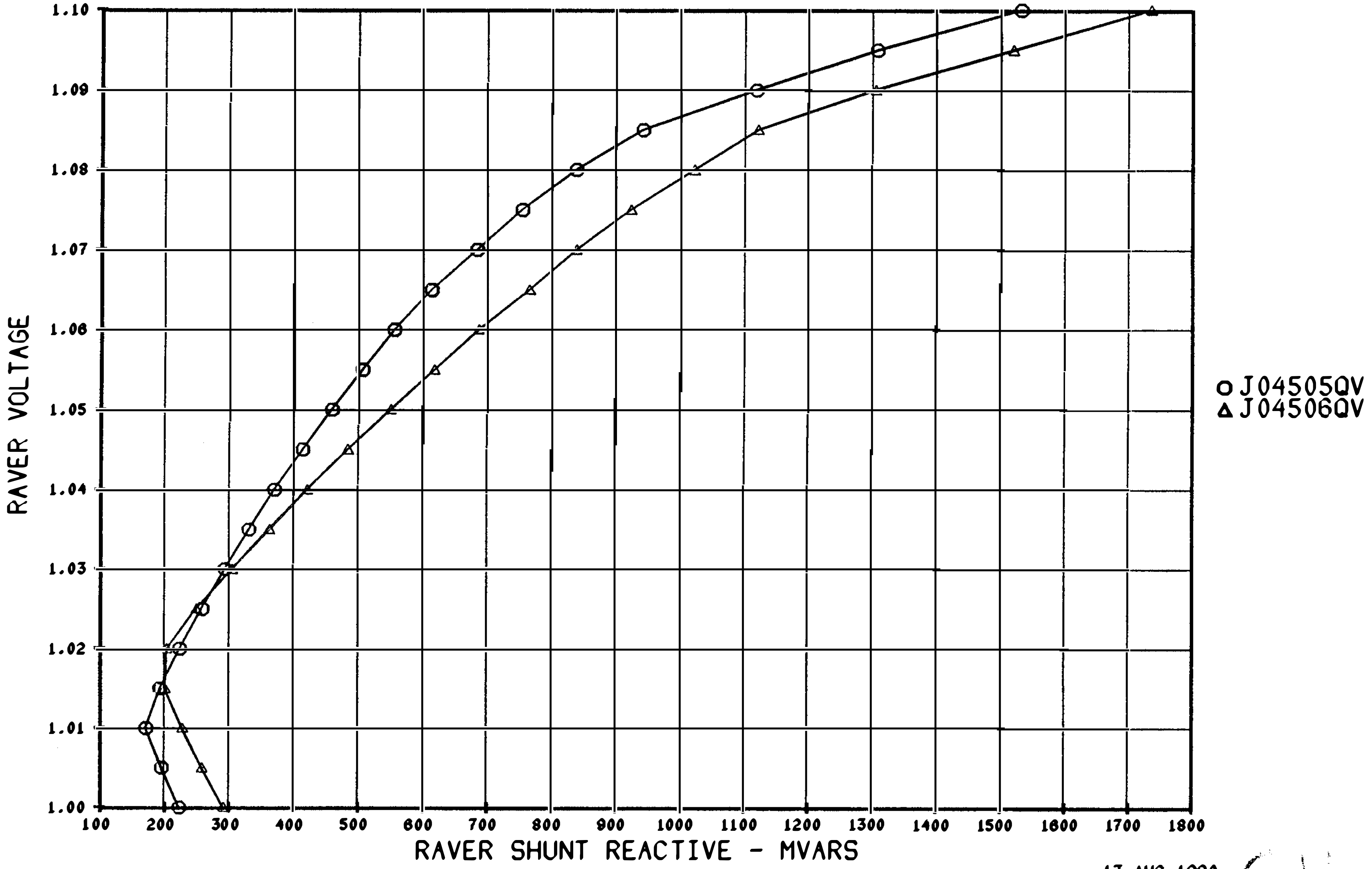


14-AUG-1990

QV-231

PLAN 3:CHIEF J-SNOQ/MONROE - 35% COMP.

300MVAR SVC'S AT KEELER AND MAPLE VL
J04505:DOUBLE COULEE-RAVER 500KV OUTAGE(J04504)
△ J04506:CHIEF J-SNOQ/MON 500KV LINES OUT(J04504)

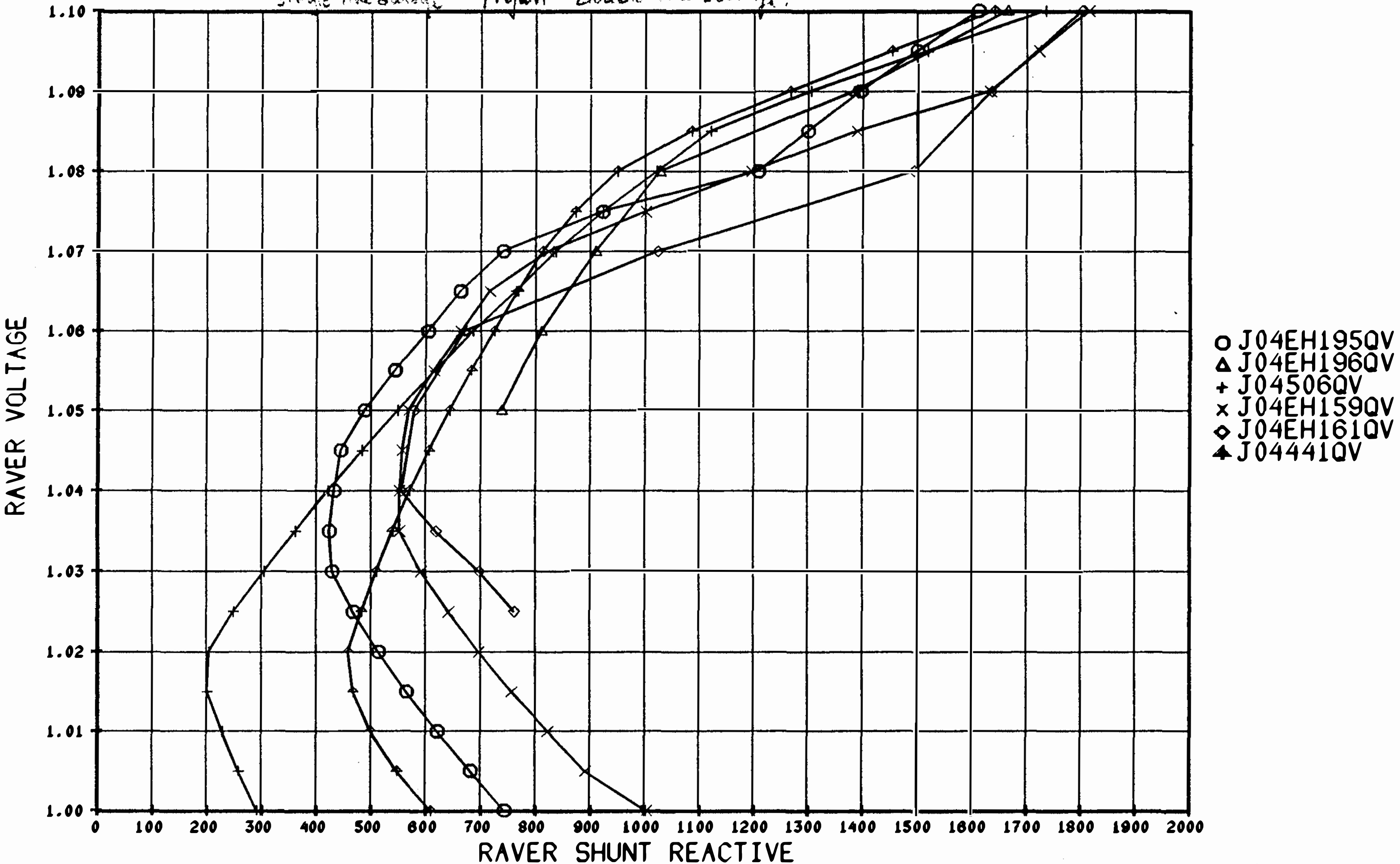


13-AUG-1990 QV 137

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE

○ J04EH195, △196 + +J04506: 35% COMP, 300 MVAR SVC'S
× J04EH159, ◇161 + ▲J04441: 500 MVAR SVC'S

single line outage 'Trojan' double line outage.

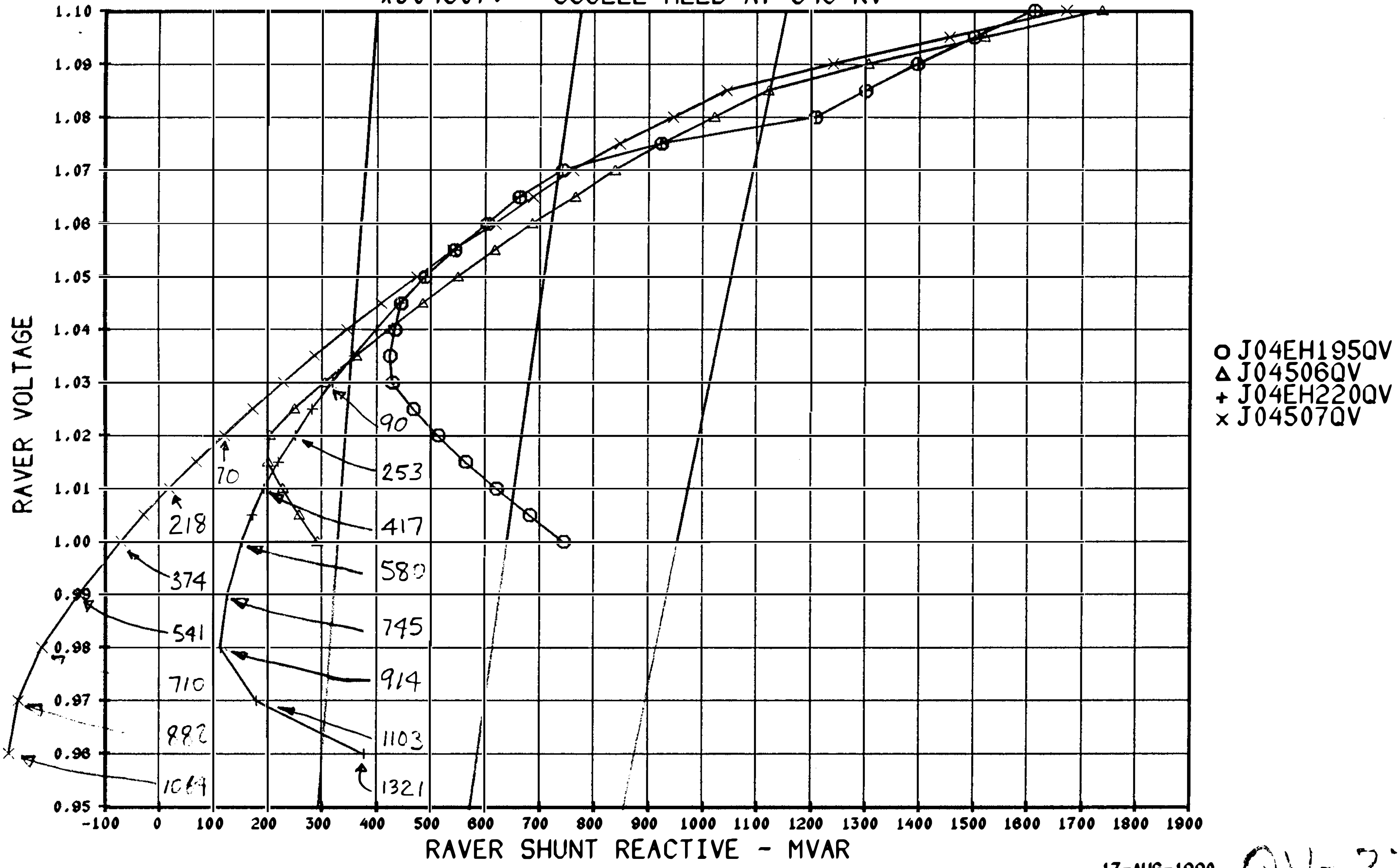


14-AUG-1990

QV-233

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE--35% COMP

300 MVAR SVC'S AT KEELER AND MAPLE VALLEY
○J04EH195: COULEE HELD BY EXISTING GENERATION
△J04506: COULEE HELD BY EXISTING GENERATION
+J04EH220: COULEE HELD AT 548 KV
×J04507: COULEE HELD AT 548 KV

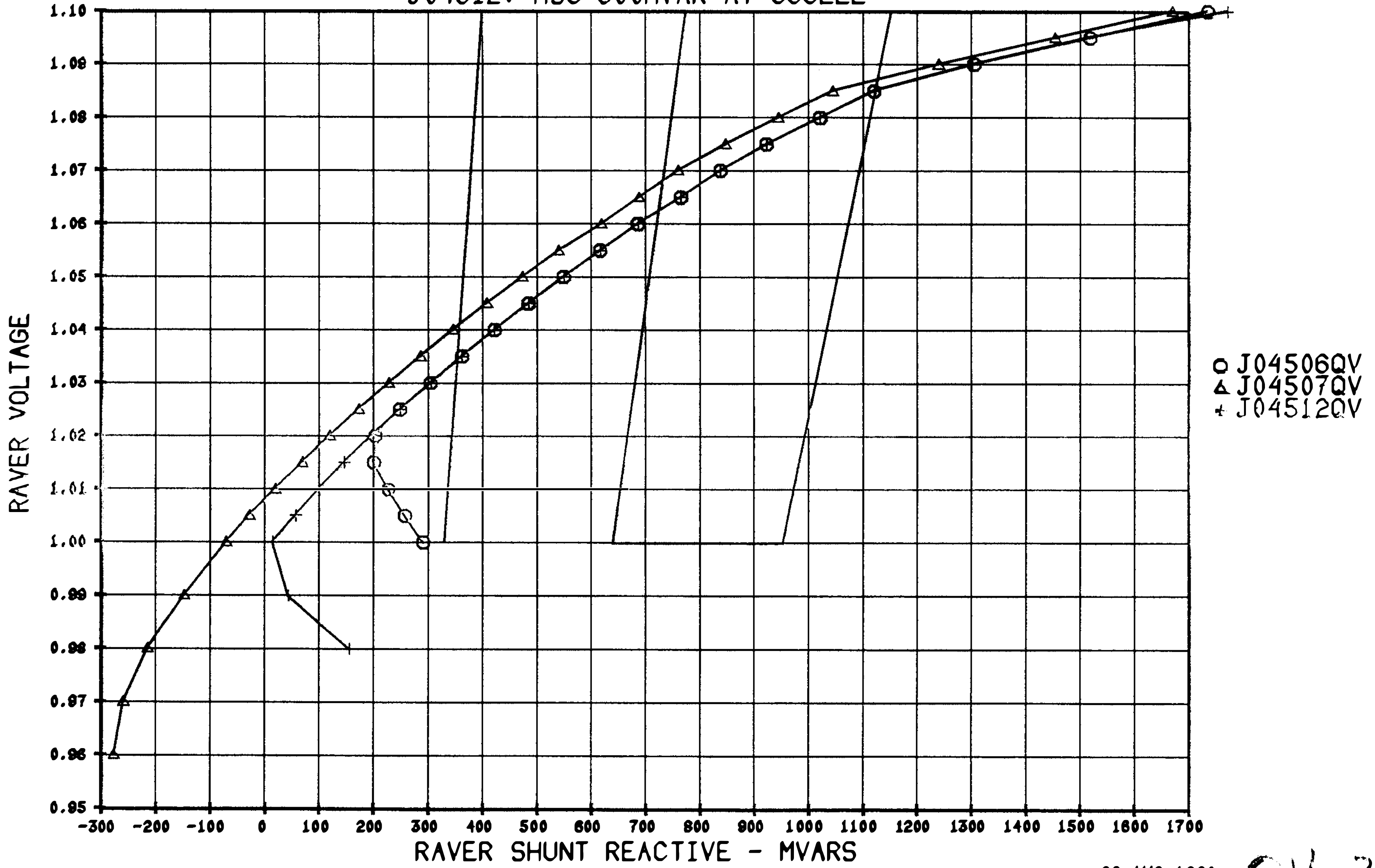


17-AUG-1990

QV-239

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.

DOUBLE COULEE-RAVER 500KV OUTAGE
300MVAR SVC'S AT KEELER AND MAPLE VL
J04506:COULEE HELD BY EXISTING GENERATION
J04507:COULEE HELD AT 548KV
J04512: MSC 300MVAR AT COULEE

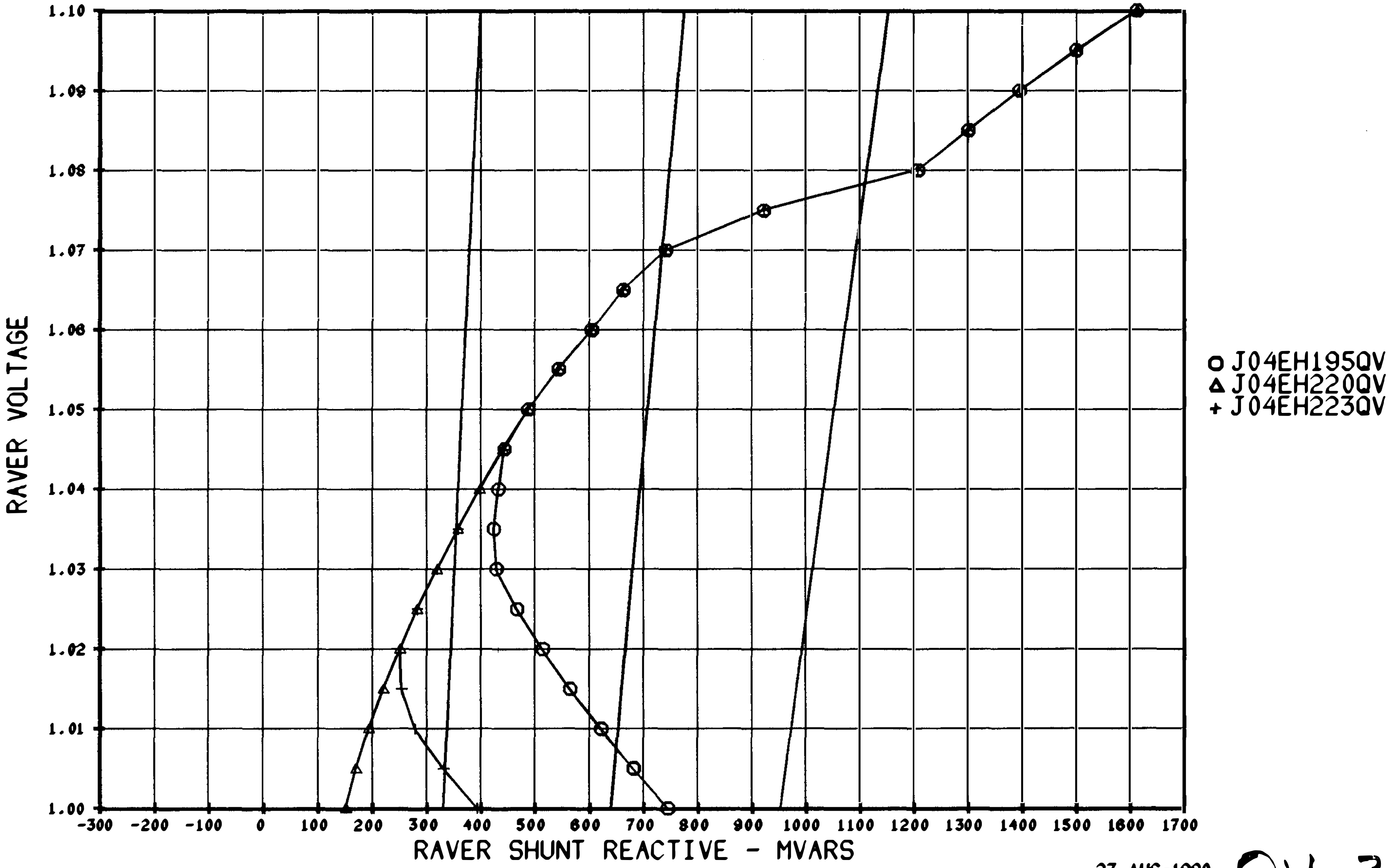


28-AUG-1990

QV-235

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.
300MVAR SVC'S AT KEELER AND MAPLE VL
J04EH195:COULEE HELD BY EXISTING GENERATION
J04EH220:COULEE HELD AT 548KV
J04EH223: MSC 300MVAR AT COULEE

[illegible]

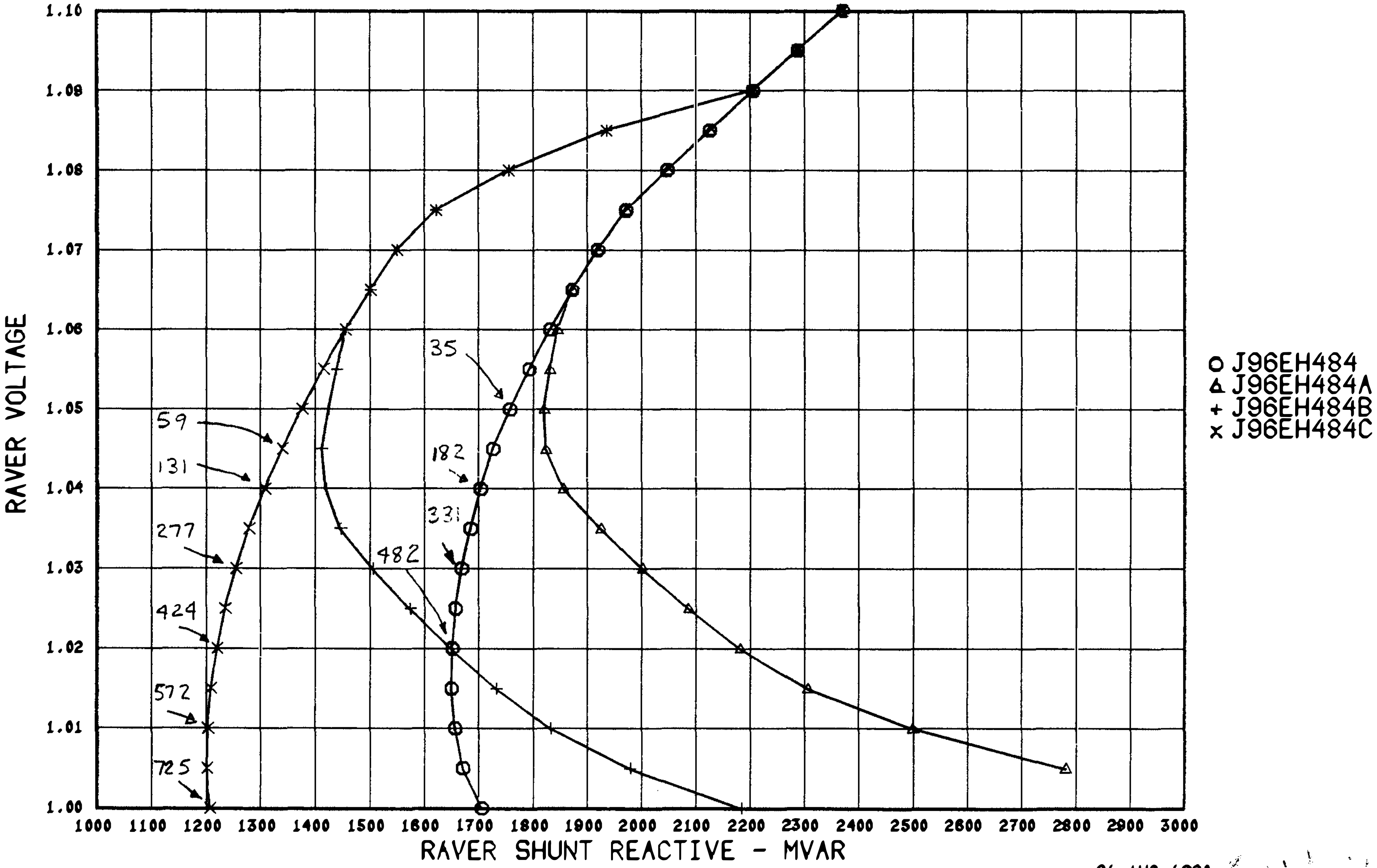


27-AUG-1990

QV-236

CHIEF JO-MONROE OUT FROM BASE J96EH158

Δ J96EH484A LDC @ PAUL ,COULEE,JOHN DAY,
DALLES, BONNEVILLE
○J96EH484 ADD HOLD AT COULEE 500 E-BUS
+J96EH484B LDC & 300 MVAR SVC @ MV & KLR
×J96EH484C LDC,SVC & HOLD AT COULEE

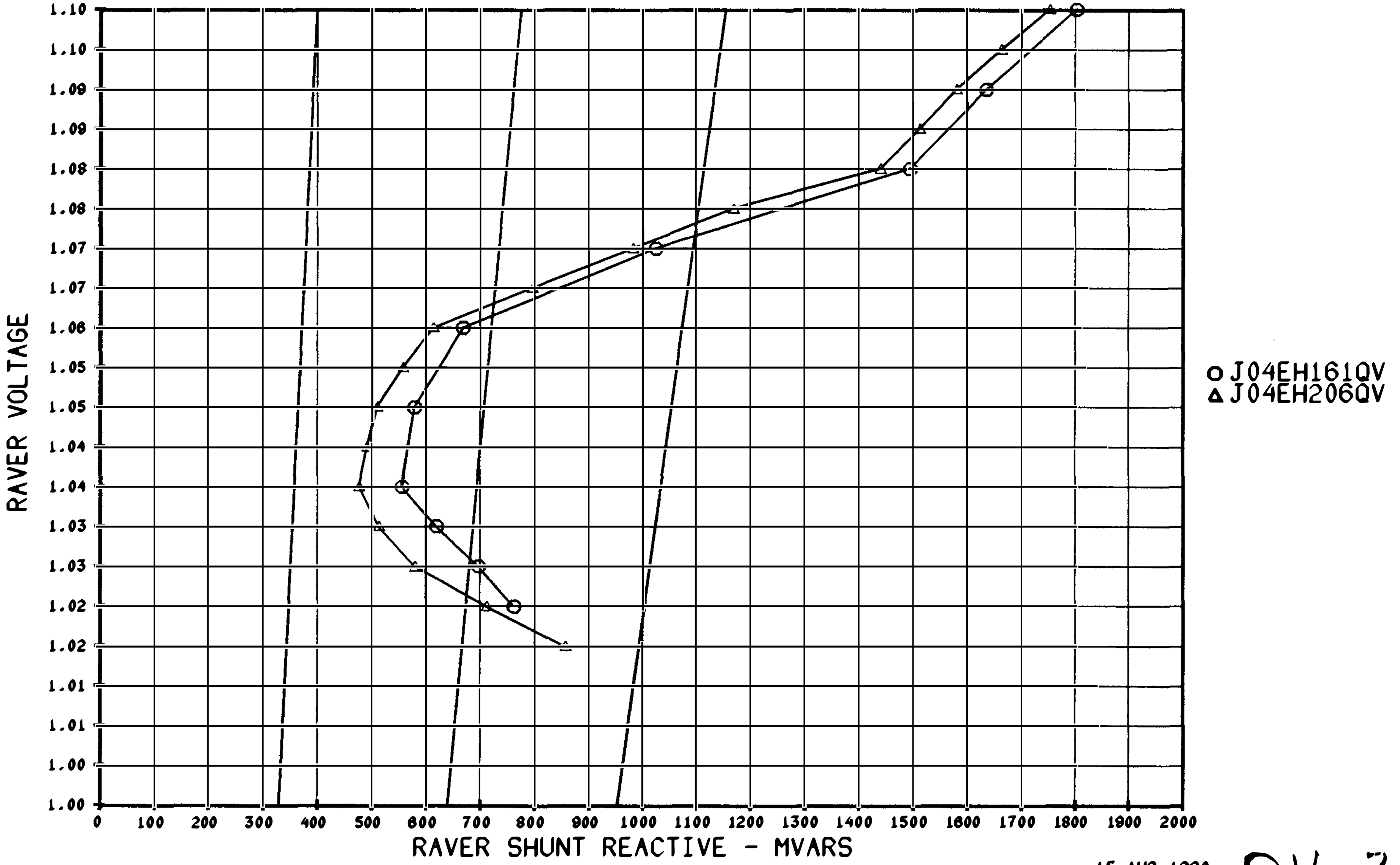


21-AUG-1990 (RV-[illegible])

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

TROJAN SCRAM -- BASED ON J04EH160

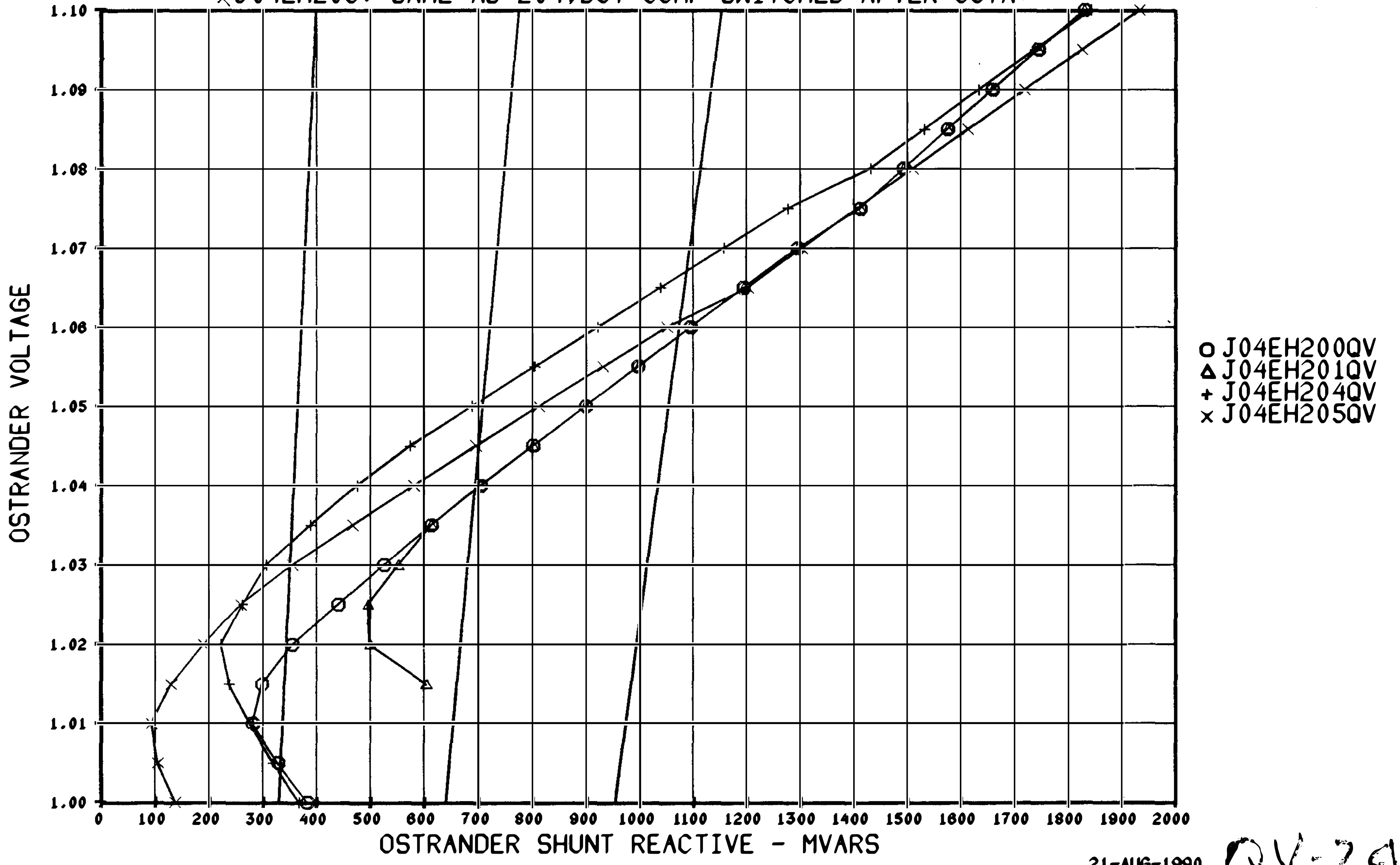
○J04EH161: 500MVAR SVC AT MAPLE VL & KEELER
△J04EH206: 500MVAR @ MV; 300MVAR @ KLR & OSTR [illegible]



15-AUG-1990

QV-240

PLAN 3: CH JO-SNOQ/MONR TROJAN SCRAM BASE J04EH1
J04EH200: 500 MVAR SVC AT KEELER & MAPLE VALLEY
J04EH201: 300 MVAR SVC AT KEELER & MAPLE VALLEY
+J04EH204: 300 MVAR SVC AT KLR & MV; 50% SERIES COMP
ON BE-OSTR IN PRIOR TO OUTAGE (J04EH197)
×J04EH205: SAME AS 204, BUT COMP SWITCHED AFTER OUTAGE

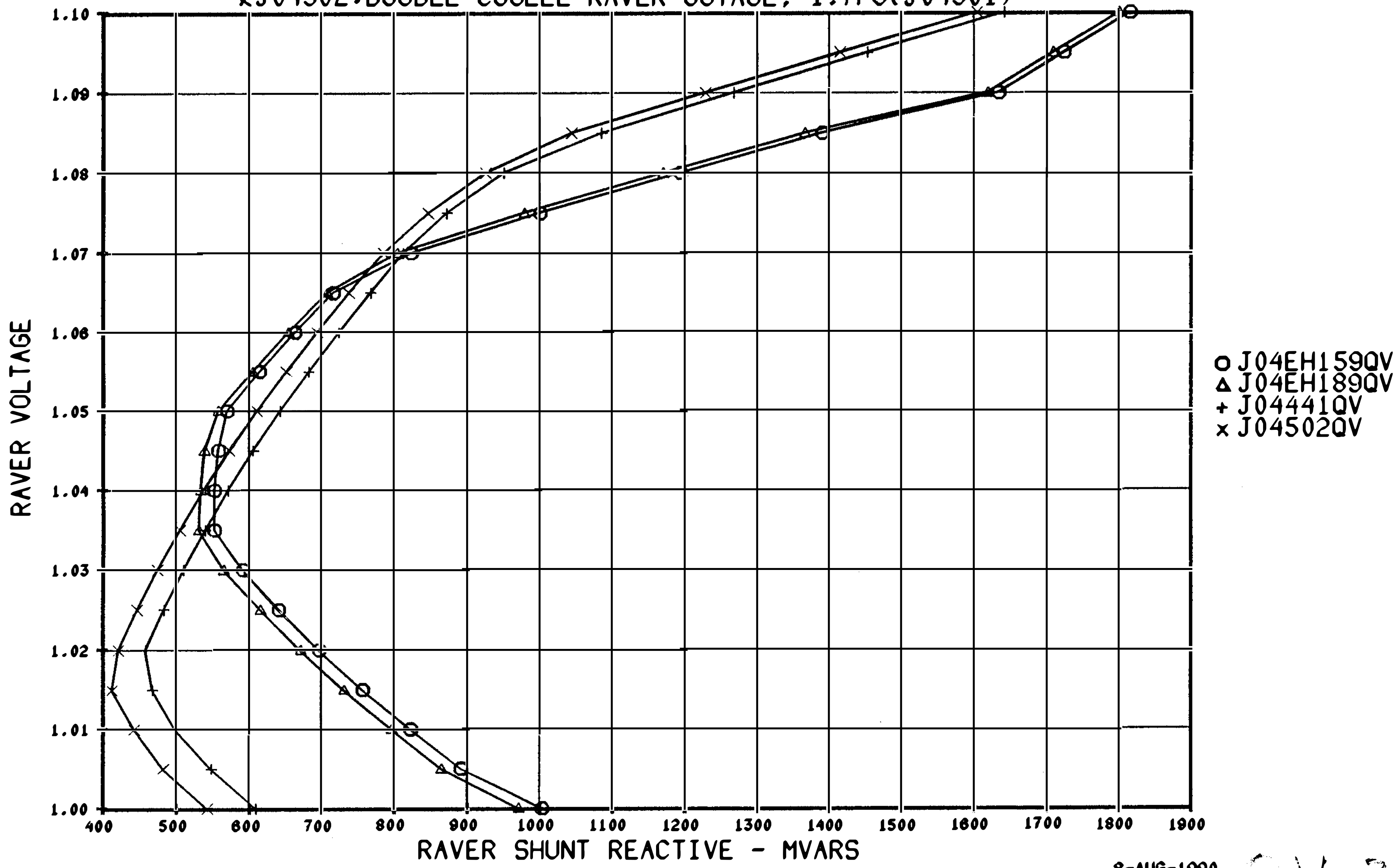


21-AUG-1990

QV-291

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE

COMPARISON OF 1.7PU AND 2.0PU LINE DESIGNS
○J04EH159:1 COULEE-RAVER LINE OUT, 2PU (J04EH158)
△J04EH189:1 COULEE-RAVER LINE OUT, 1.7PU(J04EH188)
+J04441:DOUBLE COULEE-RAVER OUTAGE, 2PU (J04440)
×J04502:DOUBLE COULEE-RAVER OUTAGE, 1.7PU(J04501)

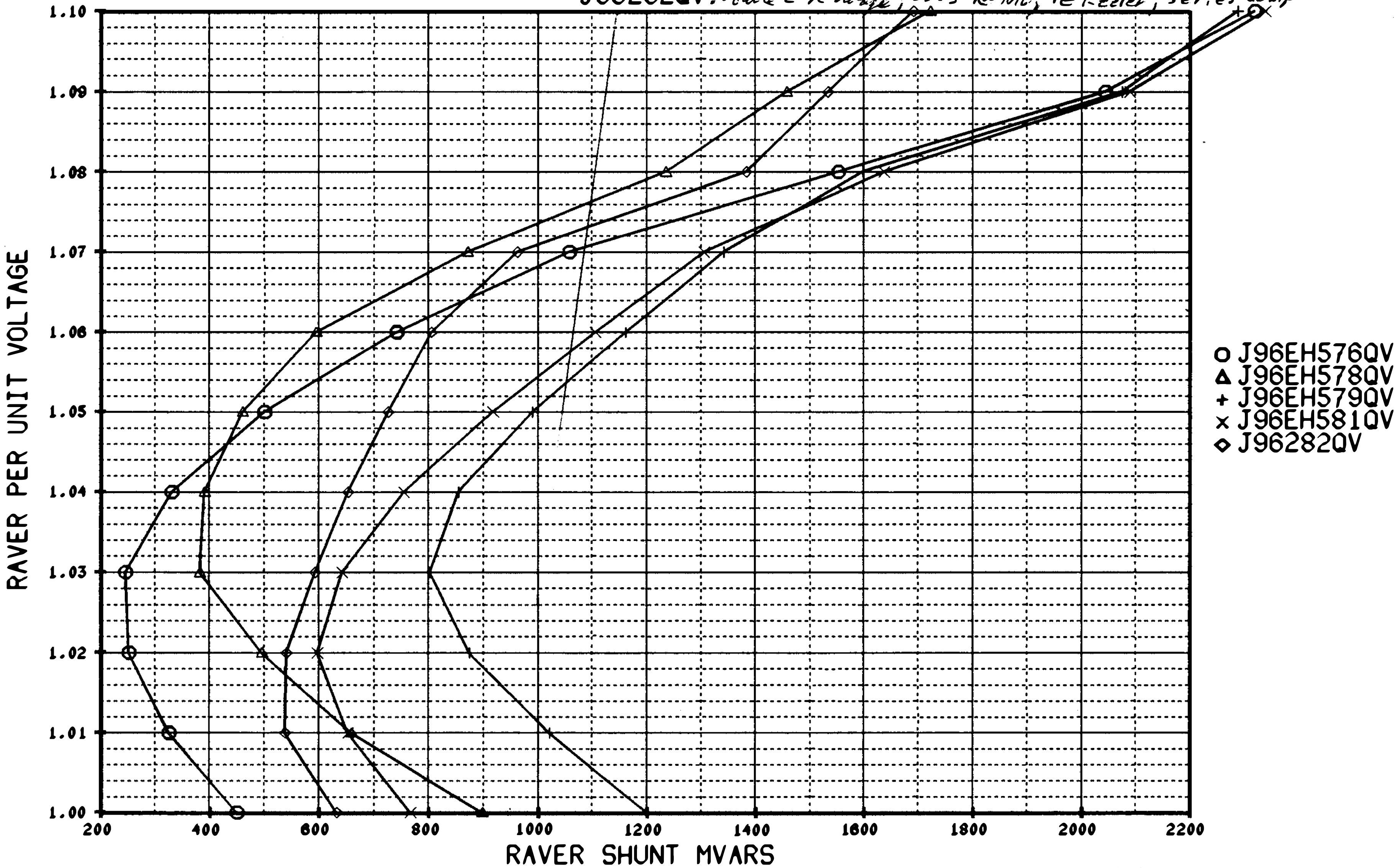


8-AUG-1990

QV-250

PSR REACTIVE ALTERNATIVE Q-V CURVES

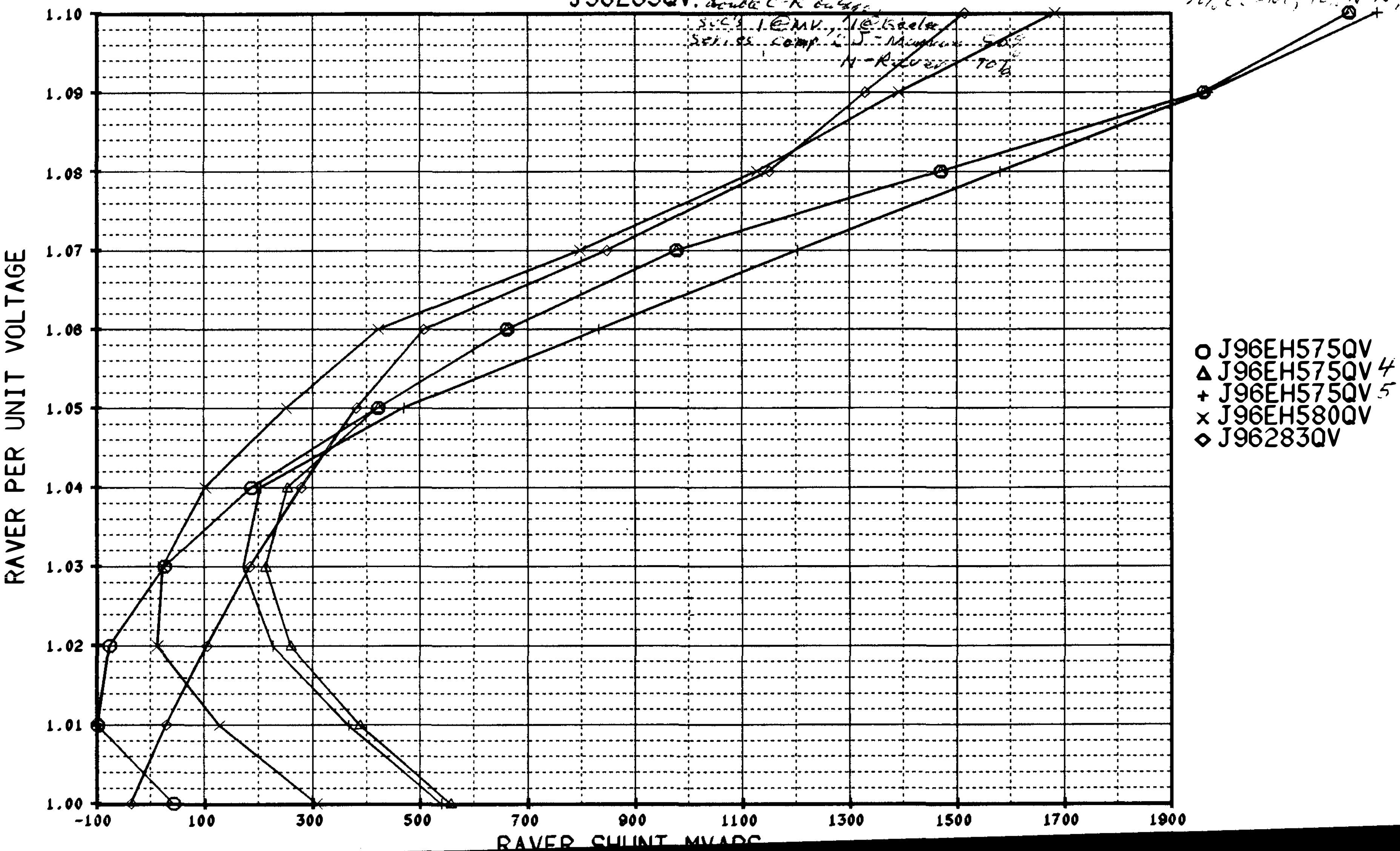
J96EH576QV: CJ-M outage SVC's 1@Snoho, 1@MV, 1@Cov, 1@Keeler, series comp C-R 42%@Columbia
J96EH578QV: Trojan outage SVC's 2@MV, 1@Keeler, Series comp 35%CJ-M, 42%C-R, 35% N-R
J96EH579QV: CJ-M outage SVC's 1@MV 1@Keeler, series comp 42%C-R, 35%N-R
J96EH581QV: CJ-M outage, SVC's 1@MV, 1@Keeler, Series Comp 50%CJ-M, 70%N-R, 42% C-R
J96282QV: double C-R outage, SVC's 2@MV, 1@Keeler, series comp



2-JUL-1990

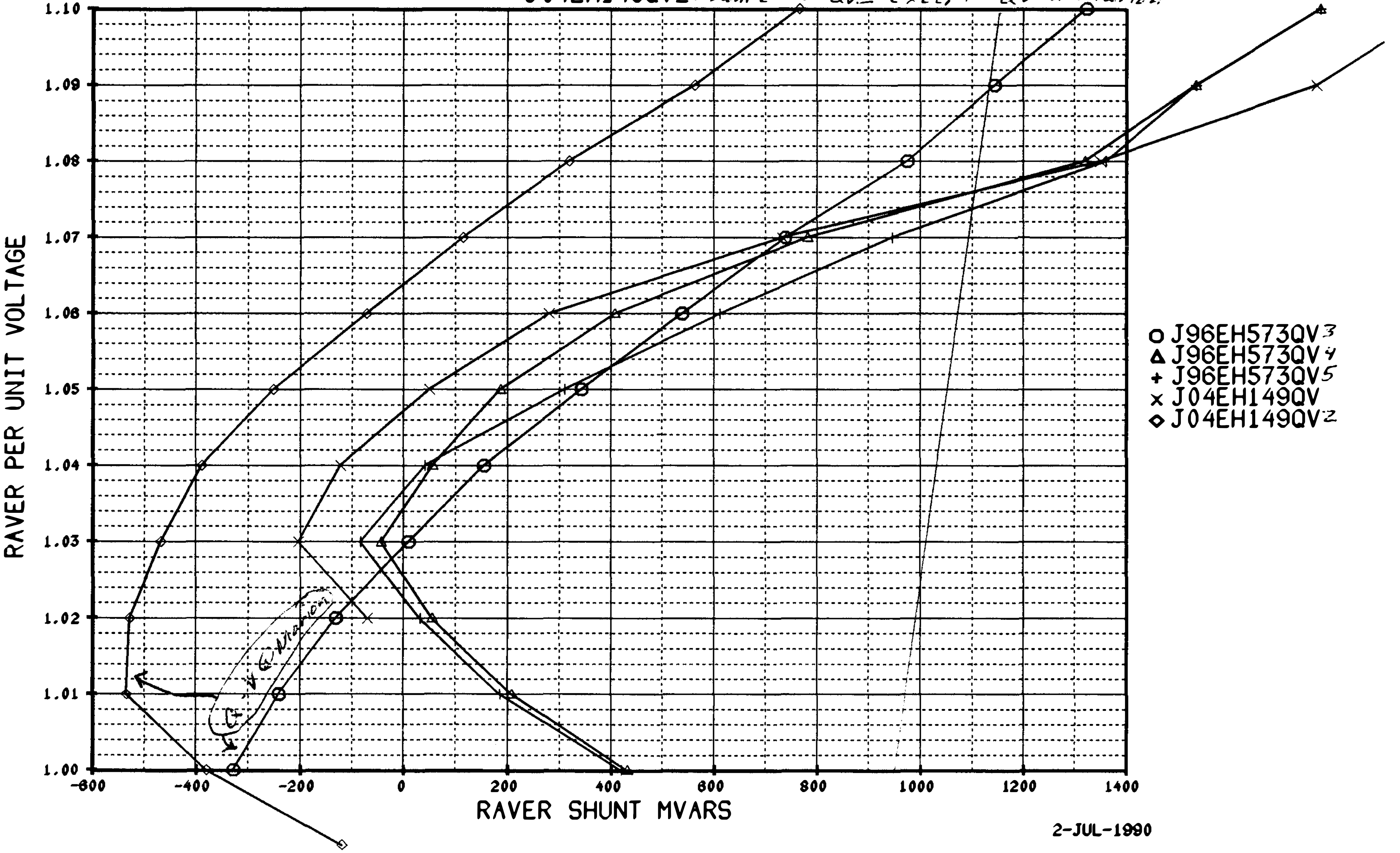
PSR REACTIVE ALTERNATIVE Q-V CURVES

J96EH575QV: CJ-M outage, SVC's 2@Snoho, 1@MV, 1@Cov, 2@Keeler, 1@CST
J96EH575QV4: CJ-M outage, SVC's @ Snoho, MV, Cov, Keeler, C-R 42.5% series comp
J96EH575QV5: CJ-M outage, SVC's 3@MV, 1@Keeler, C-R 42% series comp
J96EH580QV: Trojan outage, SVC's 1@MV, 1@Keeler, series comp all 500 lines 50% CJ-M, 70% N-R, 42% C-R
J96283QV: double C-R outage, SVC's 1@MV, 1@Keeler, Series comp CJ-Marion 50%, N-Raver 70%



PSR REACTIVE ALTERNATIVE Q-V CURVES

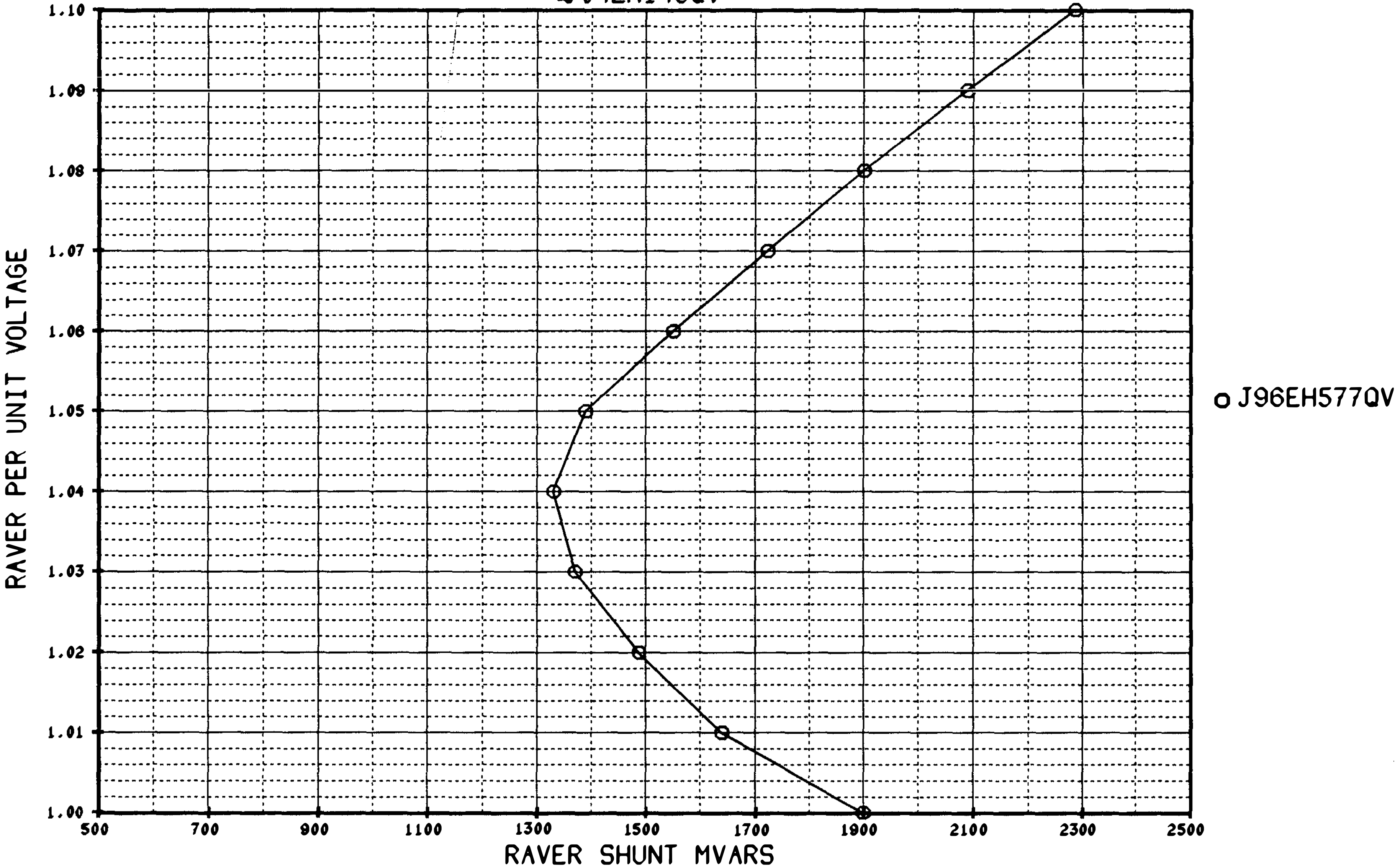
J96EH573QV3: same as QV4 except QV at Marion
J96EH573QV4: Trojan outage, SVC's @ Sncho, Cov, MV, Keeler; C-R 42% Series Comp
J96EH573QV5: Trojan outage, SVC's @ MV (3) and Keeler
J04EH149QV: Trojan outage, series comp on 5-500kV lines, SVC's same as J96
J04EH149QV2: same as QV_ except QV at Marion



2-JUL-1990

PSR REACTIVE ALTERNATIVE Q-V CURVES

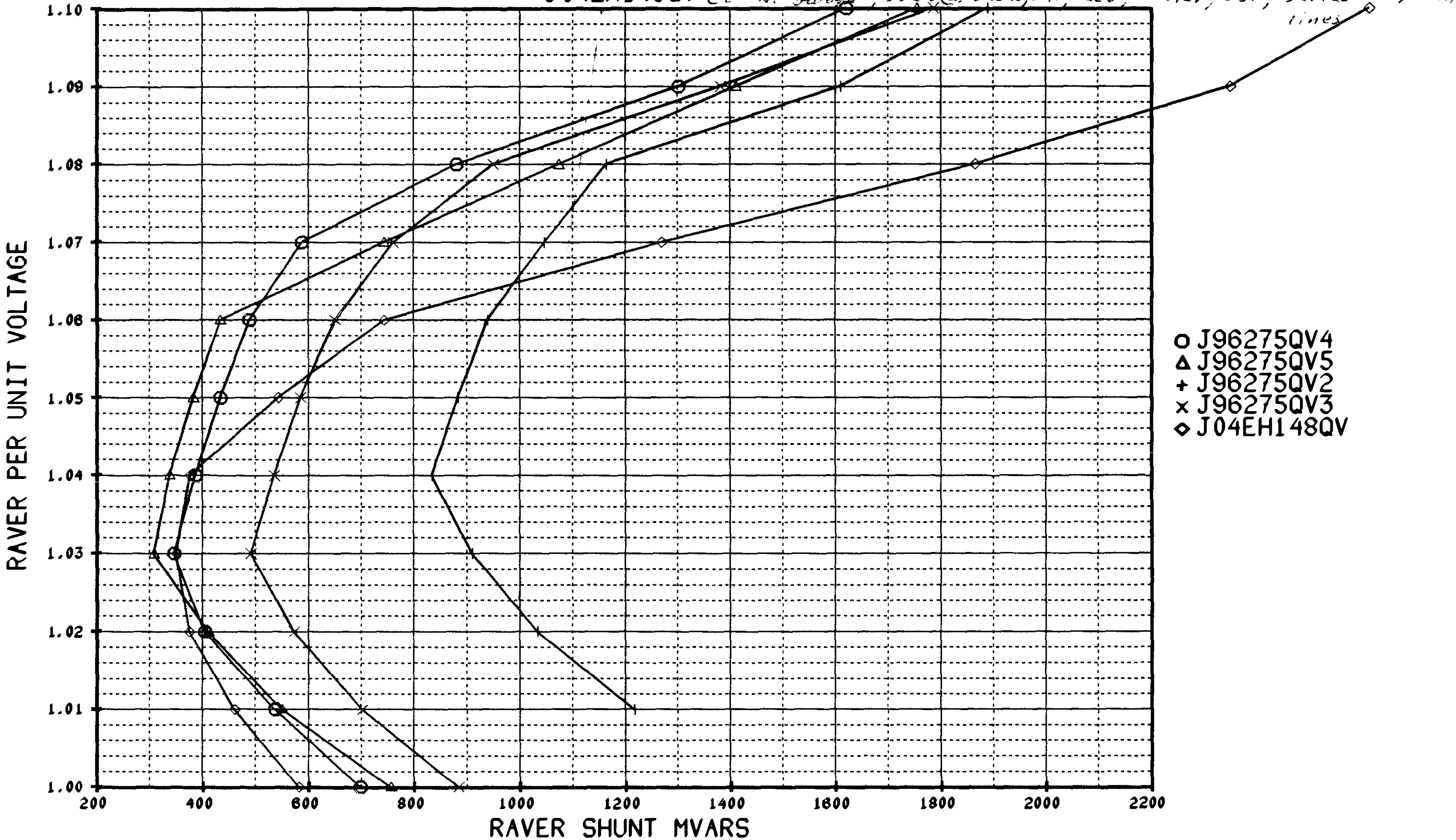
J96EH577QV: CJ-Monroe outage, C-K [illegible] 42%, [illegible] SCC's
~~J96275QV3~~
~~J9R275QV4~~
~~J96275QV5~~
~~I04EH148QV~~



2-JUL-1990

PSR REACTIVE ALTERNATIVE Q-V CURVES

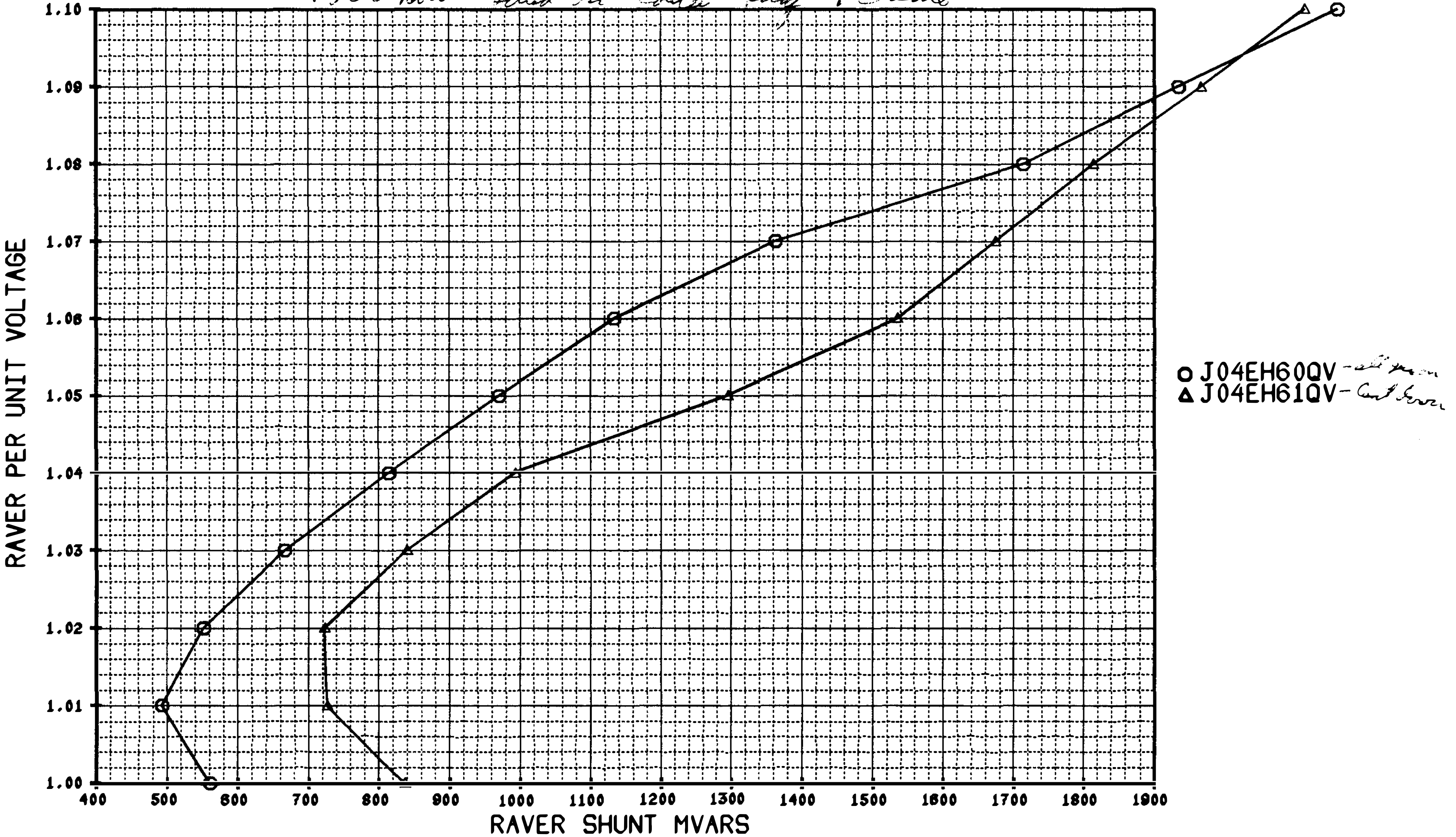
J96275QV2: double C-R outage SVC's 1@ MV, 1@ Cov, 1@ Keeler
J96275QV3: double C-R outage SVC's 1@ Snoho, 1@ MV, 1@ Cov, 2@ Keeler
J9R275QV4: double C-R outage SVC's 1@ Snoho, 1@ MV, 1@ Cov, 1@ Keeler
J96275QV5: double C-R outage SVC's 1@ MV, 1@ Keeler
J04EH148QV: C J-M outage, SVC's @ Snoho, MV, Cov, Keeler, OST, series comp all lines



2-JUL-1990

J2004 ABNORMAL COLD ALL LINES IN SERVICE

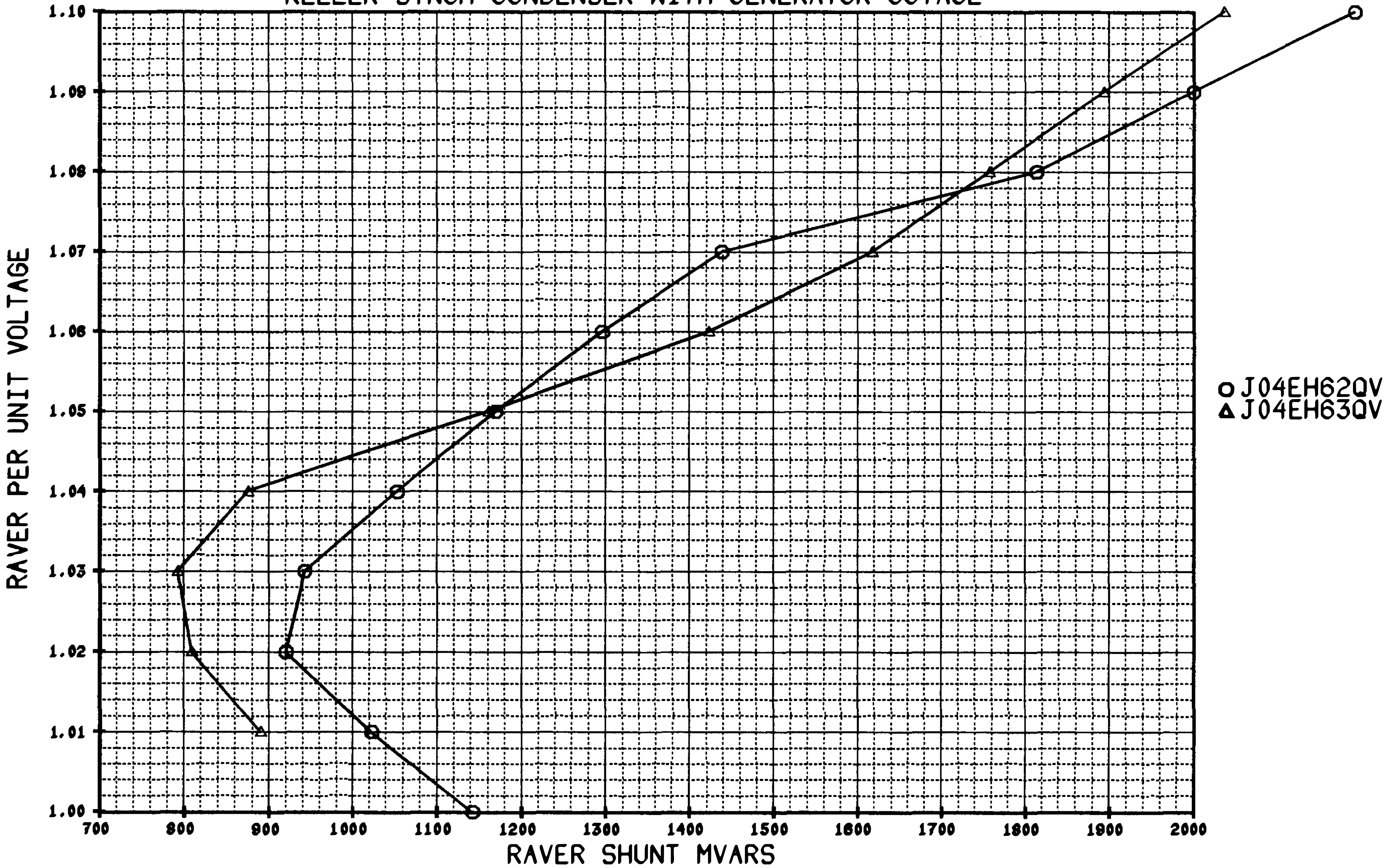
1500 MW sched on [illegible]-[illegible] [illegible] line



11-APR-1990

DC LINE FROM COULEE TO SNOQUALMIE

LOADED TO 1500MW PRIOR TO CONTINGENCY
AFTER CONTINGENCY DC RAMPED TO 3000MW
TEST OF CJ-MONROE OUTAGE AND TEST OF TROJAN
OUTAGE (ONE CENTRALIA UNIT ALREADY DOWN)
KEELER SYNCH CONDENSER WITH GENERATOR OUTAGE



10-APR-1990

TABLES

TABLE 100: LOSS SAVINGS OF FEASIBLE ALTERNATIVES

(In peak MW's; top number is PNW losses, lower number is BPA losses)

Alternative	1996	2000	2004(1)	2004+(1)
Base System	-0-	-0-	N/A	N/A
	-0-	-0-		
	J96243, J96244	J0037, J0038		
Plan 1	70.2	91.5	82.0	82.0
Chief Joe-Monroe	58.0	73.7	67.9	67.9
	J96261, J96262	J0035, J0036	J04343	J04343
Plan 2	66.9	78.3	65.1	69.3
Chief Joe-Snoqualmie	53.6	62.2	53.8	58.0
500-kV	J96258, J96259	J0022, J0021	J04226	J04347
Plan 2	77.7	90.6	76.9	
Chief Joe-Snoqualmie	64.3	74.0	65.0	
765-kV line op @ 500	J96271, J96272	J0046, J0047	J04227	
Plan 2			141.5	141.5
Coulee/Chief Joe-			122.6	122.6
Snoqualmie 765-kV line			J04228	J04228
Plan 3	73.9	86.1	77.1	84.9
Chief Joe-Snoq/Mon	59.1	68.2	63.6	70.4
4-Bunting	J96241, J96242	J0023, J0024	J04345	J04348
Plan 3 Chief Joe-Snoq/Mon 4-Seahawk	Older J96 studies showed an additional 6.6 MW BPA and 6.9 MW PNW losses are available if 4-Seahawk conductor is used.			
Plan 4	51.0	71.6	74.2(2)	78.7(2)
Hanford-Snoqualmie	39.9	54.5	57.4	61.1
	J96267, J96268	J0042, J0043	J04344	J04349
Plan 5	65.12	77.73	68.7	73.4
Sickler-Snoqualmie	49.6	59.5	56.1	60.9
	J96269, J96270	J0044, J0045	J04346	J04350
Plan 6	2.4	10.13	-0-	-0-
Reactive Alternative	xxx	xxx	-0-	-0-
	J96273, J96273loss	J0040, J0041	J04370	J04370
Plan 7	69.4	82.4	63.9	67.8
Coulee-Olympia/Snoq	58.2	68.2	54.6	58.1
500-kV	J96289, J96290	J00104, J00105	J04508	J04510
Plan 8	60.1	73.5	58.2	63.7
Chief Joe-Sickler-	50.0	59.7	49.7	53.9
Snoqualmie 500-kV	J96291, J96292	J00106, J00107	J04509	J04511

(1) Loss savings for 2004 are referenced against loss of Reactive Alternative, not base system without additions as is the case for 1996 and 2000.
(2) 2004 base has WNP-1 in operation which increases the loss savings of Plan 4.

TABLE 15C.

........................1/09/90...

PUGET SOUND VOLTAGE PLANNING ASSUMPTIONS

....

RESOURCES

1. The Puget Sound area hydro generation will generate at median water firm peaking levels for winter prior to January 6 (reduced generation on the Skagit River). Snoqualmie Falls will be assumed frozen with no generation during abnormal cold.

2. The PSP&L combustion turbines will be generating during abnormal cold except Whitehorn unit #3 and Shuffleton units are off.

3. The PSP&L combustion turbines are off during normal winter peak load.

4. PGE's Beaver combustion turbine/combined cycle plant is off.

5. Coulee serves as a baseload generator with 4500MW generation.

6. Snake River projects provide peaking generation.

....

INTERTIE SCHEDULES

7. BCH to PNW schedule is 250MW during normal and abnormal cold. After the BCH-WWP intertie is completed in the mid 1990's, the total BCH-PNW schedule will be 850MW. Phase shifters on the eastern BCH system will cause 600MW to flow directly to the WWP system. The Nelway phase shifter will be adjusted to minimize inadvertent flow. This assures the Ingledow to Custer powerflow will consistently be about 250MW.

8. BCH is using two Burrard units as synchronous condensers for normal and abnormal winter loads. Zero reactive is generated prior to a contingency.

9. PNW-PSW interchange is zero during abnormal cold if PNW resources are sufficient to meet the load cold weather load.

10. PNW imports from the PSW on the DC intertie if PNW resources are insufficient to meet the assumed cold weather load.

11. PNW-PSW interchange during normal peak is 1000MW DC and 2000MW AC export to PSW in 1996. Export in later years decreases to allow PNW resources to meet the assumed normal load.

12. Transmission additions to return the Canadian Entitlement (1400MW firm in 2003) will be addressed in a separate planning study.

....

SYSTEM DESIGN

13. The operating point will be planned to provide 500MVARS shunt reactive margin from the voltage instability point.

14. The newly revised Reliability Criteria is applied.

TABLE 15C

15. The system will be designed to restore full load immediately following the contingency unless a detailed system study shows the load cannot be fully restored with a 95% voltage level at BPA delivery points. The system will not be designed to use the direct load trip scheme now being installed at Intalco and Kaiser.

……

LOAD LEVEL ASSUMPTIONS

16. The CY89 load forecasts and power factors for normal peak are reasonable.

17. The peak load level above the PNUCC forecast experienced during the February 1989 cold snap is the abnormal cold load level for planning. Snohomish PUD abnormal cold load for planning is slightly higher due to their own 1987 study. Multipliers for abnormal cold load for the four major utilities are: PSP&L 116%, SCL 111%, SPD 123%, TCL 120%. The utilities report that the February 1989 conditions reflect reduced school and business loads. The power factor for abnormal is the same as normal weather.

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SYSTEM ADDITION ASSUMPTIONS

Prior to 1993

Raver 500kv shunt capacitors (brings total to 952MVARS)
Columbia series capacitor upgrade (2400A, 22.5%)
Olympia-Port Angeles 230kv loop-in at Shelton
Shelton-Port Angeles 230KV loop-in at Fairmount
Port Angeles 115kv terminals in advance of added Daishowa load
   (assumed schedule: phase 1 - fall 1993, phase 2 - fall 1995)
Olympia 230kv shunt capacitors (2-150MVAR banks, remove old 100MVAR bank)
Custer-Bellingham 230kv #2 line
BCH Nelway phase shifter
BCH Nicola-Meridian series capacitors (50%)
BCH Nicola-Ingledow series capacitors (50%)
TCL shunt capacitors at Southwest (100MVARS), Pearl (60MVARS), Northeast (80)
      and Cowlitz (60MVARS)

Prior to 1996

Cowlitz-Olympia 230kv line
Cowlitz Falls Integration (Mayfield-Mossyrock 230kv loop-in)
Port Angeles 115kv shunt capacitors (Daishowa phase 1, 2-23.7MVAR banks)
Shelton 230kv shunt capacitors (Daishowa phase 1, 1-114MVAR bank)
Fairmount-Port Angeles 230kv line (3rd line, Daishowa phase 1)
Shelton-Fairmount 230kv line (3rd line, Daishowa phase 2)
Olympic Peninsula Reinforcement with 500kv to Shelton
Allston 500/230kv transformer #2
Ostrander 500kv shunt capacitors (1-312MVAR bank)
Keeler 500kv shunt capacitors (1-312MVAR bank)
BCH Williston-Kelly Lake 500kv #3 line with series capacitors
BCH Kelly Lake-Cheekye 500kv #2 line with series capacitors
BCH Ingledow static var device (150MVAR)
BCH-WWP intertie (600MW added import assumed for both normal and abnormal)

Prior to 2004

No assumed additions after 1996.

……

TABLE 151: LINE AND TRANSFORMER RATINGS

The new reliability criteria requires that abnormally cold weather loads must be served during maingrid outages using -15 deg C ambient equipment limits. Main grid outages include the 500-kV system, 345-kV system and the transformers from these systems to the 230-kV grid. Moderate cold weather loads must be served during 230-kV system outages using a -10 deg C ambient. The ratings of critical lines are as follows:

			Max Oper	Rating at Ambient Temperature				
	Owner	Condctr	Temp	-15 C	-10 C	-5 C	20 C	35 C
Bellingham-Sedro	BPA	Drake	60	1124	1082	1037	776	357
Berrydale-Talbot Hill	PSPL							
Bothell-Sammamish	SCL	Tern	100	1363	1333	1303	1133	1015
	PSPL	Tern	100	1363	1333	1303	1133	1015
Bothell-Snohomish #1	BPA	Drake	90	1308	1275	1271	1083	948
Bothell-Snohomish #2	BPA	Drake	100	1391	1361	1329	1156	1035
	SCL	Mallard		1377	1347	1345	1170	1048
Bothell-Snoking	SCL	Mallard	100	1377	1347	1345	1170	1048
	BPA	Drake	100	1391	1361	1329	1156	1035
Broadstreet-Massachuset	SCL							
Christopher-Obrien*	PSPL	Bittern		1616	1567	1517	1228	1011
Cottage Br-Snoqualmie	PSPL	2/0 cu7						
Covington-Creston BPA	BPA	Drake	80	1252	1217	1180	1000	847
Covington-Obrien	PSPL							
Covington-Tacoma A	BPA	Drake	80	1252	1217	1180	1000	847
Lakeside-Talbot Hill #1	PSPL	Tern						
Lakeside-Talbot Hill #2	PSPL	4/0 cu7						
Monroe Tap-Sedro Tap #1	BPA	Drake	70	1191	1153	1113	907	728
Monroe Tap-Sedro Tap #2	BPA	Drake	70	1191	1153	1113	907	728
Monroe-Snoking Tap	BPA	Chukar	70	1942	1879	1813	1434	1139
Snohomish-Murray	BPA	Drake	50	1049	1001	952	644	357
Snohomish-Murray+	BPA	Drake	100	1391	1361	1329	1156	1035
Snoking-Maple Valley	SCL	Mallard						
Talbot Hill-Obrien	PSPL	Tern						

*Estimated using 75 deg C bittern with BPA Assumptions

+Upgraded in BPA line sag program

Transformers

Station	voltage	nominal rating	thermal summer	emergency summer	thermal winter	emergency winter
Covington #1	500/230	1008	1107	1317	1256	1512
Covington #2	500/230	1008	1087	1317	1236	1512
Maple Valley	500/230	1792	1862	2136	2089	2523
Monroe	500/230	1008	1177	1353	1325	1512
Tacoma	500/230	1344	1429	1665	1621	1983

The above emergency ratings are based on 60% load factor.
No transformer can be loaded above emergency rating at any time.
No transformer can be loaded above thermal without an outage.

TABLE 170

OTHER THERMAL PROBLEMS IN THE PUGET SOUND AREA

As mentioned in the main text, there are three problems that exist prior to the assumed energization of the CM reinforcement (10-96) and will not necessarily be solved by this project. They are: a breaker failure at Raver, the integration of the new PSPL line into Lake Tradition and the Massachusetts-Broadstreet 115-kV line overload.

A breaker failure at Raver could cause loss of the Raver-Snoqualmie and Raver-Tacoma lines, which, prior to the CM additions, would cause the Covington transformers to overload as shown in J96254. Reinforcement of the CM transmission would reduce the severity of this problem. It is assumed that this problem is corrected by rearranging the bus layout at Raver (somehow) and this fix will eliminate the problem in later years. However, the effect of each plan on the existing bus layout is analyzed below.

There are also many line overload problems in the Lake Tradition area that are the result of poor integration of Puget's new 230-kV cross mountain circuit. The heavy loading of the 115-kV lines in this area are further aggravated by external outages. The Massachussetts-Broadstreet overload is caused by throughflow which occurs during maingrid equipment outages. Nothing is assumed to be added to correct these problems, however the effect of each CM reinforcement plan is analyzed with respect to these problems below.

Plan 1

This CM line addition alleviates the breaker failure problem at Raver until about 2004 (J04232).

Terminating the new CM line at Monroe improves (but does not correct) the Massachussetts-Broadstreet overload and Lake Tradition integration problems.

Plan 2

This CM line addition will alleviate the breaker failure problem at Raver (J96257), however, by about 2005 the problem will reoccur (J04216). The addition of the second Maple Valley 500/230-kV transformer (in 2006) will delay this even further.

Terminating the new CM line at Snoqualmie aggravates the Massachussetts-Broadstreet overload and Lake Tradition integration problems.

Plan 3

This CM line addition will alleviate the breaker failure problem at Raver (J96255), however, by about 2003 the problem will reoccur (J04207). The addition of the Snohomish 500/230-kV transformer (in 2010) will delay this even further.

Terminating the new CM line at both Monroe and Snoqualmie does not change the Massachussetts-Broadstreet overload and Lake Tradition integration problems significantly.

Plan 4: same as Plan 2.

Plan 5: same as Plan 2.

Plan 7

This CM line addition alleviates the breaker failure problem at Raver (J96287), however, by about 2002 the problem will reoccur (J04497). The addition of the second Maple Valley 500/230-kV transformer (in 2012) will again delay the problem.

Terminating a new CM line at Snoqualmie aggravates the Massachussetts-Broadstreet overload and Lake Tradition integration problems.

Plan 8

This CM line addition alleviates the breaker failure problem at Raver (J96288), however, by about 2003 the problem will reoccur (J04498). The addition of the second Maple Valley 500/230-kV transformer (in 2006) will again delay this problem.

Terminating the new CM line at Snoqualmie aggravates the Massachussetts-Broadstreet overload and Lake Tradition integration problems.

TABLE 201 - LINE UPGRADES

PUGET SOUND AREA LINE	Upgrade BEFORE XMTN PLAN	Upgrade AFTER XMTN PLAN	PLAN
PSP Bellingham-Sedro 230-kV	970A	1020A spring	all
PSP Blumaer-Electron Heights 115	440A	470A summer	all
PSP Electron Hghts-Krain Corner Tap (on Elct Hts-White Rv 115-kV line)	340A	360A summer	all
PSP St Clair-White River 115 line	720A	760A summer	all
PSP Obrien-Talbot Hill 230 line	700A	860A summer	all
BPA Covington-Tacoma A 230 line	600A	630A summer	all
PSP Maple Valley-Talbot Hill 230 #1&2	---	1900A summer	all
SCL Bothell-Snohomish 230 #3 (created from loopin)	---	1200A summer	plan 1
PSP Beverly Park-Hilton 115	---	600A summer	plan 1
SCL Maple Valley-Snoking 230	---	950A summer	plan 1
PSP Lakeside-Sammamish 115 #1&2	---	650A summer	plan 1

OKANOGAN AREA LINES			
BPA Brewster-Ophir Tap 115	280A	300A summer	all
	310A	330A spring	all
BPA Ophir Tap-Okanogan 115	250A	270A summer	all
	280A	300A spring	all

Table 202

A96CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 250MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
OBRIEN-TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SNOQ 500	N/A	N/A	90%	92%
			TACOMA 500/230	98%	110%	112%	111%
			CHRIS-COVINGTN 230	92%	102%	104%	103%
			CHRIS-OBRIEN 230	100%	103%	105%	106%
BREWSTER-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	151%	158%	161%	162%
OKANOGAN-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	137%	144%	147%	148%

Table 203

A96CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1000MW INGLEDOW>CUSTER NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER-ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	94%	100%	102%	103%
ST CLAIR-WHITE RV 115	552A	(1015A)	NO OUTAGE				
			RAVER-PAUL 500	93%	98%	99%	99%
OBRIEN-TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A	86%	89%	N/A
			RAVER-SNOQ 500	N/A	100%	111%	113%
			TACOMA 500/230	106%	118%	120%	120%
			CHRIS-COVINGTN 230	99%	109%	112%	111%
			CHRIS-OBRIEN 230	103%	106%	108%	109%
BREWSTER-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	148%	154%	157%	158%
OKANOGAN-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	134%	140%	143%	144%
HOLCOMB-NASELLE 115	420A		LONGVW-LONGVW T 230	120%	123%	125%	125%

Table 204

A96CY89 STUDIES

RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOW>CUSTER TROJAN OFF								A96 CASE #'S
				FO NO PLAN	PFLOW	FO MONROE PLAN	PFLOW	FO MON-SNOQ PLAN	PFLOW	FO SNOQ PLAN	PFLOW	
BLUMAER-ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	142	147	147	153	149	155	151	155	141,142,143,144
ELECTHTS-WR KC TP 115	306A	(447A)	RAVER-PAUL 500	110	112	113	115	114	117	115	116	SAME AS ABOVE
			ELECTHTS-WHITE RV 115	97	96	100	99	102	100	102	100	145,146,147,148
ST CLAIR-WHITE RV 115	552A	(1015A)	NO OUTAGE	63		66		67		67		
			RAVER-PAUL 500	129	134	137	138	135	140	136	139	SAME AS ABOVE
OBRIEN-TALBOT H 230	552A	(1015A)	NO OUTAGE	90		101		104		104		
			RAVER-SNOQ 500	112	112	137	139	148	149	154	153	149,150,151,152
			TACOMA 500/230	125	124	134	135	138	139	138	139	153,154,155,156
			CHRIS-COVINGTN 230	114	115	123	127	126	127	126	130	157,158,159,160
			CHRIS-OBRIEN 230									
MAPLE VL-TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	95	95	102	103	107	107	108	108	161,162,163,164
LAKESIDE-SAMMAMISH 115	552A	(1015A)	LAKESIDE-SAMMAMISH	N/A	87	114	114	106	106	97	98	165,166,167,168
			MONROE-SNOQ 500	95	95	116	118	N/A		N/A		173,135,134,133
			SNOK TP-SNOQUALM 500	N/A				100	87			134
MAPLE VL-SNOKING 230	890A	(1035A)	MONROE-SNOQ 500	N/A		106	108	N/A		N/A		SAME AS ABOVE
			MAPLE VL 500/230	N/A		N/A		N/A		N/A		
BREWSTER-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	142	138	147	142	150	146	152	148	169,170,171,172
OKANOGAN-R T 115	180A	(353A)	DOUGLAS-WELLS 230	128	130	133	135	137	139	138	140	SAME AS ABOVE
ERLY PK-ILTON 115	552A		MONROE-SNOQULAM 500	N/A	87	107	107	N/A		N/A		SAME AS ABOVE
BOTHELL-SNOHOSH 3 230			MONROE-SNOQULAM 500	N/A		112	113 (N)	N/A		N/A		SAME AS ABOVE

Table 205

A00CY89 STUDIES

: .RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 250MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
OBRIEN-TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SNOQ 500	N/A			
			TACOMA 500/230	101%	110%	115%	114%
			CHRIS-COVINGTN 230	95%	109%	107%	106%
			CHRIS-OBRIEN 230	106%	110%	111%	112%
BREWSTER-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	152%	160%	162%	163%
OKANOGAN-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	138%	146%	148%	149%
HOLCOMB-NASELLE 115	420A		LONGVW-LONGVW T 230	112%	116%	117%	117%

Table 206

A00CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1000MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
ST CLAIR-WHITE RV 115	552A	(1015A)	NO OUTAGE				
			RAVER-PAUL 500	91%	97%	98%	98%
OBRIEN-TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A	92%	N/A	N/A
			RAVER-SNOQ 500	N/A	101%	108%	111%
			TACOMA 500/230	108%	124%	122%	122%
			CHRIS-COVINGTN 230	100%	116%	113%	113%
			CHRIS-OBRIEN 230	108%	112%	112%	113%
LAKESIDE-SAMMAMISH 115	552A	(1015A)	LAKESIDE-SAMMAMISH	N/A	102%	N/A	N/A
			MONROE-SNOQ 500				
BREWSTER-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	150%	156%	160%	161%
OKANOGAN-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	136%	142%	146%	147%
TROJAN-ST MARYS 230	1315A	(1507A)	ALLSTON-KEELER 500	96%	99%	100%	100%
TROJAN-RIVERGATE 230	1315A	(1507A)	ALLSTON-KEELER 500	97%	100%	101%	101%
BOTHELL-SNOHOMH 3 230			MONROE-SNOK TAP 500	N/A	107%	N/A	N/A

Table 2.07

A00CY89 STUDIES

RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOW>CUSTER TROJAN OFF			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	138	145	146	147
ELECTHTS- WR KC TP 115	306A	(447A)	RAVER-PAUL 500	109	114	114	115
			ELECTHTS-WHITE RV 115	98	103	103	102
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE	62	67	67	67
			RAVER-PAUL 500	128	134	134	135
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	93	108	108	108
			RAVER-SNOQ 500	111	138	149	153
			TACOMA 500/230	128	142	143	143
			CHRIS-COVINGTN 230	118	131	131	131
			CHRIS-OBRIEN 230	115	117	120	121
MAPLE VL- TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	97	107	110	110
LAKESIDE- SAMMAMISH 115	552A	(1015A)	LAKESIDE-SAMMAMISH	93	126	107	99
			MONROE-SNOK TP 500	N/A	104	N/A	N/A
			SNOK TP-SNOQ 500	N/A	123	97	N/A
MAPLE VL- SNOKING 230	890A	(1035A)	MONROE-SNOQ 500	N/A			
			MAPLE VL 500/230	N/A			
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	144	150	153	155
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	131	136	139	141
RLY PK- TON 115	552A		SNOK TP-SNOQ 500	N/A	103	N/A	N/A
BOTHELL- 1,2,3 SNOHOMSH 230			MONROE-SNOK TP 500	N/A	140	100	N/A
BOTHELL- SNOKING 230	1048A		MONROE-SNOK TP 500	92	111	N/A	N/A

Table 208

A04CY89 STUDIES

3 ,RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 250MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
OBRIEN-TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SNOQ 500	N/A			
			TACOMA 500/230	95%	114%	112%	111%
			CHRIS-COVINGTN 230	N/A	106%	104%	102%
			CHRIS-OBRIEN 230	102%	107%	108%	109%
BREWSTER-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	153%	161%	164%	164%
OKANOGAN-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	139%	147%	149%	150%
HOLCOMB-NASELLE 115	420A		LONGVW-LONGVW T 230	111%	115%	116%	116%

Table 209

A04CY89 STUDIES

RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1000MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	N/A	96%	96%	97%
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE				
			RAVER-PAUL 500	91%	98%	98%	98%
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A	N/A	87%	N/A
			RAVER-SNOQ 500	N/A	N/A	102%	104%
			TACOMA 500/230	104%	121%	121%	120%
			CHRIS-COVINGTN 230	96%	112%	111%	110%
			CHRIS-OBRIEN 230	105%	108%	111%	111%
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	152%	159%	162%	163%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	138%	145%	147%	148%
BOTHELL- SNOHOMH 3 230			MONROE-SNOK TAP 500	N/A	113%	N/A	N/A
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	120%	124%	125%	125%

Table 2.10

A04CY89 STUDIES

RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOW>CUSTER TROJAN OFF			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	132	140	141	142
ELECTHTS- WR KC TP 115	306A	(447A)	RAVER-PAUL 500	108	113	114	114
			ELECTHTS-WHITE RV 115	99	105	105	104
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE	62	67	67	66
			RAVER-PAUL 500	125	132	132	133
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	87	107	105	103
			RAVER-SNOQ 500	101	132	142	145
			TACOMA 500/230	124	142	141	140
			CHRIS-COVINGTN 230	113	129	129	127
			CHRIS-OBRIEN 230	112	115	117	117
MAPLE VL- TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	90	105	105	105
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	145	151	155	156
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	131	136	140	142
COVINGTON- WHITE RV 230	730A		COVINGTN-WHITE RV 230	93	97	99	100
BOTHELL- 1,2,3 SNOHOMSH 230			MONROE-SNOK TP 500	N/A	147	N/A	N/A
ELL- ING 230	1048A		MONROE-SNOK TP 500	108	127	N/A	N/A
AKESIDE- SNOKING 230	980A		SNOK TP-SNOQ 500	N/A	116	N/A	N/A

Table 211

SPG94CY89 STUDIES

RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1800MW CUSTER>INGLEDOW					
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN FO	SNOQ PLAN PF	PF #
BREWSTER-	180A	(353A)	DOUGLAS-WELLS 230	170%	182%	185%	185%		
OPHIR T 115			DOUGLS-SICKLR 500/230	159%	185%	188%	186%		
OKANOGAN-	180A	(353A)	DOUGLAS-WELLS 230	156%	168%	171%	171%		
OPHIR T 115			DOUGLS-SICKLR 500/230	147%	170%	173%	172%		
HOLCOMB-	420A		LONGVW-LONGVW T 230	105%	111%	111%	111%		
NASELLE 115									
BELLNGHM-	660A		MONROE-SNOK TP 500				113		
SEDRO 230			SNOK TP 500					106	SPG94114
BELNGM P-	387A		BELLNGHM-SEDRO 230	109%	105%	106%	115%		
SEDRO 1 115									
BEV PK-	276A		SNOK TAP-SNOQUALM 500				103		
GOLDBART 115			SNOK TP 500					106	SPG94114

Table 2.12

SPG94CY89 STUDIES

RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER-ELECTHTS 115	387A	(587A)	RAVER-PAUL 500	136%	142%	144%	144%
ELECTHTS-WR KC TP 115	387A	(447A)	RAVER-PAUL 500	104%	108%	109%	109%
			ELECTHTS-WHITE RV 115	91%	95%	96%	96%
ST CLAIR-WHITE RV 115	552A	(1015A)	NO OUTAGE				
			RAVER-PAUL 500	157%	162%	164%	164%
OBRIEN-TALBOT H 230	723A	(1015A)	NO OUTAGE	N/A	88%	90%	N/A
			RAVER-SNOQ 500	91%	116%	125%	129%
			TACOMA 500/230	108%	117%	119%	119%
			CHRIS-COVINGTN 230	100%	108%	110%	110%
			CHRIS-OBRIEN 230	100%	101%	103%	104%
MAPLE VL-SNOKING 230	890A	(1035A)	MONROE-SNOQ 500		102%		
			MAPLE VL 500/230				
BREWSTER-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	156%	163%	167%	169%
OKANOGAN-OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	143%	149%	154%	155%
BOTHELL-SNOHOMH 3 230			MONROE-SNOQUALM 500		121%		
BOTHELL-SAMMASH 230	1015A		MONROE-SNOQUALM 500	74%	101%	91%	
ELL-ING 230	1048A		MONROE-SNOK TP 230	103%	133%		
			MONROE-SNOQUALM 500		126%		
AMMAMSH 115/230			SAMMAMSH 115/230 1	96%	107%	106%	103%
CHEHALIS-TACOMA A 230	1070A		PAUL-RAVER 500	97%	101%	102%	103%

TABLE 302

TECHNICALLY FEASIBLE TRANSMISSION ALTERNATIVES REJECTED FOR ECONOMIC REASONS

1. CHIEF JOE-SNOQUALMIE 765-KV LINE

Assumptions used for 765-kV study:

a. 765/500-kV transformers will be 500 MVA/phase, 10.5% impedance.

b. Phase shifting transformers will be on 500-kV sending end and have same size and impedance as step-up transformers.

c. 765-kV transmission line will be 6-Seahawk, 2 PU, double circuit design.

d. Plan 2, the Chief Joe and Snoqualmie terminations, will be tested to determine the feasibility of this voltage class.

e. If a 765-kV line is built, it will initially operate at 500-kV until 2004 and then converted to its design voltage.

f. The 765-kV plan will have same SVC's added as the 500-kV Plan 2: at Maple Valley and Keeler.

Results of 765-kV study

a. Operating a 765-kV line at 500-kV provides about 50 MVARs additional reactive over a 500-kV line for the three critical outages (compare J04198QV and J04200QV in QV-160, J04EH73QV and J04EH76QV in QV-161, and J04EH82QV and J04EH84QV in QV-162). Uprating this line to 765-kV operation does not provide an appreciable improvement due to the additional impedance of the transformation at each end (compare J96EH26QV and J96EH139QV in QV-164 and J9610QV and J96103QV in QV-164. Also voltage control for all operating conditions is much more difficult than 500-kV lines. Several switched and fixed shunt reactors will be required.

b. To make the first 765-kV line attractive (without a 765-kV grid), the line must be force-loaded. Adding phase shifters to the sending end would enable the line to be loaded to a predetermined level. Loss savings favor about 2000 MW loading on each line (Table 350). Surge Impedance Loading (SIL), with terminating transformer impedance added, is also about 2000 MW.

c. The voltage stability performance of several line loadings were studied. For the worst double line outage, the performance was better for lower initial loadings as shown in QV-166 (probably due to problems at Chief Joe). For the single Coulee-Raver line outage, performance was better for higher pre-outage flows as shown in QV-167. The single Chief Joe-Snoqualmie 765-kV line outage also is better for higher pre-outage loadings, but the differences are not as great as shown in QV-168. This makes sense since one of the phase shifted lines is removed in this case.

d. 2000 MW pre-loading of the new 765-kV line appears to be optimal.

e. Adjusting the phase shift of the new line after an outage occurs was investigated. QV-169 shows the effect of increasing and decreasing the phase shift angle after the worst single line outage occurs. From these studies it appears to be beneficial to decrease the angle after a single line outage occurs and detrimental to increase the angle. Adjusting the phase shift after double line outages was not investigated at this time since a phase shift adjustment will not help for a double 765-kV line outage.

f. The remaining studies assume that each new line is loaded to 2000 MW prior to any outage and the pre-outage phase shift angle is held after the outages occurs.

g. The phase shifter impedance does not have an appreciable difference in the performance (compare J04EH78QV and J04EH88QV in QV-161.).

h. Performance of the 765-kV line plan with 2000 MW loading (as compared to the 500-kV line) appears to be better at the start of the QV curves for the three critical outages. But as the voltage drops through the QV curve, the performance drops off sharply apparently due to voltage collapse at Chief Joe. This is especially true for the double Coulee-Raver line outage where most of the power must go through Chief Joe. QV-160 compares the double line outages, QV-161 the single line outages and QV-162 the Trojan scram.

i. From the performance of the above, at least one of the 765-kV lines will need to be extended to Coulee.

j. The performance of a Chief Joe/Coulee-Snoqualmie 765-kV double circuit line is shown in J04EH102QV, J04EH103QV and J04EH105QV in QV-165. J04203QV in QV-160 gives a good indication of how this plan would operate during the loss of the new double circuit line. This plan has 500 MVAR SVC's at Keeler and Maple Valley like the 500-kV plans and is not necessarily optimized. Comparing these curves with those in QV-121 (the same plan at 500-kV), it is estimated that this line addition would last only about 2 years longer than a 500-kV double circuit line.

k. The loss savings of this plan are as follows (with Snoking Reinforcement): These also included in Table 100.

	1996*	2004+
Chief Joe-Snoqualmie 500-kV SDC	66.9	65.1
Chief Joe-Snoqualmie 765-kV SDC operated at 500-kV	77.7	76.9
Chief Joe/Coulee-Snoqualmie 765-kV SDC phase shifted to 2000 MW		141.5

* 1996 losses compared to base system
\+ 2004 losses compare to reactive plan

l. There is a benefit of a 765-kV line as part of a future 765-kV grid that is hard to evaluate at this time.

Conclusion

The additional expense of constructing the new line to 765-kV does not appear to but justified by the QV performance. There is a significant loss savings though.

TABLE 302 Continued

TECHNICALLY FEASIBLE TRANSMISSION ALTERNATIVES REJECTED FOR ECONOMIC REASONS

2. COULEE-SNOQUALMIE DIRECT CURRENT LINE

A Coulee-Snoqualmie DC line was modeled for abnormal cold 2004 system conditions. A 1500MW power schedule is needed with all lines in service (J04EH60QV, J04EH61QV). The base case with one Centralia unit down needs one SVC at Maple Valley for the reactive margin (J04EH61QV). Normal winter conditions were not modeled.

The post transient outage of the Chief Jo-Monroe 500kv line needs DC fast ramping to 3000MW. One SVC at Maple Valley is needed to provide reactive margin (J04EH62QV).

The post transient Trojan outage with one Centralia unit down and an SVC at Keeler is slightly less severe than the Chief Jo-Monroe outage (J04EH63QV). This also needs DC fast ramping to 3000MW.

The estimated cost of this plan is 3 times the cost of the comparable AC plan.

A Celilo-Snoqualmie DC line was not studied because the area interchange assumptions for normal winter do not allow full use of the existing Celilo DC terminal for scheduling power to Snoqualmie. Another Celilo terminal is needed in addition to longer line length (290 miles vs. 190 miles). This provides no apparent benefit for the increased cost.

3. HIGH-PHASE-ORDER TRANSMISSION LINE (SIX-PHASE, 500-kV+)

Similar problems to 765-kV analysis listed above. Reliability is reduced from standard double-circuit lines: would need to plan for loss of entire circuit during abnormally cold weather (presently just plan for one circuit on double-circuit towers). These requirements would make this alternative even more expensive than a similar 765-kV AC three-phase alternative. And like the 765-kV plan, there does not appear to be any justification for additional cost.

TABLE 303

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

Alternative	Comments
1. Chief Joe-Raver 500-kV double circuit line.	Voltage Stability performance was inferior to northern termination plans, 4 of 5 existing 500-kV CM lines already terminated at Raver.
2. Chief Joe-Raver 500-kV double circuit and Raver-Snoqualmie 500-kV #2 lines.	Performance is similar to preferred plans, however, 4 of 5 existing 500-kV CM lines already terminated at Raver.
3. Coulee-Raver 500-kV double circuit line.	Coulee termination does not improve performance of the critical single line outage, 4 of 5 existing 500-kV lines already terminated at Raver
4. Ashe-Snoqualmie 500-kV double circuit line.	Performance is OK, but not any better than a Hanford termination.
5. Chief Joe-Monroe/Snoqualmie 500-kV double circuit, add Raver-Snoqualmie #2 and use with one existing Coulee-Raver line to form Coulee-Snoqualmie 500-kV line.	Tying existing line into Snoqualmie degrades performance.
6. Chief Joe-Coulee 500-kV single circuit line.	Slight improvement in performance, not enough to justify 30 miles of line construction and terminations.
7. Monroe-Raver-Paul 500-kV single circuit line.	Improvement is small, comparable to a 500-kV shunt capacitor group, not economic.
8. Monroe-Raver-Olympia 500-kV single circuit line.	Not quite as good at Monroe-Raver-Paul (#7).
9. Naneum Switchyard (tie Coulee-Raver lines, Vantage-Raver and Sickler-Raver lines together near Ellensburg).	Little effect on performance for abnormally cold weather conditions.
10. Naneum Switchyard and Grand Coulee-Naneum 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
11. Naneum Switchyard with shunt capacitors.	Cap group is effective addition.
12. Naneum Switchyard with series capacitors within station.	Shunt caps more effective per MVAR.

TABLE 303 Continued

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

13. Naneum Switchyard, Naneum-Snoqualmie 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
14. Naneum Switchyard, Naneum-Monroe 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
15. Naneum Switchyard, 500-kV single-circuit tap line to Hanford-Grand Coulee.	Little improvement in system performance when compared to existing system.
16. Naneum Switchyard, Naneum-Hanford 500-kV single circuit line.	Little improvement in system performance when compared to existing system.
17. 500-kV single circuit tap line from Sickler to existing Grand Coulee-Hanford 500-kV line.	Little improvement in system performance when compared to existing system.
18. Sickler-Monroe 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
19. Sickler-Monroe 500-kV double circuit line, 500-kV single circuit tap line from Sickler to existing Grand Coulee-Hanford 500-kV line.	Not enough improvement for Coulee-Raver outage.
20. Sickler-Snoqualmie 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
21. John Day-Paul 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
22. John Day-Allston 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
23. John Day-Allston 500-kV Raver-Olympia 500-kV single circuit line.	Better than #22 but still mediocre.
24. Lower Monumental-Hanford 70% Series Compensation - 136 MVAR.	These additions are ineffective in correcting the problem.

TABLE 303 Continued

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

25. Raver-Snoqualmie 500-kV single circuit line, Snoqualmie switchyard.	Surprisingly effective, but not nearly enough to correct problem. This will be investigated in conjunction with CM alternatives.
26. Raver-Snoqualmie 500-kV single circuit line, Raver-Covington 500-kV single circuit line.	Similar to #25.
27. Raver-Snoqualmie, Raver-Covington and Raver-Tacoma 500-kV single circuit lines.	Similar to #25.
28. Covington-Maple Valley 500-kV single circuit line, Covington and Maple Valley switchyards.	Most effective of westside line construction, but still not enough to correct problem. This will be investigated in conjunction with CM alternatives.

TABLE 310

INVESTIGATIONS OF QV PERFORMANCE FOR TRANSMISSION LINE ALTERNATIVES

The general development of the transmission line options is detailed in this table. Most of this development was done on Plans 2 and 3. This discussion covers many of the options and refinements that were investigated in this study.

1996 QV PERFORMANCE

With a new Chief Joe-Snoqualmie/Monroe or Chief Joe-Snoqualmie line added, the three critical outages for the Puget Sound area are 1) loss of one Coulee-Raver 500-kV line during abnormally cold weather, 2) loss of Trojan with one Centralia unit previously out-of-service, also during abnormally cold weather and 3) loss of both Coulee-Raver 500-kV lines during normal winter peak loads.

The new line with the LDC's proposed in the assumptions and the Snoking Reinforcement project do not provide the necessary reactive margins in either the Puget Sound or Portland areas without SVC's. A 300 MVAR SVC is required on the Keeler 230-kV bus to provide the necessary reactive margins in the Portland area for the Trojan scram. The QV performance of these additions are shown in the attached QV-131. The required 500 MVAR on-line margin cannot be obtained without switching the existing shunt capacitors at Raver or adding additional high-speed reactive. A 300 MVAR SVC is therefore required on the Maple Valley 230-kV bus to provide this margin. The performance of these additions is shown in QV-132, which has the required margins without switching capacitors after the outage.

Additions of series compensation were studied in 1996 as an alternative to SVC additions. As shown in QV135 (Normal winter outages) and QV-136 (abnormal cold weather outages), the addition of SVC's is much more effective at this time. However, once these SVC's are added, the addition of series comp becomes much more effective (QV-137). Series capacitor additions may be more appropriate rather than the increases in SVC size due to performance and loss savings. This will be discussed later.

2000 QV PERFORMANCE - SOLVING PROBLEMS IN THE PORTLAND AREA

With Plan 3, the QV-outages for 2000 (QV-220) were compared with 1996 (QV-132). The line outages are marginal in 2000, but since additional cap groups are available at Raver during these outages, that group can be switched automatically (MSC) after the outage in conjunction with the Maple Valley SVC. The Trojan Scram outage, however, has just a 500 MVAR margin in 2000, and the base system already has all three caps groups energized. Therefore, system reinforcement will be needed by 10-2000 in the Portland area. Increasing the SVC at Keeler to 500 MVAR will provide enough support for this outage through 2004, as shown in study QV-221 and will be assumed as the long range support for this initial planning process. Other options exist, which include:

1. 300 MVAR SVC at Ostrander

This is about equally effective per MVAR as Keeler (QV-222) and would provide additional reliability due to the different location. Also MSC switching a 300 MVAR capacitor group at Ostrander was nearly as effective as the SVC (QV-240).

2. Series compenstation on Ashe-Marion and Big Eddy-Ostrander lines

Ashe-Marion compensation didn't seem to help much (compare QV-215 with QV-223) but the Big Eddy-Ostrander line, which is heavily loaded during these conditions, seems to help as much as a 300 MVAR SVC at Ostrander (QV-216). Because this is an old line with small conductor, continuous series compensation is probably not desirable, however, switching the comp after outages is actually better (QV-241).

3. Tap lines from Big Eddy to the Hanford-Ostrander and the Ashe-Marion

These tap lines were studied to relieve the bottleneck between Big Eddy and Ostrander. These were not very effective as shown in QV-218.

2004 QV PERFORMANCE - SOLVING PROBLEMS IN PUGET SOUND AREA

After the Portland reactive problems are solved (by increasing the SVC at Keeler to 500 MVAR), the Puget Sound area again experiences problems. QV-223 shows the 2004 system with only a 300 MVAR SVC at Maple Valley. The double Coulee-Raver line outage does not have sufficient margin in these cases. To meet the reactive margins for this critical double line outage, the operating voltage at Raver must be nearly 550-kV or the existing 500-kV shunt capacitors at Raver must be automatically switched with the outage. As discussed below, to maintain reactive margins at Monroe and prevent overvoltages at Raver, MSC at Raver is favored.

Comparing QV-223 with QV-220, the critical single line outage will not have the required 500 MVAR margin (even with MSC at Raver) in 2003. Support will be needed by 10-2002. Increasing the SVC at Maple Valley will correct the system through 2004 as shown in QV-221 and will be the assumed long range plan. Again other options exist:

1. An additional 300MVAR SVC at Snohomish

An additional SVC in the North Puget Sound area (as opposed to increasing the size of the Maple Valley SVC) would provide some additional reliability by separating the facilities. This also more effective for the CM plans that have lines terminated south of Monroe.

2. Series compensation of the new line

Compensation of the new lines was investigated as a second phase reinforcement (as an alternative to the SVC increases at Maple Valley). Previous loss savings studies indicated that the optimal compensation level for the future system with a new 4-bunting conductor line into the Snoqualmie/Monroe area would be 35% on the new line and 40% total on the Coulee-Raver lines. Since these J96 studies showed only about a 2 MW loss savings for all this compensation and due to the need for some variable reactive supply in the load area, SVC's were selected as the best reinforcement initially. However, once SVC's are installed in the load area, series comp becomes more attractive.

As noted earlier, the J04 cases contain an error in the Coulee-Raver series compensation. 45% comp was inadvertantly used instead of the planned 22.5%. This error results in slightly over-optimistic QV curves. As shown in QV-230, the EH winter QV curves for Plan 3 with the corrected impedances have about 150 MVARs less margin. With the lower compensation levels, more shunt reactive can be on in the base. The double line outage shows the largest difference, obviously since a larger amount of series reactive is lost with these outages. All three curves for Plan 3 (with the correct compensation level) still have the required 500 MVAR margin.

If 35% compensation is added on the new circuits, the critical outages change. The worst single line outage becomes the new Chief Joe-Monroe circuit and the worst double line outage becomes loss of the new double circuit line (QV-231 and QV-232).

If the compensation is added in lieu of the 200 MVAR additions to the SVC's at Maple Valley and Keeler, performance is improved for the line outages as shown in QV-233. For the single and double line outages, the knees of the QV curves move to the left by about 125 to 250 MVARs. The Trojan scram, however, appears to get worse if the series comp is added (compare J04EH196QV and J04EH161QV). In fact the curve for the series comp case (J04EH196) will not solve below 1.05 pu voltage. The reason for this appears to be that the Keeler SVC is hitting the ceiling and the system collapses in the Portland area (note that the J04EH196 curve starts to solve better than 161 at Raver but drops off sharply below 1.08 pu voltage). Although series comp improves the Puget Sound area line outages, separate reinforcement, such as the Keeler SVC increase or others mentioned above, will also be needed in the Portland area. Otherwise this option looks attractive, especially since the series comp should "grow" with the load, that is, it will provide increasing MVARs to the system as the line loadings increase. Series compensation, as a second phase reinforcement to the transmission line options, should be studied further.

3. Mechanically Switched Capacitors at Grand Coulee

A general observation from the QV curves of the transmission line options is that the knees tend to coincide with the Coulee generators reaching Qmax. Curves were run with an infinite VAR source at Coulee as a comparison (QV-234). These cases were run on Plan 3 with 35% compensation. Included on this curve is the unscheduled reactive required at Coulee to hold the pre-fault voltage. These numbers show that initially it doesn't take much reactive to make a significant difference at Raver. However, larger reactive additions at the source have a diminishing effect at the receiving end. Limited reactive additions may be beneficial. Due to the large number of machines at Coulee to provide VAR regulation, shunt capacitor additions at Coulee are all that is needed to provide this benefit.

Curves QV-235 and QV-236 show the addition of a 300 MVAR MSC at Coulee for the double and single line outages respectively. These curves show that a 300 MVAR shunt capacitor addition at Coulee provides about 200 MVARs at Raver. In other words, a 300 MVAR MSC at Coulee is equivalent to a 200 MVAR SVC in Puget Sound. These capacitors can either be energized prior to outage or mechanically switched after outages occur.

Similar studies were run in J96 without any system reinforcement beyond LDC's at Paul, Coulee, John Day, Dalles and Bonneville and the 300 MVAR SVC's at Maple Valley and Keeler (QV-237). This addition is not quite as effective at moving the curves to the left but it does drop the knees considerably. Apparently with the reduced system impedance from the line additions, supporting the sending end of the transmission lines becomes more effective.

MSC's at Coulee (and other generating plants such as Chief Joe) should be investigated in more detail.

DOUBLE LINE OUTAGE

To obtain adequate reactive margins at Raver for the double Coulee-Raver line outage, all three capacitor groups are required on line or MSC switched after the outage. If the capacitors are on line prior to the outage, overvoltages may exist on the system (J04440) and adequate margins might not exist at Monroe, since having all 3 cap groups on at Raver do not allow any capacitors on at Monroe. As an example, refer to QV-225 which shows no margin at Monroe for the double Coulee-Raver line outage. QV-226 shows the performance at Raver for the double Coulee-Raver line outage with one, two and three cap groups on at Raver prior to the outage.

Another option to improve the double line outage performance would be to develop the Naneum switchyard, as in Plan 5. The switchyard development may also have some loss savings benefits. Series comp on the new lines would also improve the double line outage.

LDC AT CHIEF JOE

With new circuits terminated at Chief Joe, the additional charging current reduces the reactive output of the generators at that dam. The addition of an LDC at Chief Joe to control the 500-kV bus, however, does not help much in addition to the other LDC's previously proposed. Refer to QV-130. The addition of shunt capacitors at Chief Joe could make an LDC there beneficial.

LINE DESIGN

As mentioned in the assumptions, a 2.0 p.u. line design was used in these studies due to poor experience on lines of the 1.7 design. Recent information indicates that the poor experience is due to 60hz withstand and that a 1.7 p.u. design would perform more favorably if additional bells were added in place of spacers on the existing tower designs. QV-250 compares the outage performance of the two designs for the single and double Coulee-Raver line outages. As can be seen, the 1.7 p.u. design is about 25-50 MVARs better that the 2.0 design. If a 1.7 p.u. line design is used, the system performance would be slightly better than shown in this study.

SHUNT REACTIVE ADDITIONS

To maintain adequate voltages on the system throughout the study period, it is assumed that shunt capacitors will be added on the 500-kV system. In reality, some capacitors will be needed on the lower voltage systems to maintain voltages for outages on these systems. However, the assumption of 500-kV capacitor additions will provide an approximation of the total shunt compensation required.

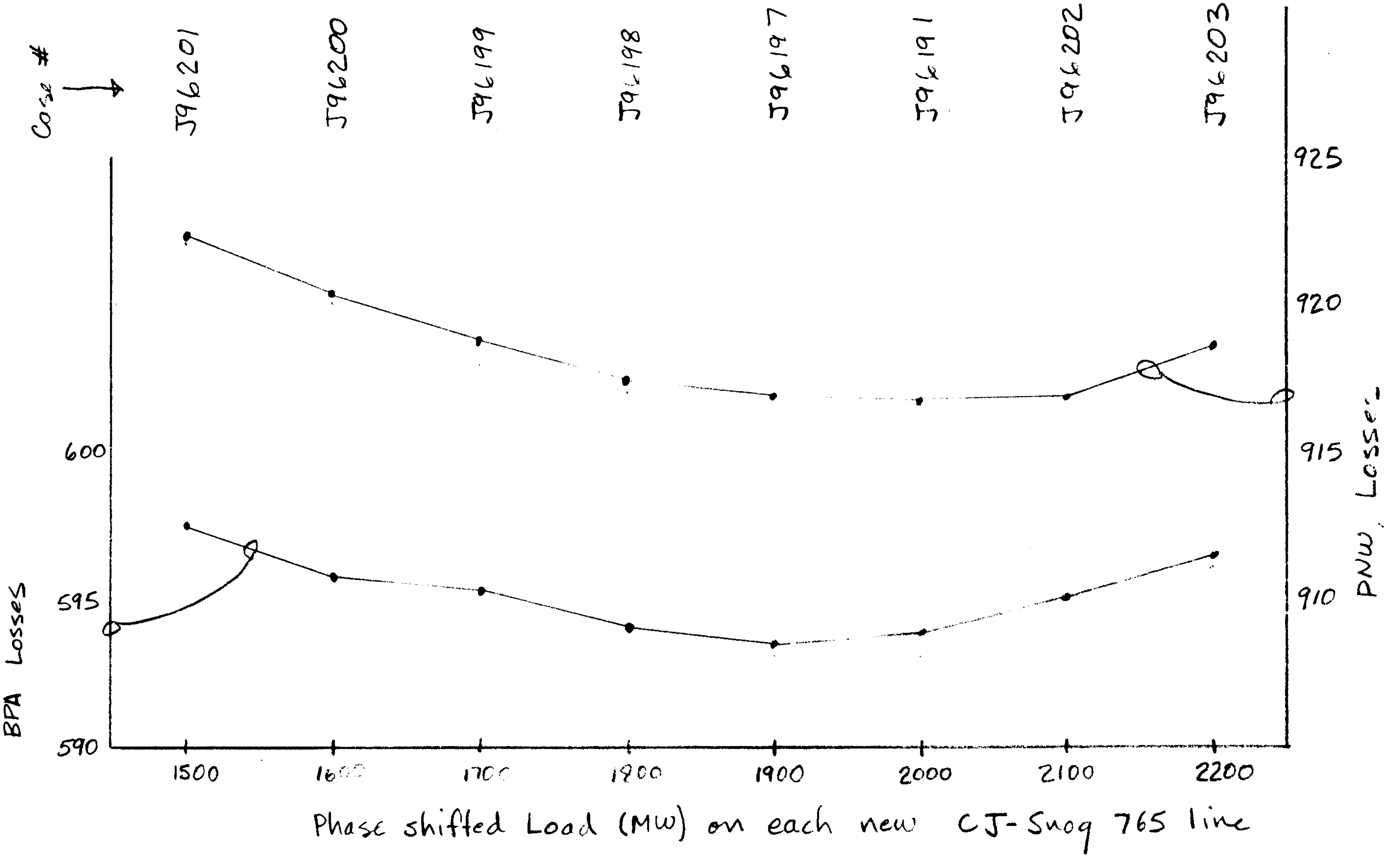
By the year 2000, additional shunt capacitor groups will be needed at Keeler and Ostrander (refer to case J00EH17). Going out to 2004, a second capacitor group is needed at Pearl and a third is needed at Ostrander (refer to case J04EH160). Because of the transmission line addition into the Puget Sound area, additional capacitors will not be required until 2002. One capacitor group is needed at Snoqualmie by 2002 and a second capacitor group at Monroe is needed by 2004. The following shunt compensation plan is assumed as a starting point for the Transmission line options:

1998 Add 500-kV shunt capacitor bank at Keeler.

2000	Add second 500-kV shunt capacitor bank at Ostrander.
2002	Add 500-kV shunt capacitor bank at Snoqualmie; Add second 500-kV shunt capacitor bank at Pearl;
2004	Add second 500-kV shunt capacitor bank at Monroe; Add third 500-kV shunt capacitor bank at Ostrander.

TABLE 350

LOSS SAVINGS OF VARIOUS
765-KV LINE LOADINGS.

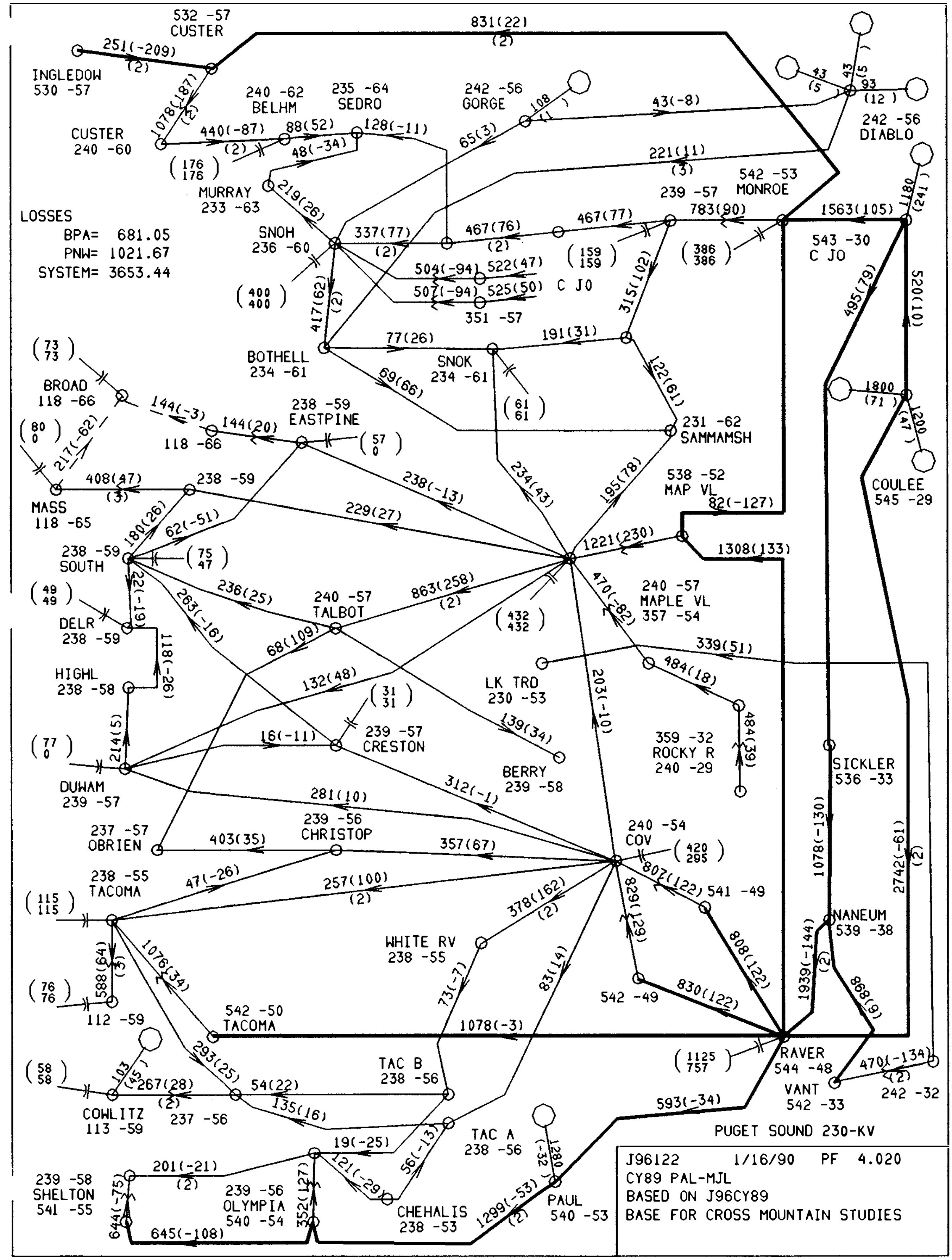


PF CASES

Powerflow Cases for North Seattle Studies

BASES	PLAN 1	PLAN 2	PLAN 3	REACTIVE PLAN	PLAN 7 & 8
J96122	J96171	J96172	J96144	A93160	J96287
J96152	J96235	J96234	J96241	A93194	J96288
J96243	J96248	J96236	J96250	SPG94116	J96EH582
J96254	J96261	J96239	J96251	A96170	J00EH17
J0008	J96262	J96249	J96255	A96174	
J00EH11	J96EH502	J96253	J96260	A96175	J04497
J96244	J96EH554	J96257	J96EH206	J96273	J04498
	J96EH555	J96259	J96EH251	J96279	J04EH160
	J96EH565	J96EH503	J96EH252	J96280	J04EH162
	J96EH566	J96EH553	J96EH315	J0049	J04EH163
	J96EH568	J96M216	J96EH328	J04EH22	J04EH165
	J96M215	J96M219	J96M146	J04EH25	J04EH166
	J96M217	J96M220	J96M147	J04EH34	J04EH167
	J96M218	J0017	J96M148		J04EH168
	J96M221	J0018	J0023		J04EH183
	J96M226	J0021	J0024		
	J96M227	J0022	J0027		
	J0035	J0025	J0028		
	J0036	J0030	J00EH34		
	J0037	J00EH25	J00EH35		
	J0038	J00EH26	J00EH39		
	J00EH28	J00EH27	J04165		
	J00EH29	J04197	J04207		
	J00EH30	J04216	J04EH26		
	J00EH31	J04EH94	J04EH42		
	J00EH32	J04EH97	J04EH110		
	J00EH112		J04440		
	J00EH113				
	J04196				
	J04232				

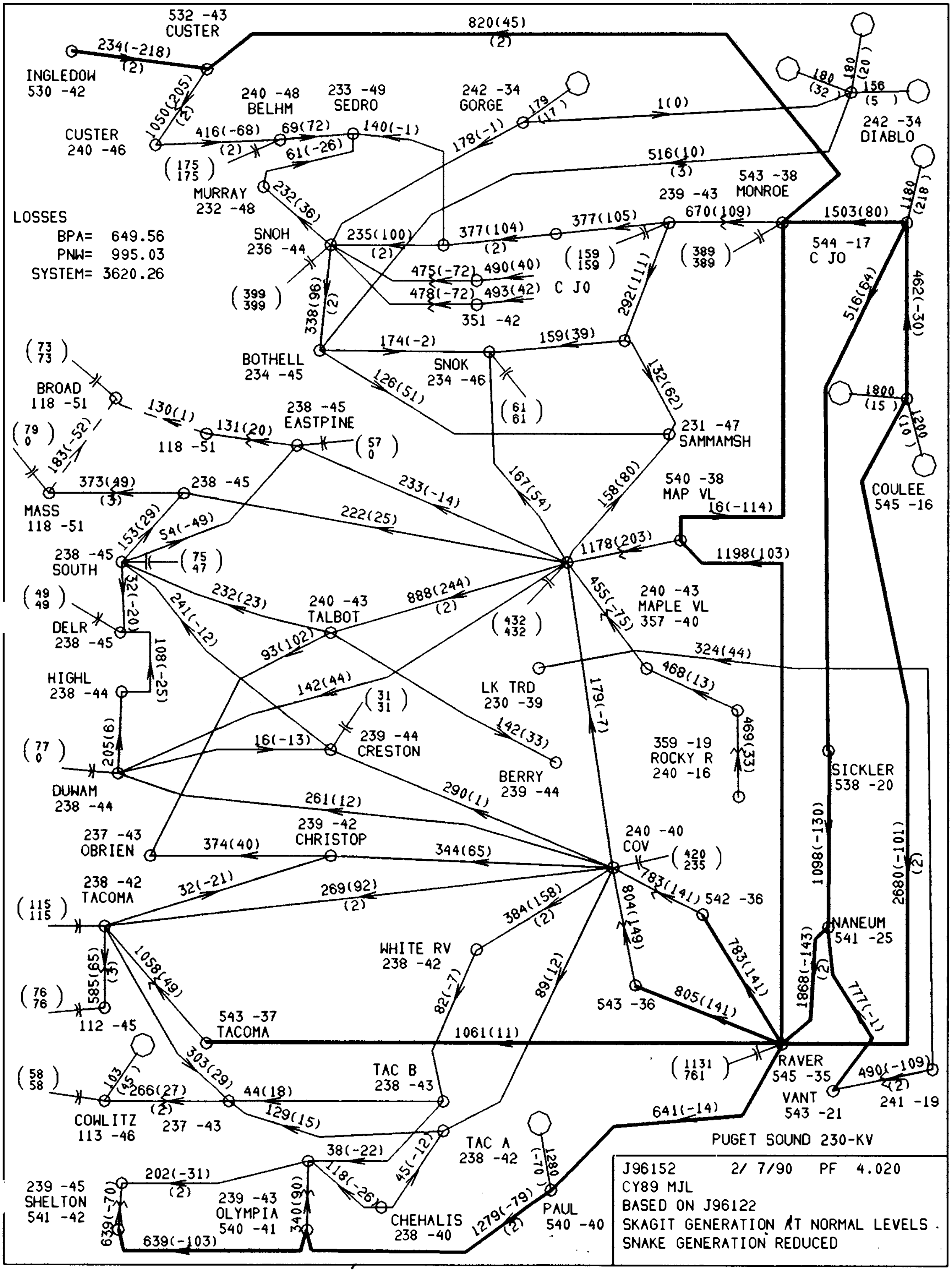
PF - BASES



PUGET SOUND 230-KV

J96122 1/16/90 PF 4.020
CY89 PAL-MJL
BASED ON J96CY89
BASE FOR CROSS MOUNTAIN STUDIES

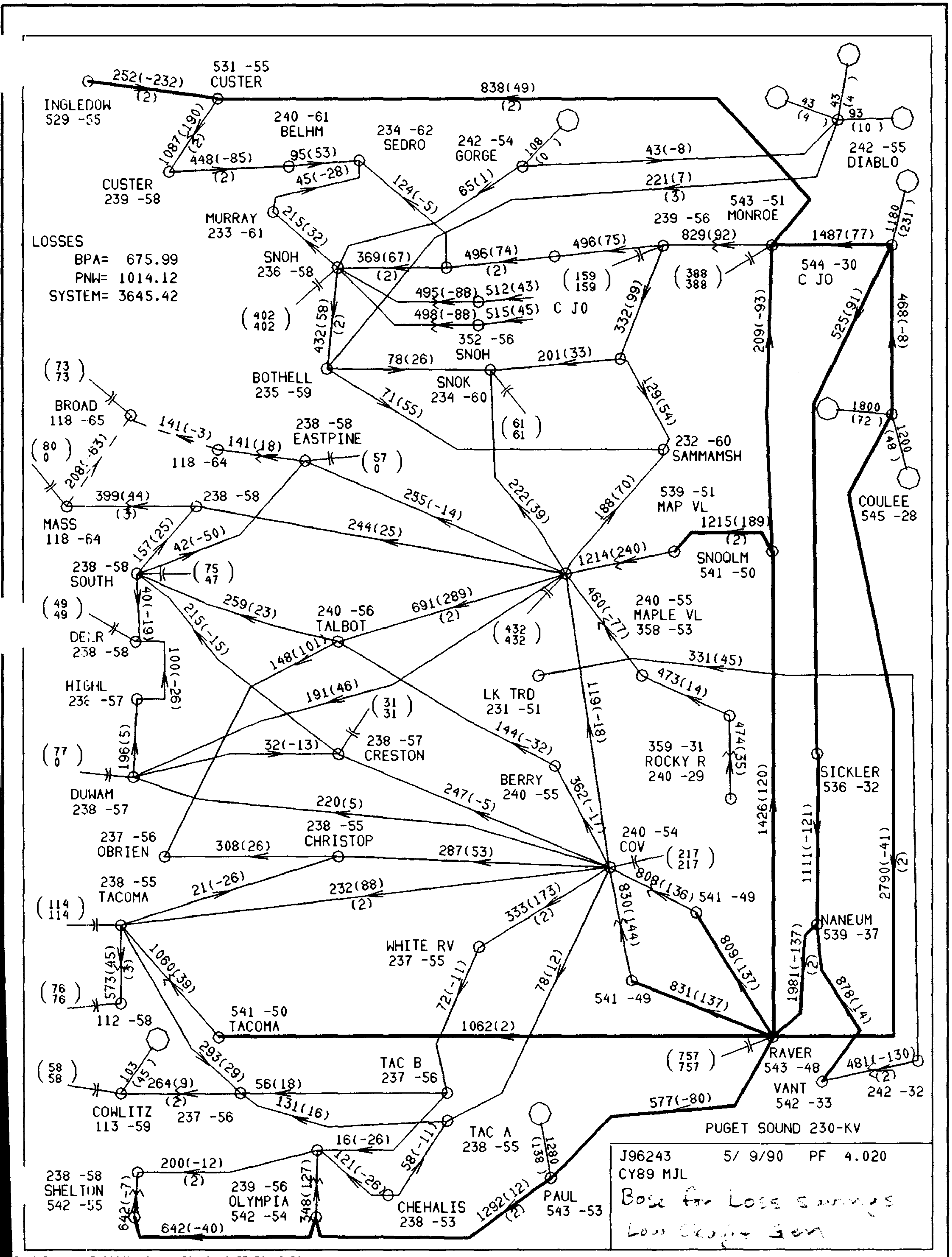
S:PQ R- PLOTTED 5-JUN-90 AT 09:46:02 HOURS



PUGET SOUND 230-KV

J96152 2/ 7/90 PF 4.020
CY89 MJL
BASED ON J96122
SKAGIT GENERATION AT NORMAL LEVELS
SNAKE GENERATION REDUCED

S:PQ R- PLOTTED 5-JUN-90 AT 09:50:20 HOURS



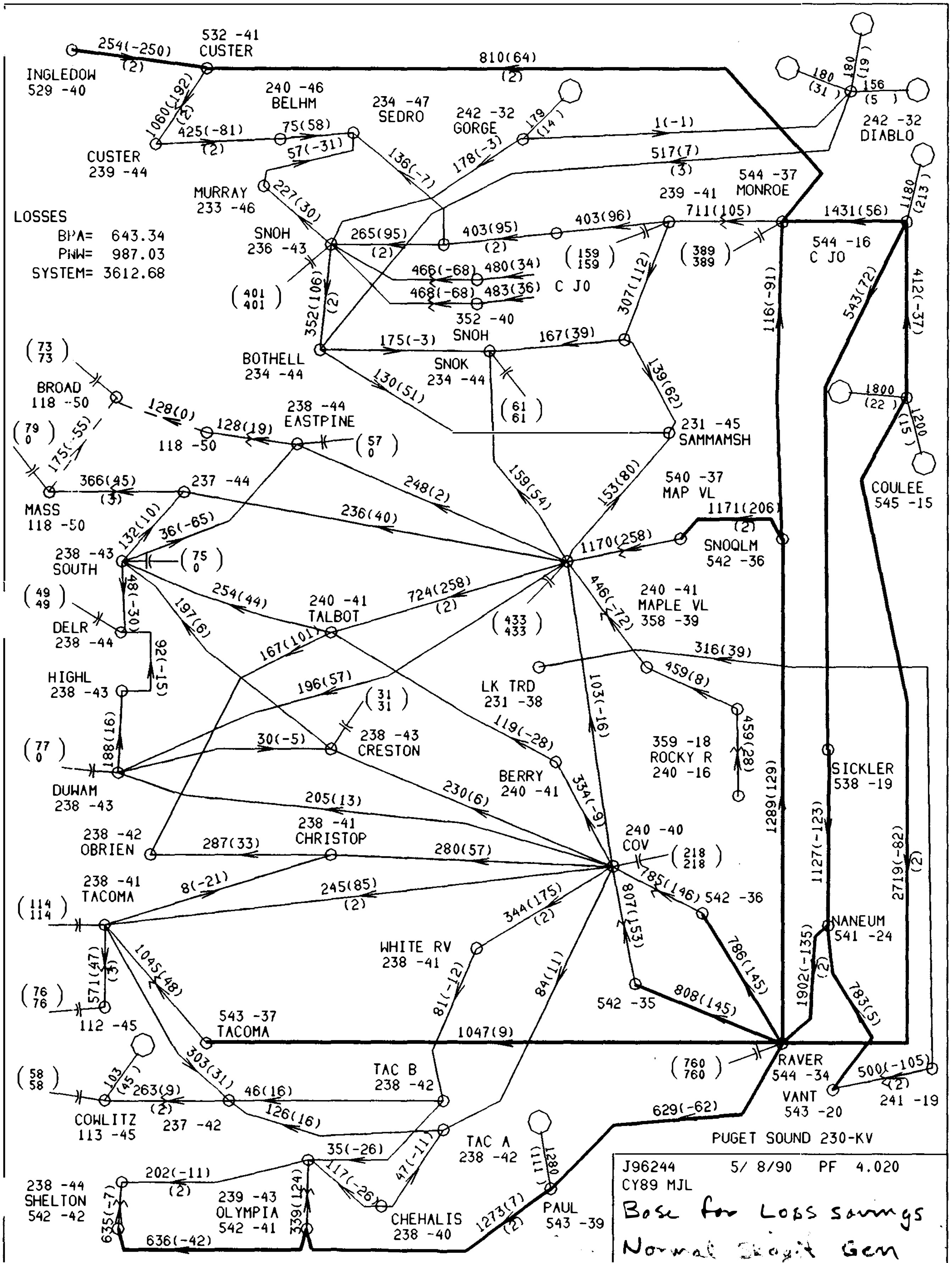
LOSSES
BPA= 675.99
PNW= 1014.12
SYSTEM= 3645.42

PUGET SOUND 230-KV

J96243 5/ 9/90 PF 4.020
CY89 MJL

Base for Loss Savings
Low Gorge Gen

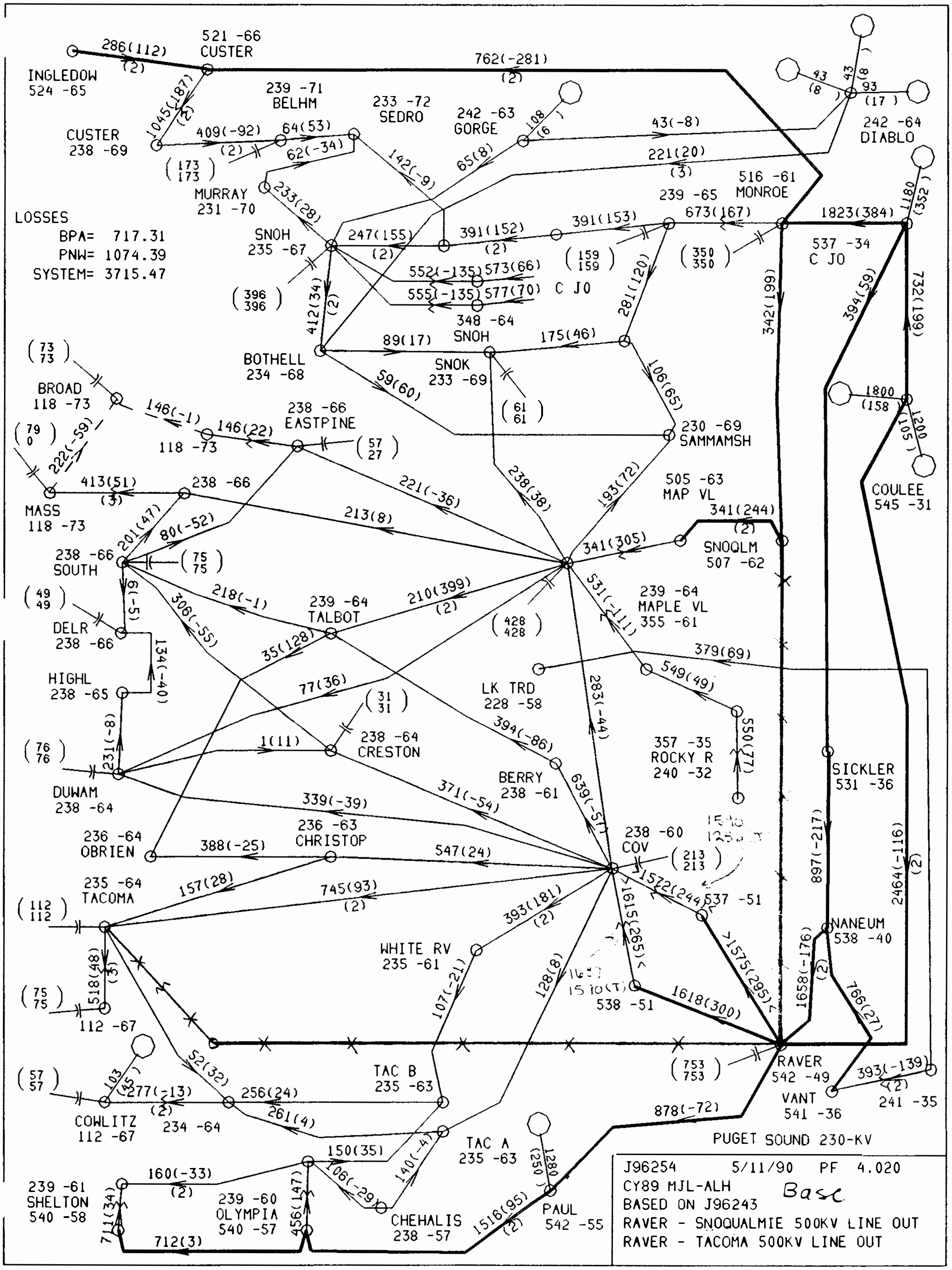
S:PQ R- PLOTTED 9-MAY-90 AT 08:53:30 HOURS



J96244 5/ 8/90 PF 4.020
CY89 MJL

Bose for Loss savings
Normal Skagit Gen

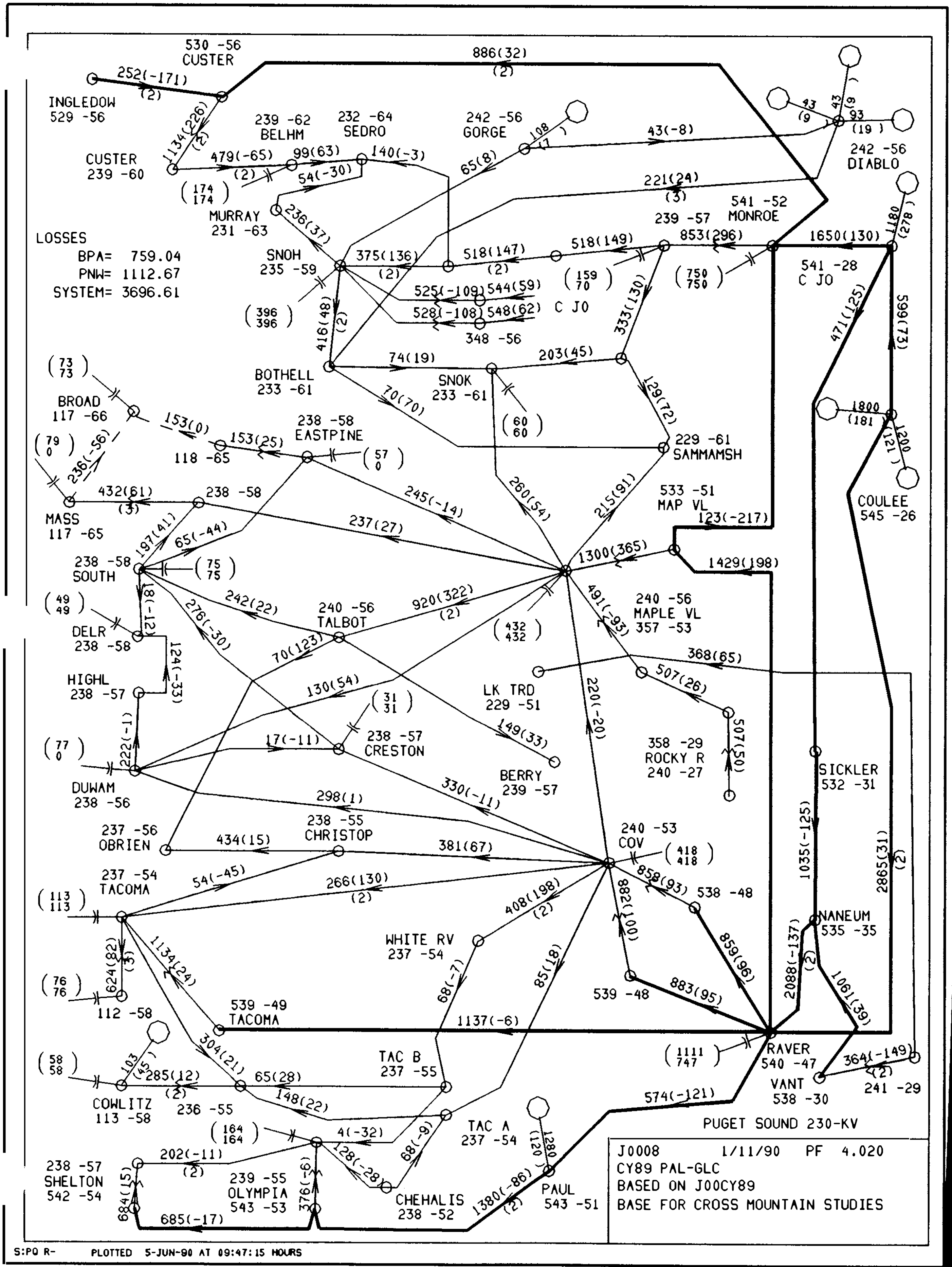
S:PO R- PLOTTED 9-MAY-90 AT 07:45:22 HOURS



PUGET SOUND 230-KV

J96254 5/11/90 PF 4.020
CY89 MJL-ALH *Base*
BASED ON J96243
RAVER - SNOQUALMIE 500KV LINE OUT
RAVER - TACOMA 500KV LINE OUT

S:PQ R- PLOTTED 11-MAY-90 AT 15:15:48 HOURS

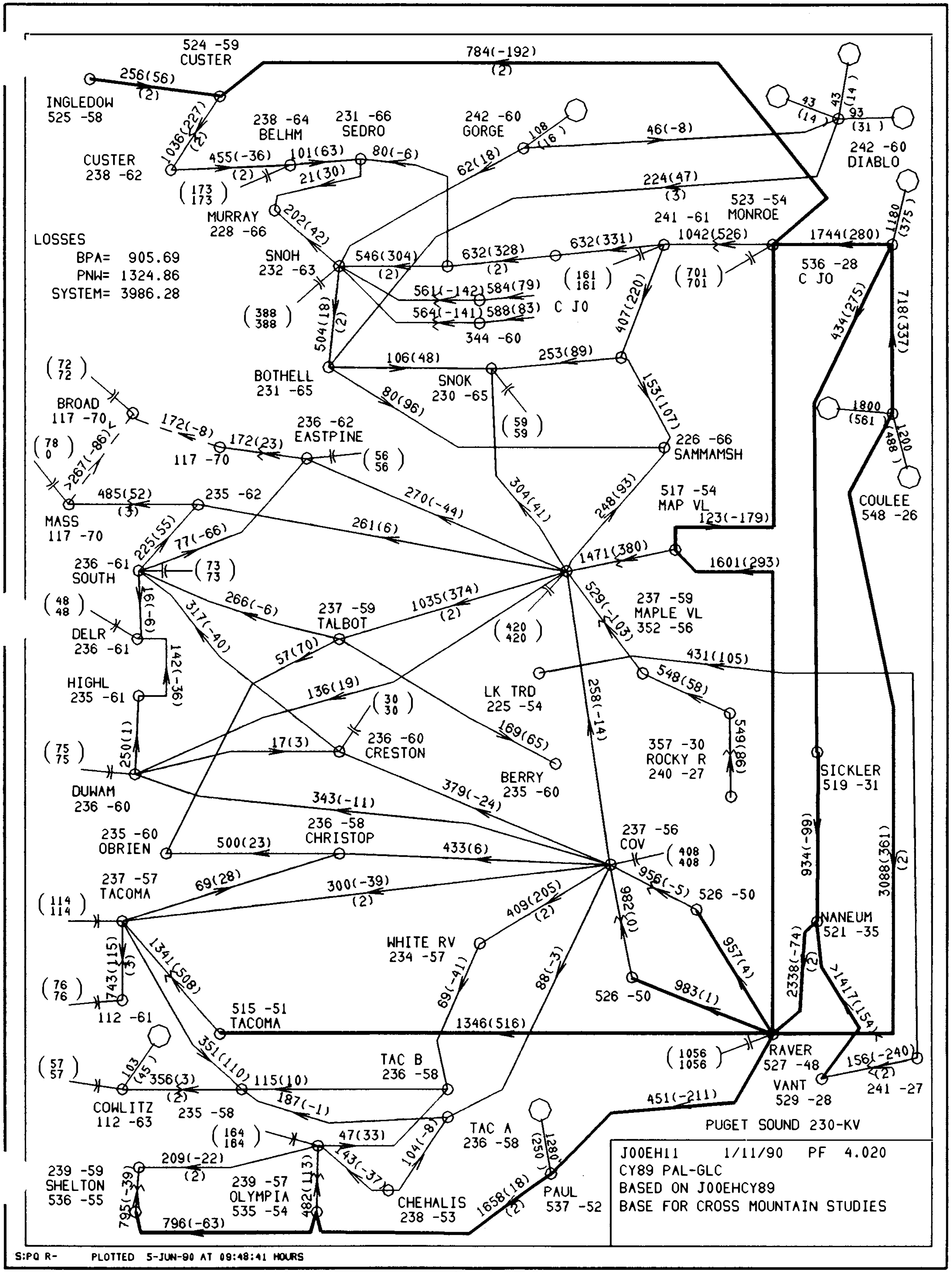


LOSSES
BPA= 759.04
PNW= 1112.67
SYSTEM= 3696.61

PUGET SOUND 230-KV

J0008 1/11/90 PF 4.020
CY89 PAL-GLC
BASED ON J00CY89
BASE FOR CROSS MOUNTAIN STUDIES

S:PO R- PLOTTED 5-JUN-90 AT 09:47:15 HOURS



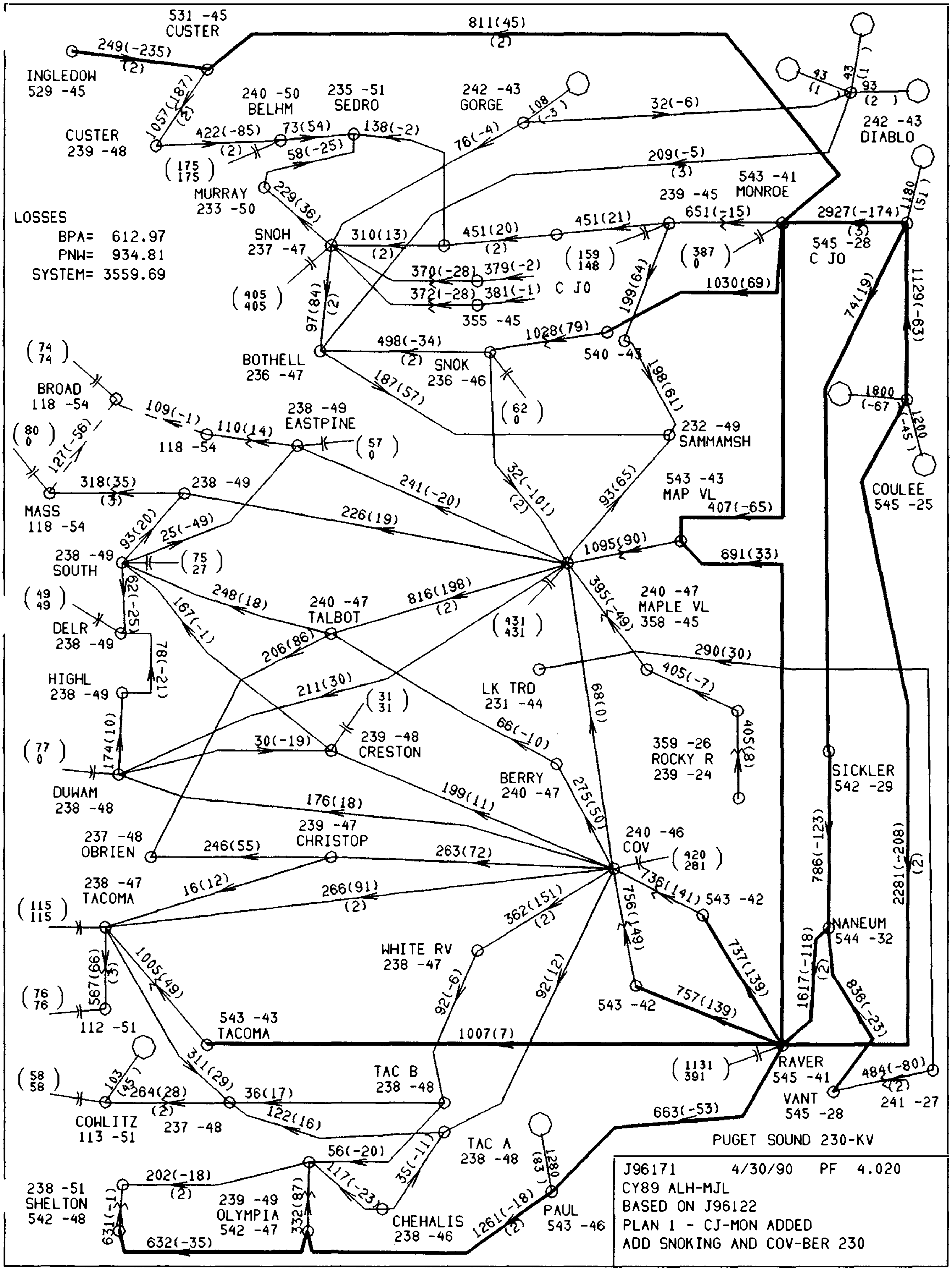
LOSSES
BPA= 905.69
PNW= 1324.86
SYSTEM= 3986.28

PUGET SOUND 230-KV

J00EH11 1/11/90 PF 4.020
CY89 PAL-GLC
BASED ON J00EHCY89
BASE FOR CROSS MOUNTAIN STUDIES

S:PQ R- PLOTTED 5-JUN-90 AT 09:48:41 HOURS

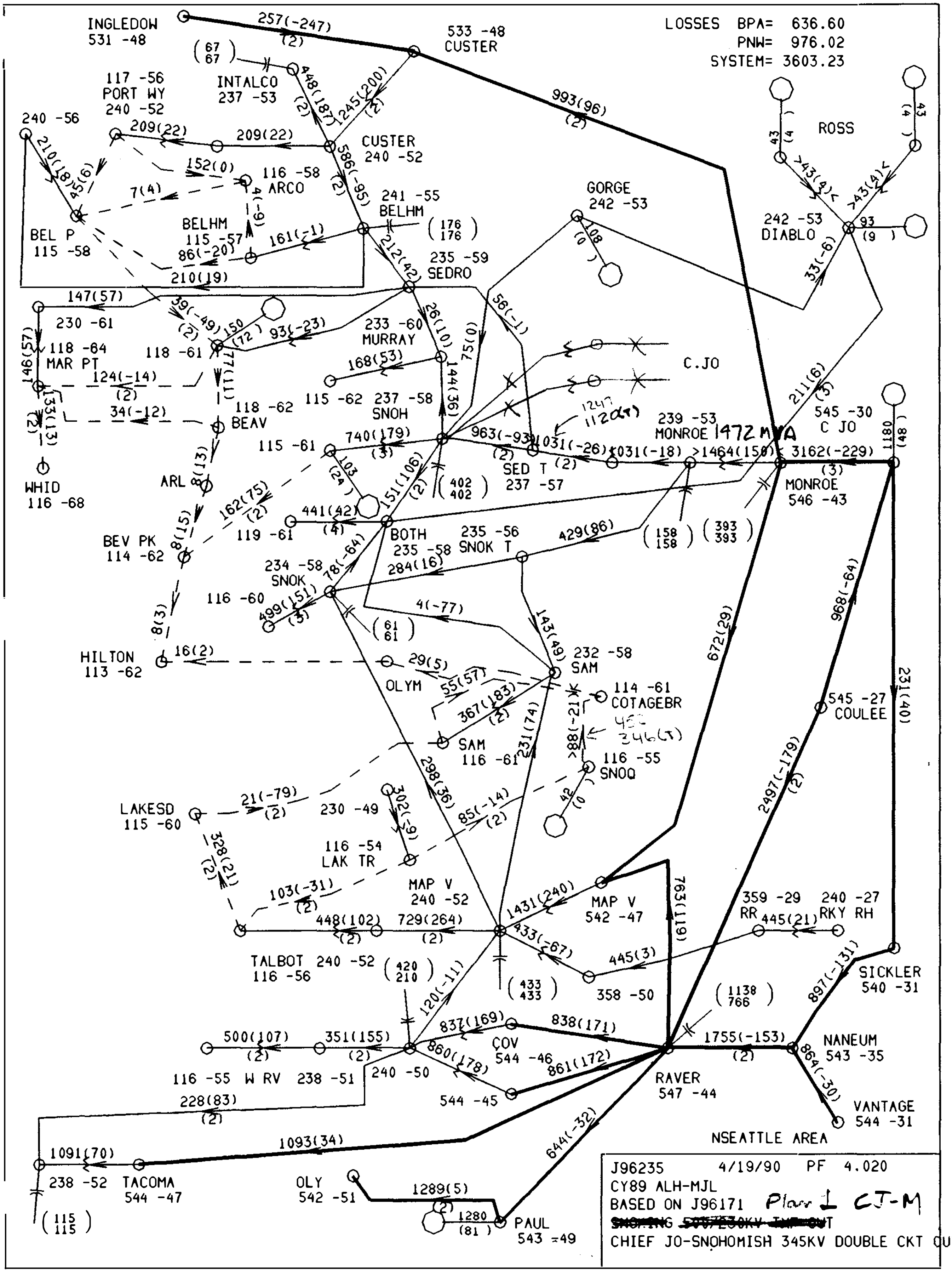
PF - PLAN 1



PUGET SOUND 230-KV

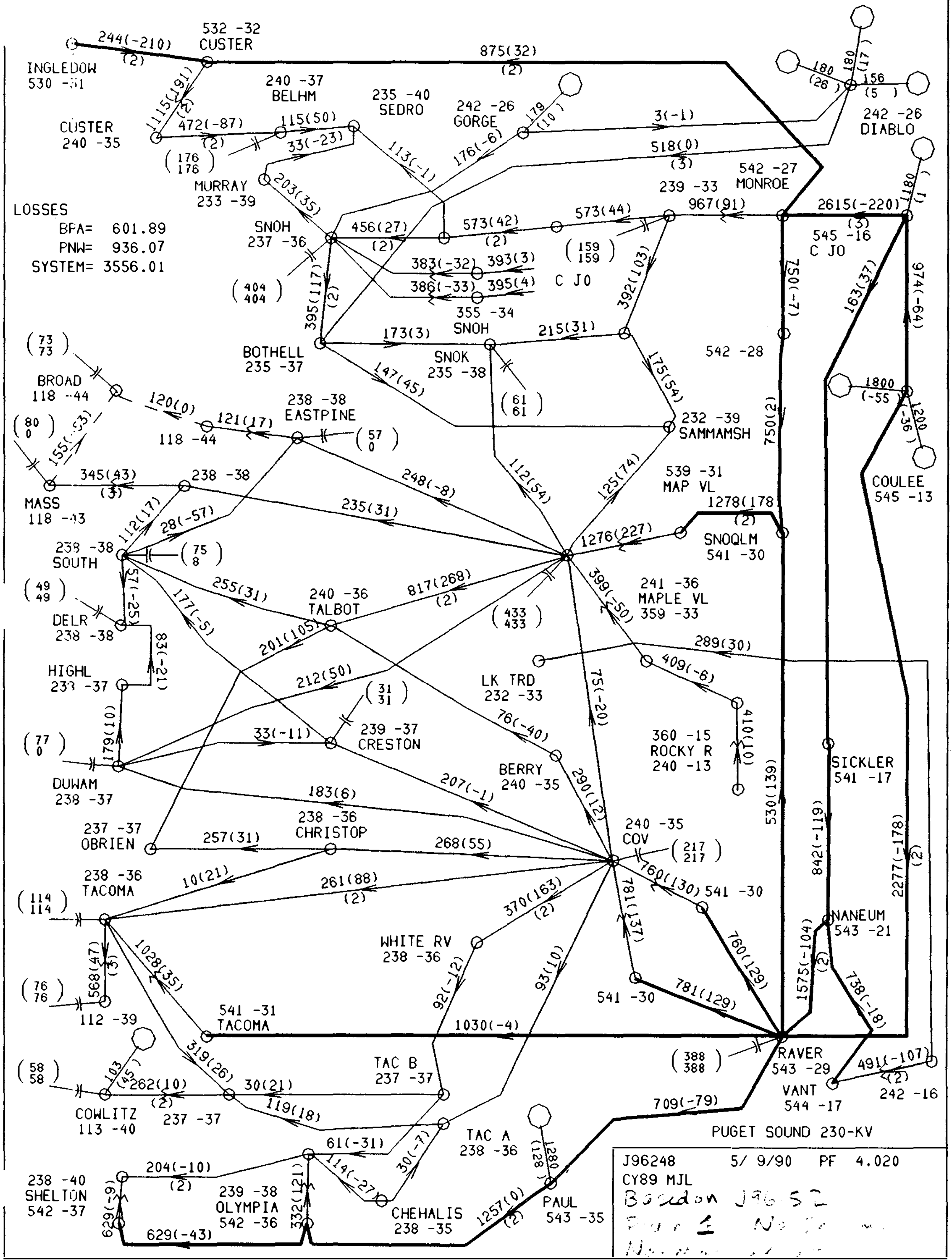
J96171 4/30/90 PF 4.020
CY89 ALH-MJL
BASED ON J96122
PLAN 1 - CJ-MON ADDED
ADD SNOKING AND COV-BER 230

S:PQ R- PLOTTED 5-JUN-90 AT 10:41:38 HOURS



J96235 4/19/90 PF 4.020
CY89 ALH-MJL
BASED ON J96171 Plan 1 CJ-M
~~SHOWING 500/230KV IMP OUT~~
CHIEF JO-SNOHOMISH 345KV DOUBLE CKT OUT

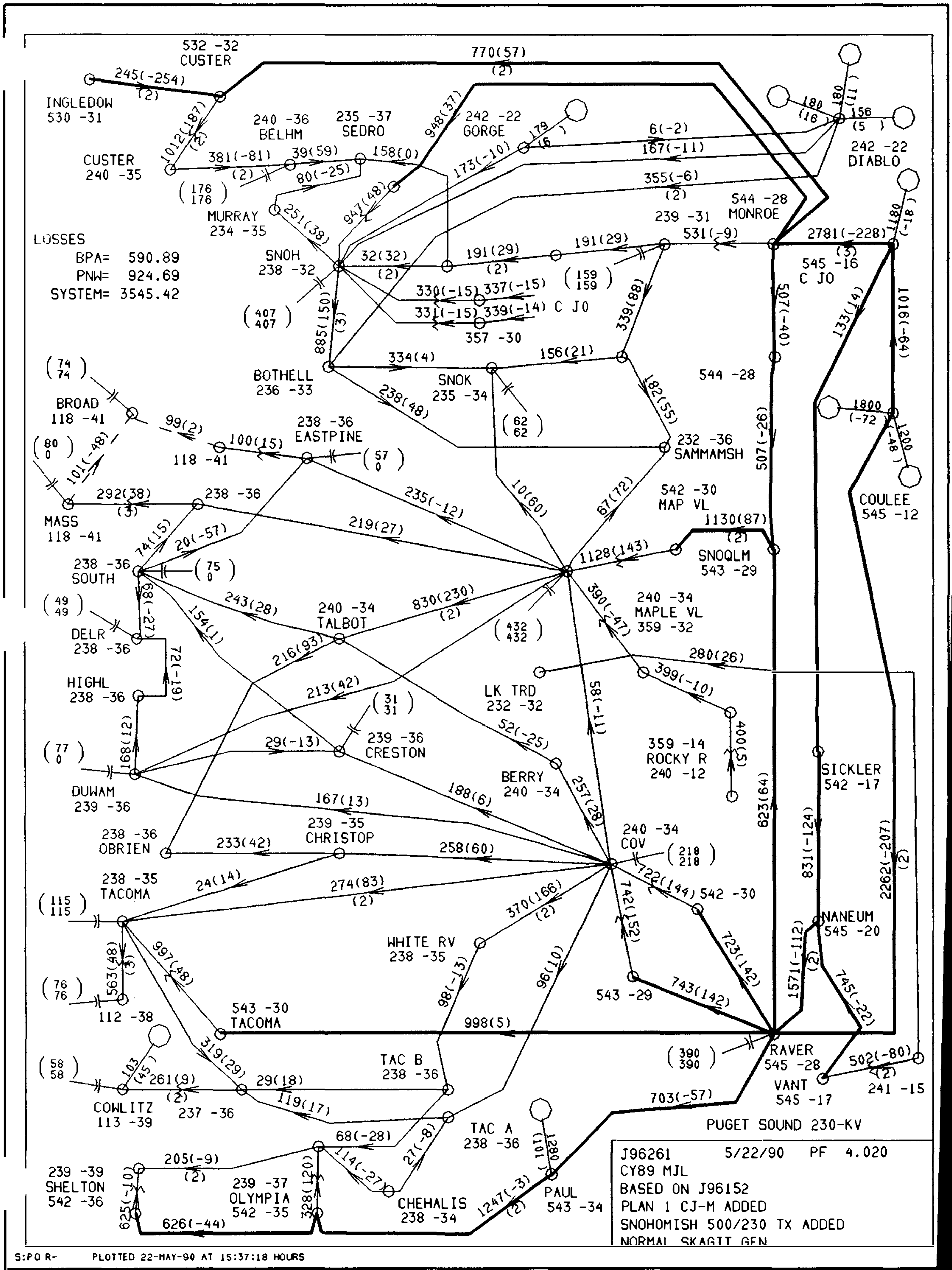
S:PQ R- PLOTTED 19-APR-90 AT 14:57:32 HOURS



PUGET SOUND 230-KV

J96248 5/ 9/90 PF 4.020
CY89 MJL
Bsedon J96 52
[illegible] 4 N [illegible]
[illegible]

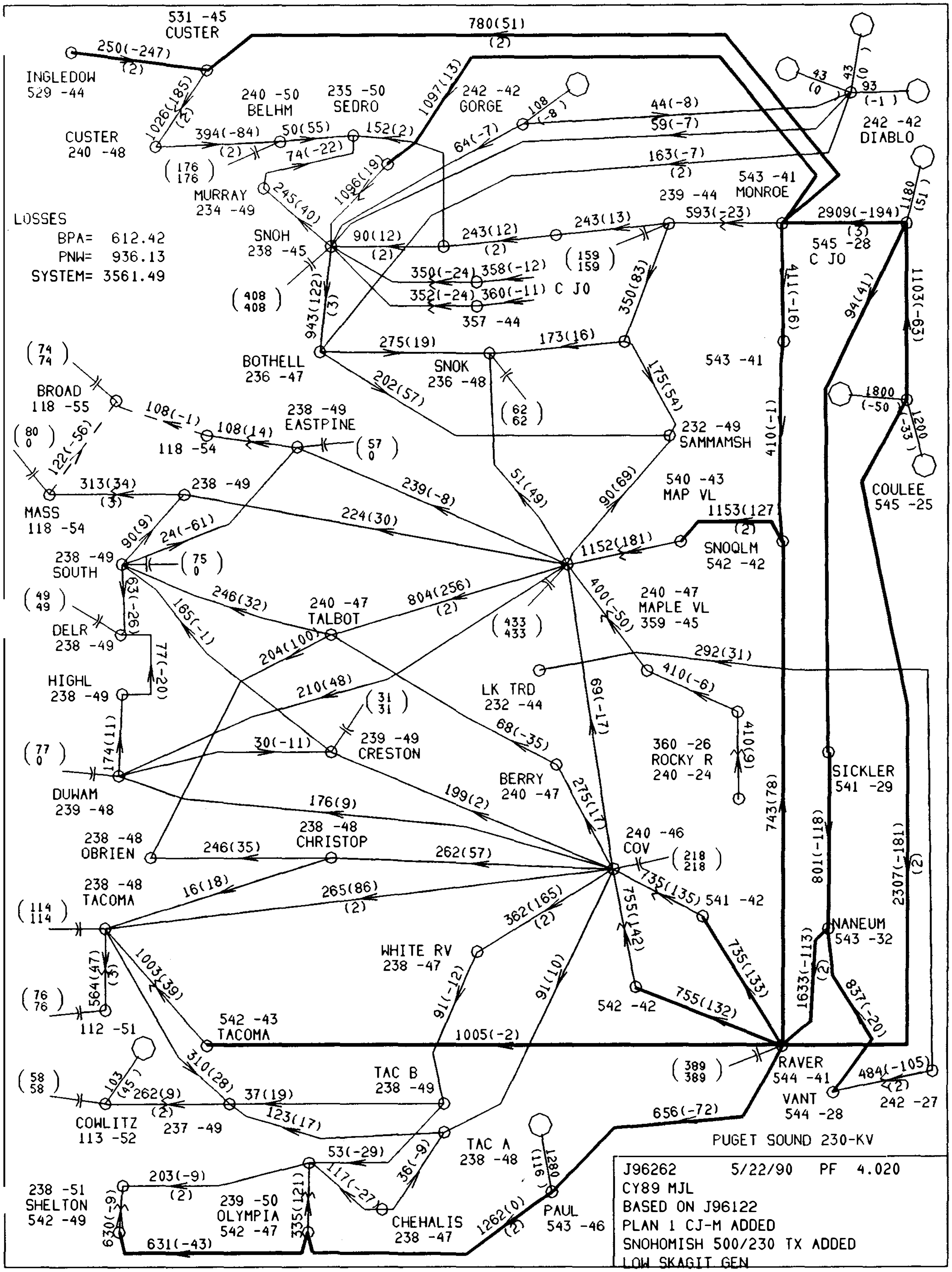
S:PQ R- PLOTTED 9-MAY-90 AT 12:40:07 HOURS



LOSSES
BPA= 590.89
PNW= 924.69
SYSTEM= 3545.42

J96261 5/22/90 PF 4.020
CY89 MJL
BASED ON J96152
PLAN 1 CJ-M ADDED
SNOHOMISH 500/230 TX ADDED
NORMAL SKAGIT GEN

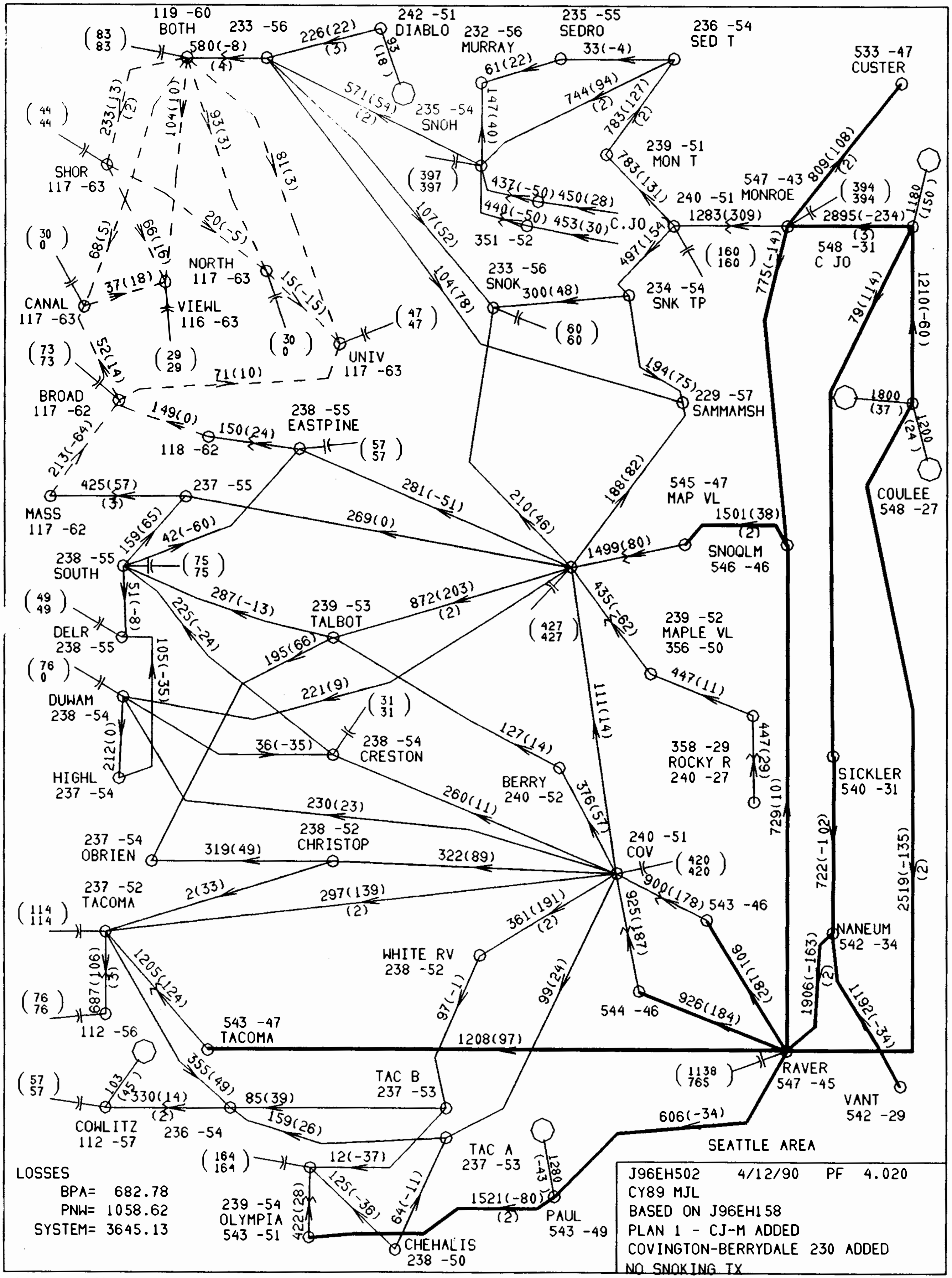
S:PQ R- PLOTTED 22-MAY-90 AT 15:37:18 HOURS



LOSSES
BPA= 612.42
PNW= 936.13
SYSTEM= 3561.49

J96262 5/22/90 PF 4.020
CY89 MJL
BASED ON J96122
PLAN 1 CJ-M ADDED
SNOHOMISH 500/230 TX ADDED
LOW SKAGIT GEN

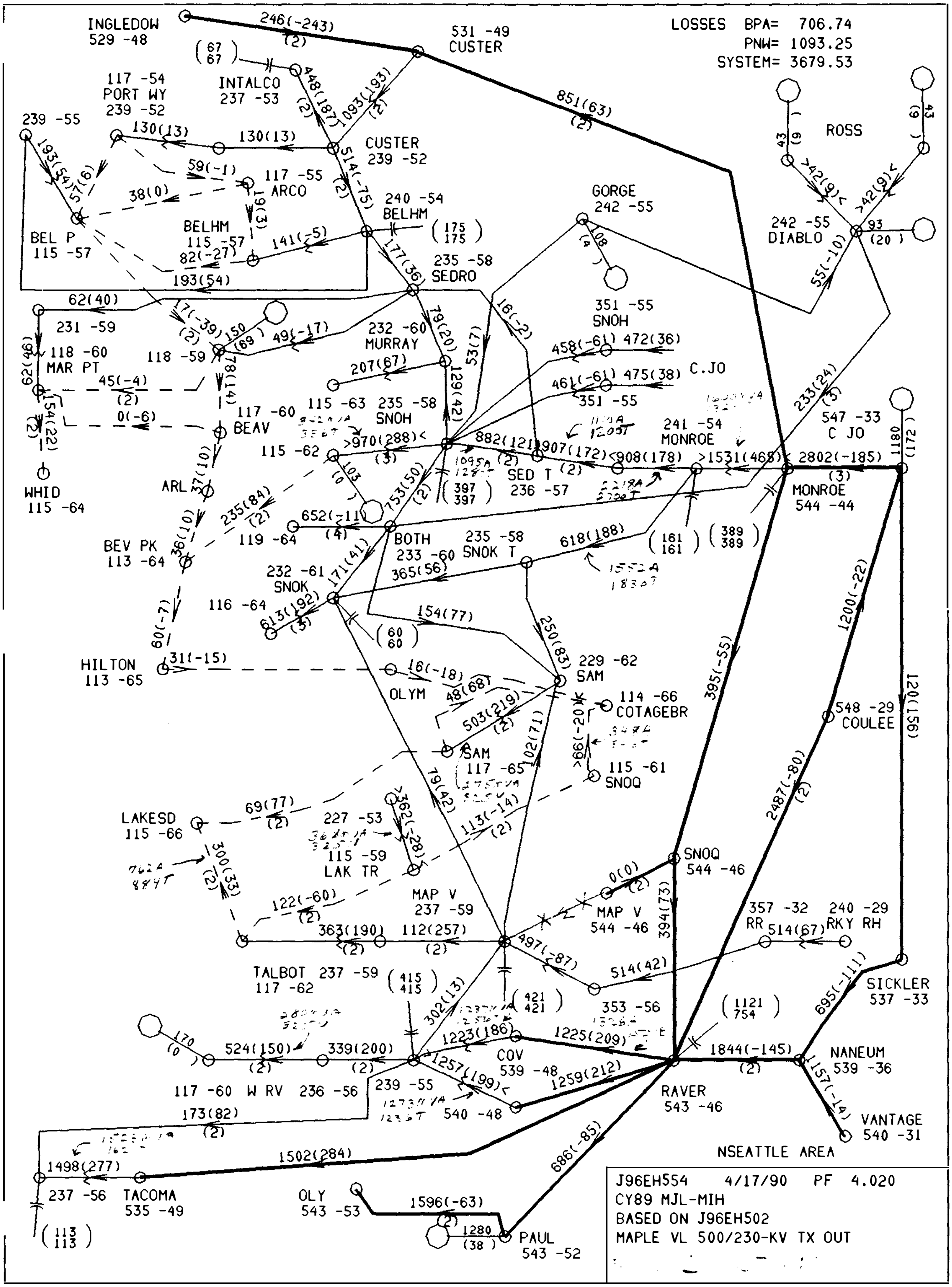
S:PQ R- PLOTTED 22-MAY-90 AT 15:40:41 HOURS



LOSSES
BPA= 682.78
PNW= 1058.62
SYSTEM= 3645.13

J96EH502 4/12/90 PF 4.020
CY89 MJL
BASED ON J96EH158
PLAN 1 - CJ-M ADDED
COVINGTON-BERRYDALE 230 ADDED
NO SNOKING TX

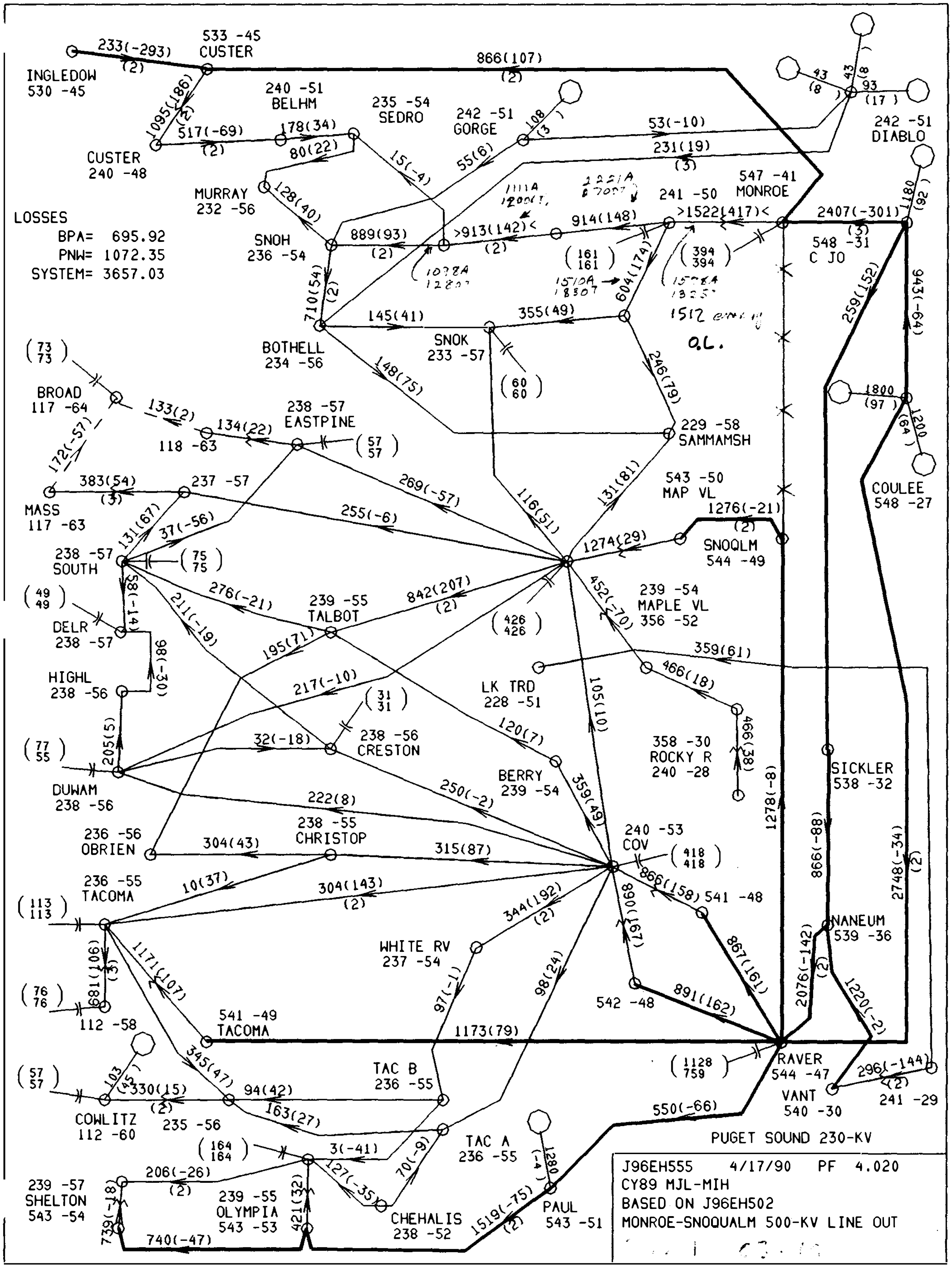
S:PQ R- PLOTTED 13-APR-90 AT 08:31:40 HOURS



LOSSES BPA= 706.74
PNW= 1093.25
SYSTEM= 3679.53

J96EH554 4/17/90 PF 4.020
CY89 MJL-MIH
BASED ON J96EH502
MAPLE VL 500/230-KV TX OUT

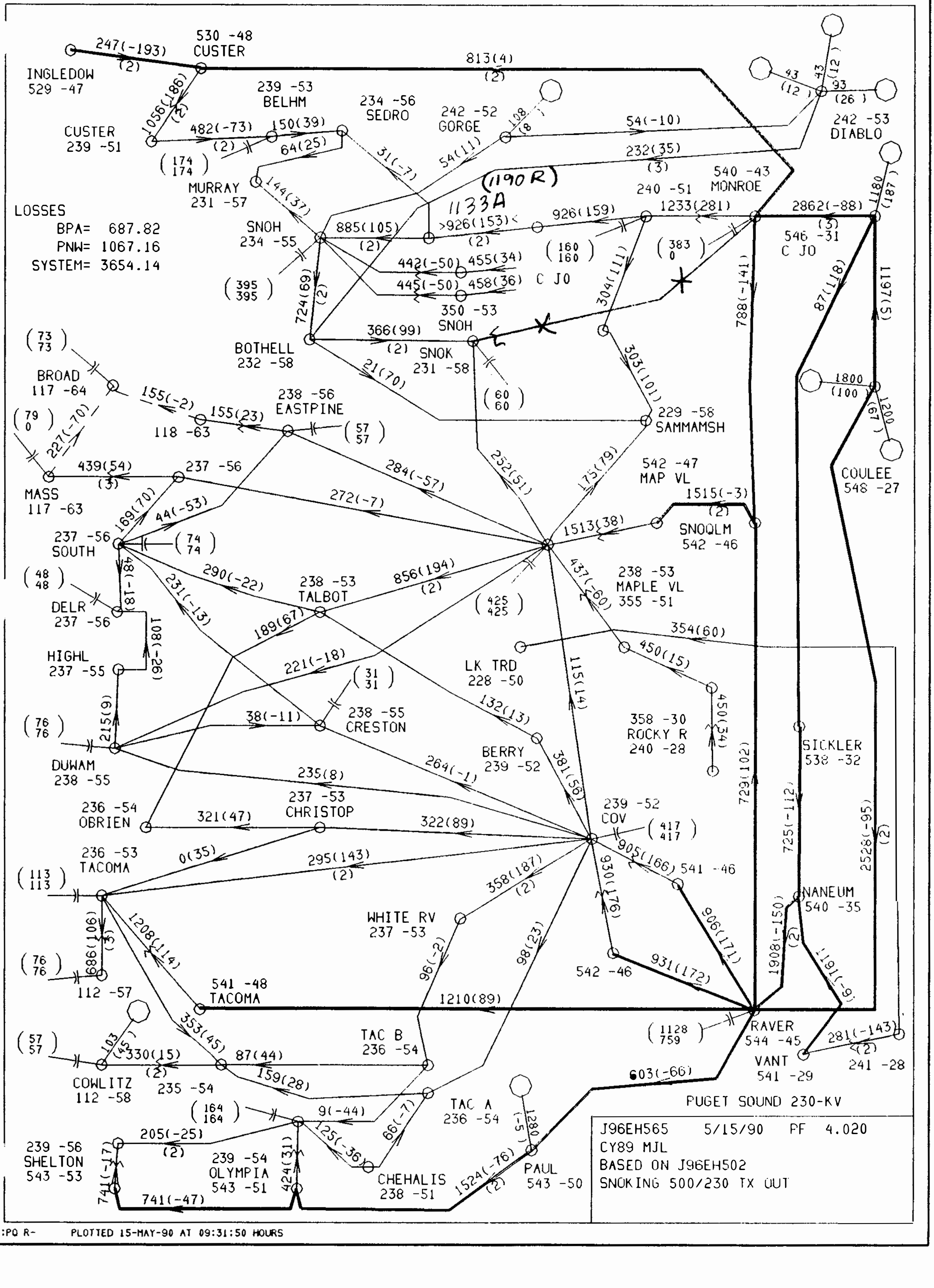
S:PQ R- PLOTTED 17-APR-90 AT 15:37:04 HOURS



PUGET SOUND 230-KV

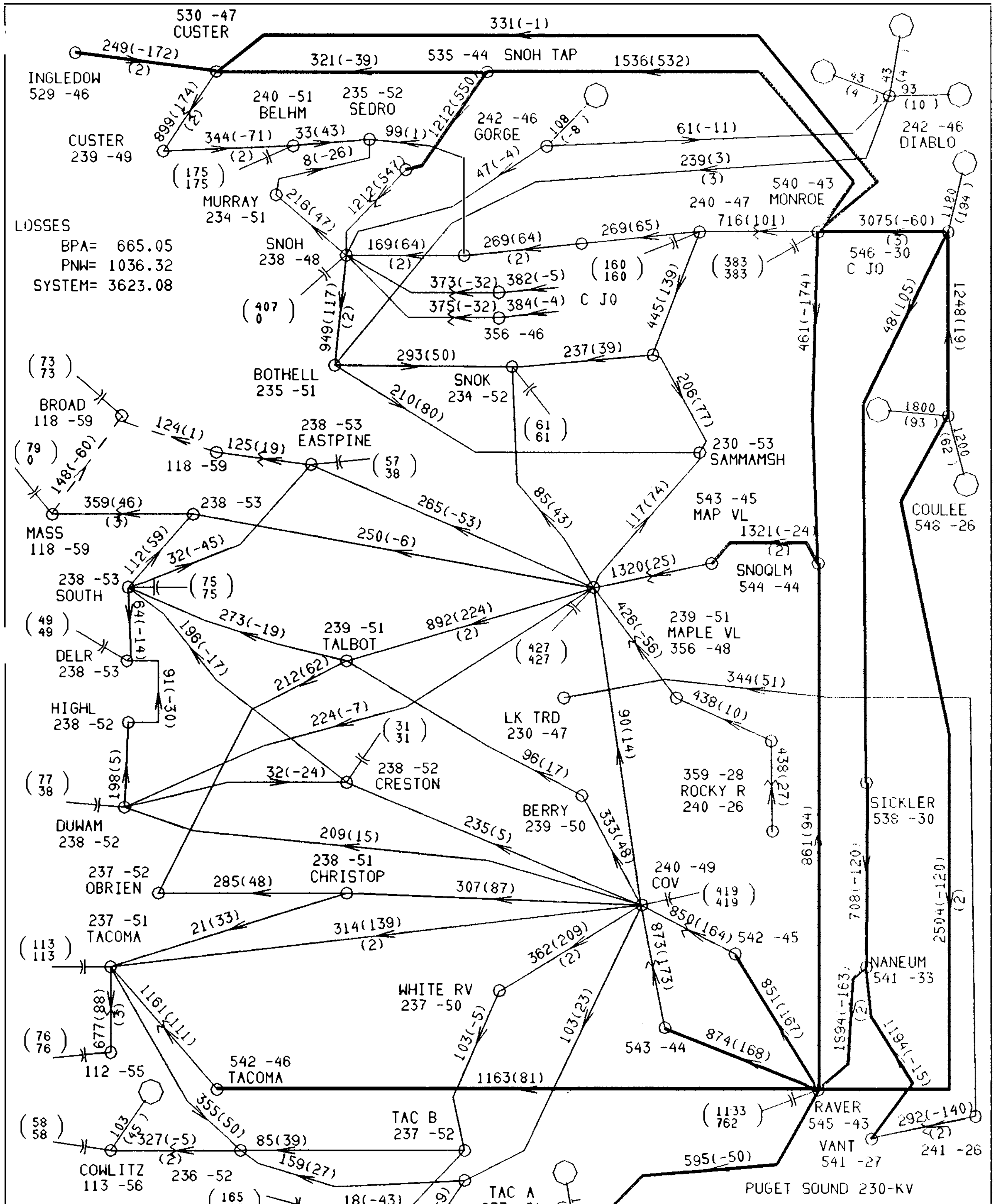
J96EH555 4/17/90 PF 4.020
CY89 MJL-MIH
BASED ON J96EH502
MONROE-SNOQUALM 500-KV LINE OUT

S:PQ R- PLOTTED 17-APR-90 AT 15:47:45 HOURS



J96EH565 5/15/90 PF 4.020
CY89 MJL
BASED ON J96EH502
SNOKING 500/230 TX OUT

S:PO R- PLOTTED 15-MAY-90 AT 09:31:50 HOURS

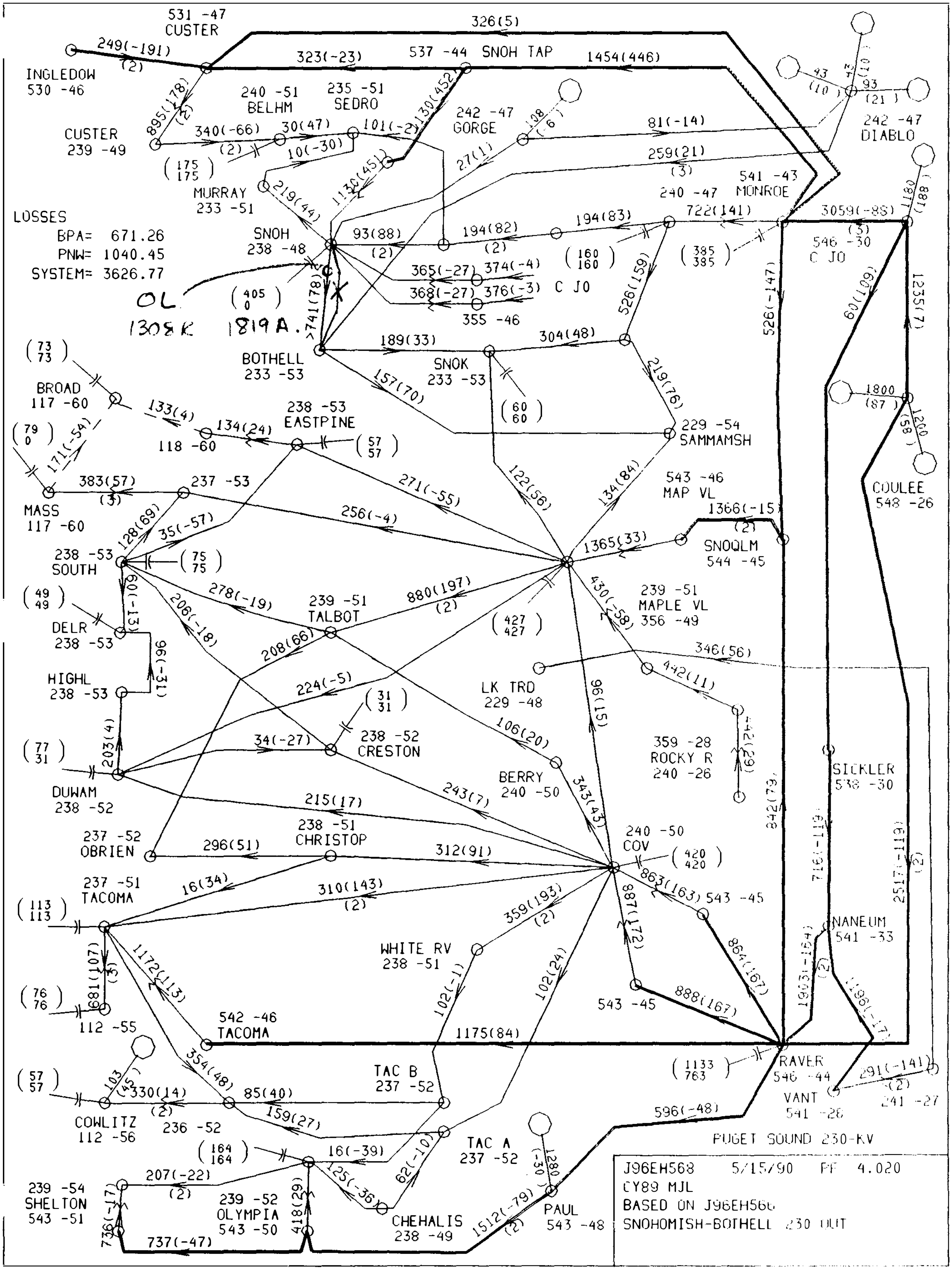


PUGET SOUND 230-KV

J96EH566 5/15/90 PF 4.020
CY89 MJL
MIH [illegible]
[illegible]
[illegible]

[illegible]

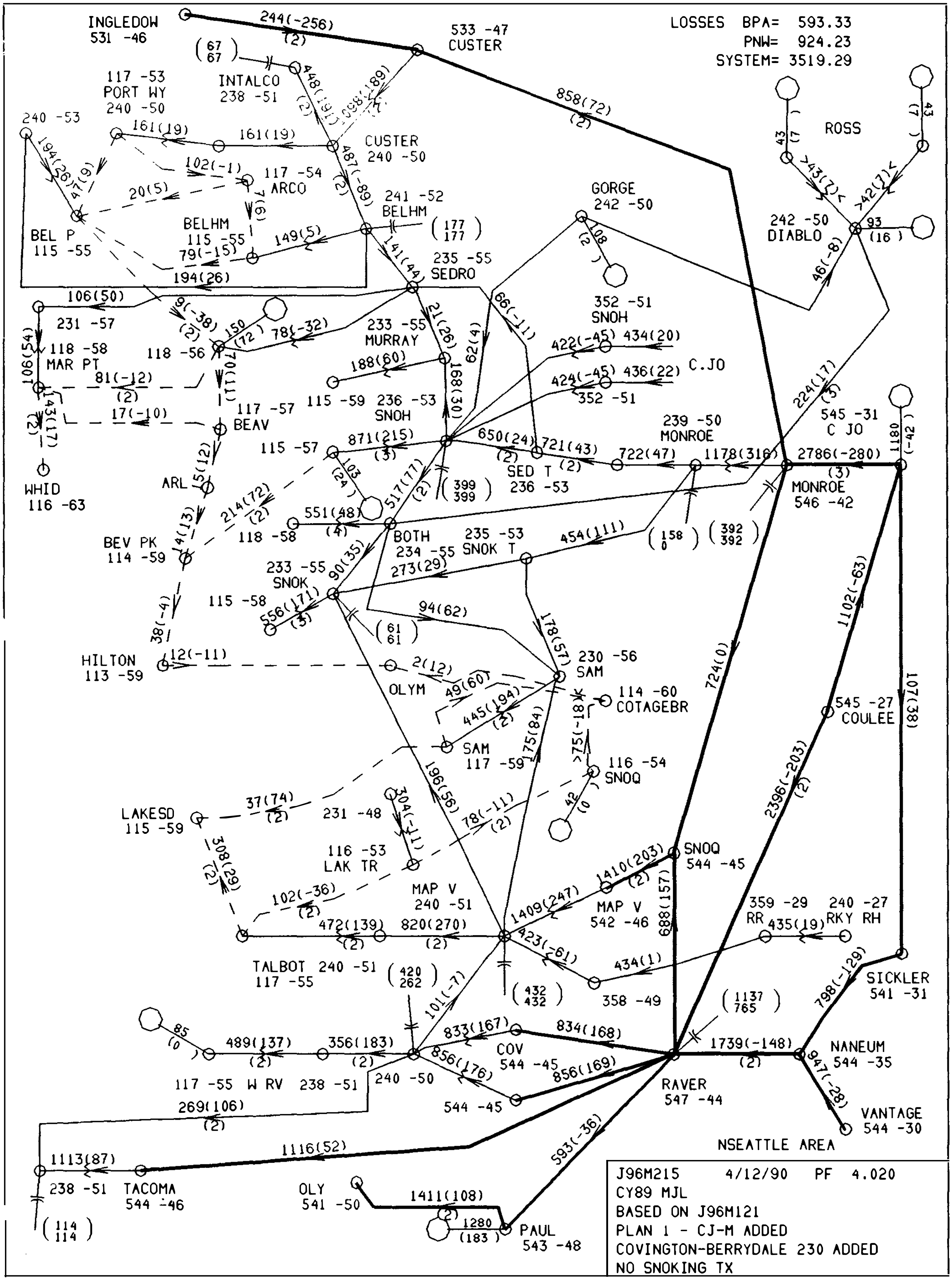
S:PQ R- PLOTTED 15-MAY-90 AT 14:46:48 HOURS



PUGET SOUND 230-KV

J96EH568 5/15/90 PF 4.020
CY89 MJL
BASED ON J96EH566
SNOHOMISH-BOTHELL 230 OUT

S:PQ R- PLOTTED 15-MAY-90 AT 15:09:25 HOURS

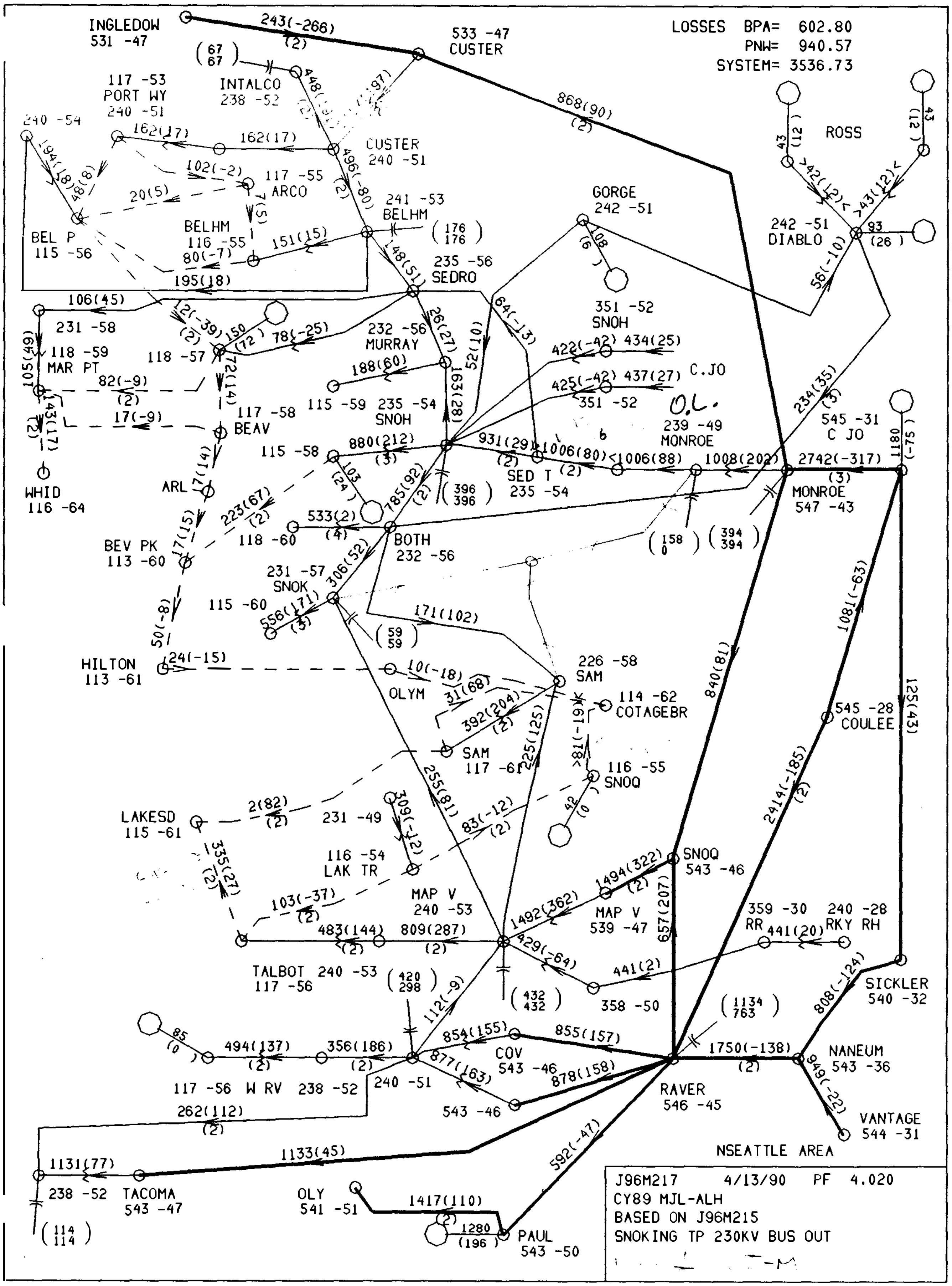


LOSSES BPA= 593.33
PNW= 924.23
SYSTEM= 3519.29

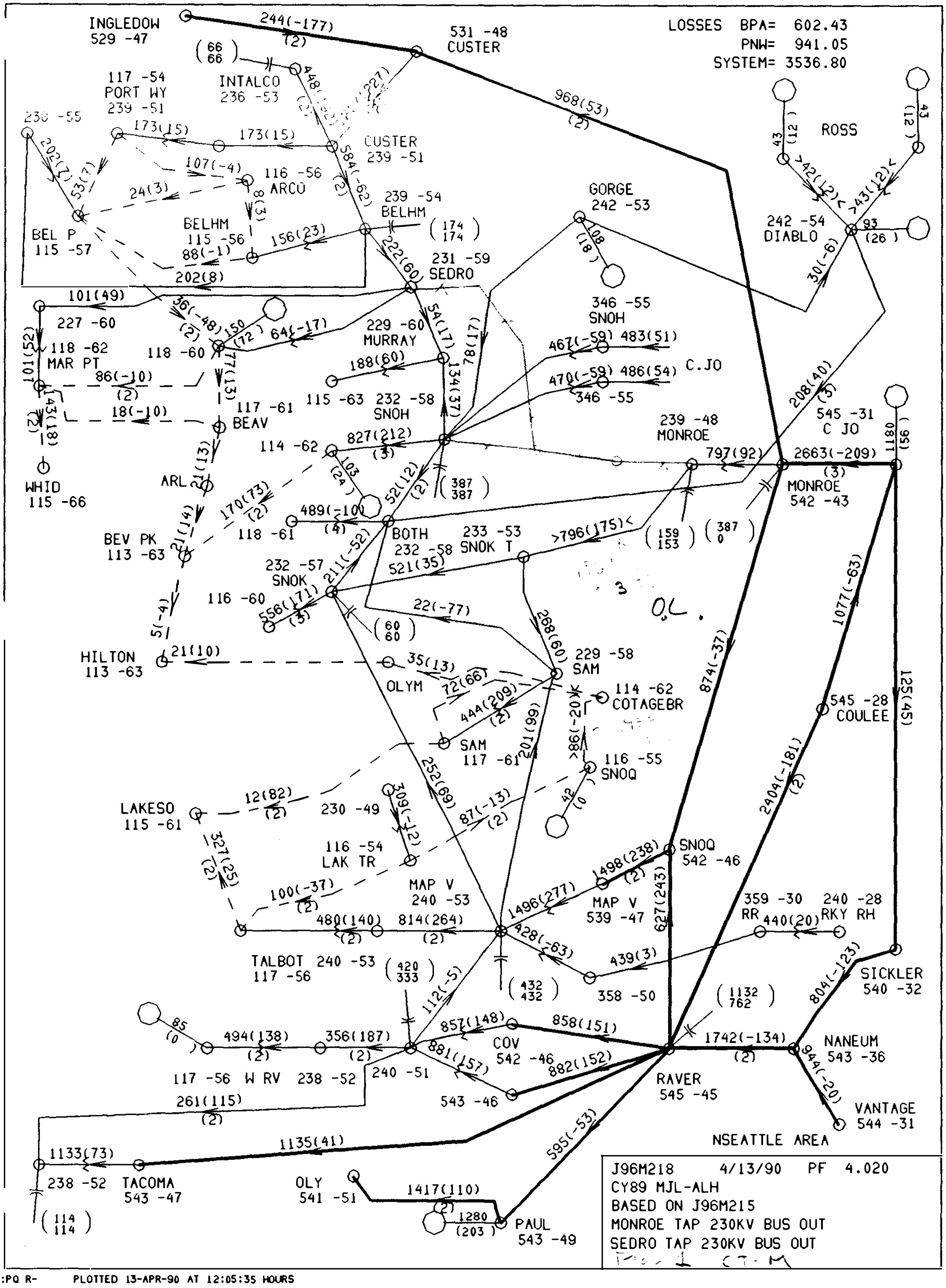
J96M215 4/12/90 PF 4.020
CY89 MJL
BASED ON J96M121
PLAN 1 - CJ-M ADDED
COVINGTON-BERRYDALE 230 ADDED
NO SNOKING TX

S:PQ R- PLOTTED 13-APR-90 AT 08:40:39 HOURS

Low Skagit Gen



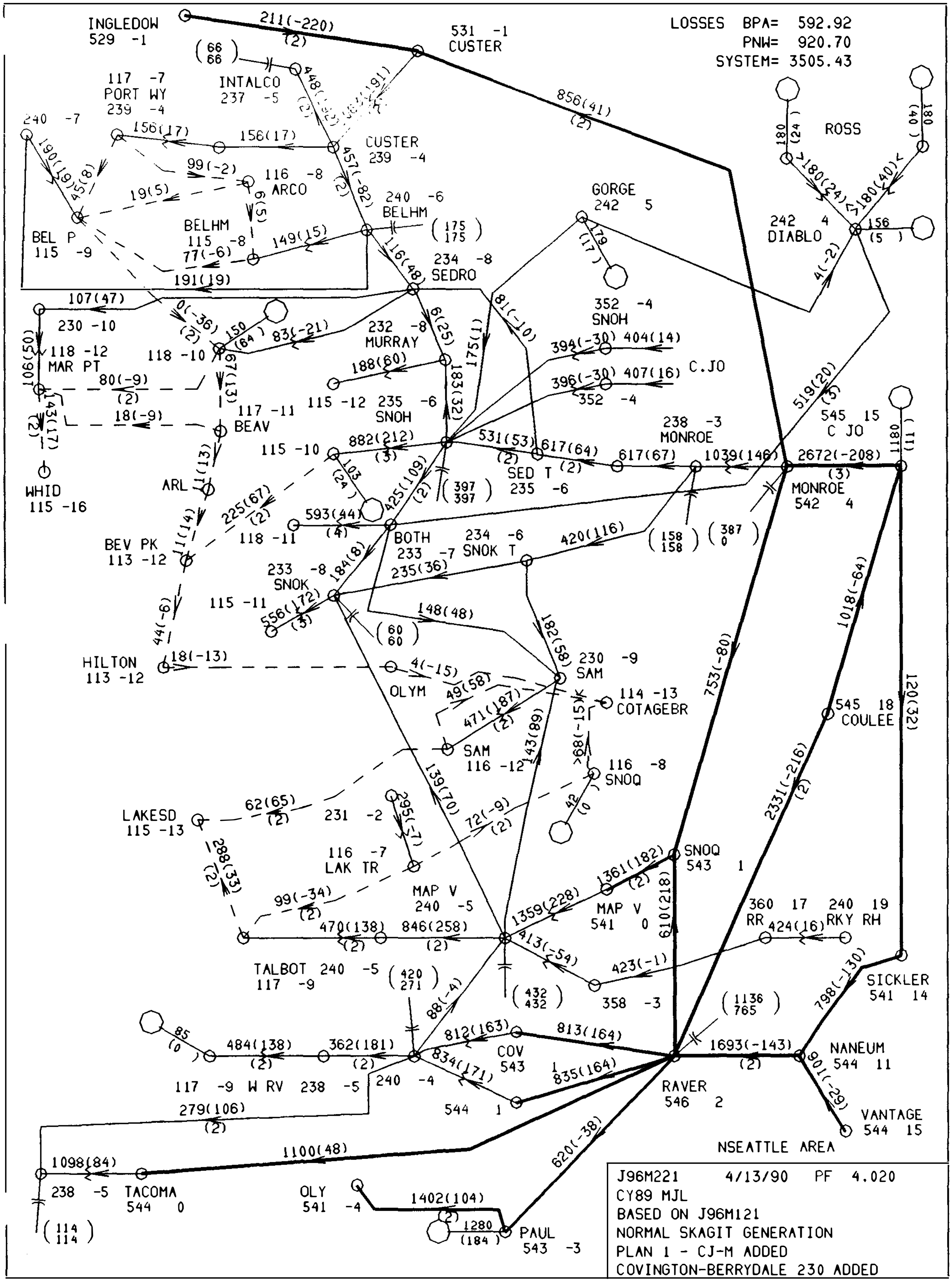
S:PQ R- PLOTTED 13-APR-90 AT 12:01:45 HOURS



J96M218 4/13/90 PF 4.020
CY89 MJL-ALH
BASED ON J96M215
MONROE TAP 230KV BUS OUT
SEDRO TAP 230KV BUS OUT
Fig. 1 CT-M

S:PQ R- PLOTTED 13-APR-90 AT 12:05:35 HOURS

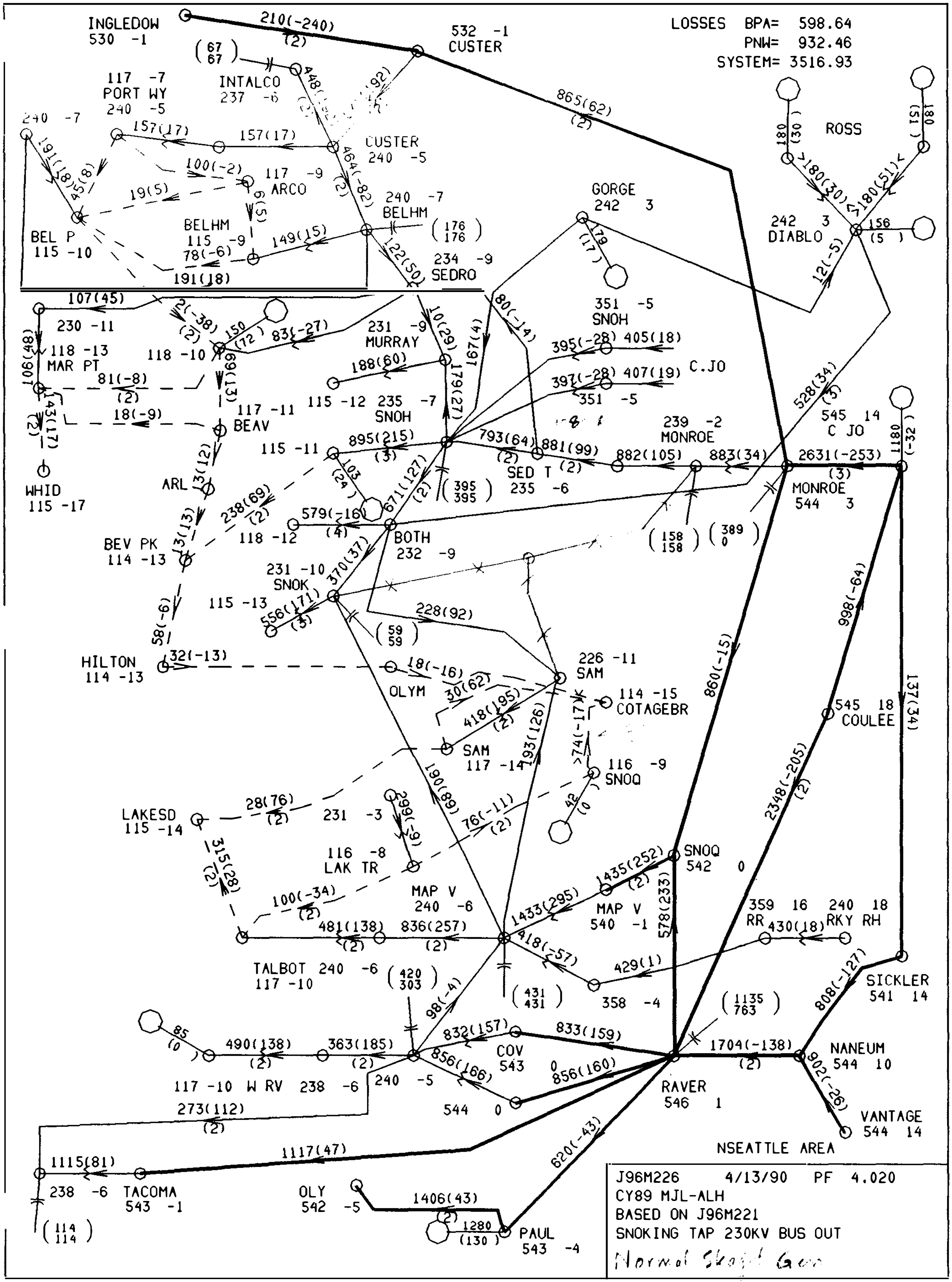
LOSSES BPA= 592.92
PNW= 920.70
SYSTEM= 3505.43



NSEATTLE AREA

J96M221 4/13/90 PF 4.020
CY89 MJL
BASED ON J96M121
NORMAL SKAGIT GENERATION
PLAN 1 - CJ-M ADDED
COVINGTON-BERRYDALE 230 ADDED
NO SNOKING TX

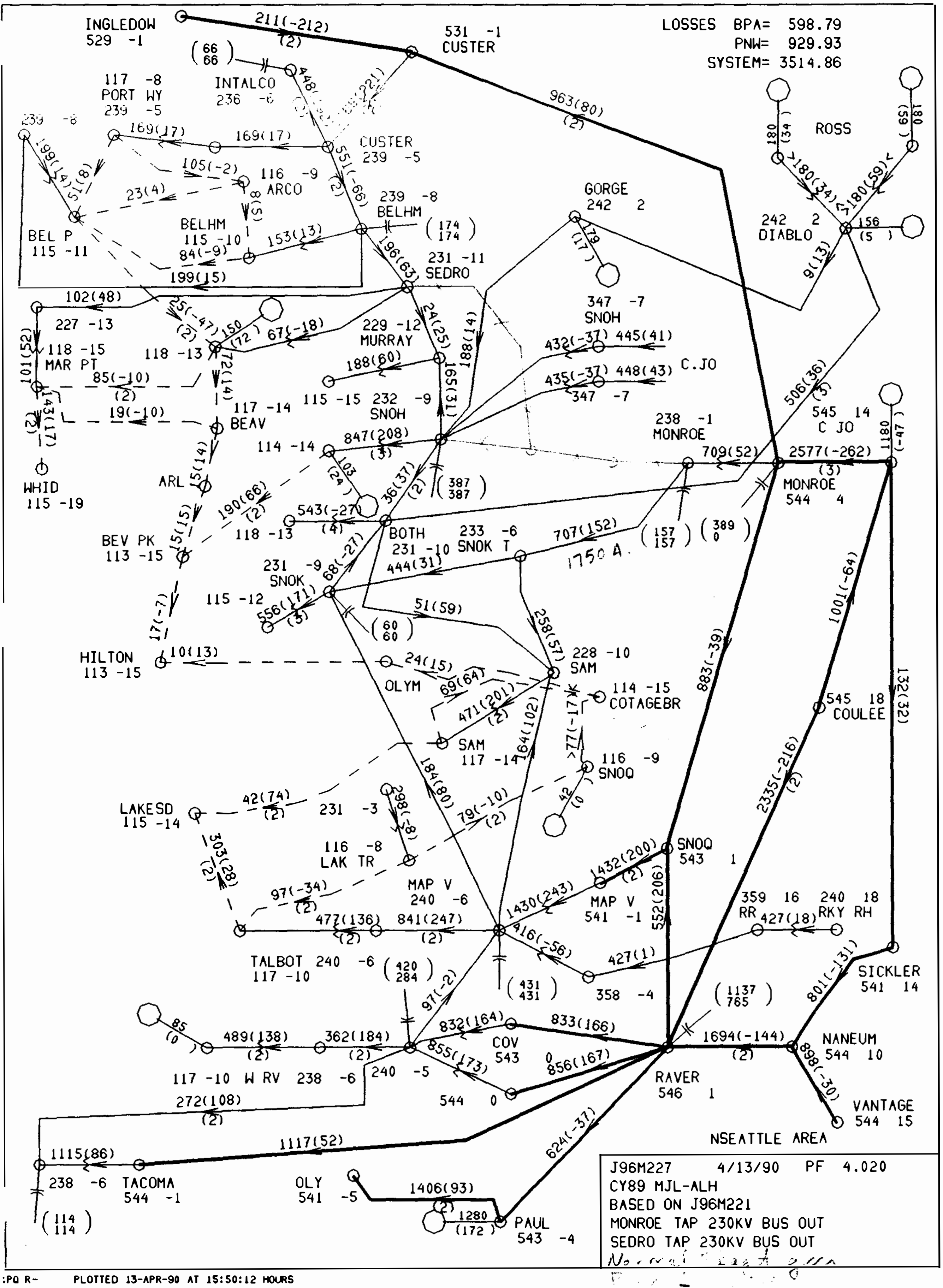
S:PQ R- PLOTTED 13-APR-90 AT 10:55:54 HOURS



J96M226 4/13/90 PF 4.020
CY89 MJL-ALH
BASED ON J96M221
SNOKING TAP 230KV BUS OUT
Normal Skagit Gen

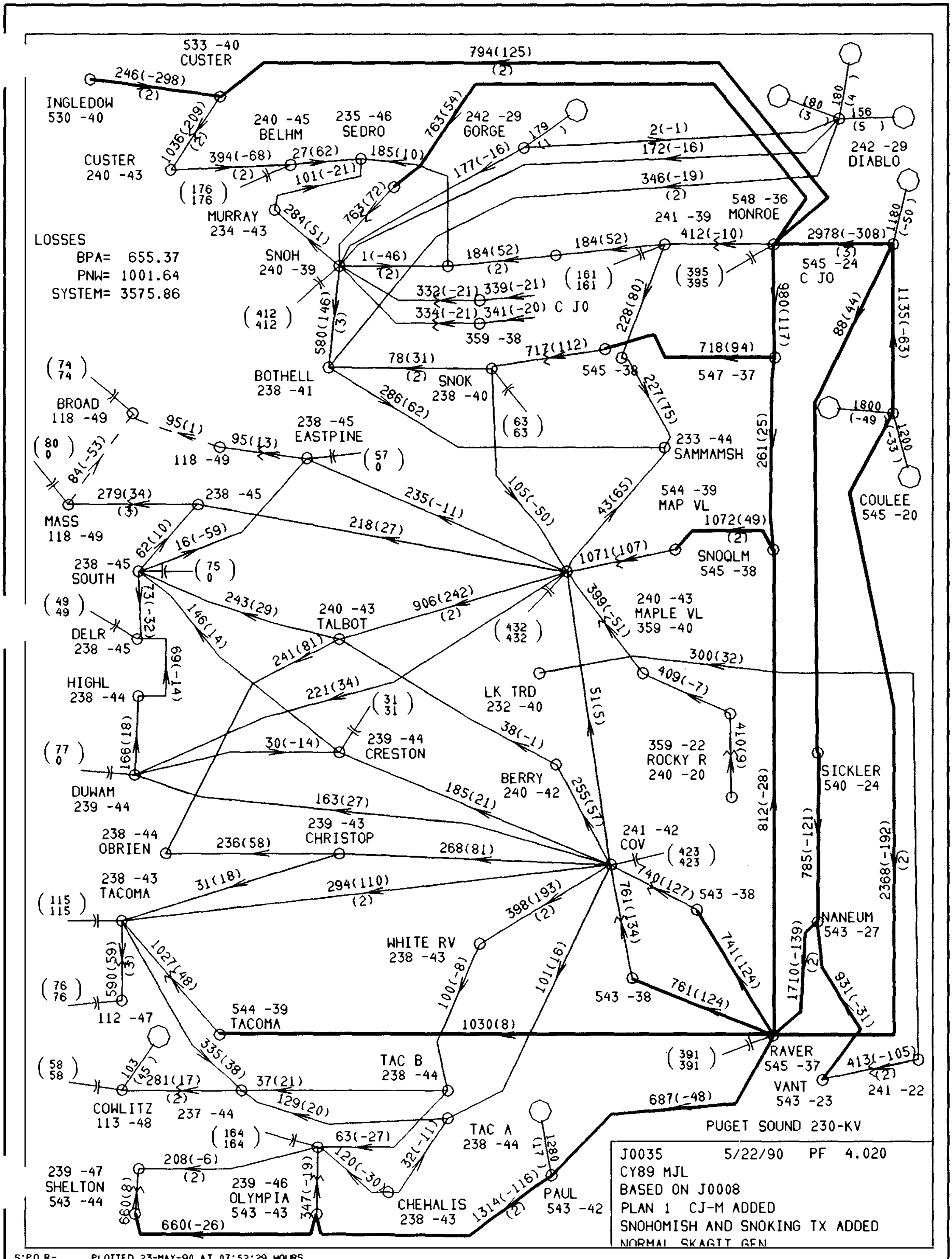
Plan 1 CJ-M

S:PQ R- PLOTTED 13-APR-90 AT 15:48:38 HOURS



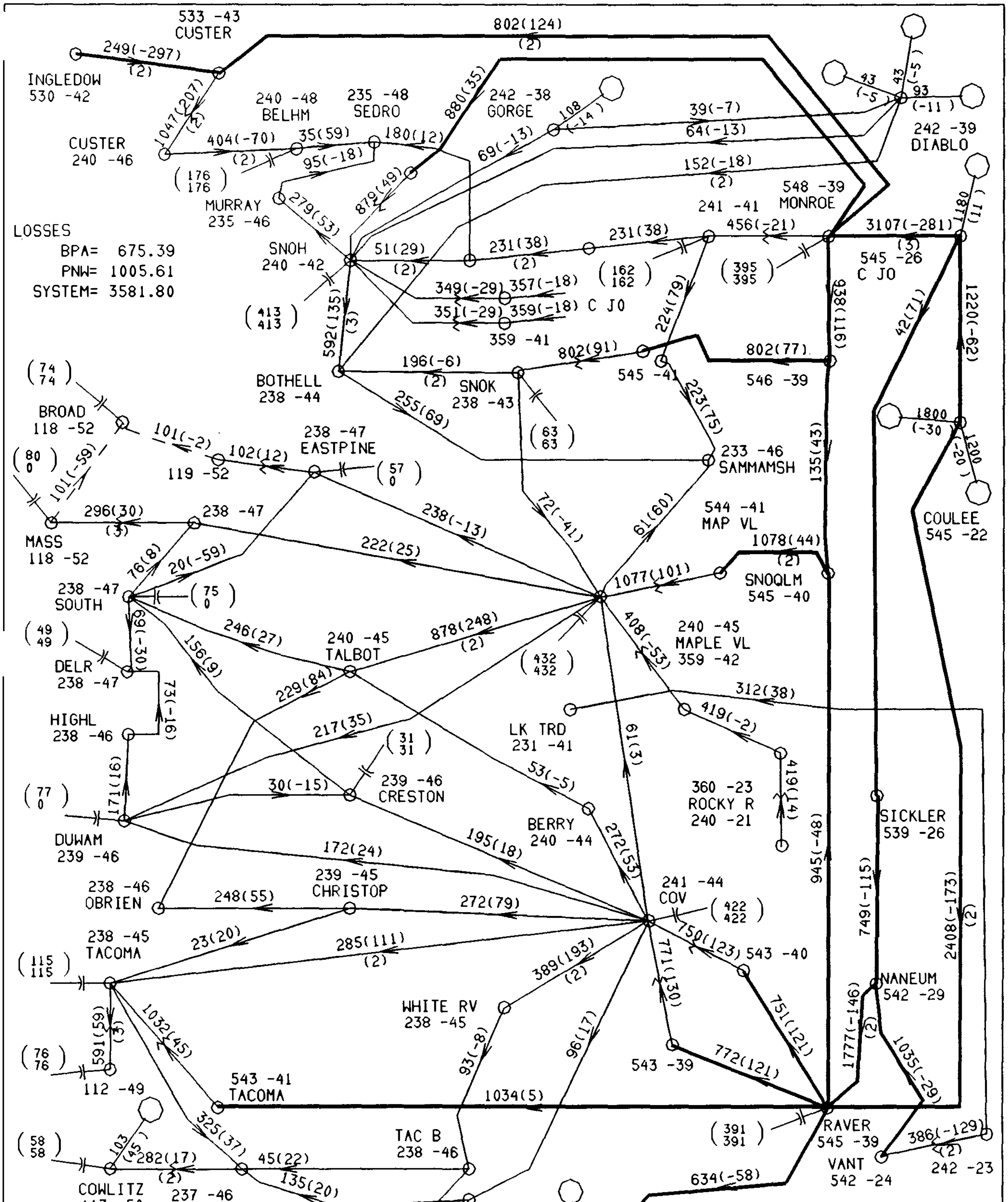
J96M227 4/13/90 PF 4.020
CY89 MJL-ALH
BASED ON J96M221
MONROE TAP 230KV BUS OUT
SEDRO TAP 230KV BUS OUT
Normal [illegible]

S:PQ R- PLOTTED 13-APR-90 AT 15:50:12 HOURS



J0035 5/22/90 PF 4.020
CY89 MJL
BASED ON J0008
PLAN 1 CJ-M ADDED
SNOHOMISH AND SNOKING TX ADDED
NORMAL SKAGIT GEN

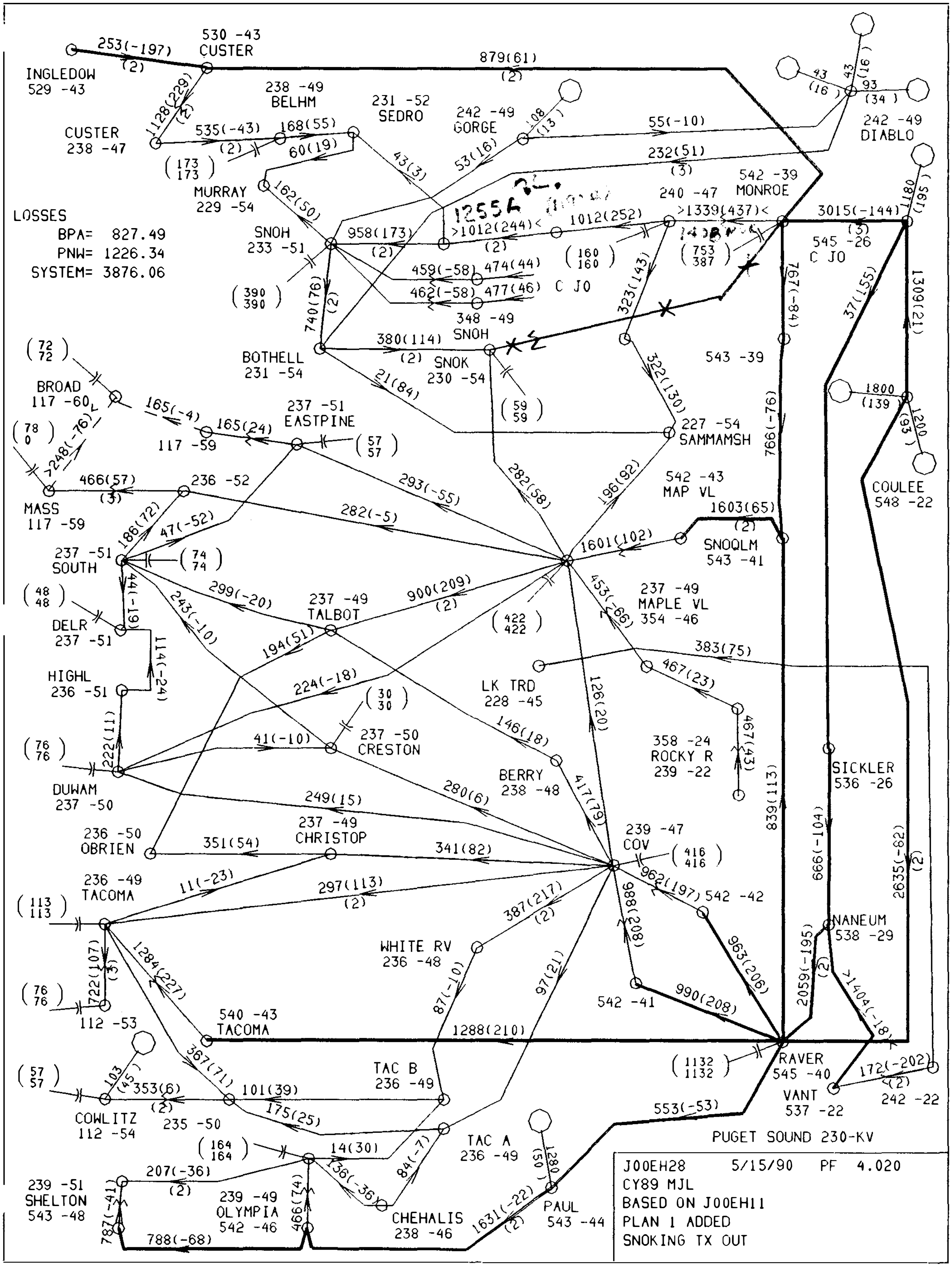
S:PQ R- PLOTTED 23-MAY-90 AT 07:52:29 HOURS



PUGET SOUND 230-KV

J0036 5/22/90 PF 4.020
CY89 MJL
BASED ON J0008
PLAN 1 CJ-M ADDED
SNOHOMISH AND SNOKING TX ADDED
LOW SKAGIT GEN

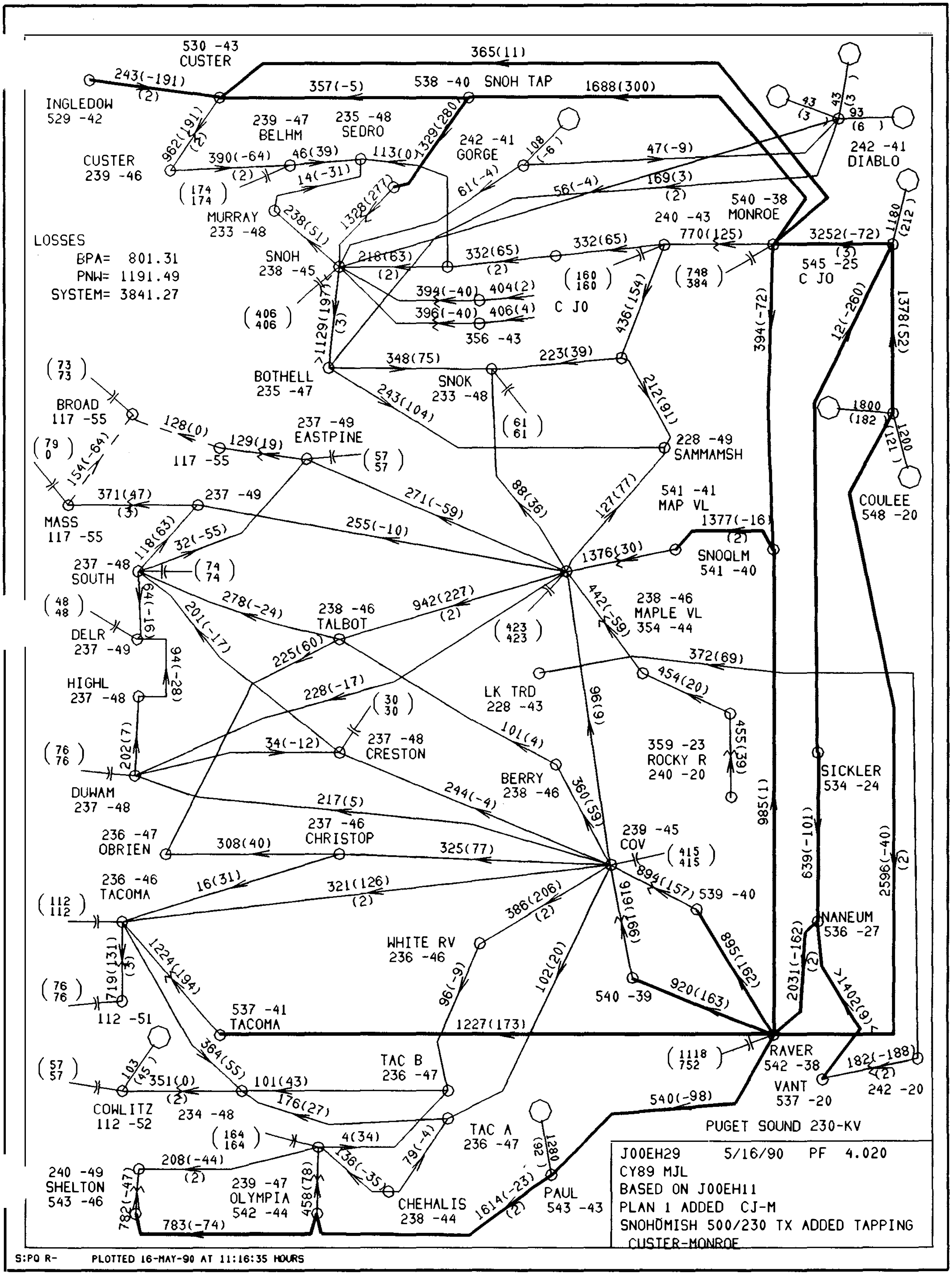
S:PQ R- PLOTTED 22-MAY-90 AT 16:47:13 HOURS



PUGET SOUND 230-KV

J00EH28 5/15/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 1 ADDED
SNOKING TX OUT

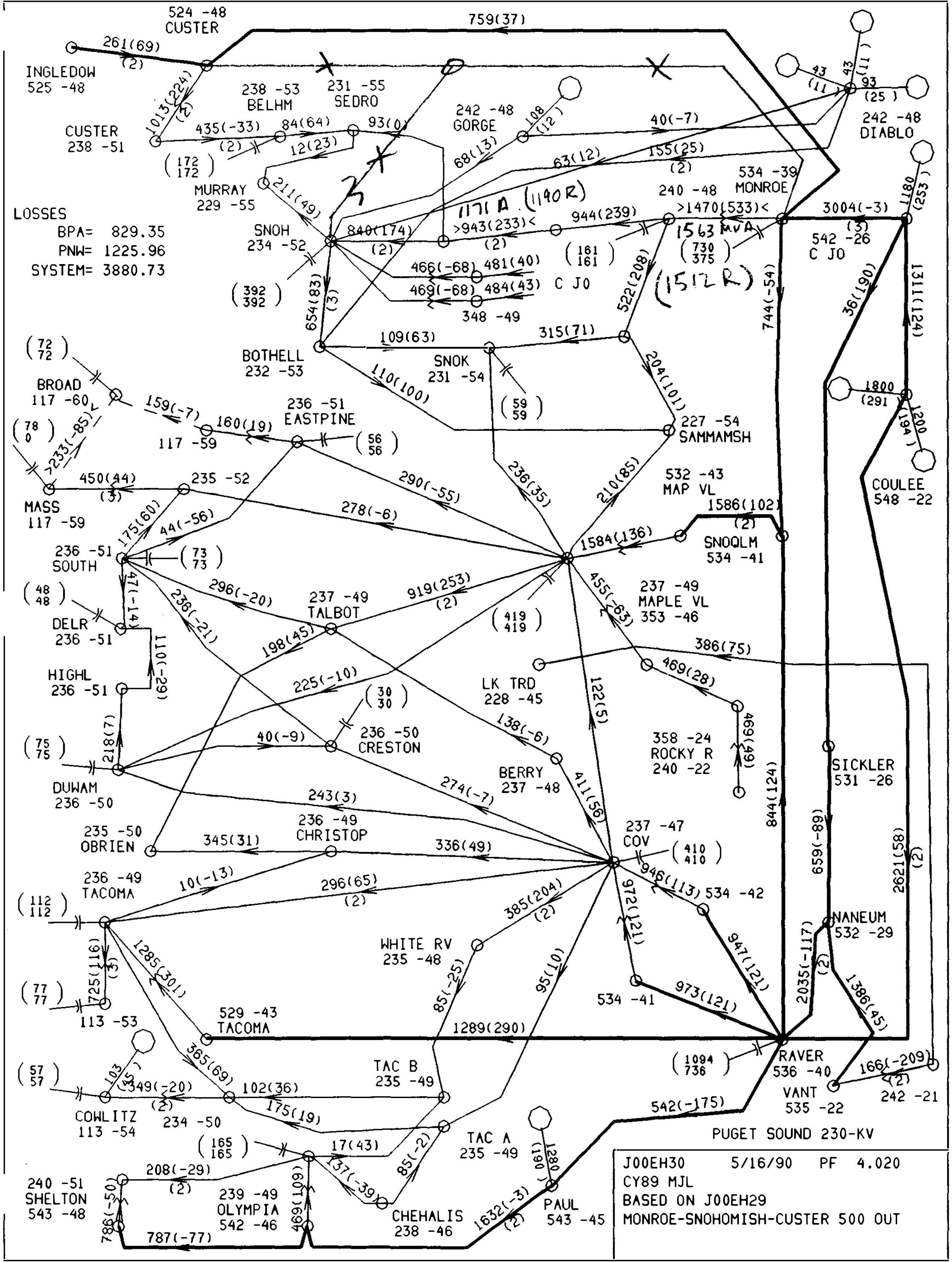
S:PQ R- PLOTTED 15-MAY-90 AT 08:04:29 HOURS



PUGET SOUND 230-KV

J00EH29 5/16/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 1 ADDED CJ-M
SNOHOMISH 500/230 TX ADDED TAPPING
CUSTER-MONROE

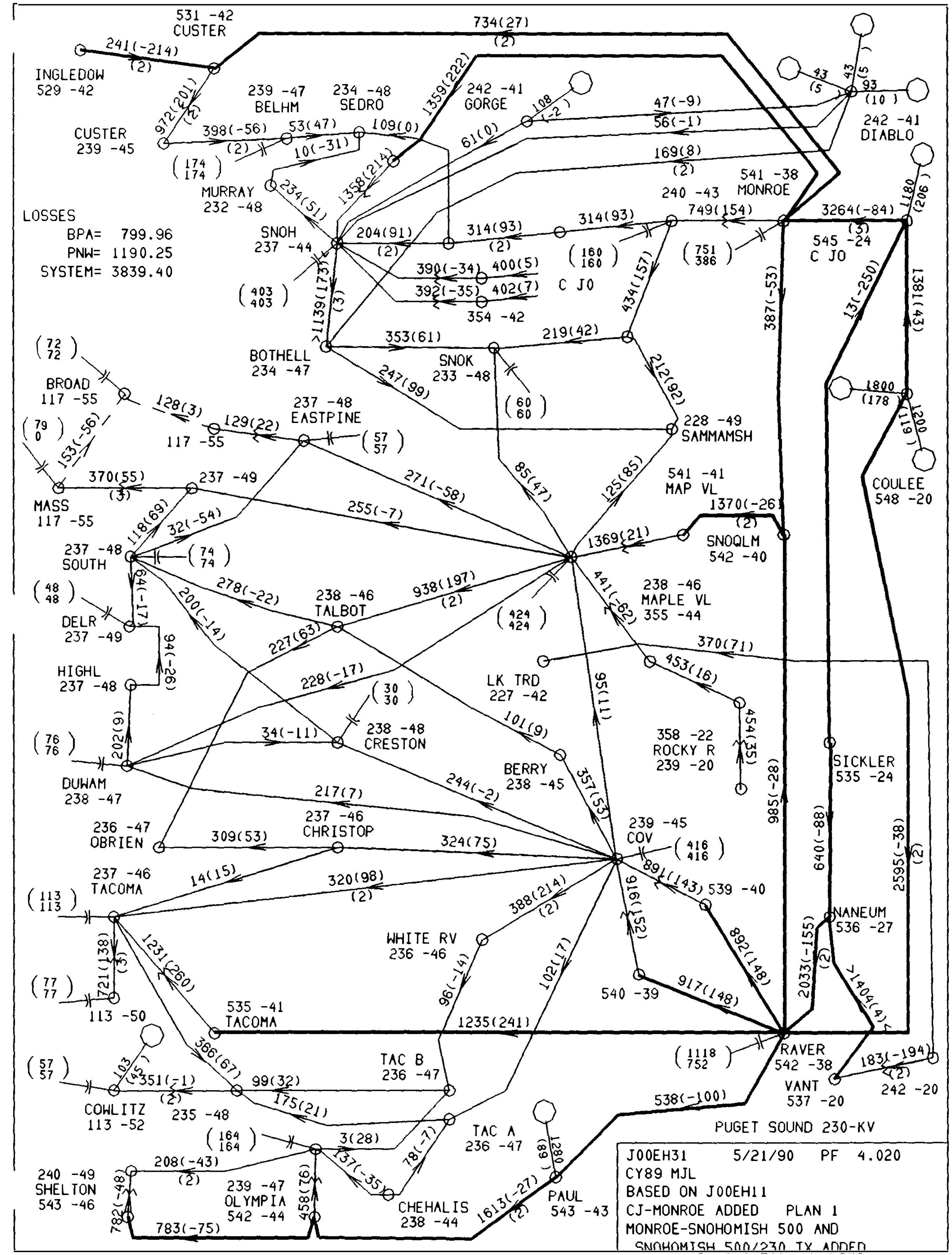
S:PQ R- PLOTTED 16-MAY-90 AT 11:16:35 HOURS



PUGET SOUND 230-KV

J00EH30 5/16/90 PF 4.020
CY89 MJL
BASED ON J00EH29
MONROE-SNOHOMISH-CUSTER 500 OUT

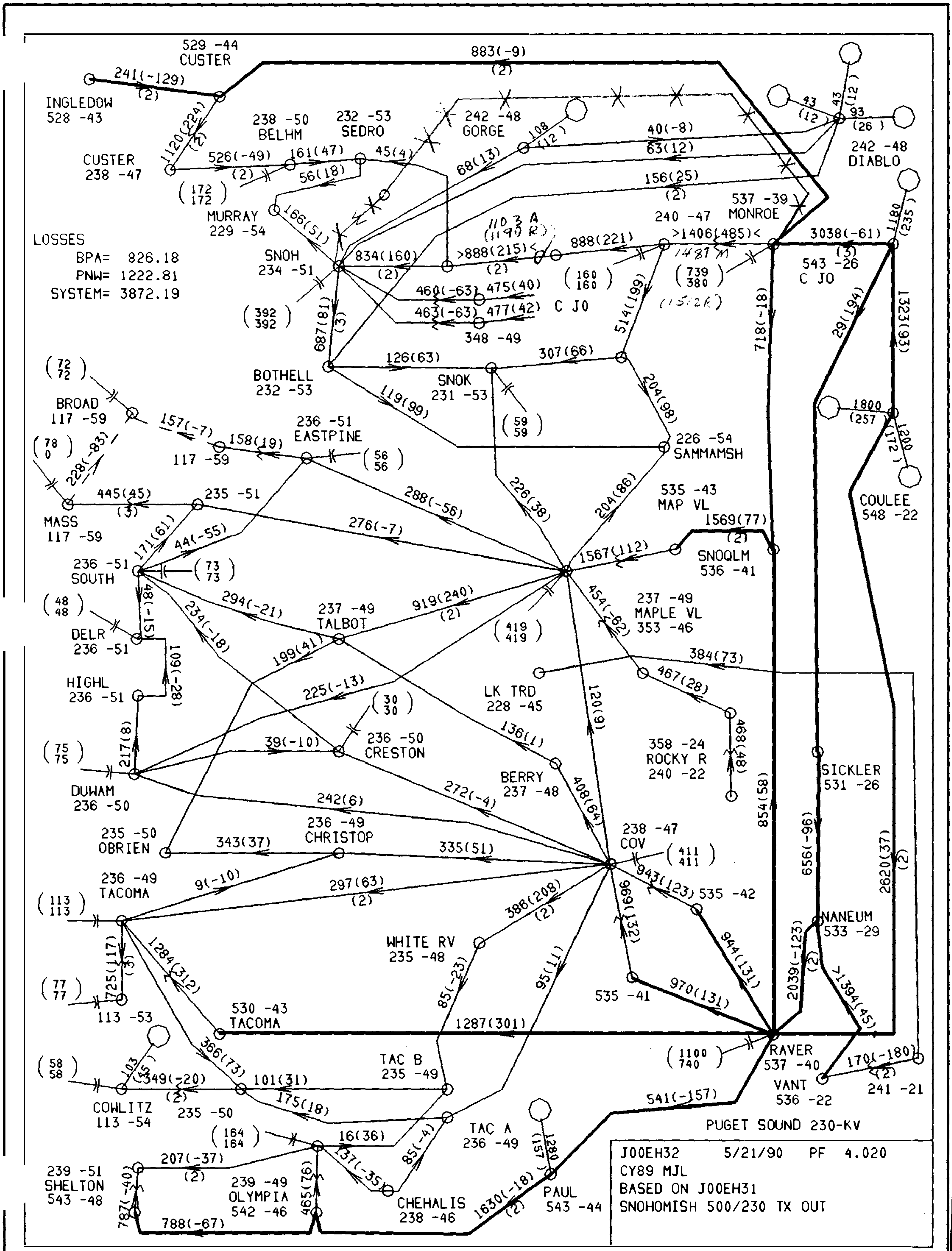
S:PQ R- PLOTTED 16-MAY-90 AT 13:43:36 HOURS



LOSSES
BPA= 799.96
PNW= 1190.25
SYSTEM= 3839.40

J00EH31 5/21/90 PF 4.020
CY89 MJL
BASED ON J00EH11
CJ-MONROE ADDED PLAN 1
MONROE-SNOHOMISH 500 AND
SNOHOMISH 500/230 TX ADDED

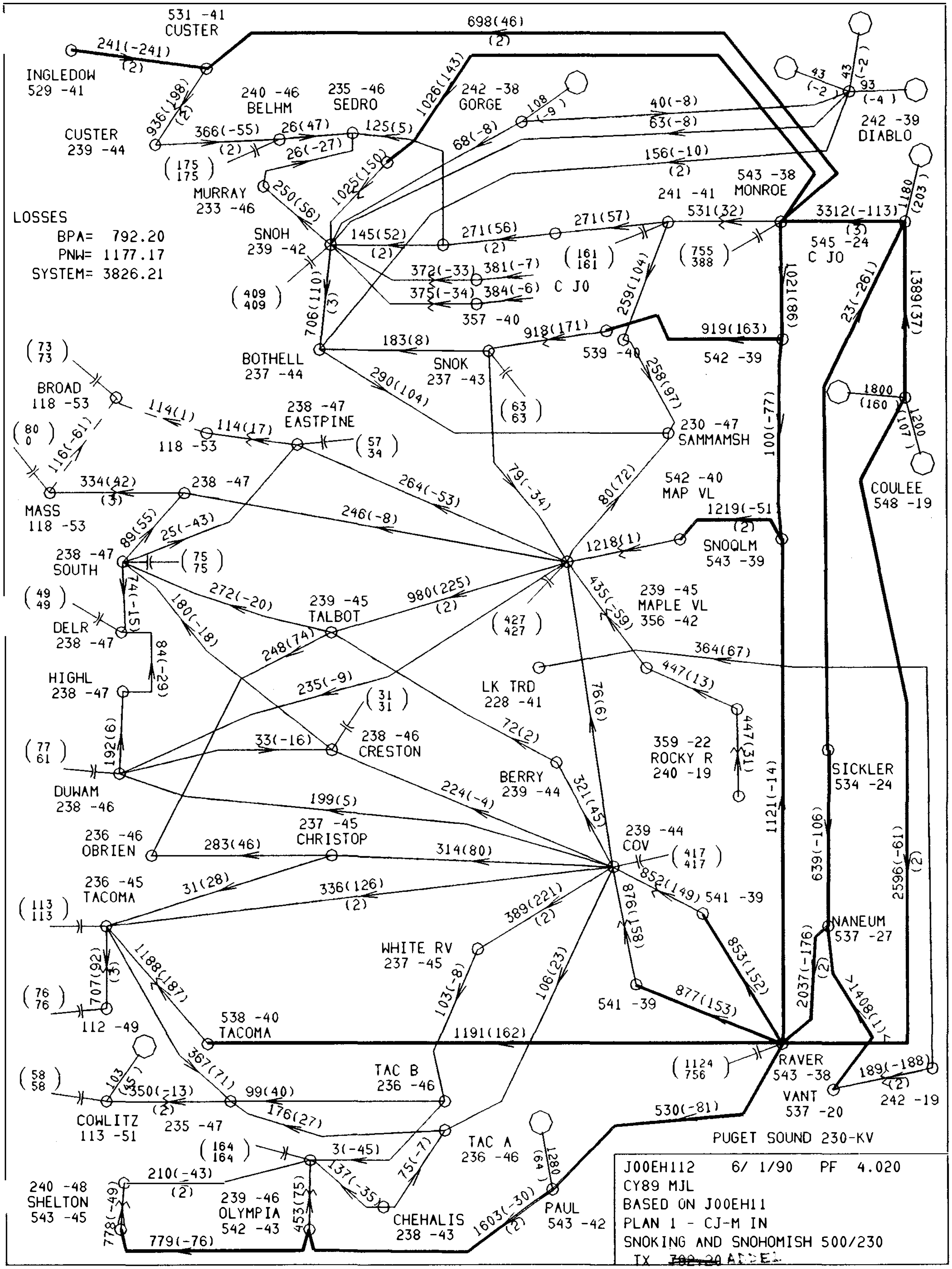
S:PQ R- PLOTTED 22-MAY-90 AT 09:11:20 HOURS



PUGET SOUND 230-KV

J00EH32 5/21/90 PF 4.020
CY89 MJL
BASED ON J00EH31
SNOHOMISH 500/230 TX OUT

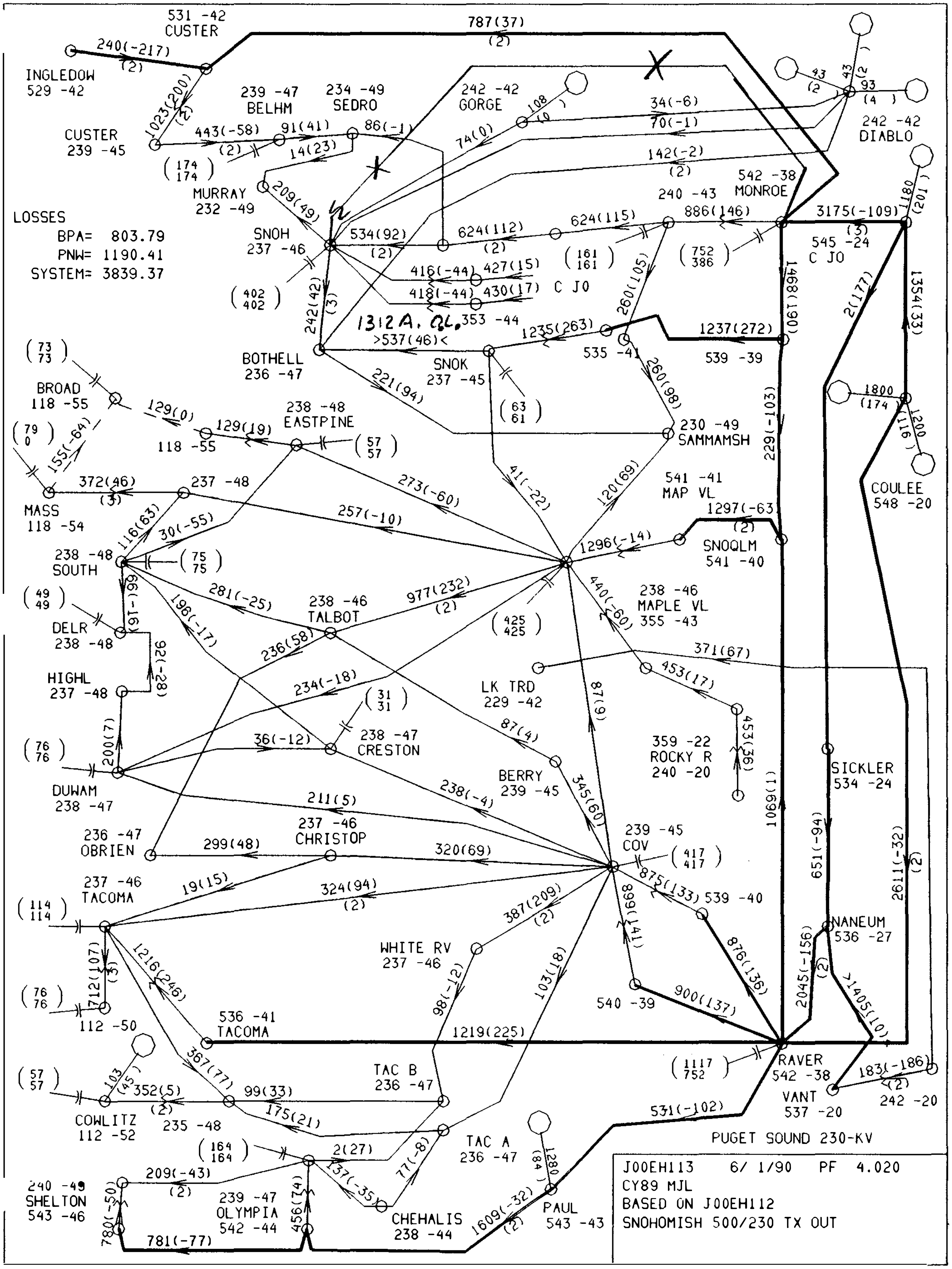
S:PQ R- PLOTTED 22-MAY-90 AT 09:12:23 HOURS



PUGET SOUND 230-KV

J00EH112 6/ 1/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 1 - CJ-M IN
SNOKING AND SNOHOMISH 500/230
TX ~~782.20~~ ADDED

S:PO R- PLOTTED 4-JUN-90 AT 07:46:44 HOURS

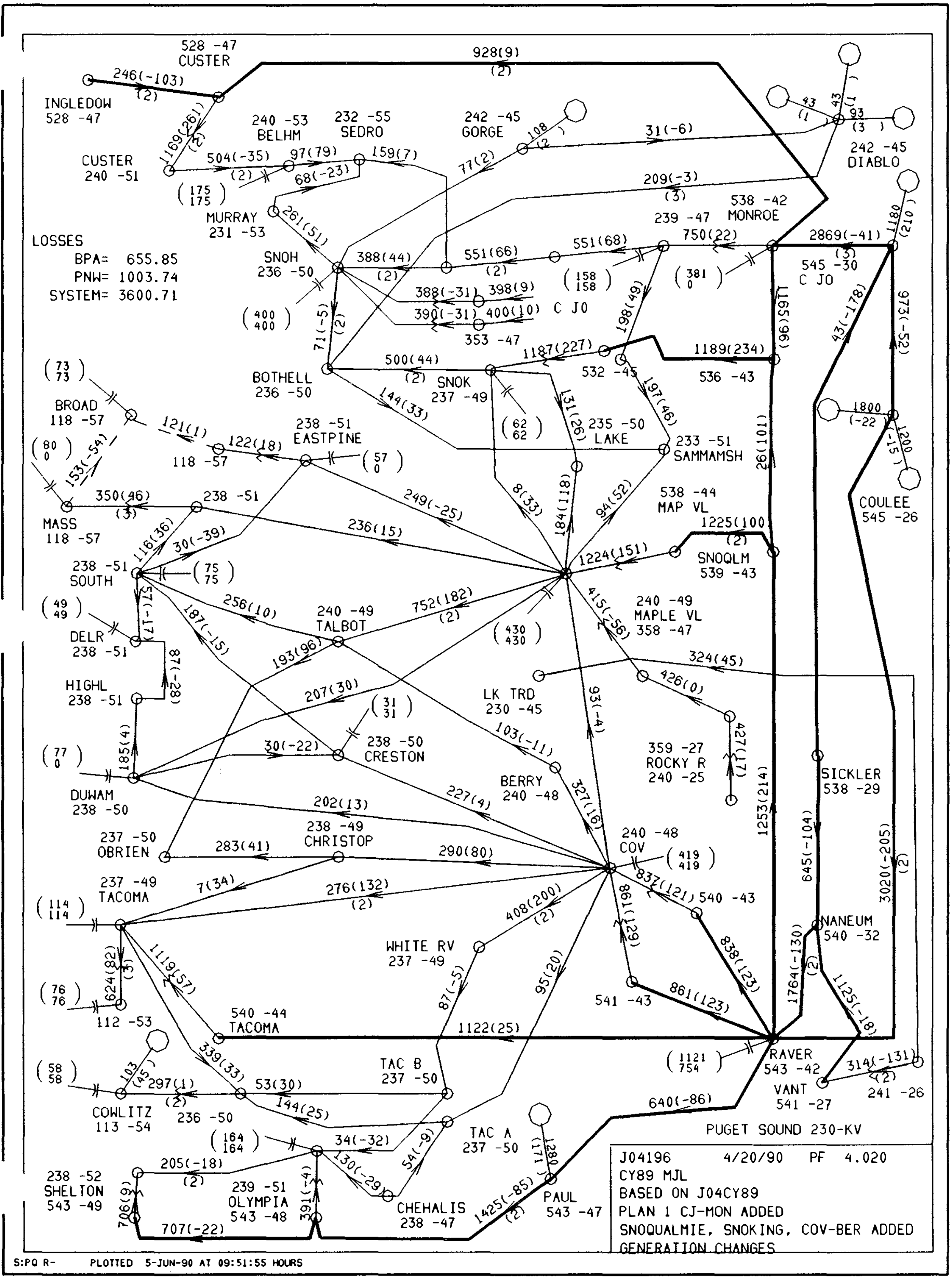


LOSSES
BPA= 803.79
PNW= 1190.41
SYSTEM= 3839.37

PUGET SOUND 230-KV

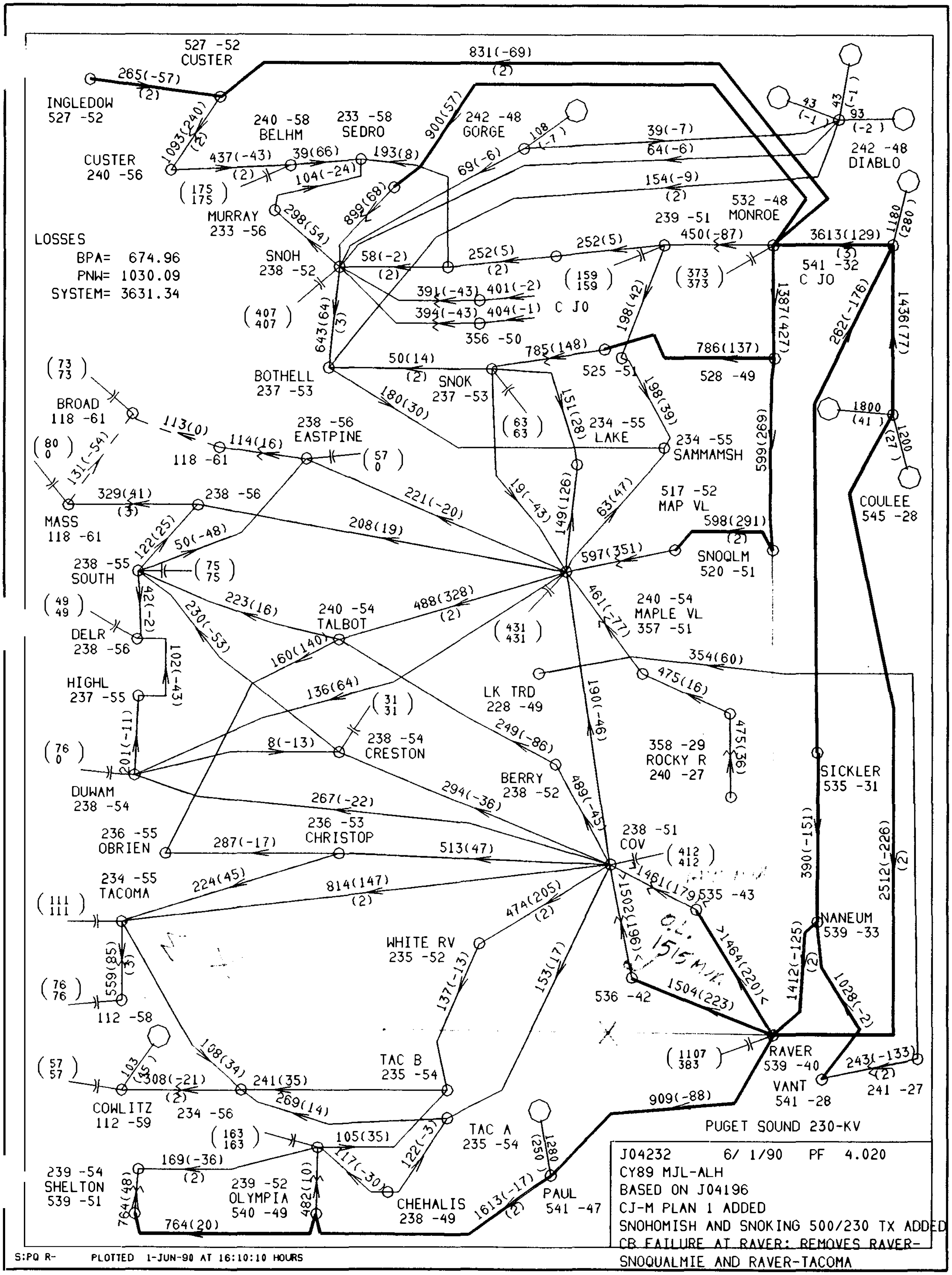
J00EH113 6/ 1/90 PF 4.020
CY89 MJL
BASED ON J00EH112
SNOHOMISH 500/230 TX OUT

S:PO R- PLOTTED 4-JUN-90 AT 07:47:23 HOURS



J04196 4/20/90 PF 4.020
CY89 MJL
BASED ON J04CY89
PLAN 1 CJ-MON ADDED
SNOQUALMIE, SNOKING, COV-BER ADDED
GENERATION CHANGES

S:PQ R- PLOTTED 5-JUN-90 AT 09:51:55 HOURS

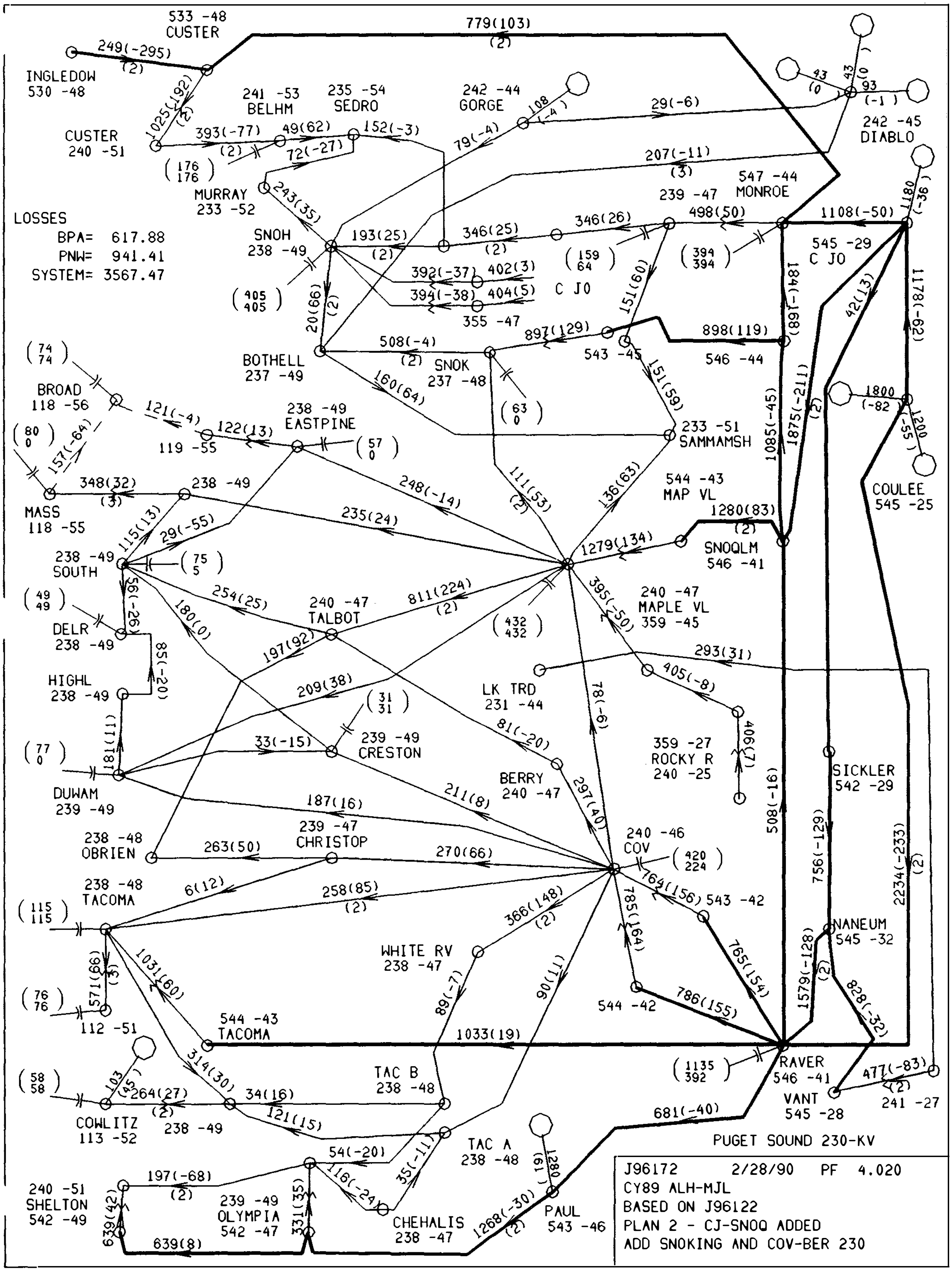


PUGET SOUND 230-KV

J04232 6/ 1/90 PF 4.020
CY89 MJL-ALH
BASED ON J04196
CJ-M PLAN 1 ADDED
SNOHOMISH AND SNOKING 500/230 TX ADDED
CB FAILURE AT RAVER: REMOVES RAVER-SNOQUALMIE AND RAVER-TACOMA

S:PQ R- PLOTTED 1-JUN-90 AT 16:10:10 HOURS

PF - PLAN 2

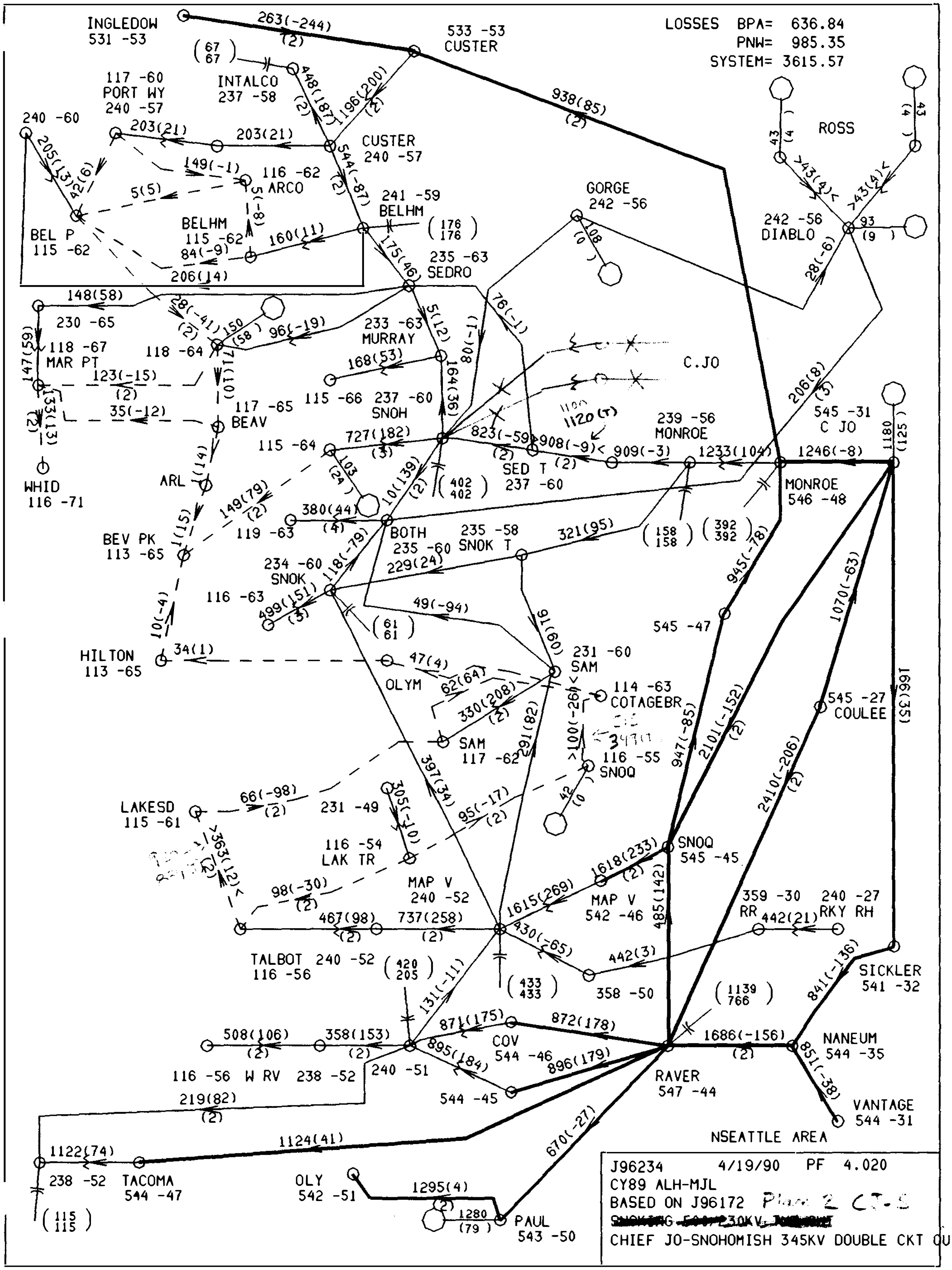


PUGET SOUND 230-KV

J96172 2/28/90 PF 4.020
CY89 ALH-MJL
BASED ON J96122
PLAN 2 - CJ-SNOQ ADDED
ADD SNOKING AND COV-BER 230

S:PQ R- PLOTTED 5-JUN-90 AT 10:42:50 HOURS

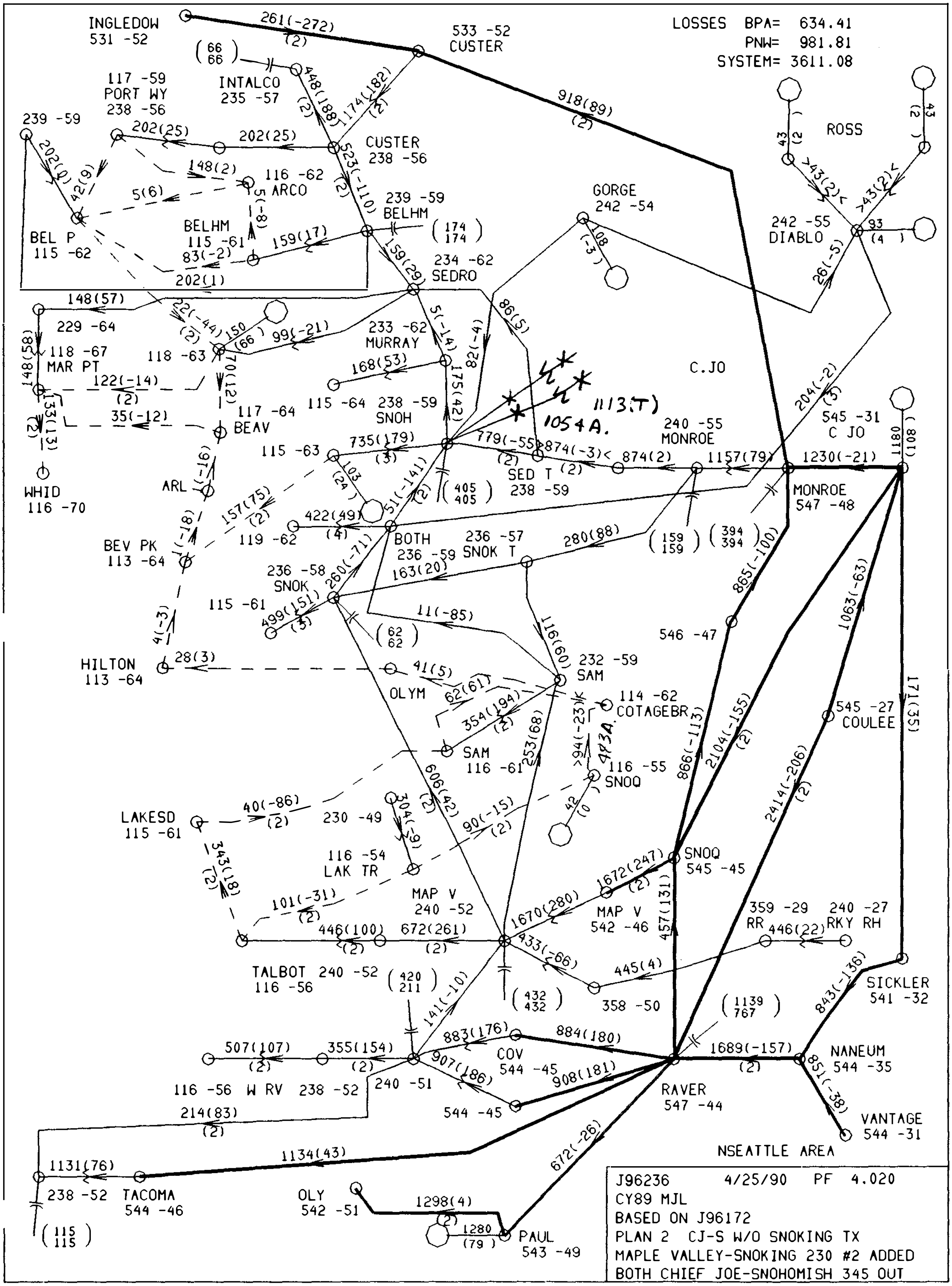
LOSSES BPA= 636.84
PNW= 985.35
SYSTEM= 3615.57



NSEATTLE AREA

J96234 4/19/90 PF 4.020
CY89 ALH-MJL
BASED ON J96172 Plan 2 CT-5
~~SNOKING 500/230KV~~
CHIEF JO-SNOHOMISH 345KV DOUBLE CKT OUT

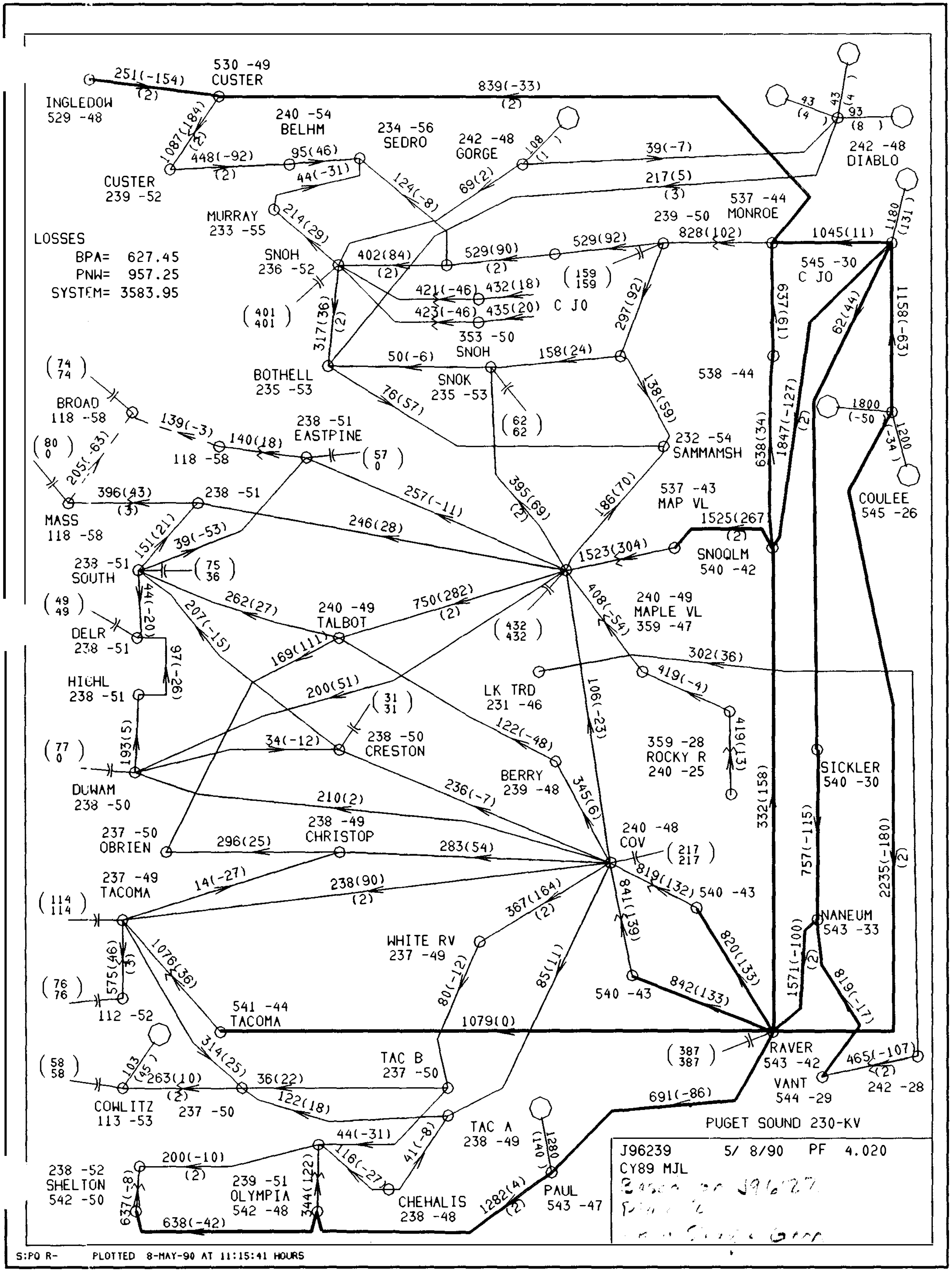
S:PQ R- PLOTTED 19-APR-90 AT 14:55:47 HOURS



LOSSES BPA= 634.41
PNW= 981.81
SYSTEM= 3611.08

J96236 4/25/90 PF 4.020
CY89 MJL
BASED ON J96172
PLAN 2 CJ-S W/O SNOKING TX
MAPLE VALLEY-SNOKING 230 #2 ADDED
BOTH CHIEF JOE-SNOHOMISH 345 OUT

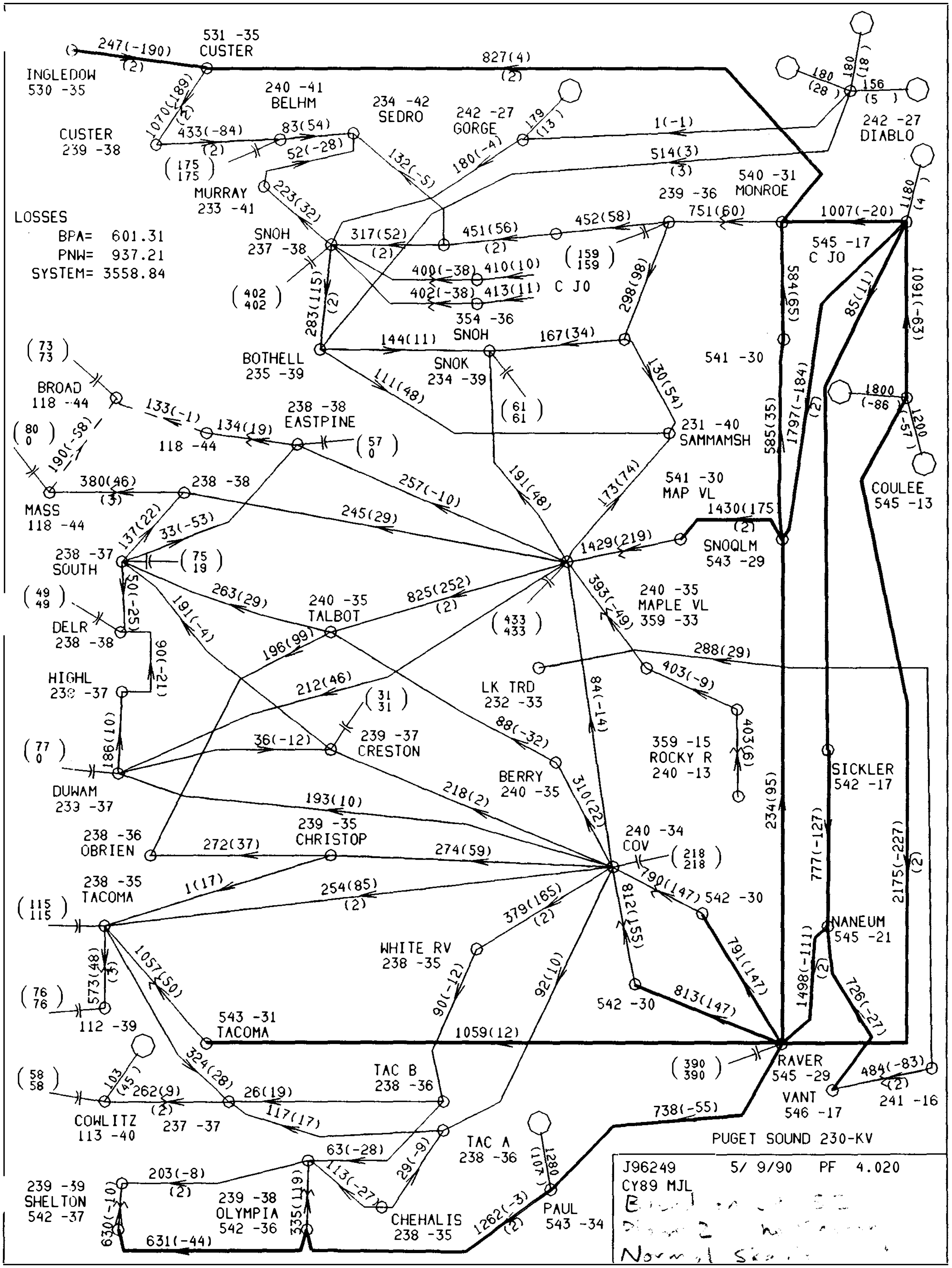
S:PQ R- PLOTTED 25-APR-90 AT 10:48:37 HOURS



PUGET SOUND 230-KV

J96239 5/ 8/90 PF 4.020
CY89 MJL
Based on J96227
[illegible]
[illegible] Gen

S:PO R- PLOTTED 8-MAY-90 AT 11:15:41 HOURS

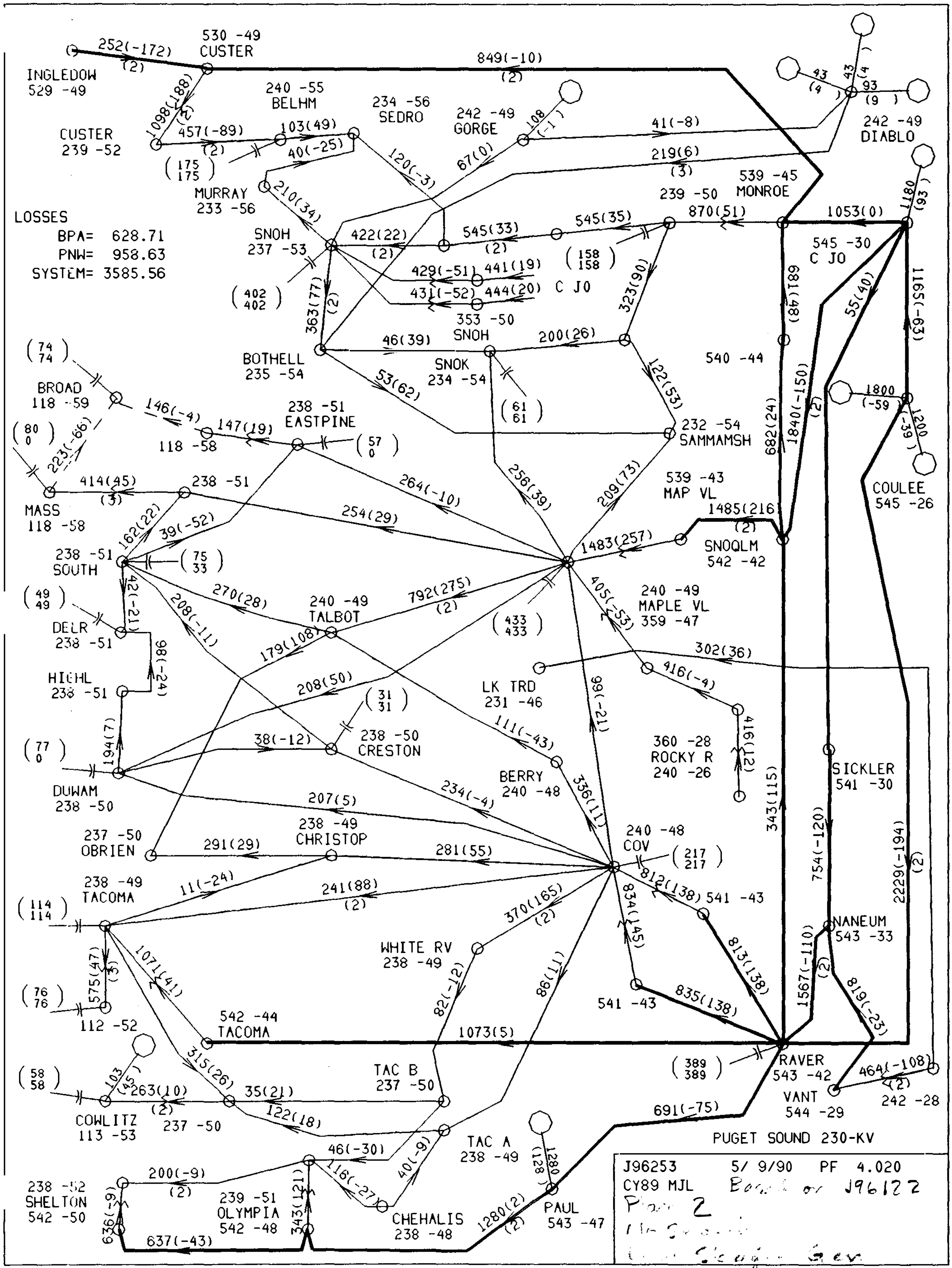


LOSSES
BPA= 601.31
PNW= 937.21
SYSTEM= 3558.84

PUGET SOUND 230-KV

J96249 5/ 9/90 PF 4.020
CY89 MJL
E[illegible]
[illegible] 2 [illegible]
Normal S[illegible]

S:PQ R- PLOTTED 9-MAY-90 AT 12:41:45 HOURS

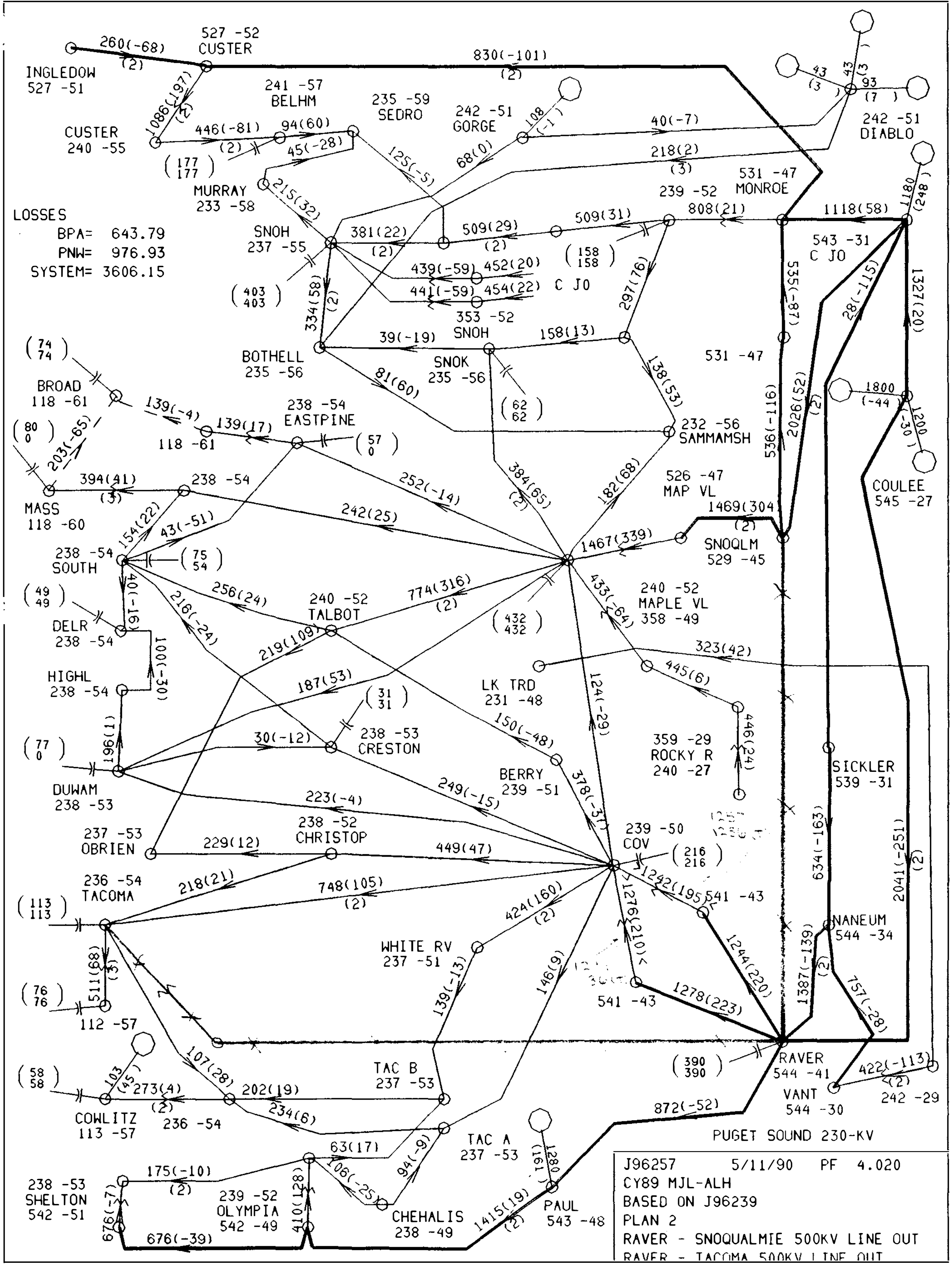


LOSSES
BPA= 628.71
PNW= 958.63
SYSTEM= 3585.56

PUGET SOUND 230-KV

J96253 5/ 9/90 PF 4.020
CY89 MJL Based on J96122
Plan 2
[illegible]
[illegible] Gen.

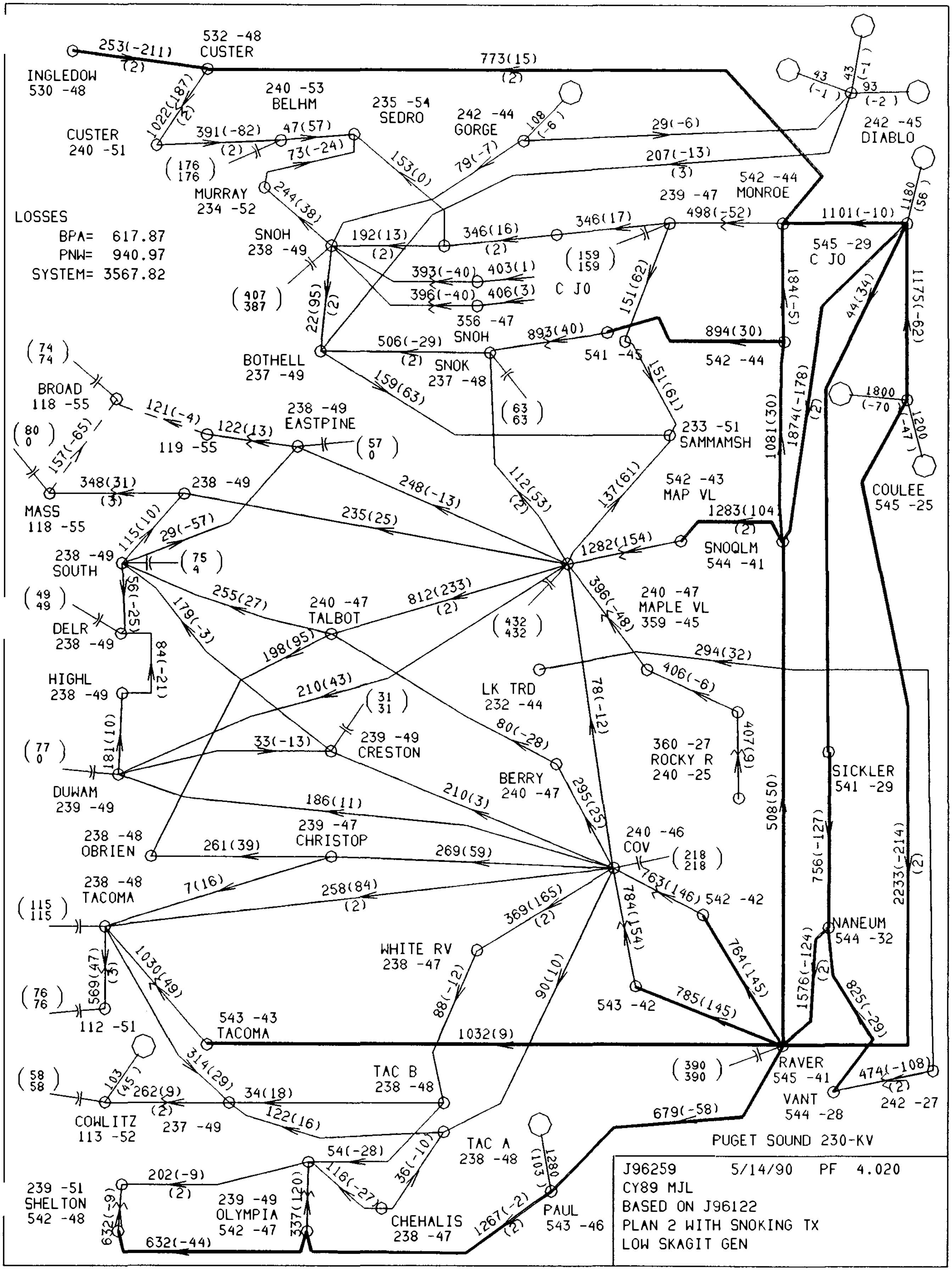
S:PQ R- PLOTTED 9-MAY-90 AT 12:47:39 HOURS



LOSSES
BPA= 643.79
PNW= 976.93
SYSTEM= 3606.15

J96257 5/11/90 PF 4.020
CY89 MJL-ALH
BASED ON J96239
PLAN 2
RAVER - SNOQUALMIE 500KV LINE OUT
RAVER - TACOMA 500KV LINE OUT

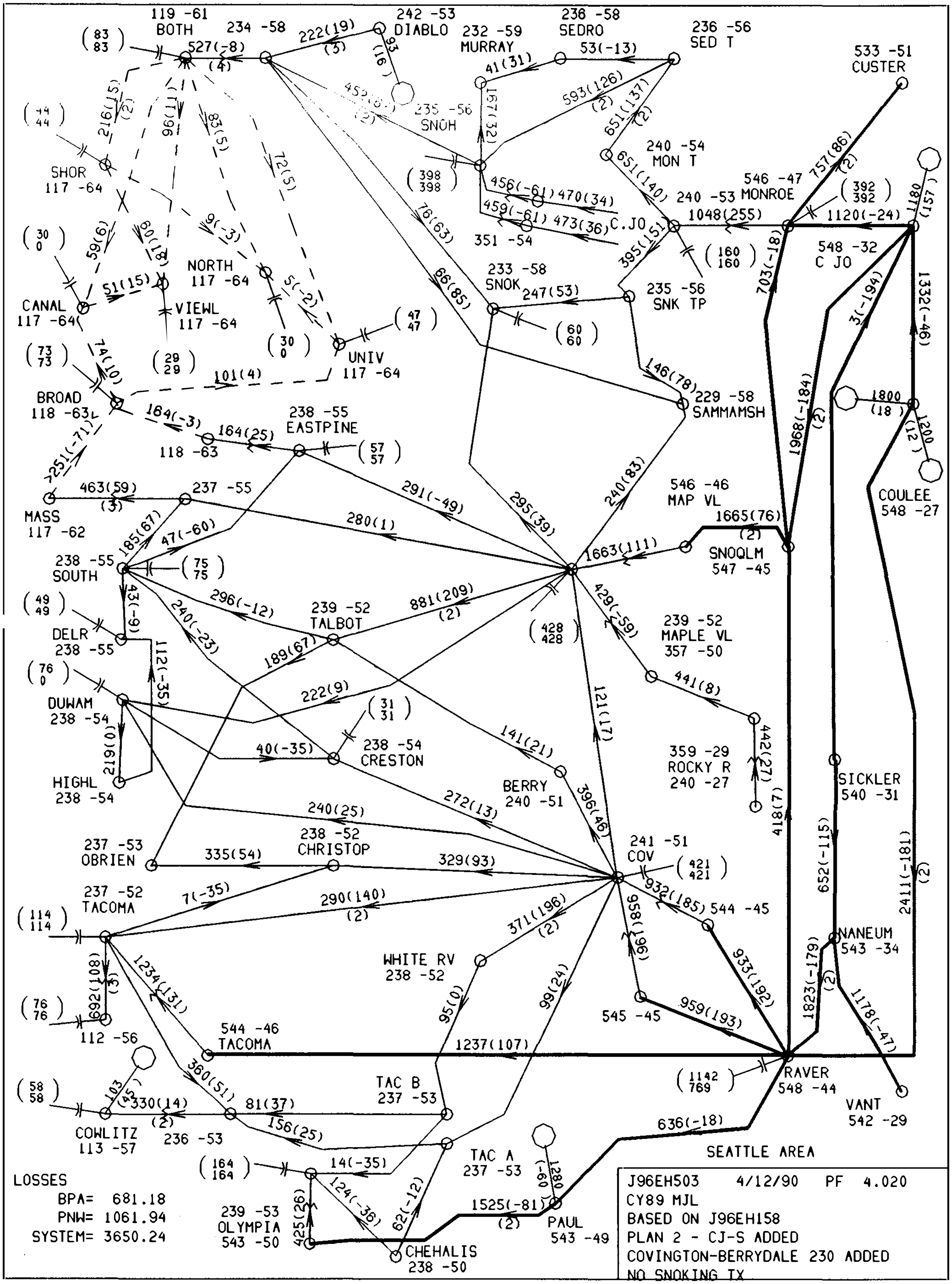
S:PQ R- PLOTTED 11-MAY-90 AT 15:39:29 HOURS



PUGET SOUND 230-KV

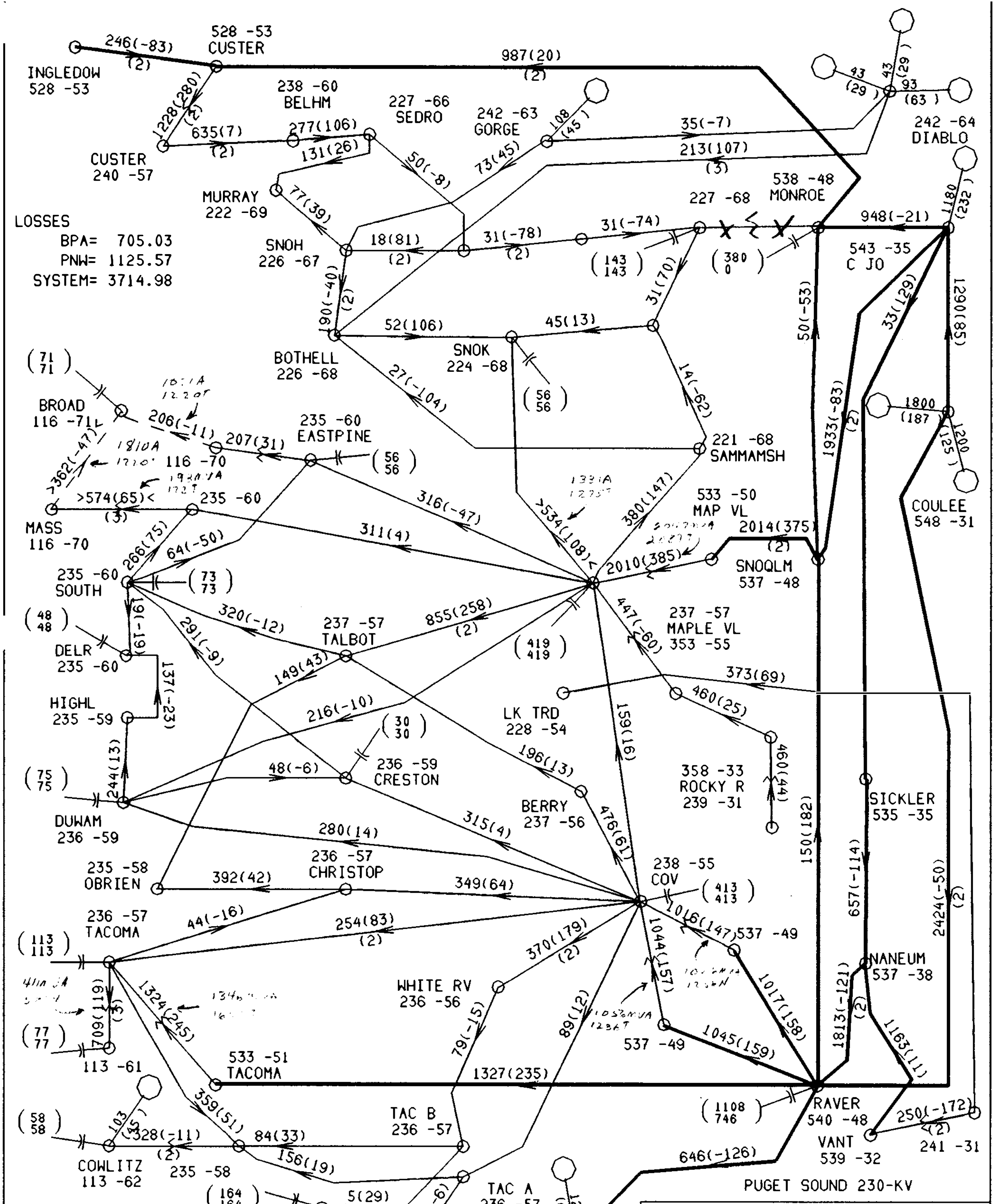
J96259 5/14/90 PF 4.020
CY89 MJL
BASED ON J96122
PLAN 2 WITH SNOKING TX
LOW SKAGIT GEN

S:PQ R- PLOTTED 14-MAY-90 AT 09:29:11 HOURS



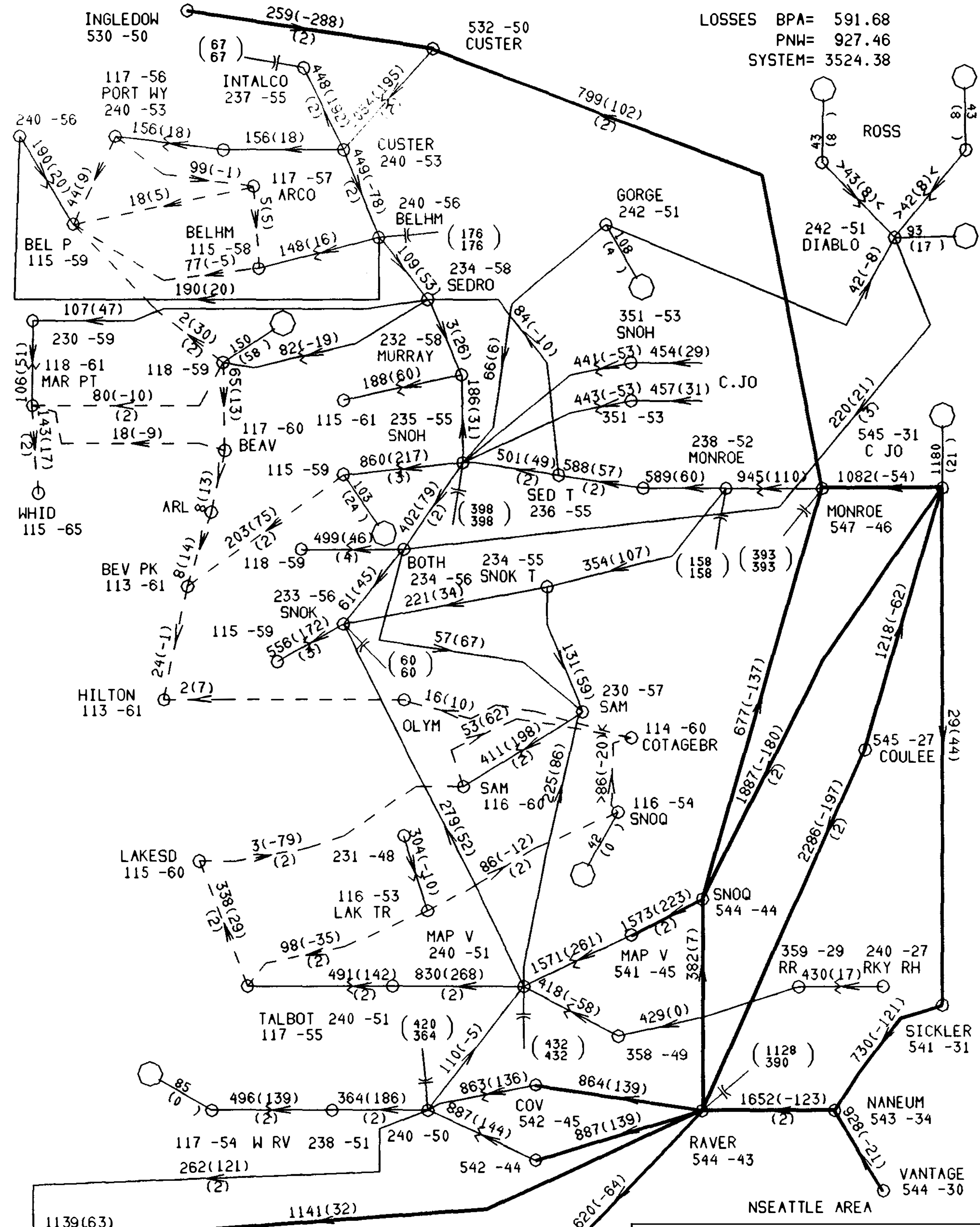
LOSSES
BPA= 681.18
PNW= 1061.94
SYSTEM= 3650.24

J96EH503 4/12/90 PF 4.020
CY89 MJL
BASED ON J96EH158
PLAN 2 - CJ-S ADDED
COVINGTON-BERRYDALE 230 ADDED
NO SNOKING TX



J96EH553 4/17/90 PF 4.020
CY89 MJL-MIH
BASED ON J96EH503
MONROE 500/230-KV TX OUT
Plan 2 CJ-S

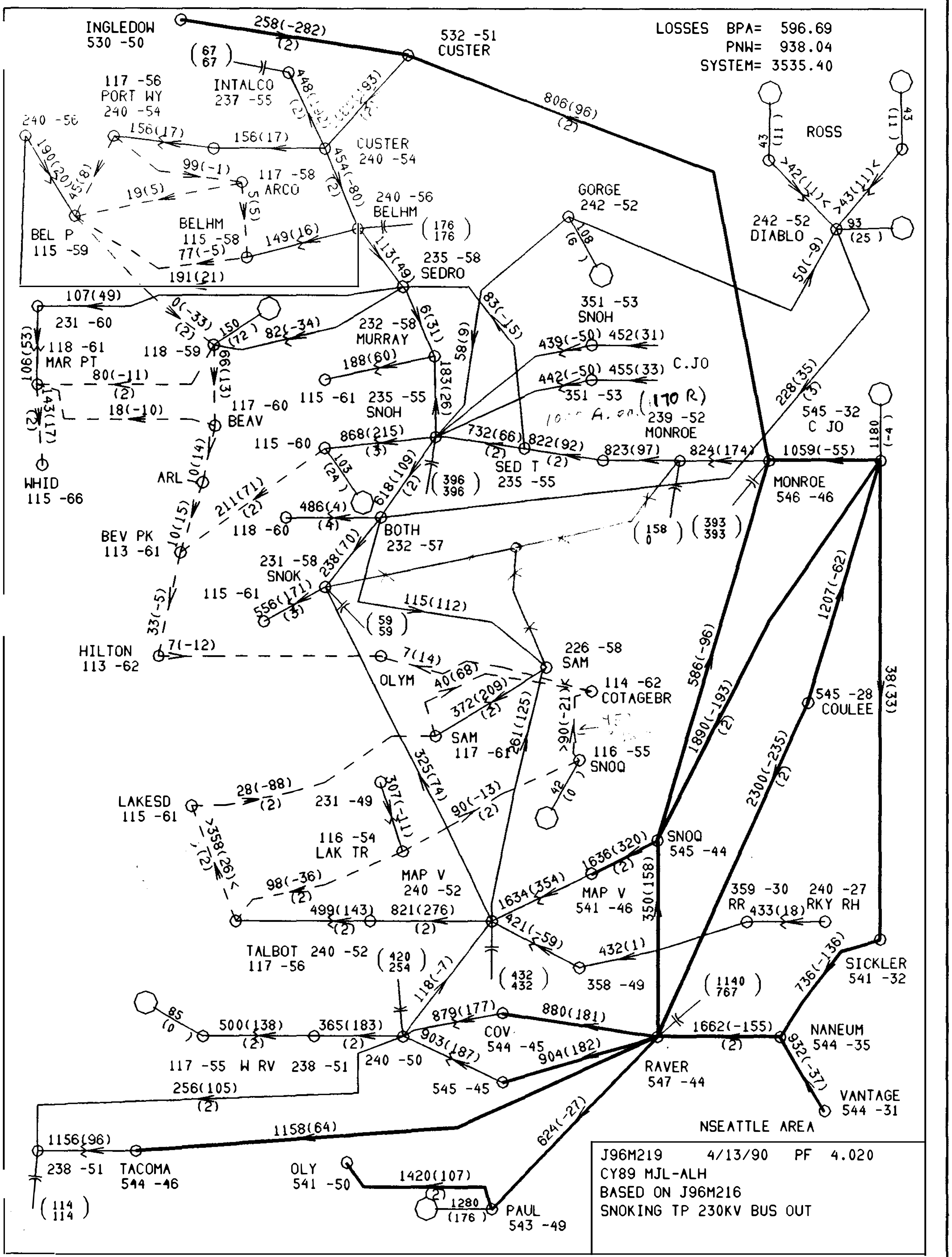
S:PQ R- PLOTTED 17-APR-90 AT 16:16:15 HOURS



LOSSES BPA= 591.68
PNW= 927.46
SYSTEM= 3524.38

J96M216 4/12/90 PF 4.020
CY89 MJL
BASED ON J96M121
PLAN 2 - CJ-S ADDED
COVINGTON-BERRYDALE 230 ADDED
NO SNOKING TX

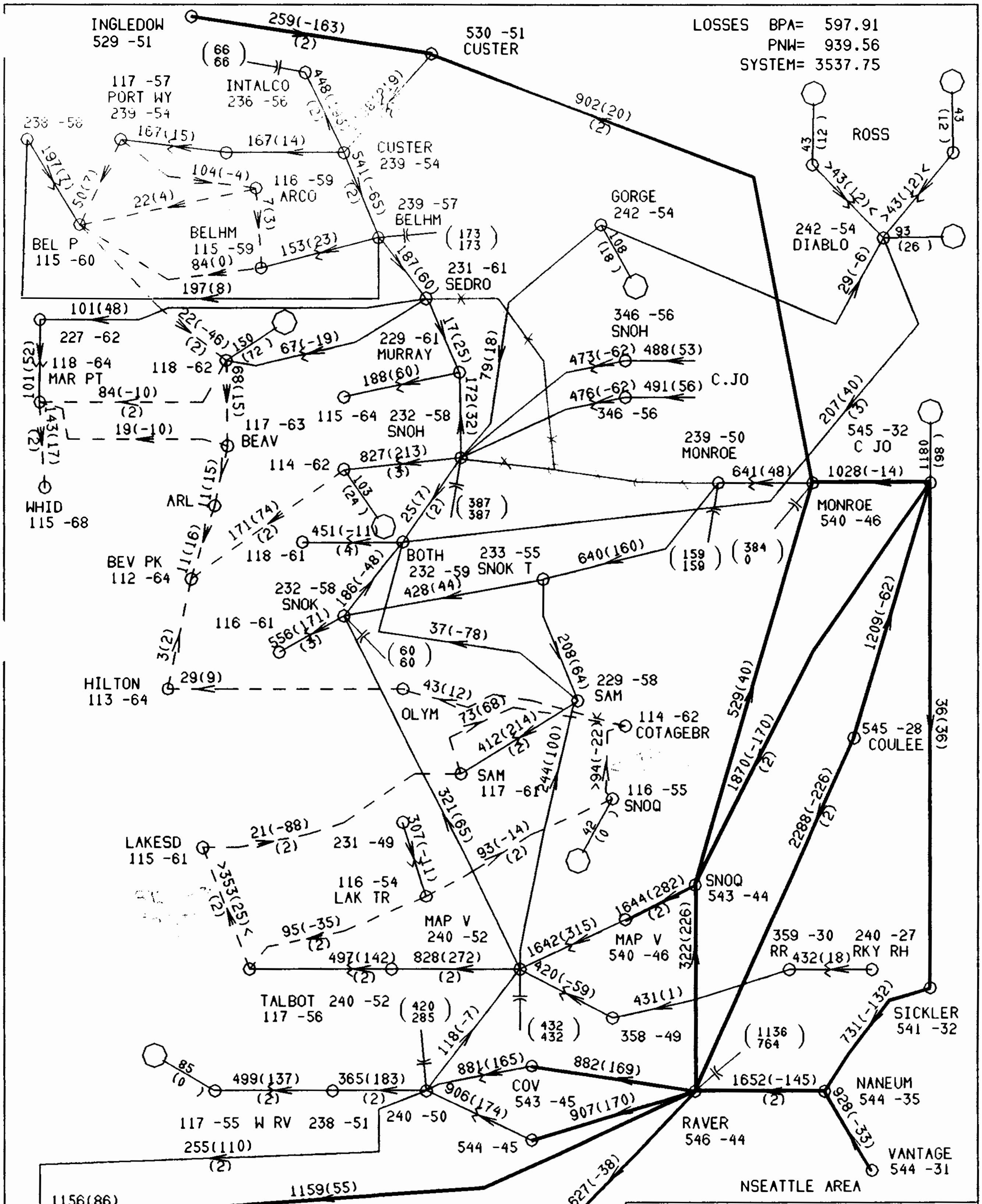
S:PQ R- PLOTTED 13-APR-90 AT 08:47:50 HOURS



LOSSES BPA= 596.69
PNW= 938.04
SYSTEM= 3535.40

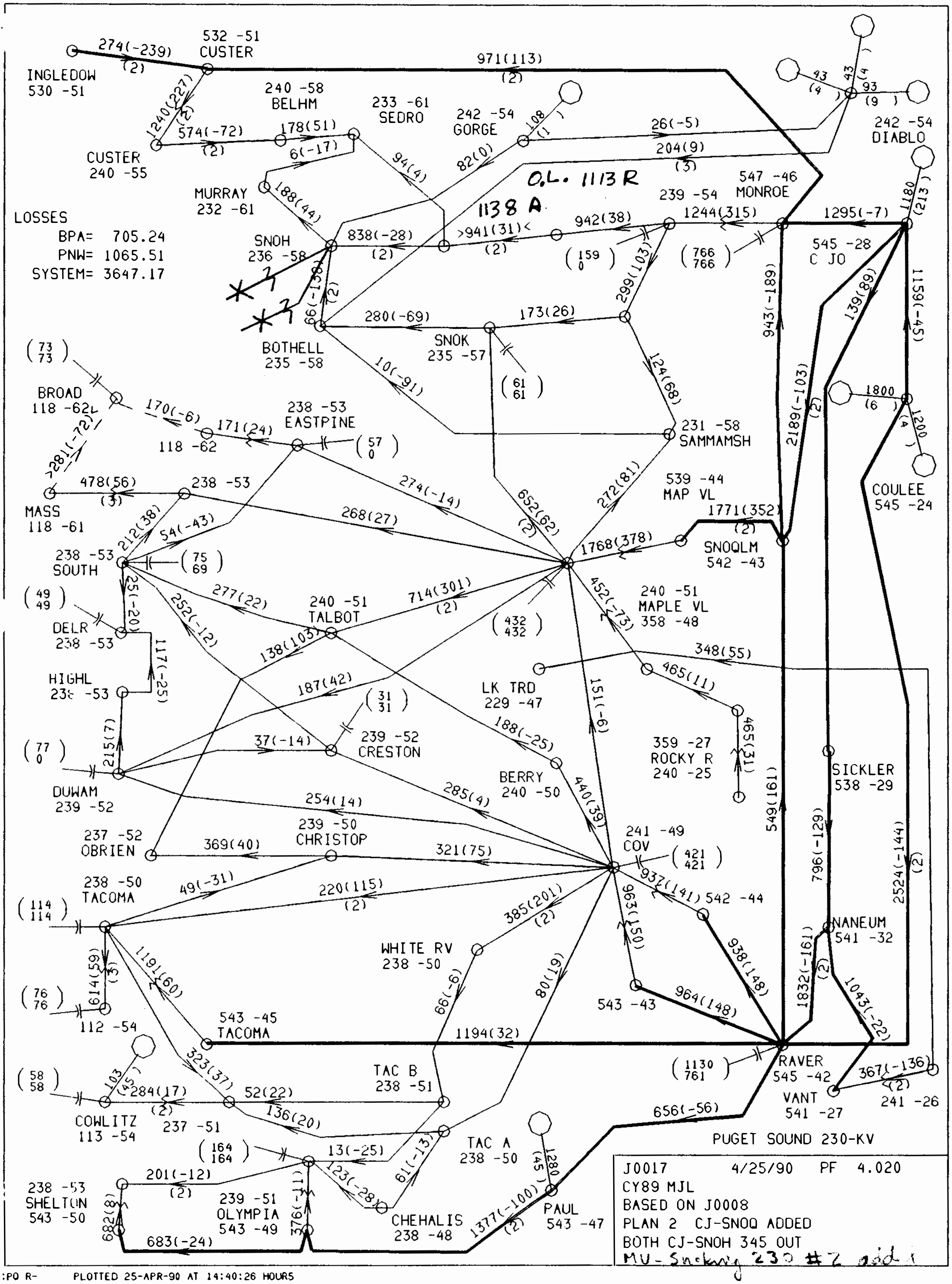
J96M219 4/13/90 PF 4.020
CY89 MJL-ALH
BASED ON J96M216
SNOKING TP 230KV BUS OUT

S:PQ R- PLOTTED 13-APR-90 AT 12:02:58 HOURS



J96M220 4/13/90 PF 4.020
CY89 MJL-ALH
BASED ON J96M216
MONROE TAP 230KV BUS OUT
SEDRO TAP 230KV BUS OUT

S:PO R- PLOTTED 13-APR-90 AT 12:04:15 HOURS

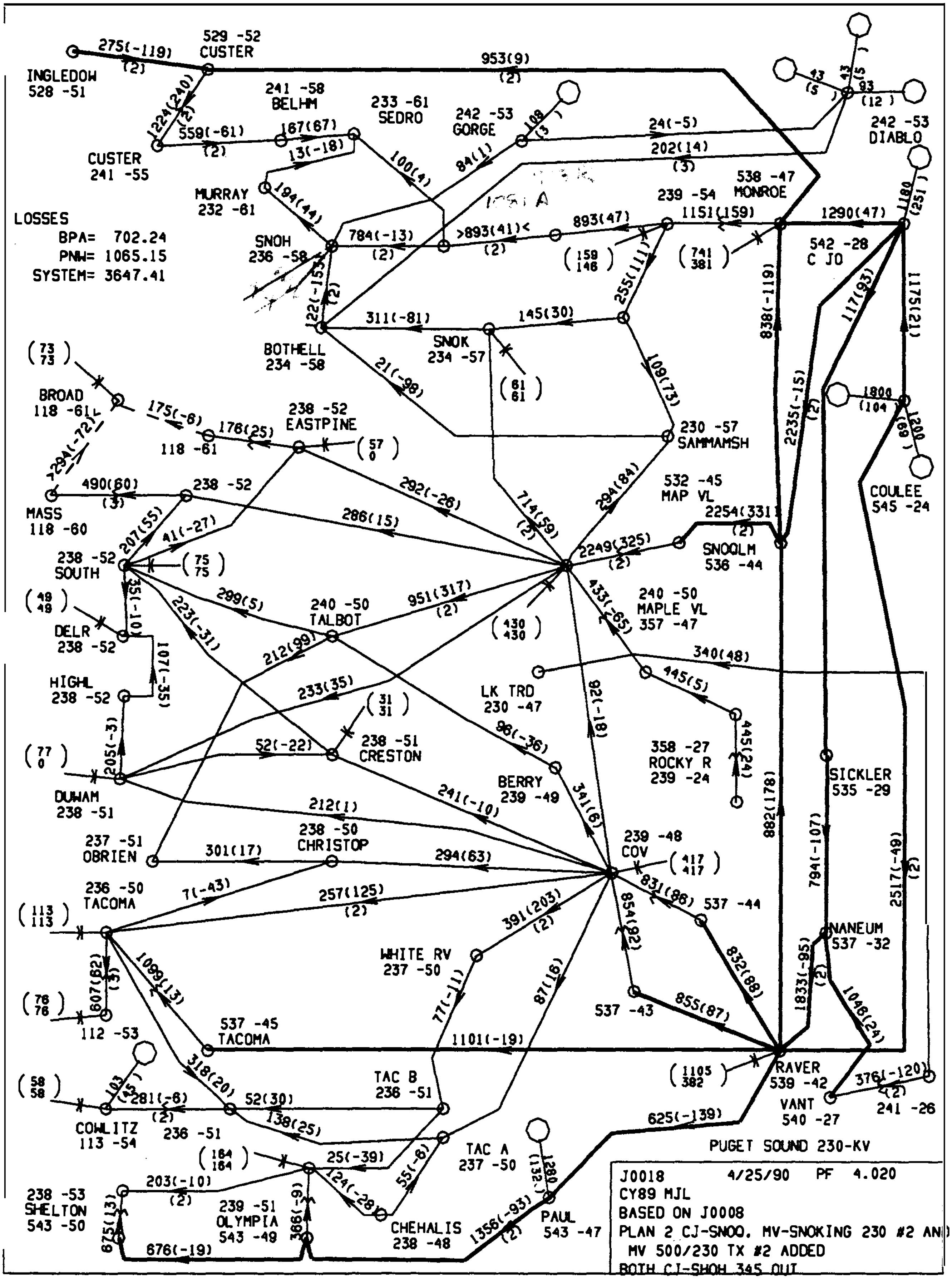


LOSSES
BPA= 705.24
PNW= 1065.51
SYSTEM= 3647.17

PUGET SOUND 230-KV

J0017 4/25/90 PF 4.020
CY89 MJL
BASED ON J0008
PLAN 2 CJ-SNOQ ADDED
BOTH CJ-SNOH 345 OUT
MU-Snoking 230 #2 add

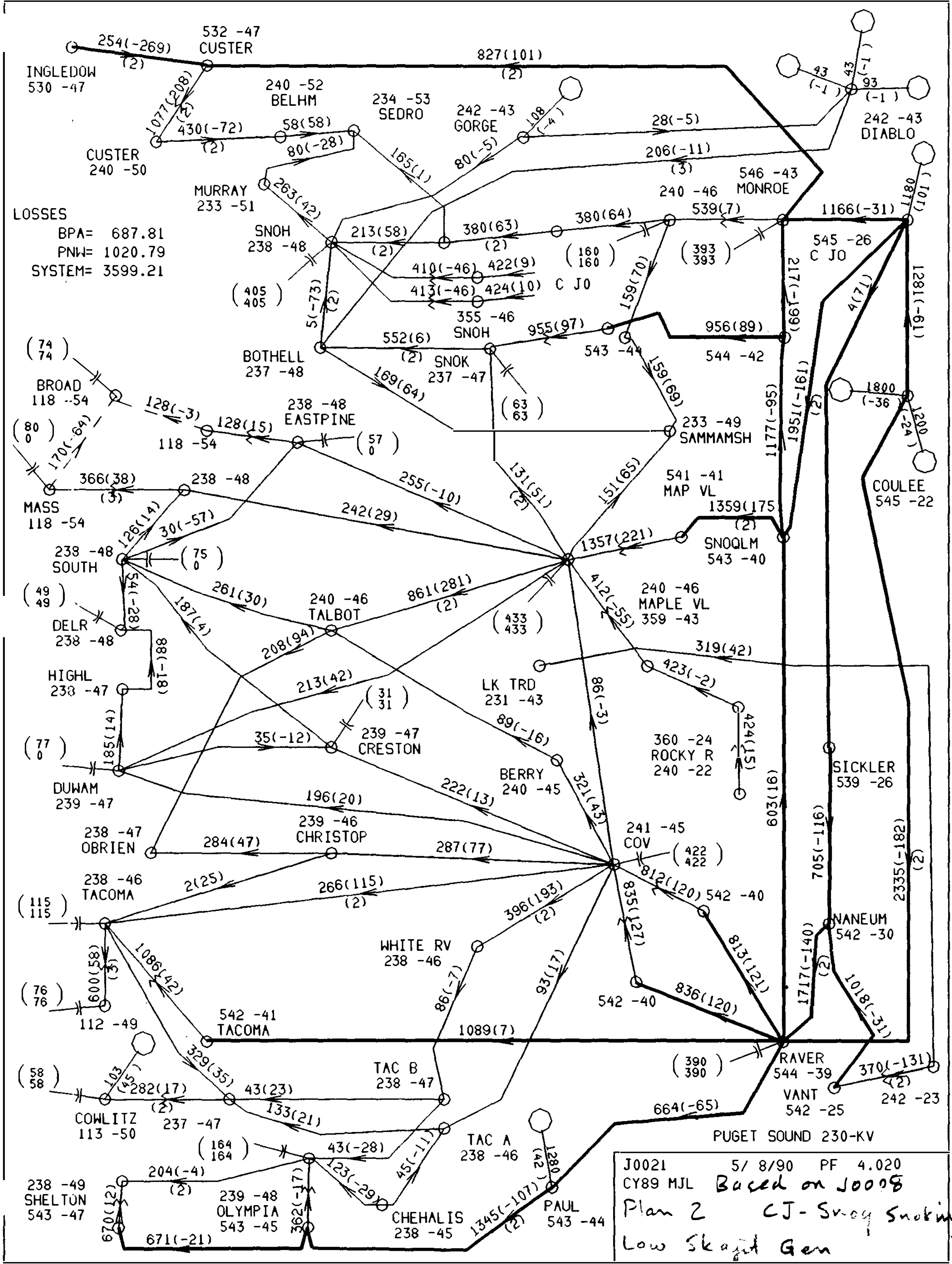
S:PO R- PLOTTED 25-APR-90 AT 14:40:26 HOURS



PUGET SOUND 230-KV

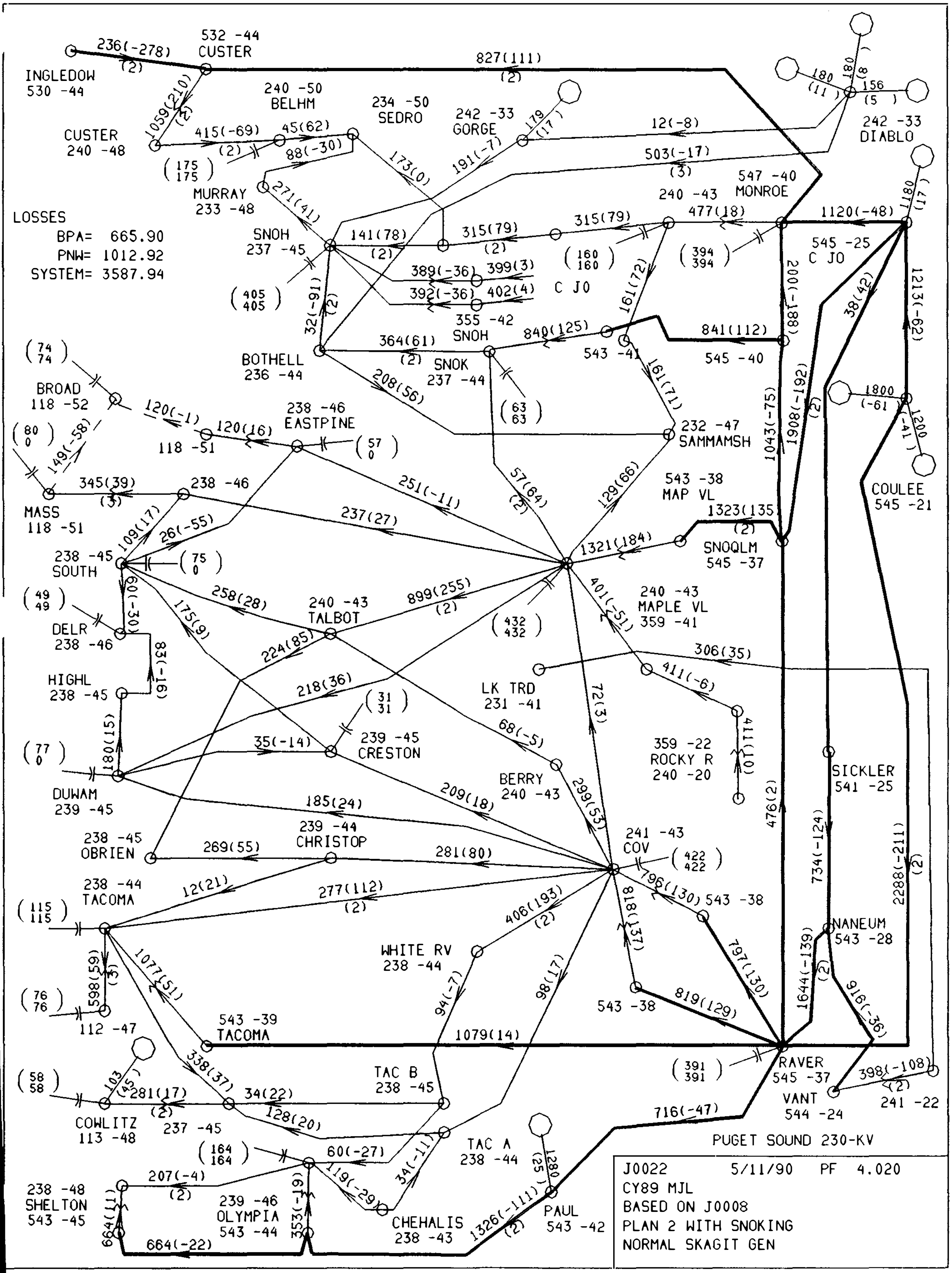
J0018 4/25/90 PF 4.020
CY89 MJL
BASED ON J0008
PLAN 2 CJ-SNOQ. MV-SNOKING 230 #2 AND
MV 500/230 TX #2 ADDED
BOTH CJ-SHOH 345 OUT

S:PO R- PLOTTED 26-APR-90 AT 09:31:25 HOURS



J0021 5/ 8/90 PF 4.020
CY89 MJL Based on J0008
Plan 2 CJ-Snoq Snoking
Low Skagit Gen

S:PQ R- PLOTTED 8-MAY-90 AT 11:00:02 HOURS

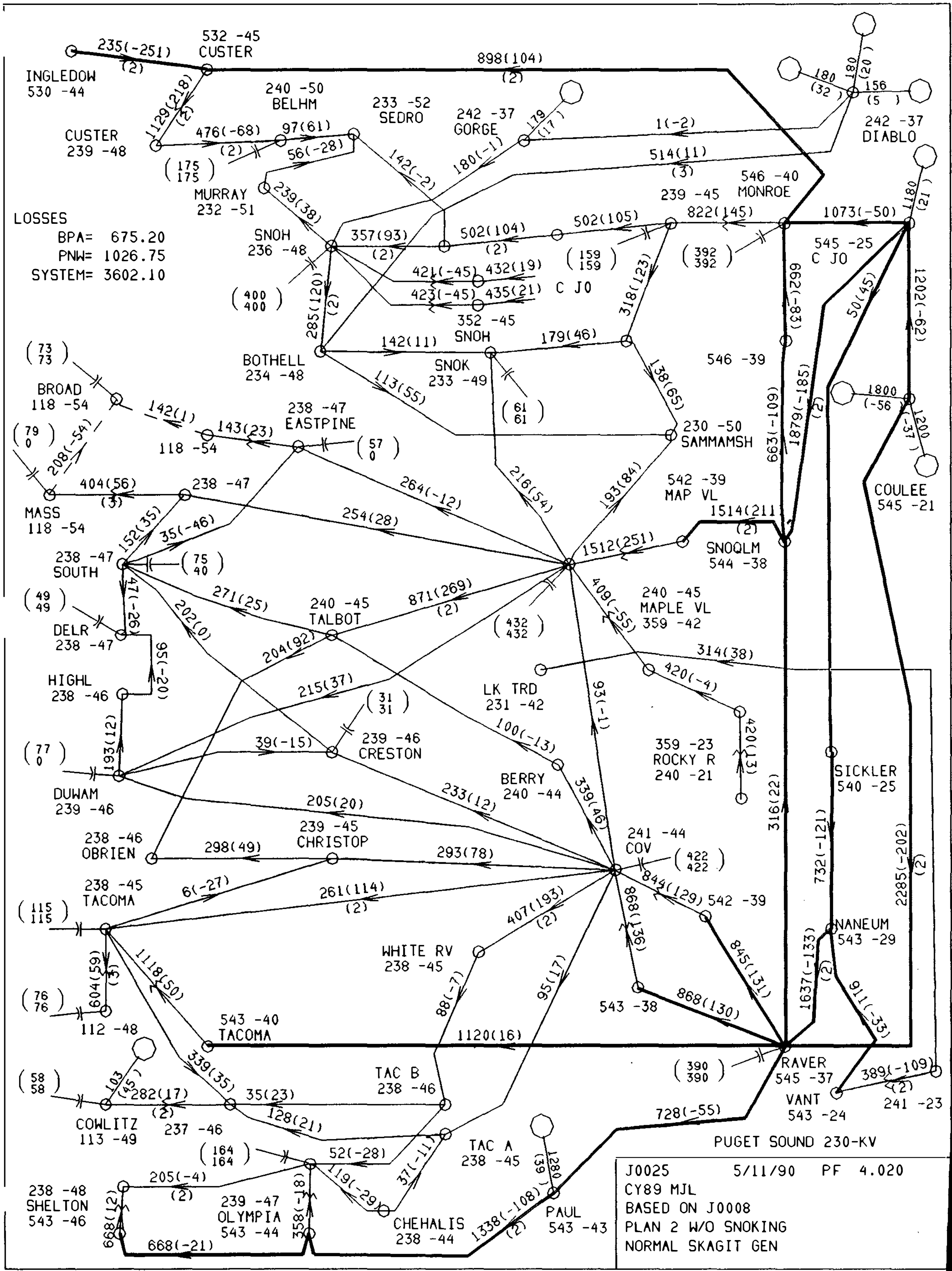


LOSSES
BPA= 665.90
PNW= 1012.92
SYSTEM= 3587.94

PUGET SOUND 230-KV

J0022 5/11/90 PF 4.020
CY89 MJL
BASED ON J0008
PLAN 2 WITH SNOKING
NORMAL SKAGIT GEN

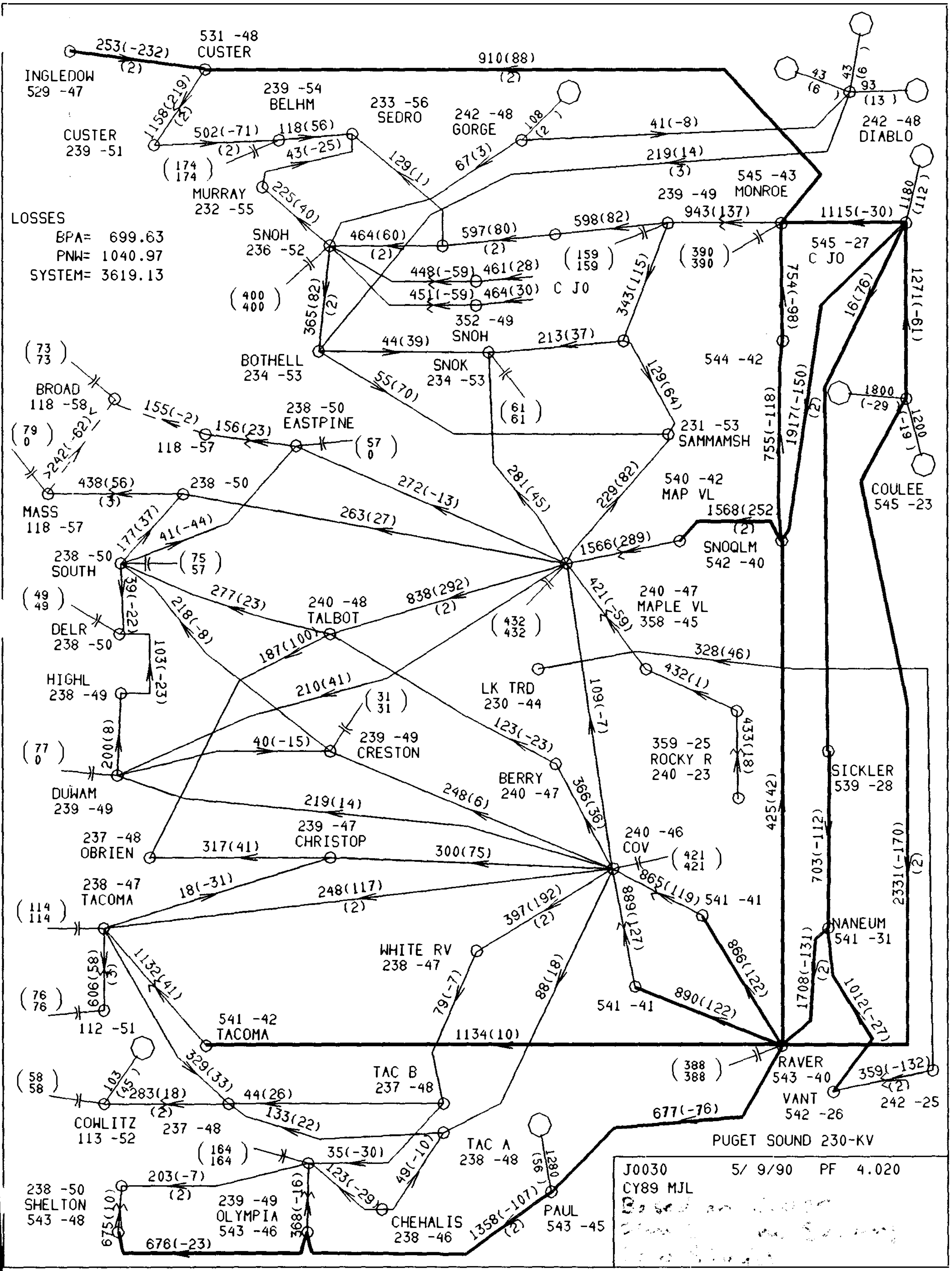
PQ R- PLOTTED 14-MAY-90 AT 07:54:06 HOURS



PUGET SOUND 230-KV

J0025 5/11/90 PF 4.020
CY89 MJL
BASED ON J0008
PLAN 2 W/O SNOKING
NORMAL SKAGIT GEN

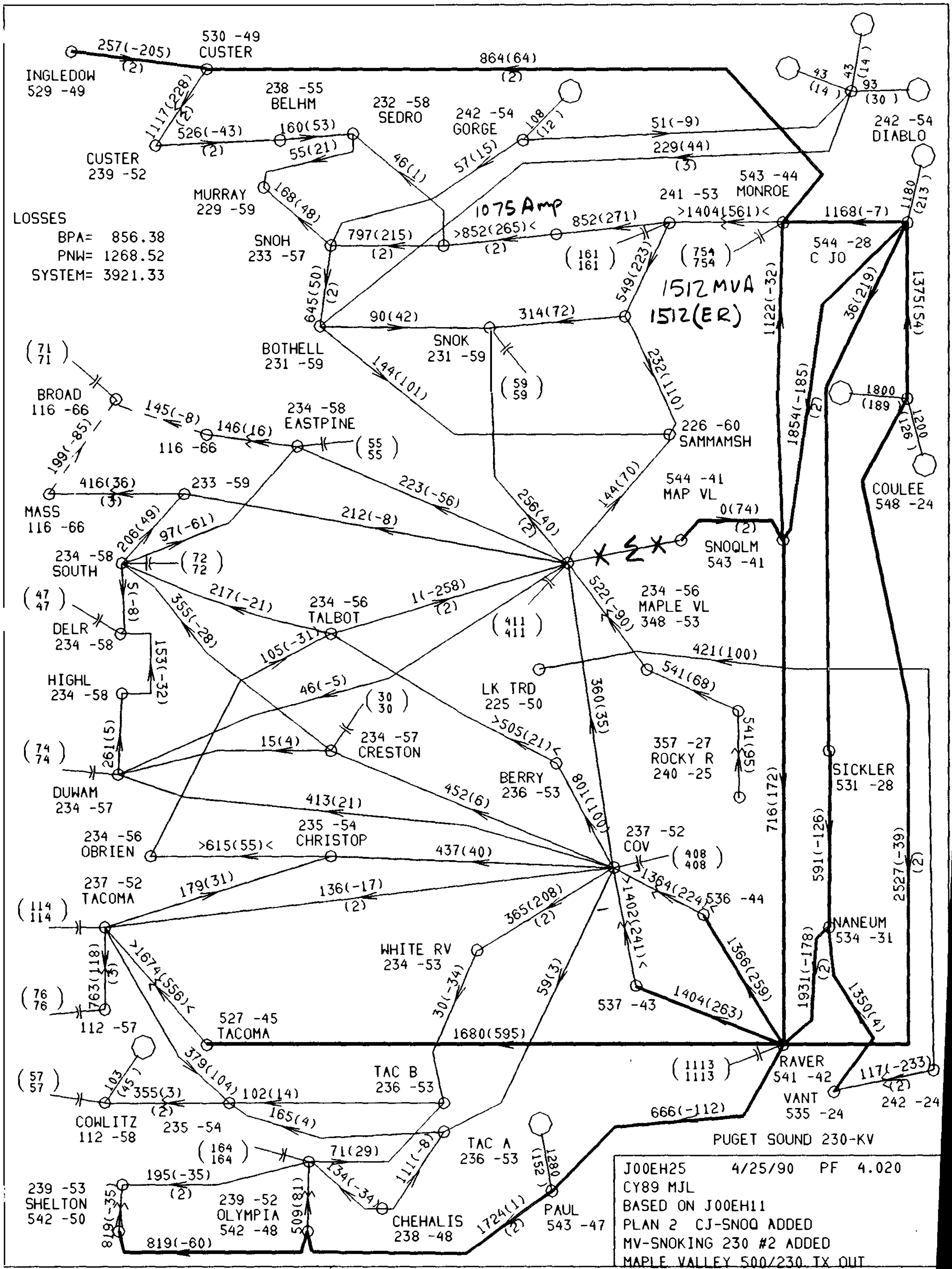
S:PQ R- PLOTTED 14-MAY-90 AT 07:50:28 HOURS



PUGET SOUND 230-KV

J0030 5/ 9/90 PF 4.020
CY89 MJL

PQ R- PLOTTED 9-MAY-90 AT 14:39:16 HOURS
]

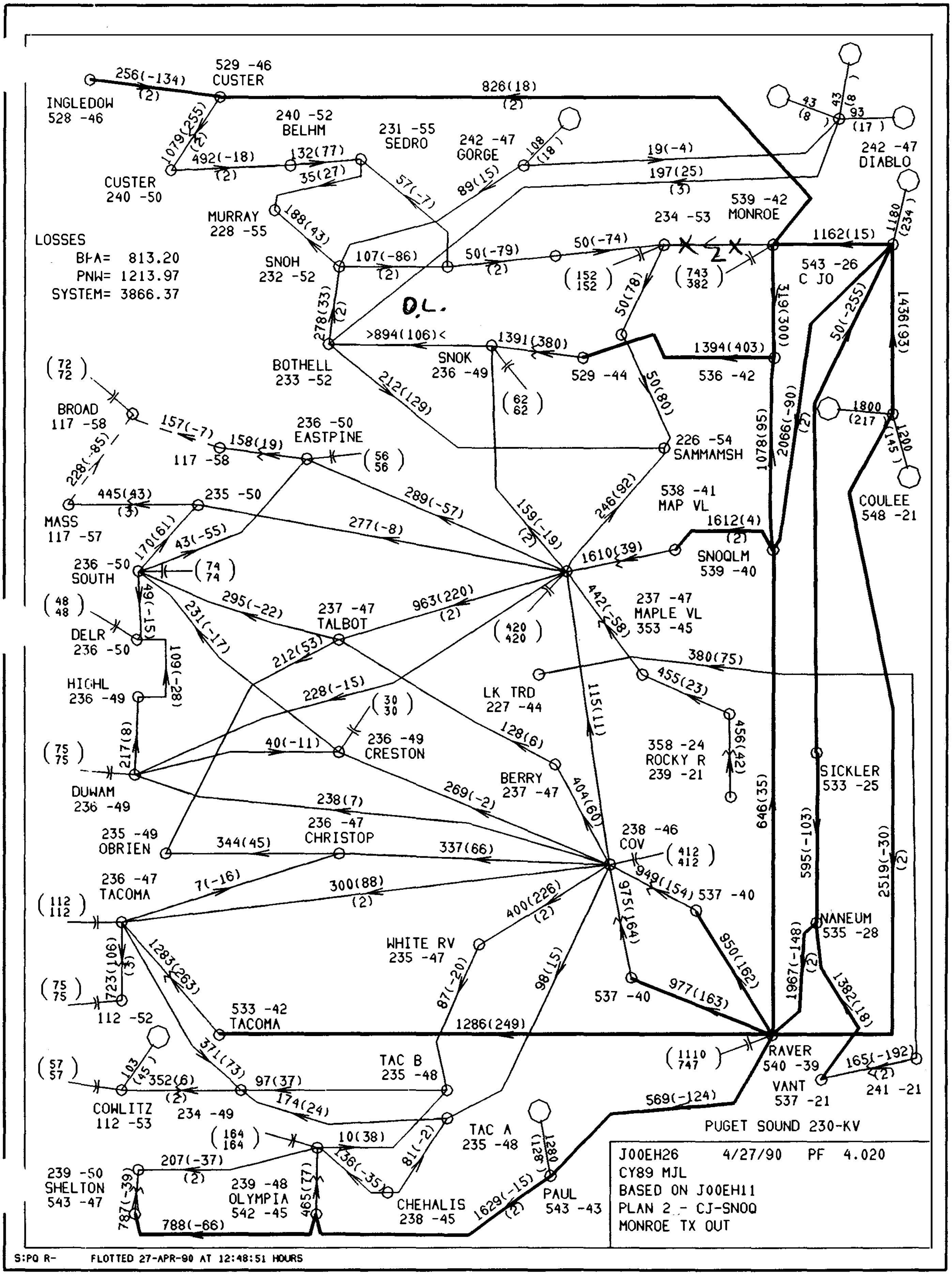


LOSSES
BPA= 856.38
PNW= 1268.52
SYSTEM= 3921.33

PUGET SOUND 230-KV

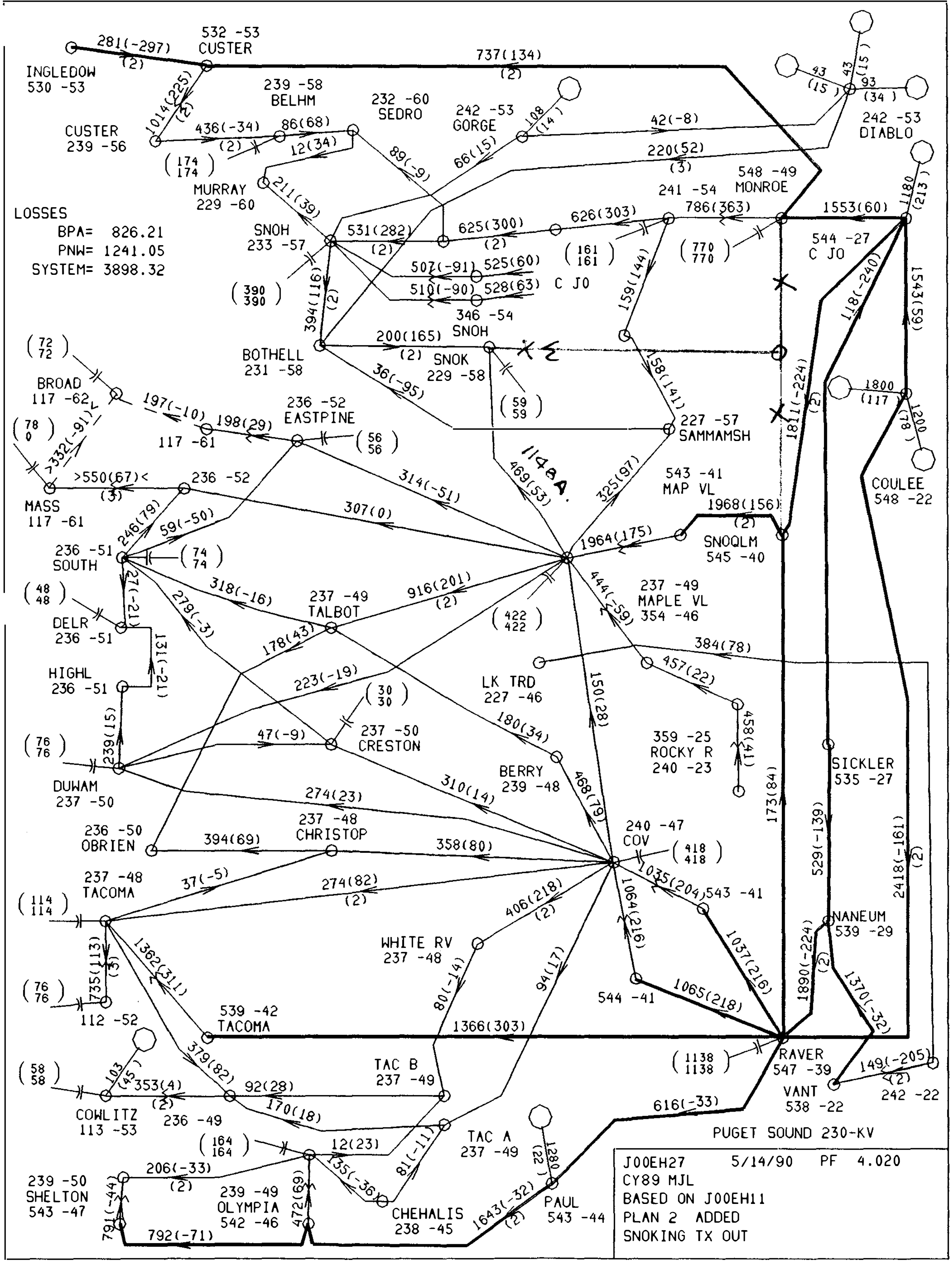
J00EH25 4/25/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 2 CJ-SNOQ ADDED
MV-SNOKING 230 #2 ADDED
MAPLE VALLEY 500/230 TX OUT

S:PQ R- PLOTTED 25-APR-90 AT 14:42:38 HOURS



J00EH26 4/27/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 2 - CJ-SNOQ
MONROE TX OUT

S:PQ R- PLOTTED 27-APR-90 AT 12:48:51 HOURS

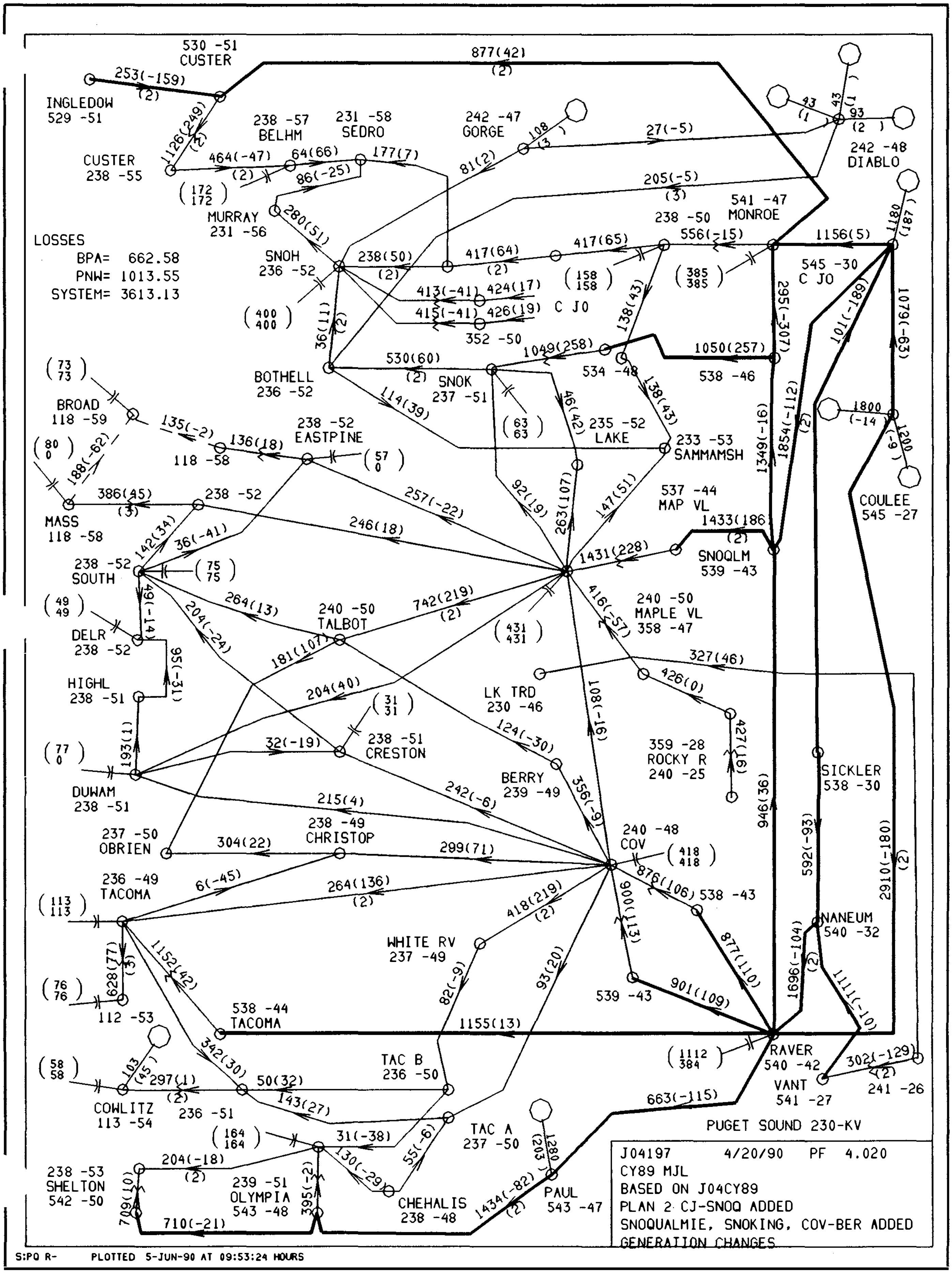


LOSSES
BPA= 826.21
PNW= 1241.05
SYSTEM= 3898.32

PUGET SOUND 230-KV

J00EH27 5/14/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 2 ADDED
SNOKING TX OUT

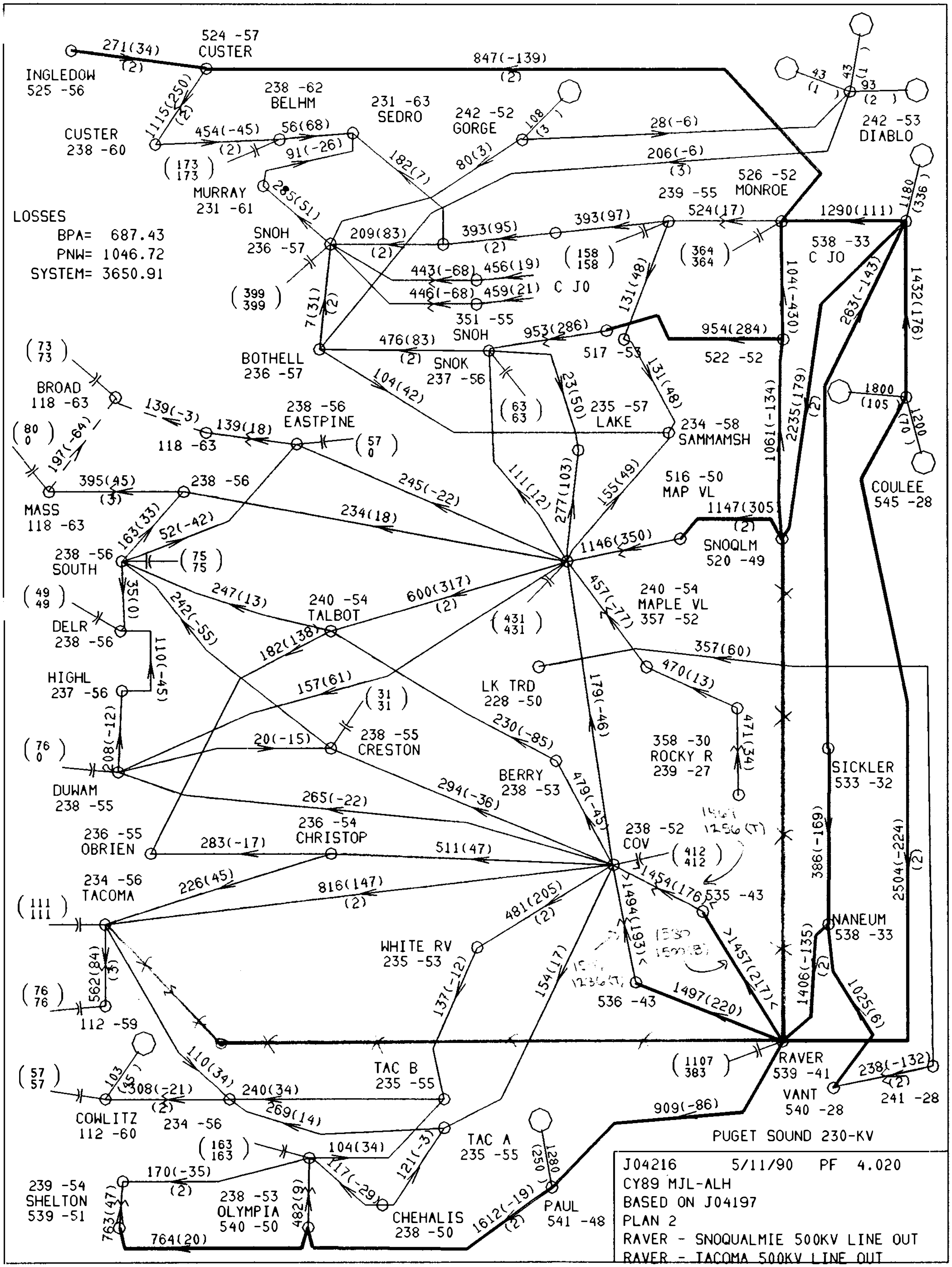
S:PQ R- PLOTTED 14-MAY-90 AT 08:23:01 HOURS



LOSSES
BPA= 662.58
PNW= 1013.55
SYSTEM= 3613.13

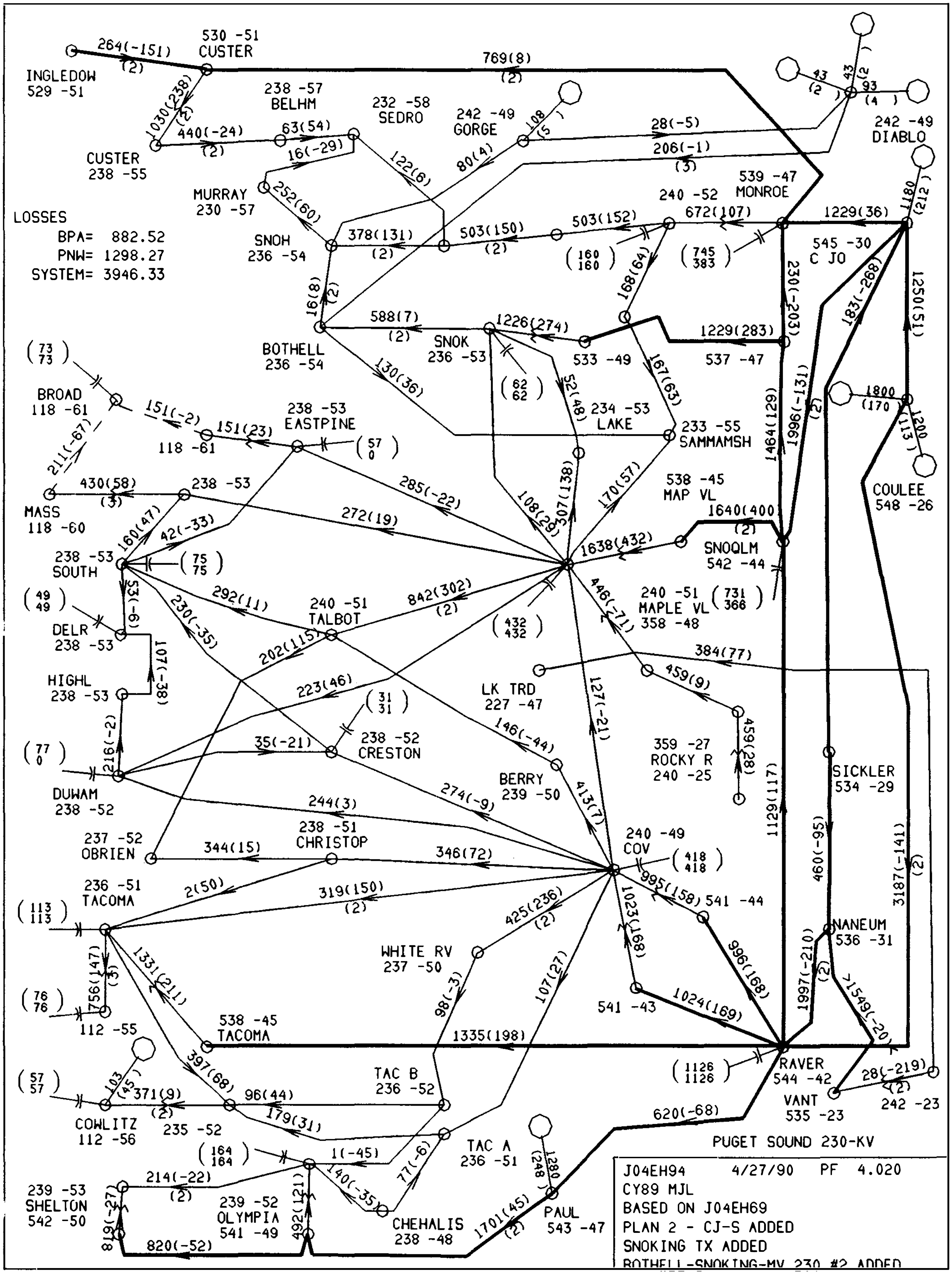
J04197 4/20/90 PF 4.020
CY89 MJL
BASED ON J04CY89
PLAN 2 CJ-SNOQ ADDED
SNOQUALMIE, SNOKING, COV-BER ADDED
GENERATION CHANGES

S:PQ R- PLOTTED 5-JUN-90 AT 09:53:24 HOURS



J04216 5/11/90 PF 4.020
CY89 MJL-ALH
BASED ON J04197
PLAN 2
RAVER - SNOQUALMIE 500KV LINE OUT
RAVER - TACOMA 500KV LINE OUT

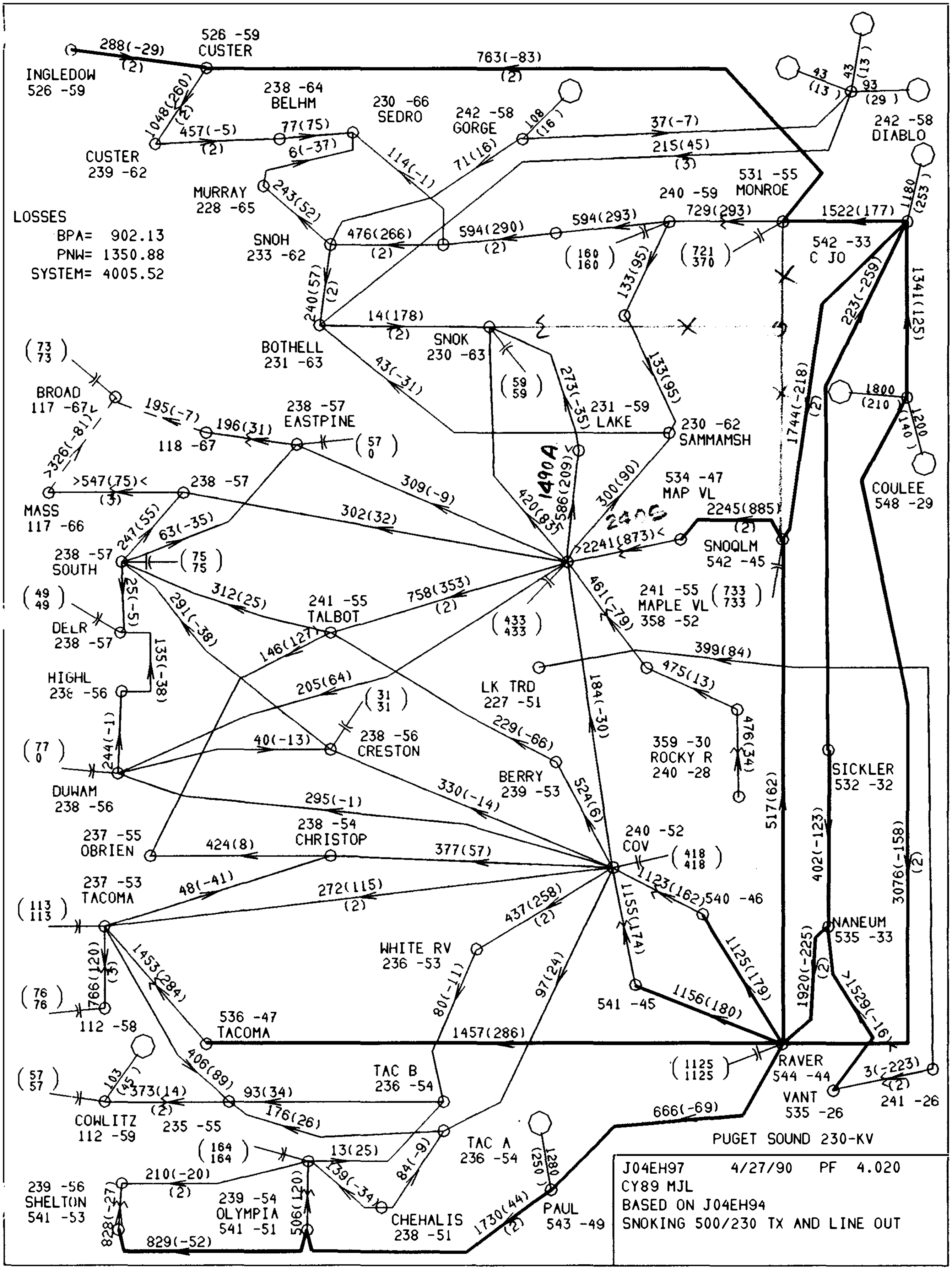
S:PQ R- PLOTTED 11-MAY-90 AT 15:41:49 HOURS



PUGET SOUND 230-KV

J04EH94 4/27/90 PF 4.020
CY89 MJL
BASED ON J04EH69
PLAN 2 - CJ-S ADDED
SNOKING TX ADDED
BOTHELL-SNOKING-MV 230 #2 ADDED

S:PQ R- PLOTTED 27-APR-90 AT 09:31:35 HOURS



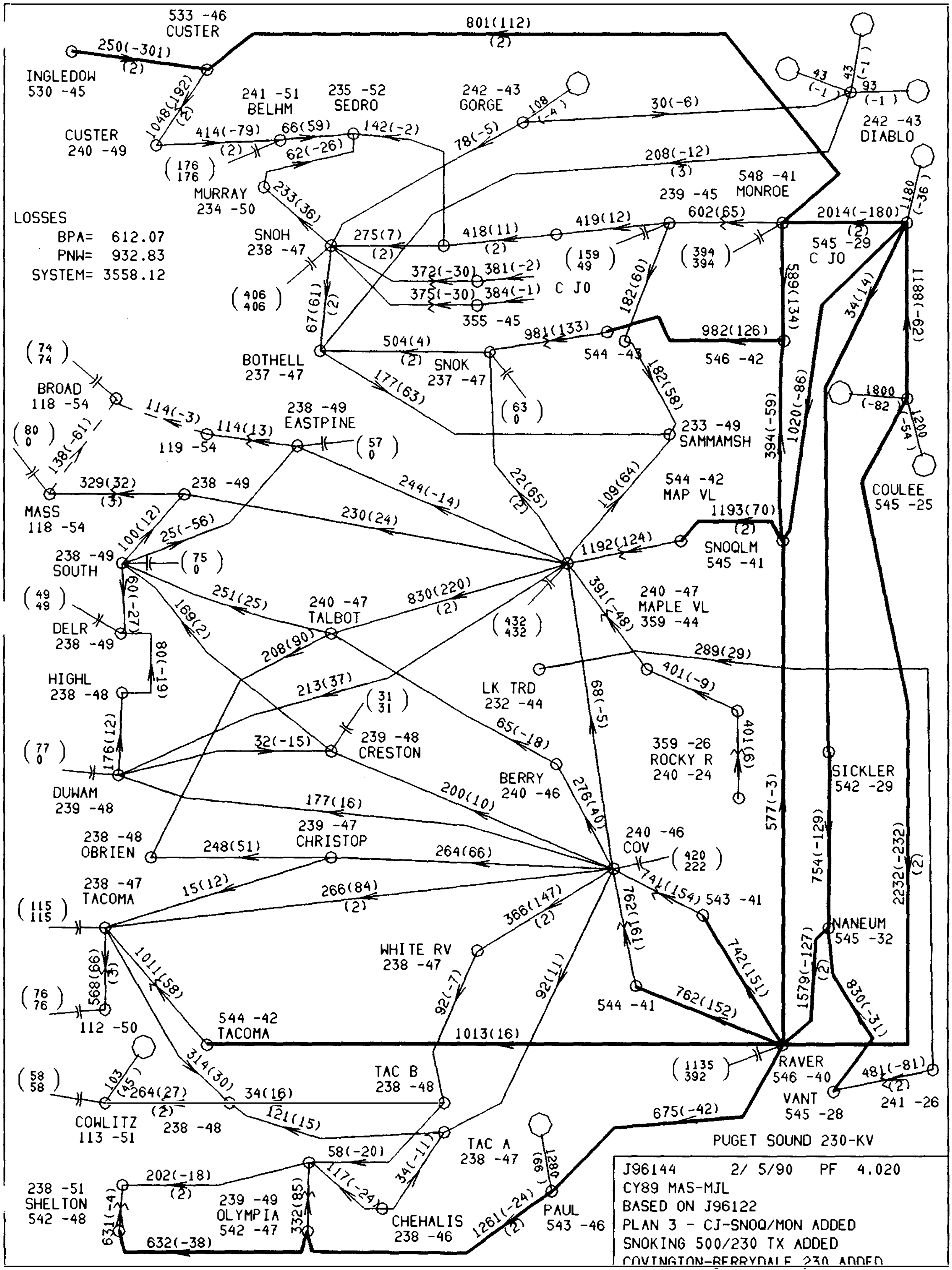
LOSSES
BPA= 902.13
PNW= 1350.88
SYSTEM= 4005.52

PUGET SOUND 230-KV

J04EH97 4/27/90 PF 4.020
CY89 MJL
BASED ON J04EH94
SNOKING 500/230 TX AND LINE OUT

S:PQ R- PLOTTED 27-APR-90 AT 15:26:31 HOURS

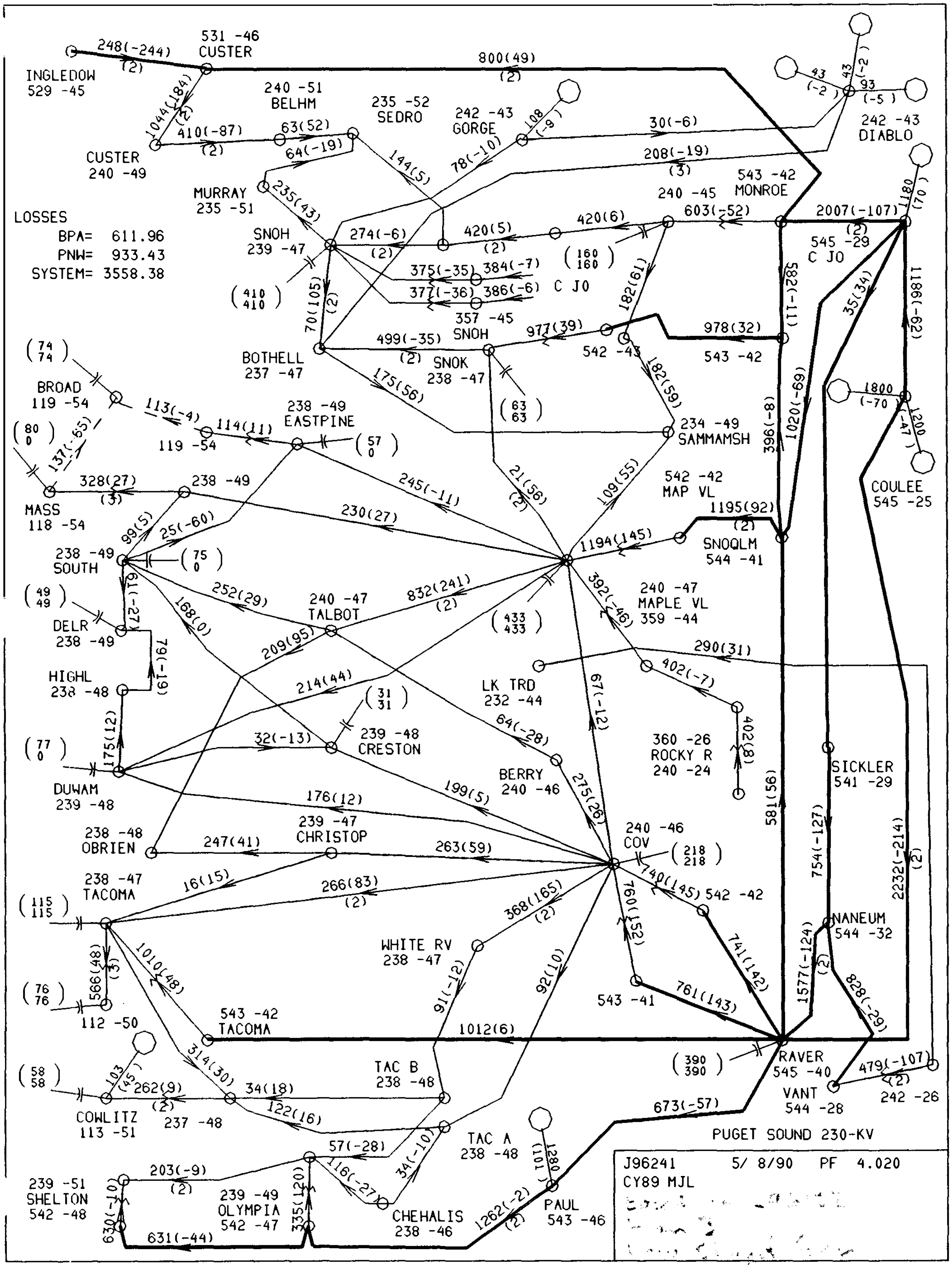
PF - PLAN 3



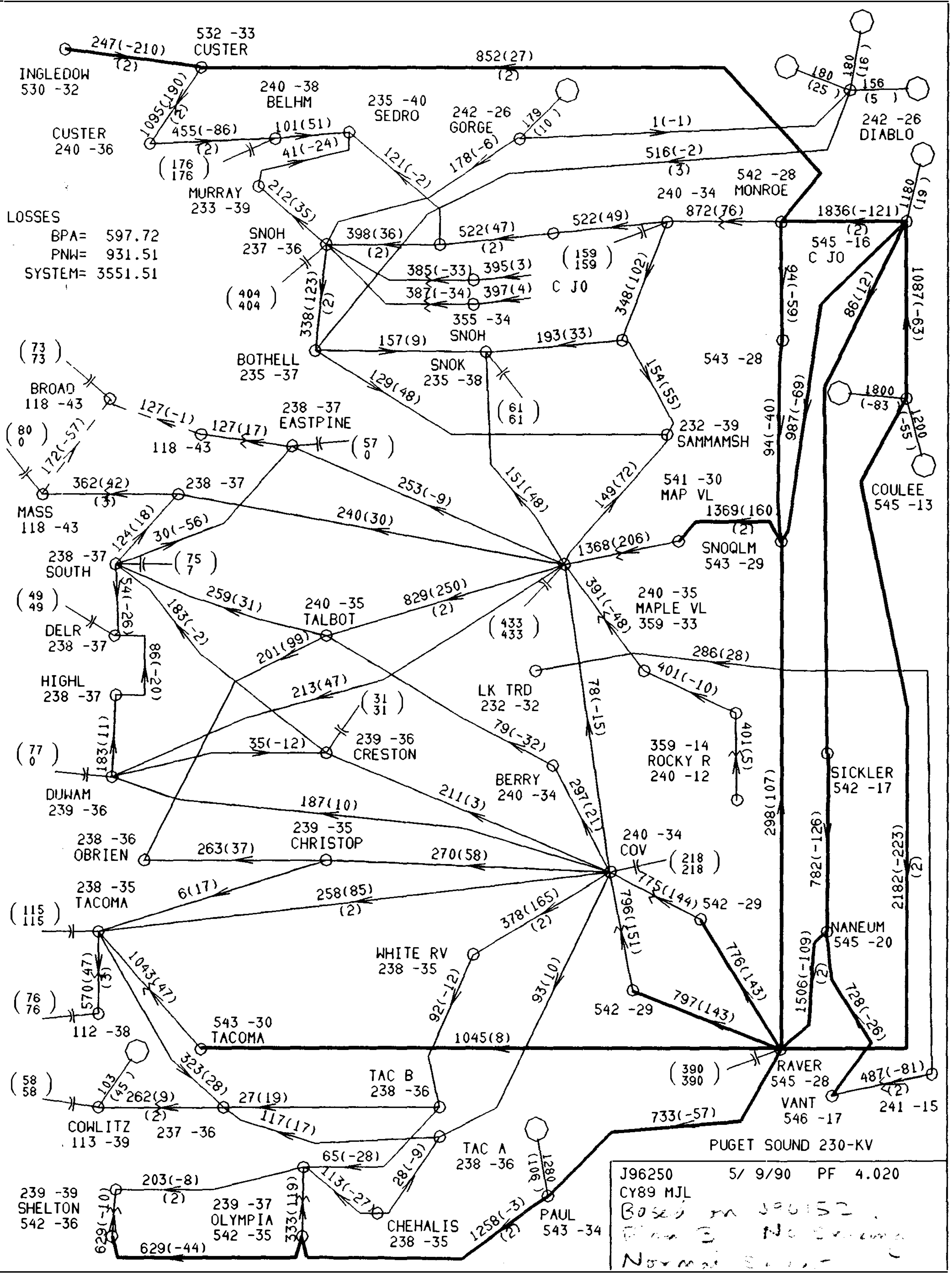
PUGET SOUND 230-KV

J96144 2/ 5/90 PF 4.020
CY89 MAS-MJL
BASED ON J96122
PLAN 3 - CJ-SNOQ/MON ADDED
SNOKING 500/230 TX ADDED
COVINGTON-BERRYDALE 230 ADDED

S:PQ R- PLOTTED 5-JUN-90 AT 08:58:07 HOURS



S:PQ R- PLOTTED 9-MAY-90 AT 07:47:07 HOURS

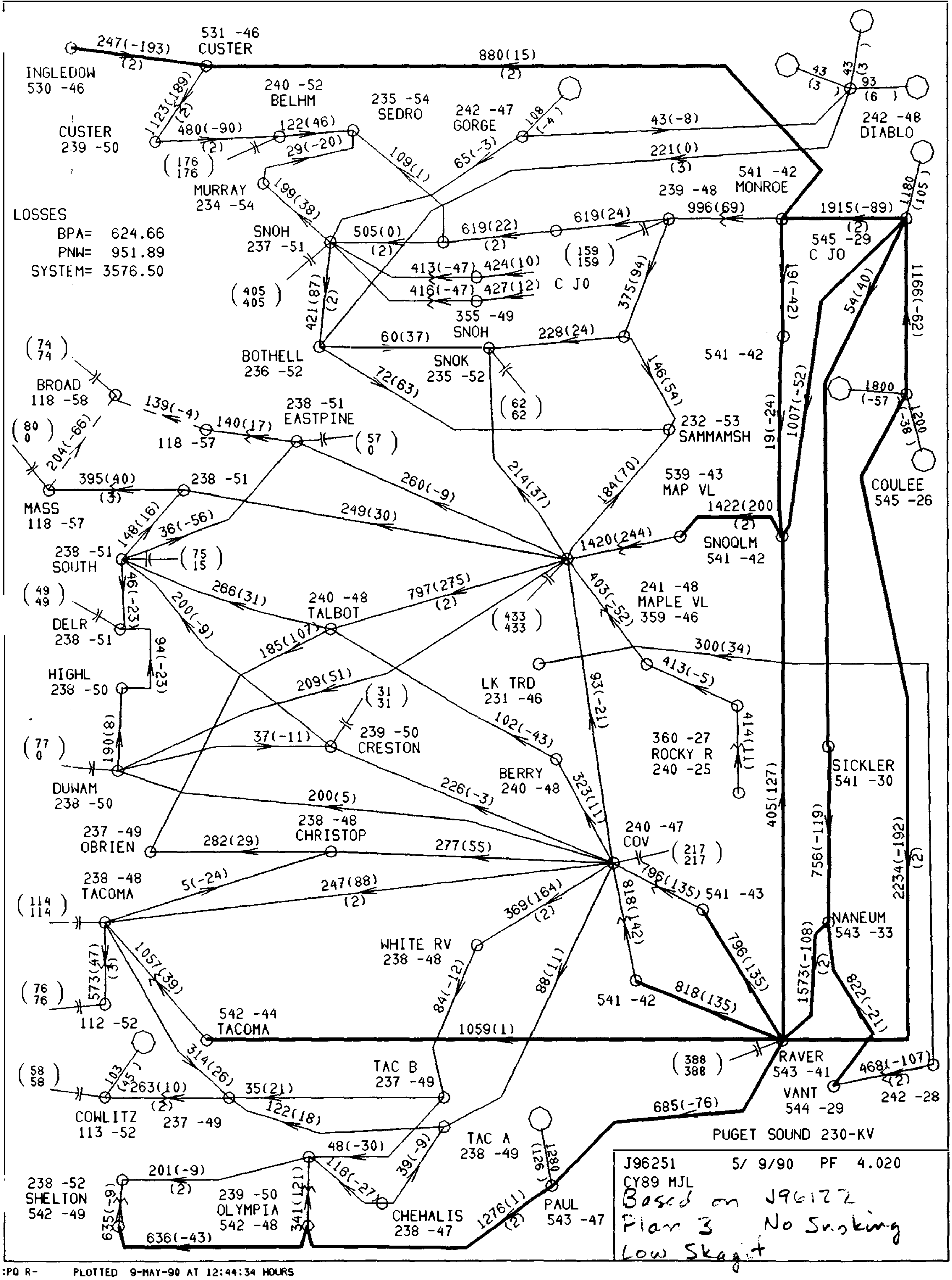


LOSSES
BPA= 597.72
PNW= 931.51
SYSTEM= 3551.51

PUGET SOUND 230-KV

J96250 5/ 9/90 PF 4.020
CY89 MJL
Based on J96152.
Plan 3 No [illegible]
Normal [illegible]

S:PQ R- PLOTTED 9-MAY-90 AT 12:43:13 HOURS

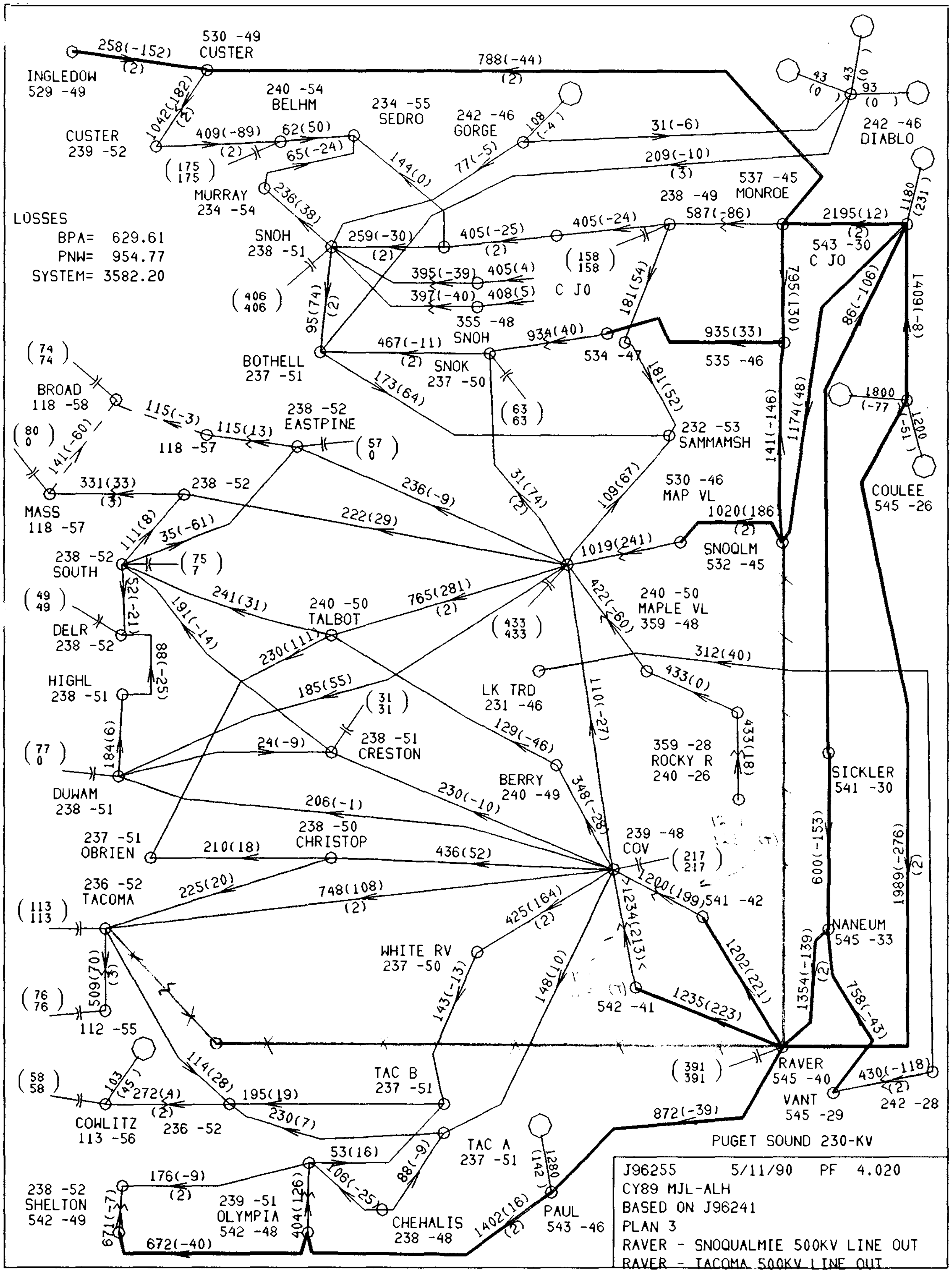


LOSSES
BPA= 624.66
PNW= 951.89
SYSTEM= 3576.50

PUGET SOUND 230-KV

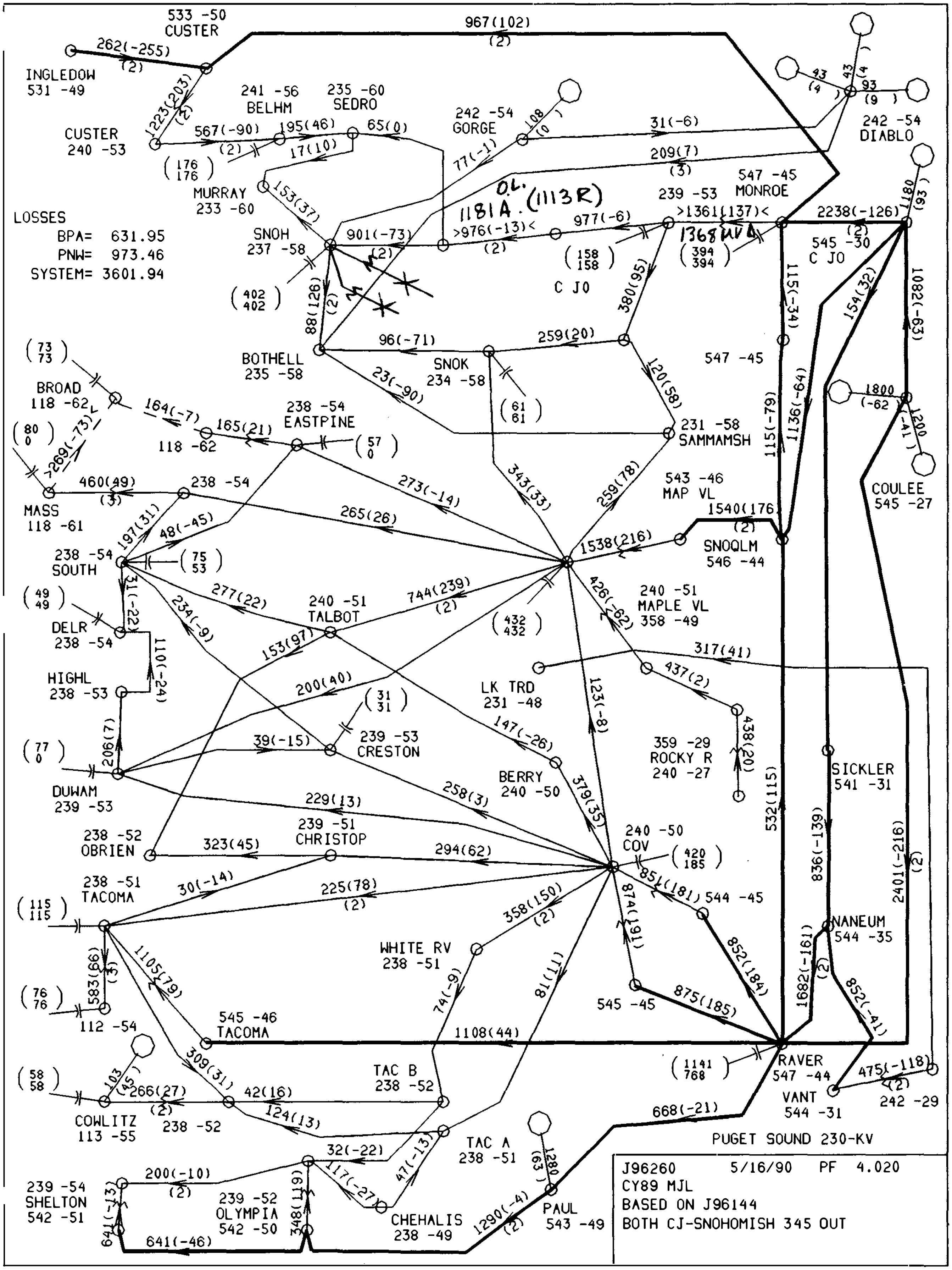
J96251   5/ 9/90   PF 4.020
CY89 MJL
Based on J96122
Plan 3   No Sinking
Low Skagit

S:PQ R-   PLOTTED 9-MAY-90 AT 12:44:34 HOURS



J96255 5/11/90 PF 4.020
CY89 MJL-ALH
BASED ON J96241
PLAN 3
RAVER - SNOQUALMIE 500KV LINE OUT
RAVER - TACOMA 500KV LINE OUT

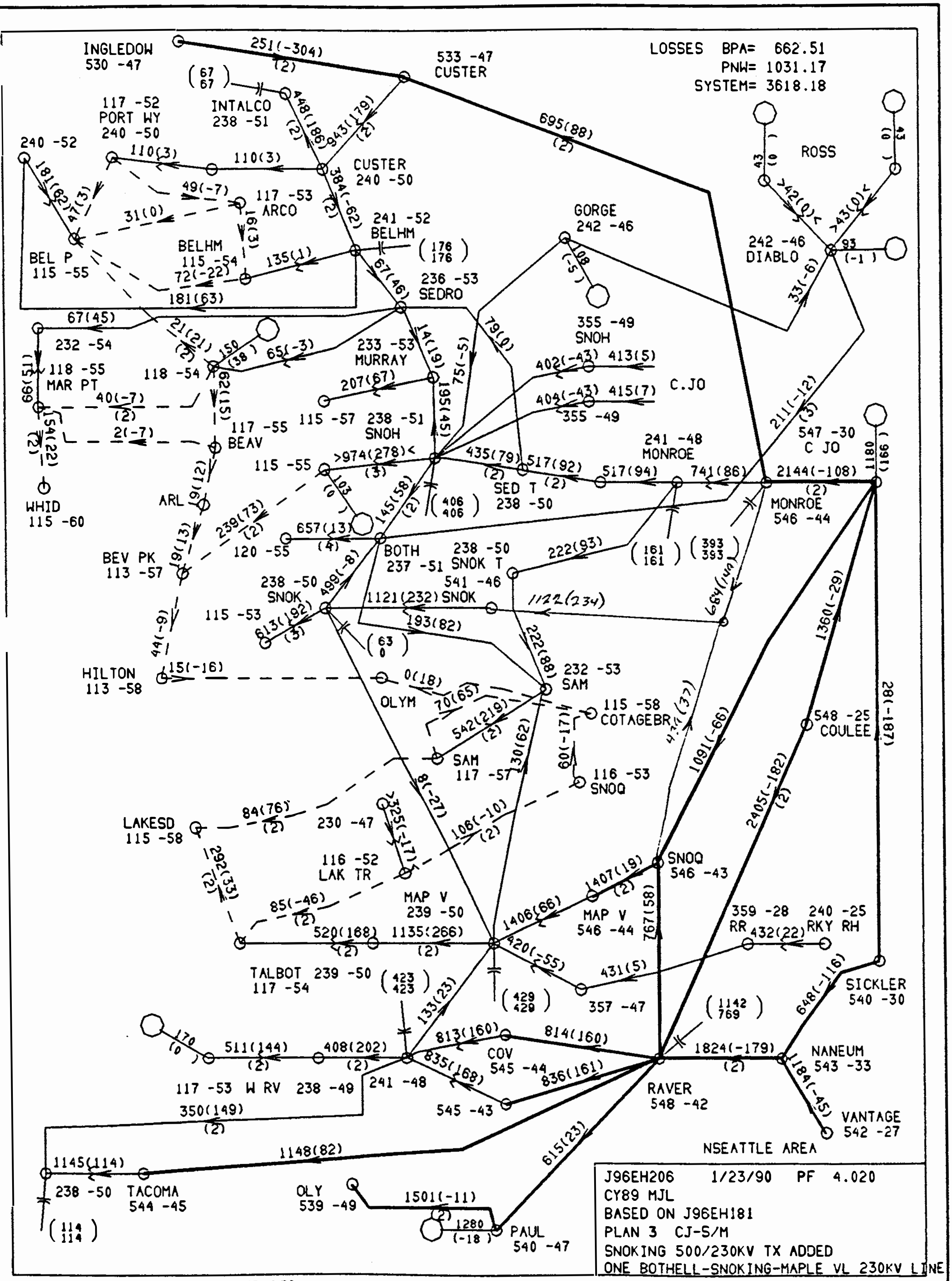
S:PQ R- PLOTTED 11-MAY-90 AT 15:34:25 HOURS



PUGET SOUND 230-KV

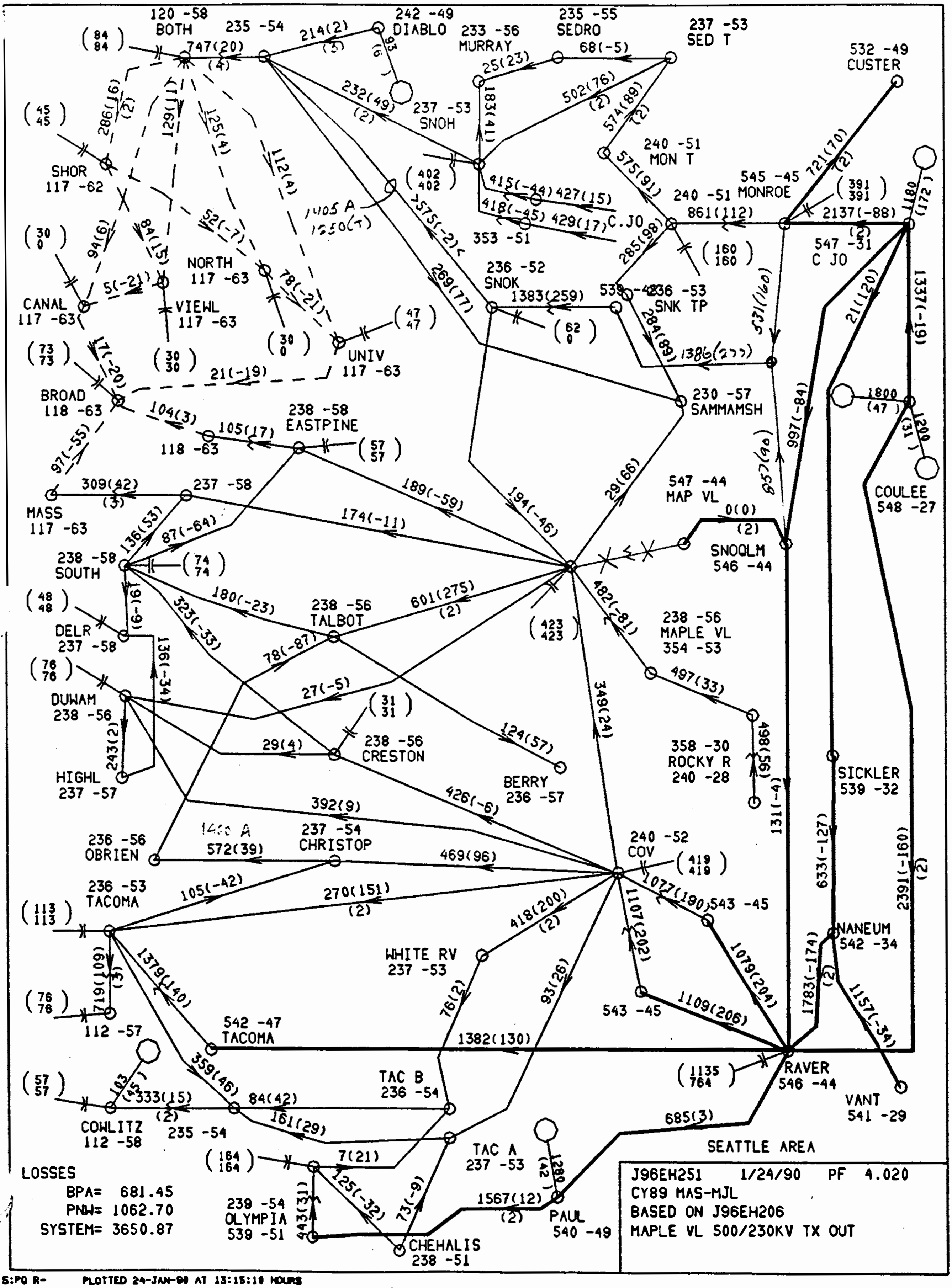
J96260 5/16/90 PF 4.020
CY89 MJL
BASED ON J96144
BOTH CJ-SNOHOMISH 345 OUT

S:PQ R- PLOTTED 16-MAY-90 AT 15:15:33 HOURS



J96EH206 1/23/90 PF 4.020
CY89 MJL
BASED ON J96EH181
PLAN 3 CJ-S/M
SNOKING 500/230KV TX ADDED
ONE BOTHELL-SNOKING-MAPLE VL 230KV LINE

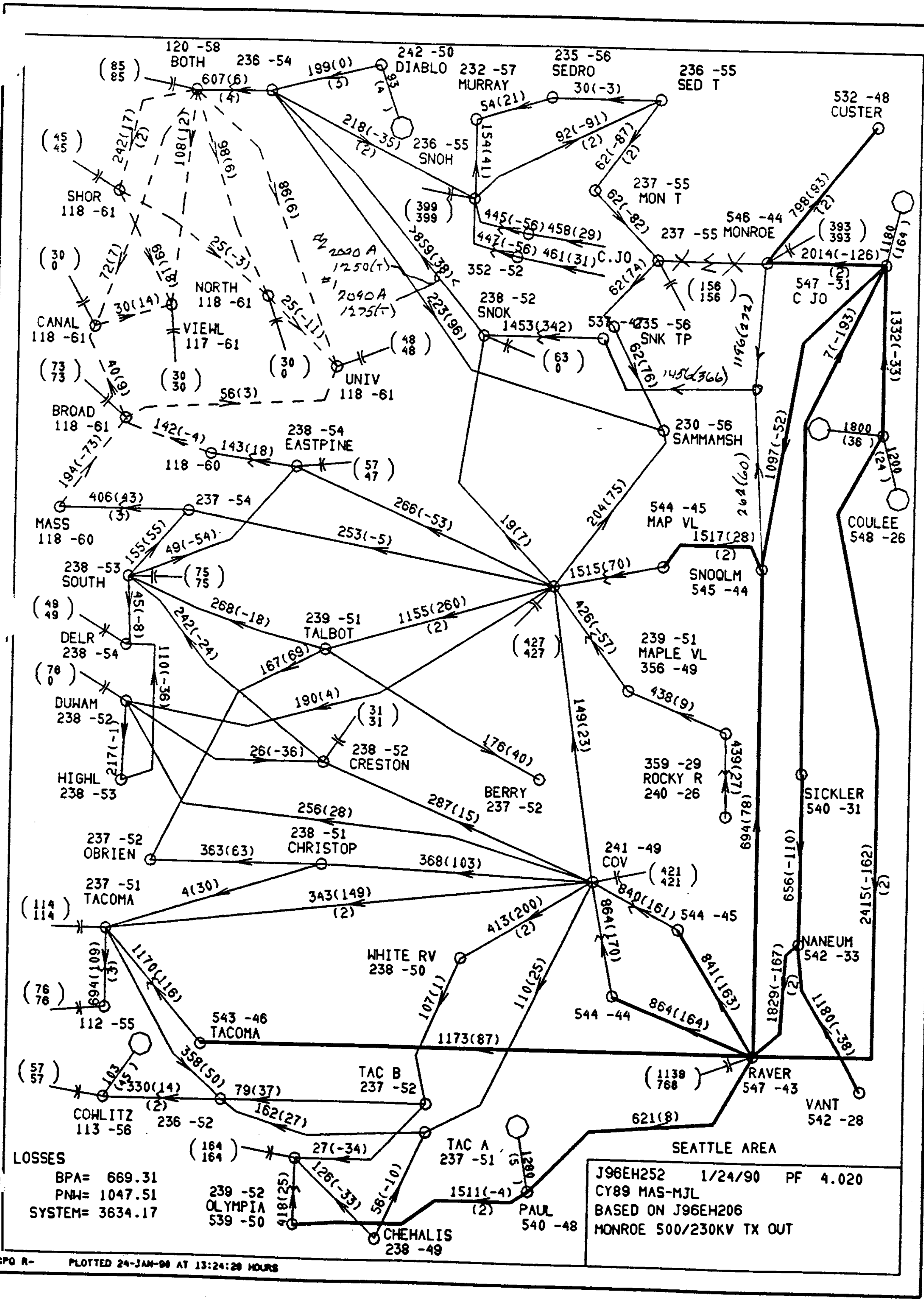
S:PO R- PLOTTED 24-JAN-90 AT 13:52:25 HOURS



LOSSES
BPA= 681.45
PNW= 1062.70
SYSTEM= 3650.87

J96EH251 1/24/90 PF 4.020
CY89 MAS-MJL
BASED ON J96EH206
MAPLE VL 500/230KV TX OUT

S:PO R- PLOTTED 24-JAN-90 AT 13:15:10 HOURS



LOSSES

BPA= 669.31

PNW= 1047.51

SYSTEM= 3634.17

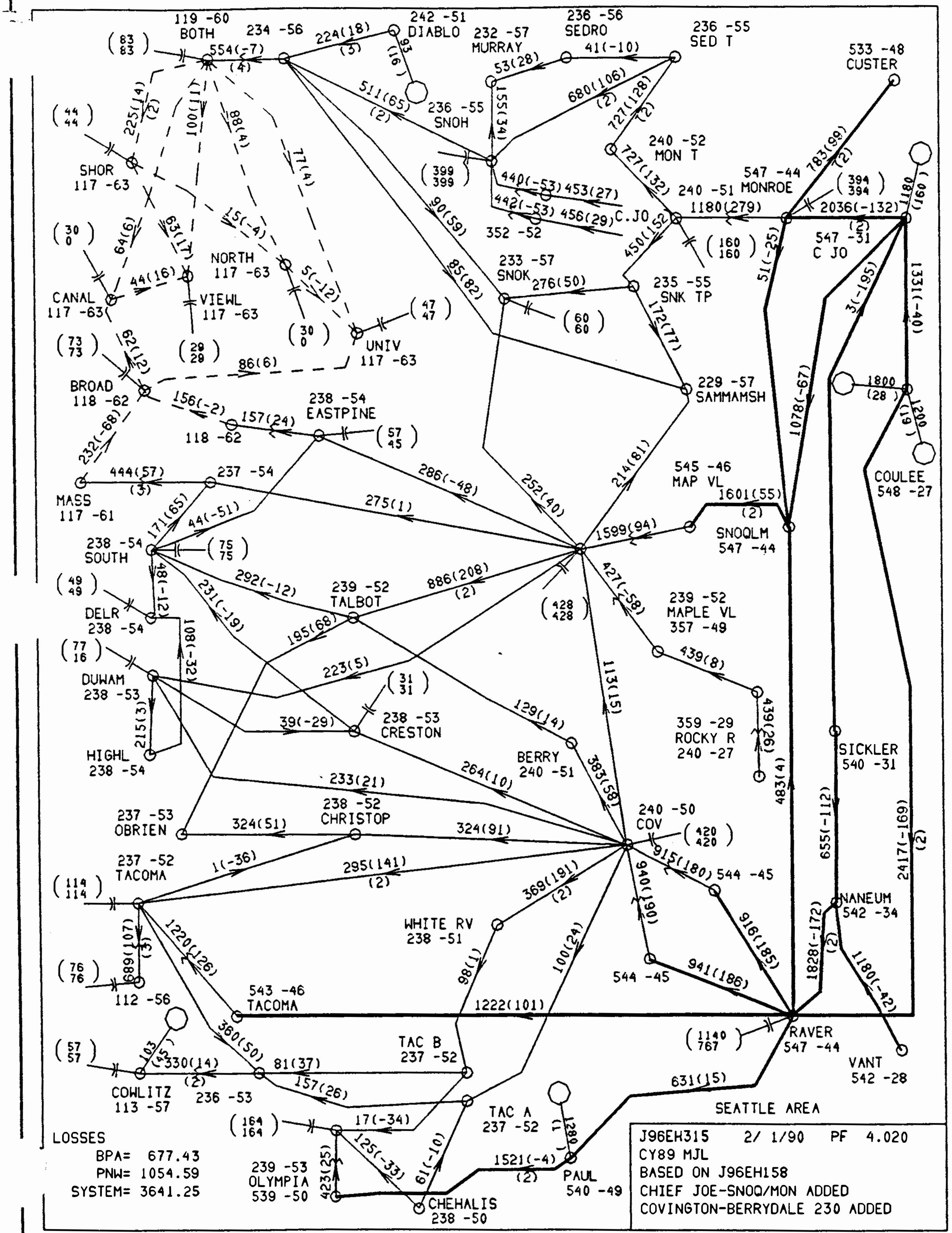
J96EH252 1/24/90 PF 4.020

CY89 MAS-MJL

BASED ON J96EH206

MONROE 500/230KV TX OUT

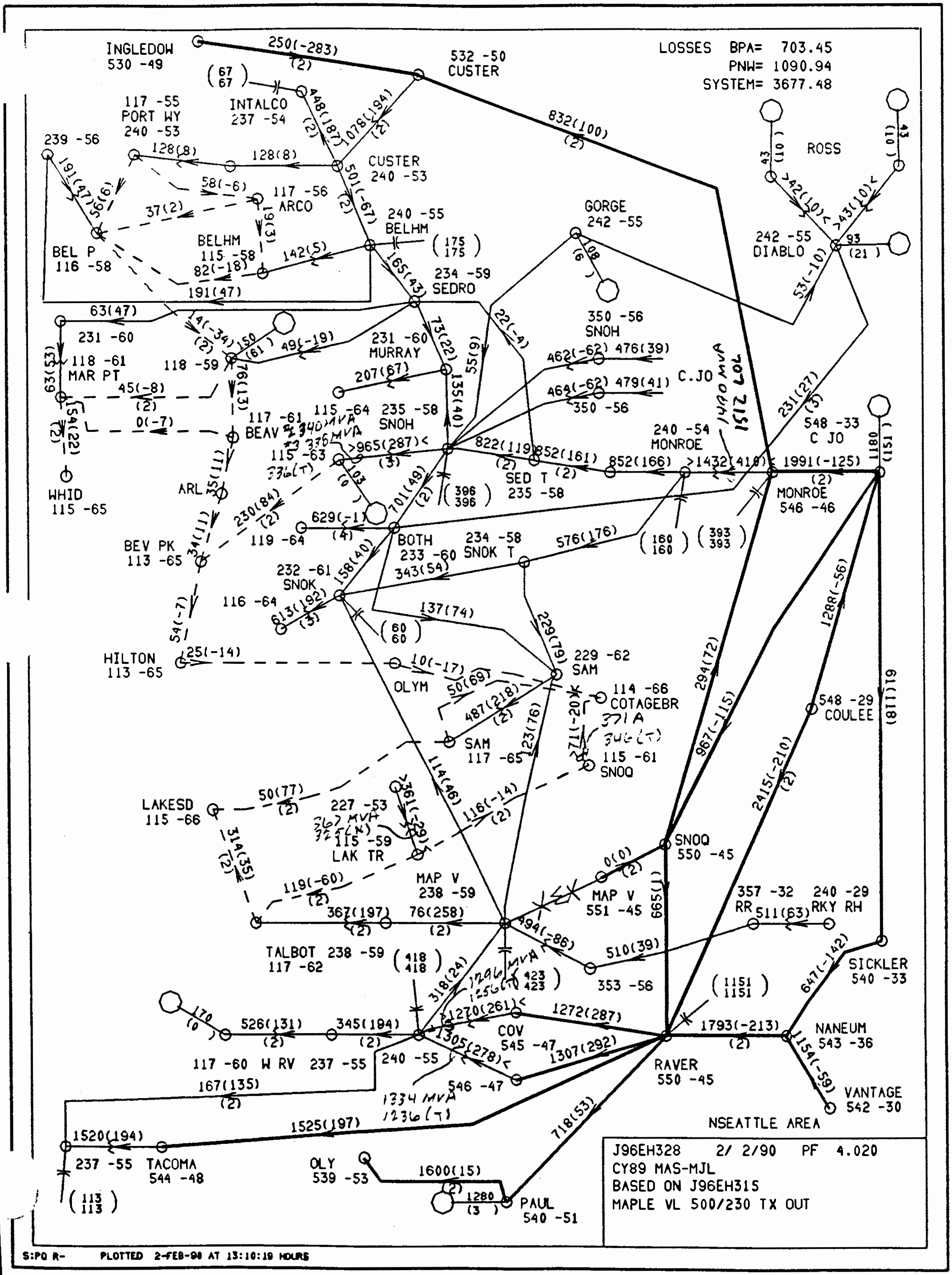
S:PQ R- PLOTTED 24-JAN-90 AT 13:24:28 HOURS



LOSSES
BPA= 677.43
PNW= 1054.59
SYSTEM= 3641.25

J96EH315 2/ 1/90 PF 4.020
CY89 MJL
BASED ON J96EH158
CHIEF JOE-SNOQ/MON ADDED
COVINGTON-BERRYDALE 230 ADDED

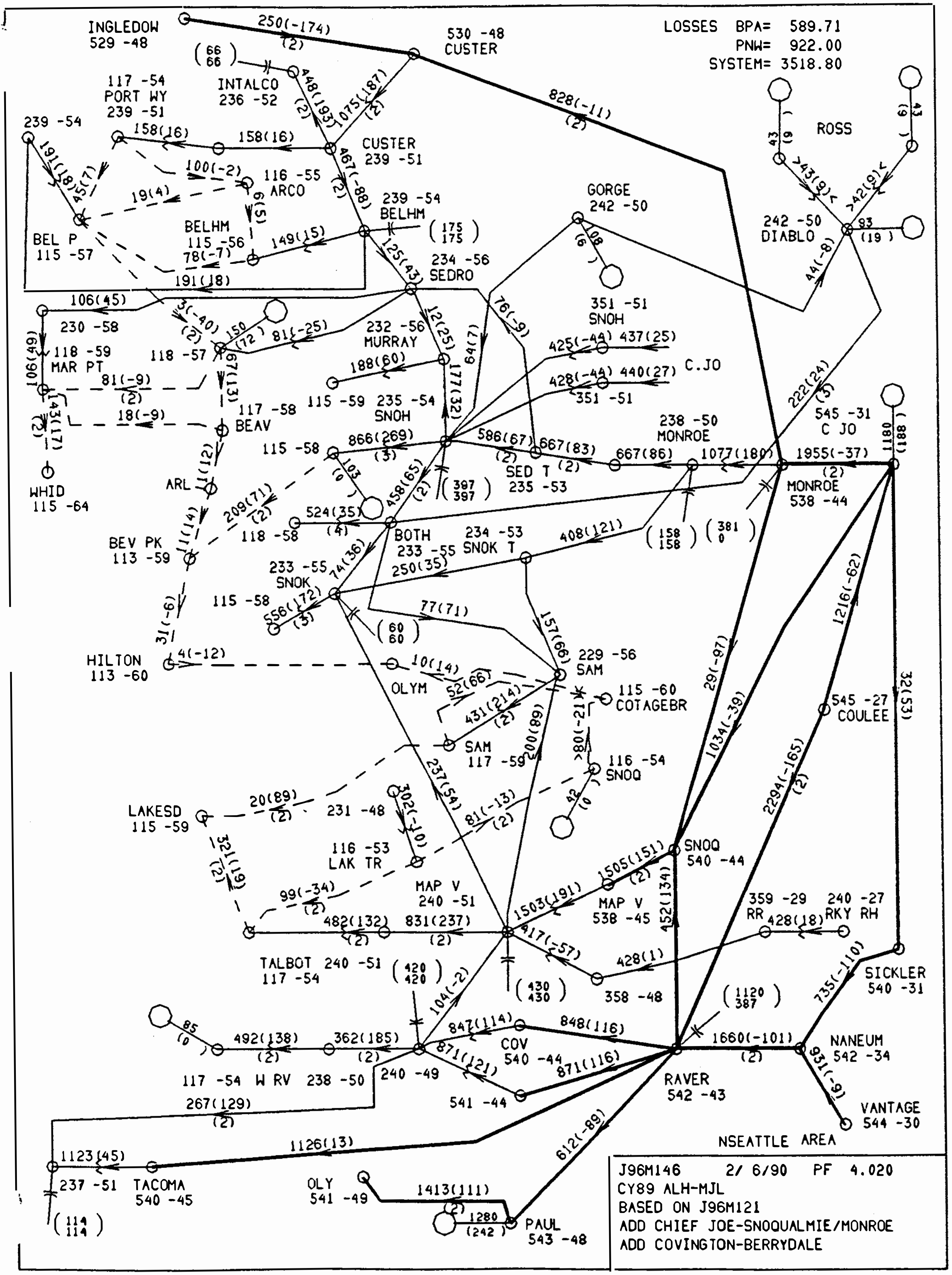
S:PO R- PLOTTED 2-FEB-90 AT 07:55:23 HOURS



LOSSES BPA= 703.45
PNW= 1090.94
SYSTEM= 3677.48

J96EH328 2/ 2/90 PF 4.020
CY89 MAS-MJL
BASED ON J96EH315
MAPLE VL 500/230 TX OUT

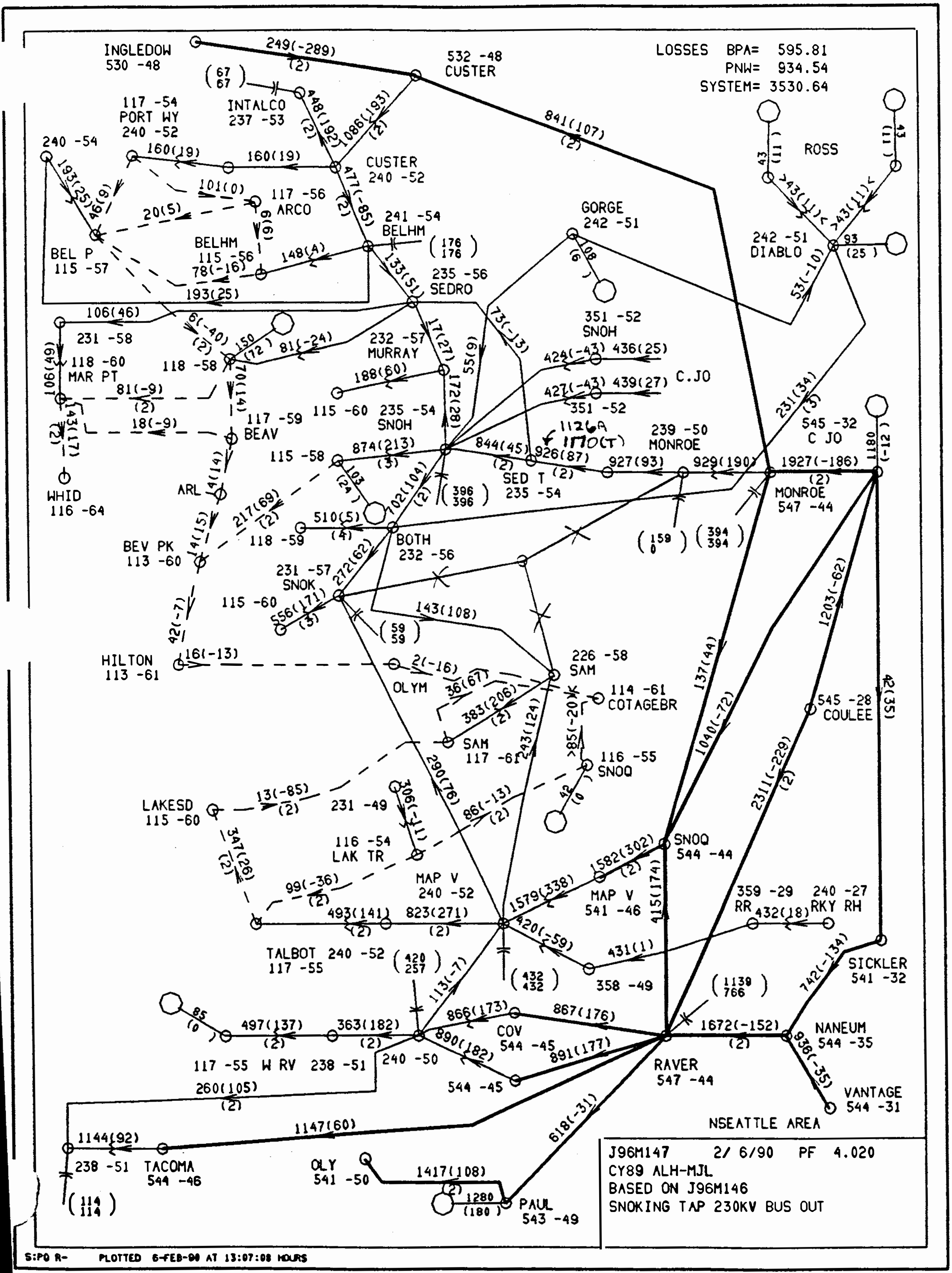
S:PQ R- PLOTTED 2-FEB-90 AT 13:10:19 HOURS



LOSSES BPA= 589.71
PNW= 922.00
SYSTEM= 3518.80

J96M146 2/ 6/90 PF 4.020
CY89 ALH-MJL
BASED ON J96M121
ADD CHIEF JOE-SNOQUALMIE/MONROE
ADD COVINGTON-BERRYDALE

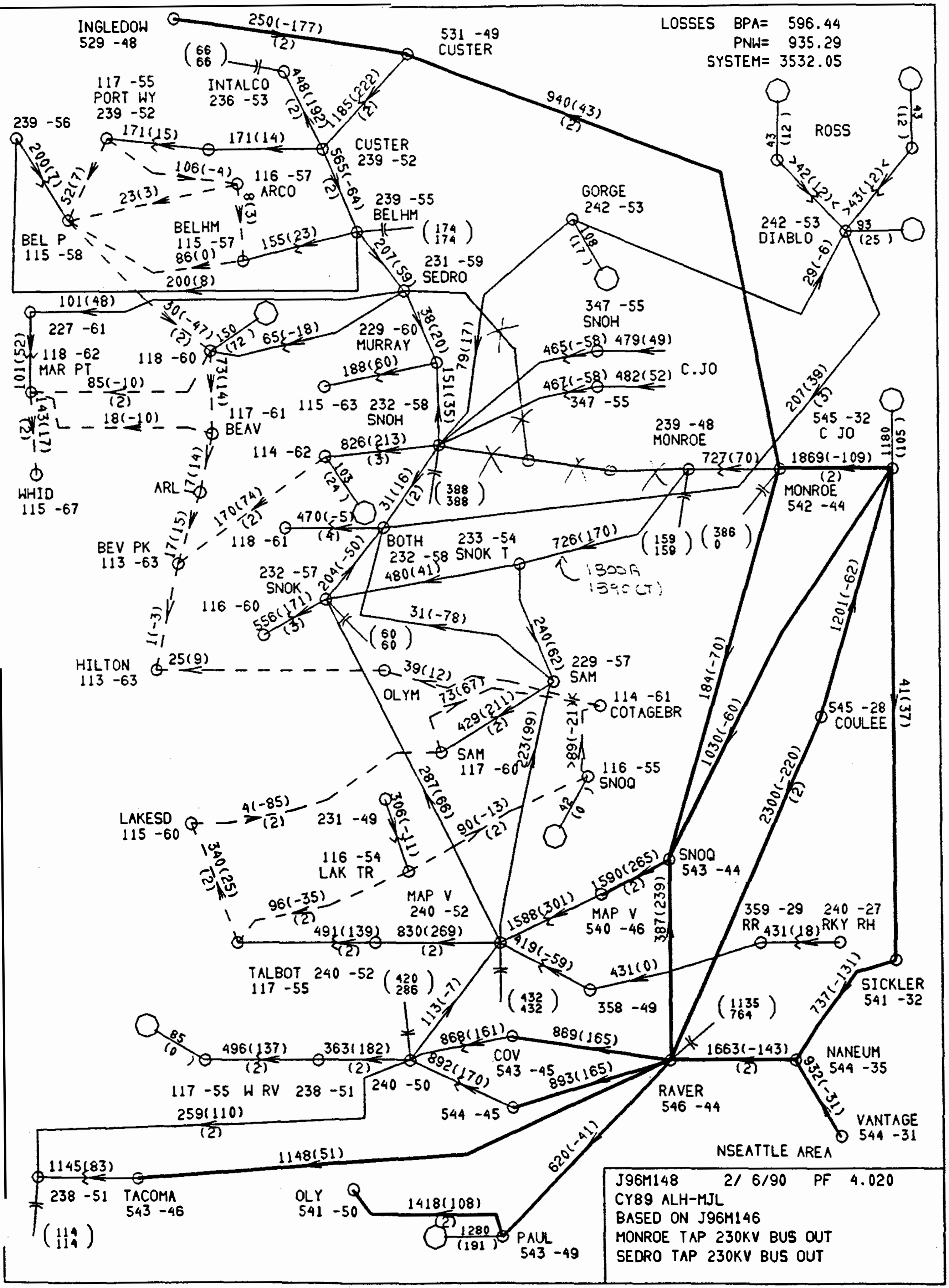
S:PO R- PLOTTED 6-FEB-90 AT 12:57:55 HOURS



LOSSES BPA= 595.81
PNW= 934.54
SYSTEM= 3530.64

J96M147 2/ 6/90 PF 4.020
CY89 ALH-MJL
BASED ON J96M146
SNOKING TAP 230KV BUS OUT

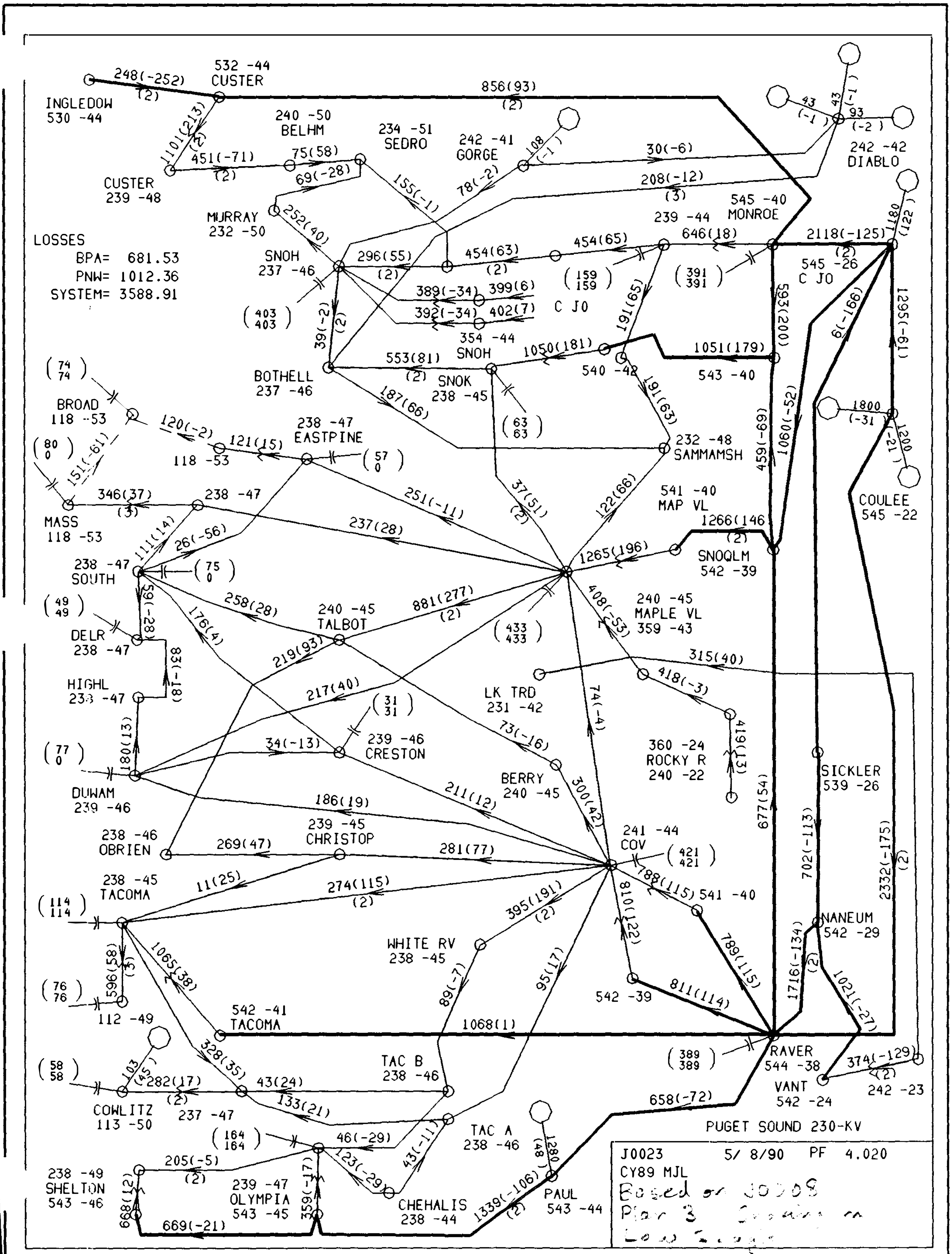
S:PO R- PLOTTED 6-FEB-90 AT 13:07:08 HOURS



LOSSES BPA= 596.44
PNW= 935.29
SYSTEM= 3532.05

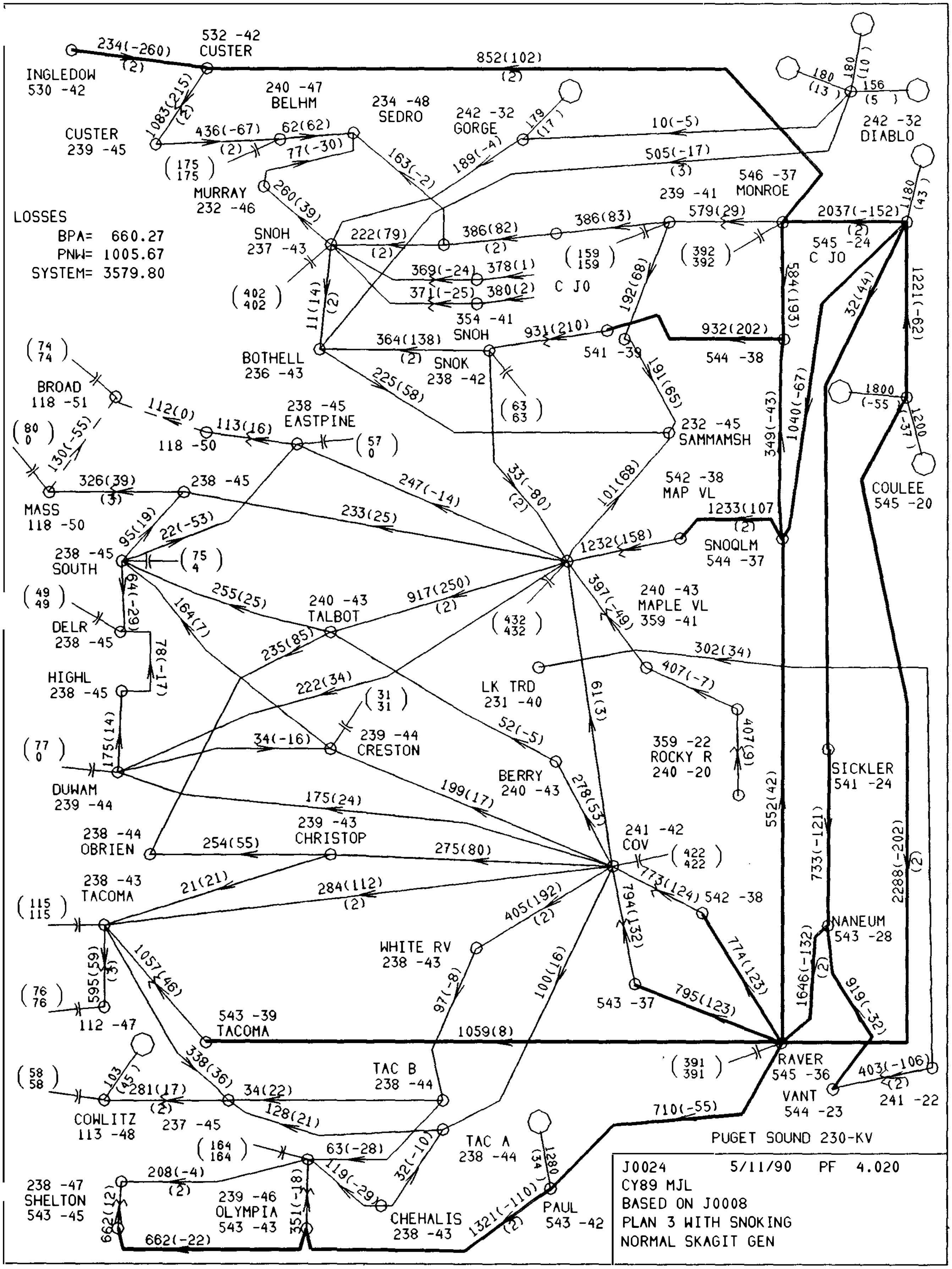
J96M148 2/ 6/90 PF 4.020
CY89 ALH-MJL
BASED ON J96M146
MONROE TAP 230KV BUS OUT
SEDRO TAP 230KV BUS OUT

S:PO R- PLOTTED 6-FEB-90 AT 13:09:19 HOURS



J0023 5/ 8/90 PF 4.020
CY89 MJL
Based on J0009
Plan 3 [illegible]
Low [illegible]

S:PO R- PLOTTED 9-MAY-90 AT 07:59:23 HOURS

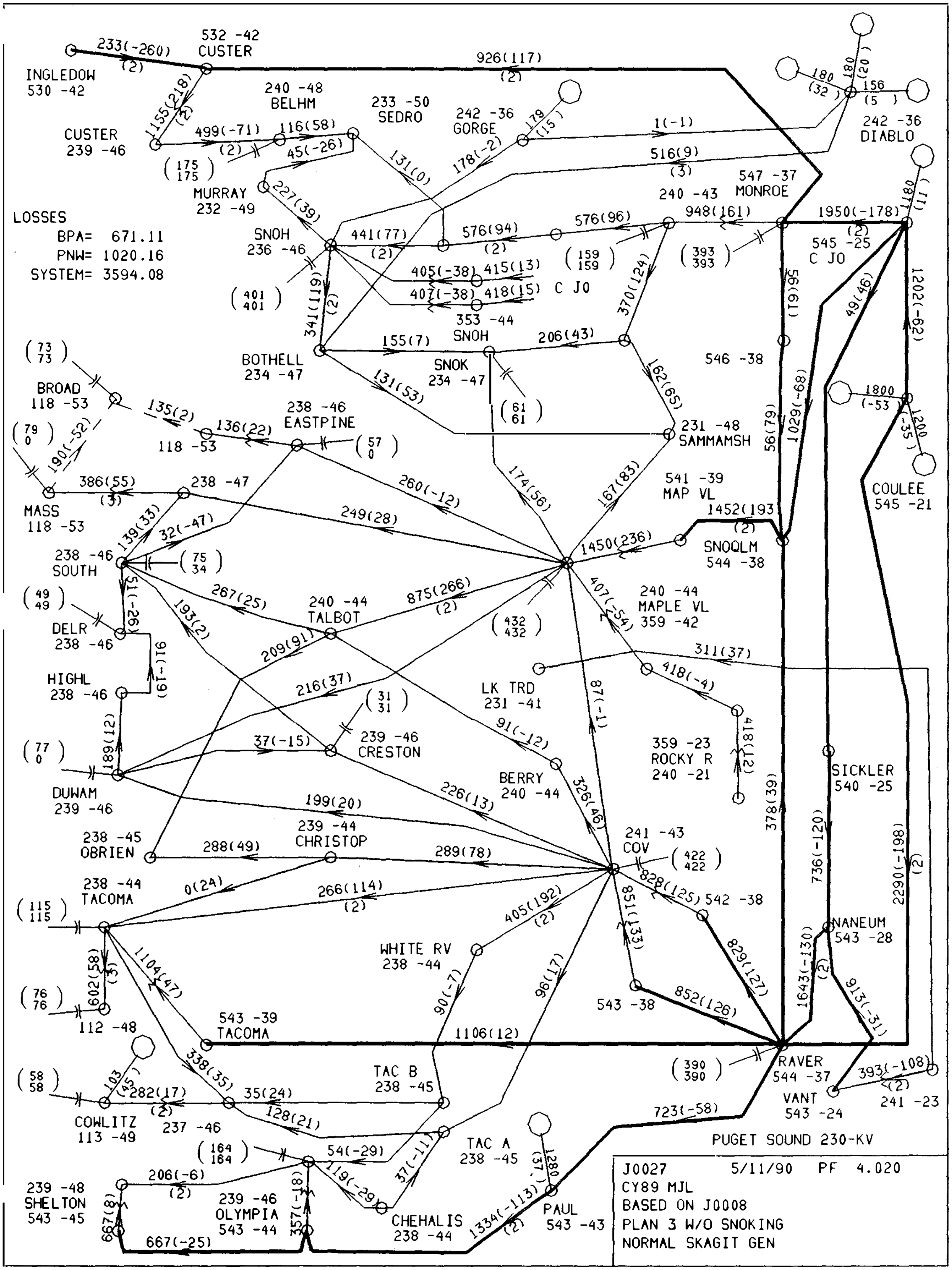


LOSSES
BPA= 660.27
PNW= 1005.67
SYSTEM= 3579.80

PUGET SOUND 230-KV

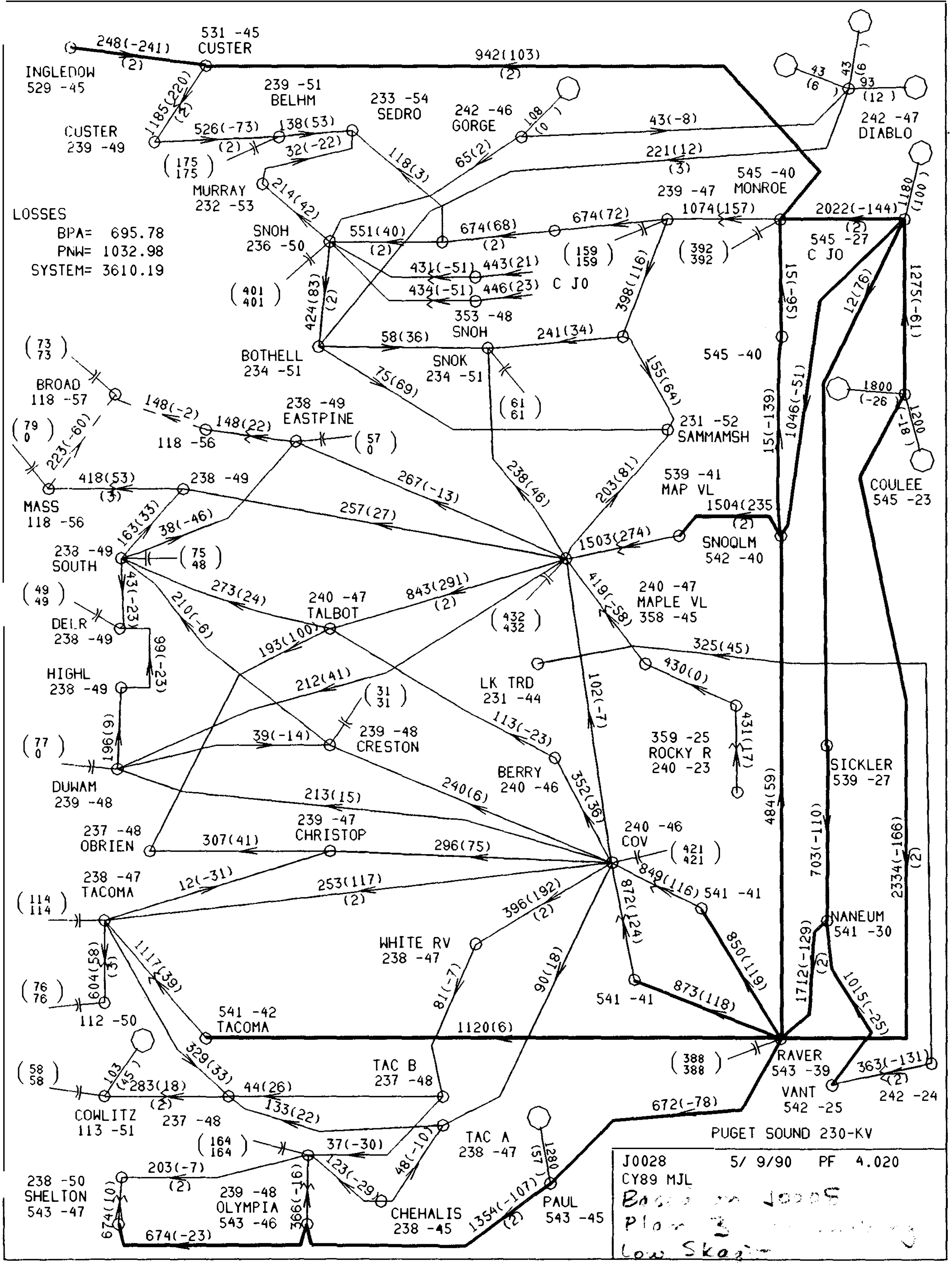
J0024 5/11/90 PF 4.020
CY89 MJL
BASED ON J0008
PLAN 3 WITH SNOKING
NORMAL SKAGIT GEN

S:PQ R- PLOTTED 14-MAY-90 AT 07:52:43 HOURS



J0027 5/11/90 PF 4.020
CY89 MJL
BASED ON J0008
PLAN 3 W/O SNOKING
NORMAL SKAGIT GEN

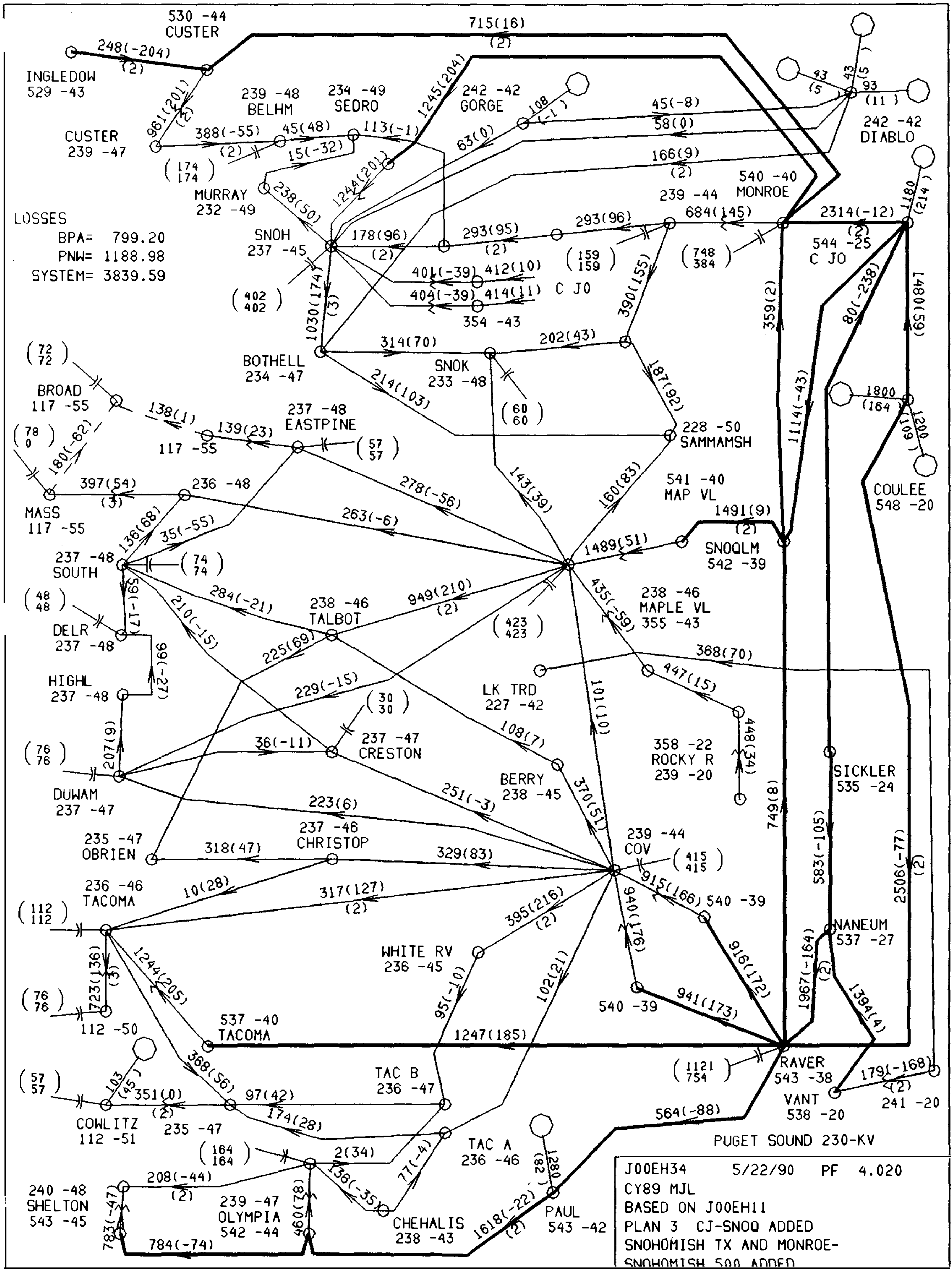
S:PQ R- PLOTTED 14-MAY-90 AT 07:51:56 HOURS



PUGET SOUND 230-KV

J0028 5/ 9/90 PF 4.020
CY89 MJL
Based on J0005
Plan 3 [illegible]
Low Skagit

S:PQ R- PLOTTED 9-MAY-90 AT 14:35:58 HOURS

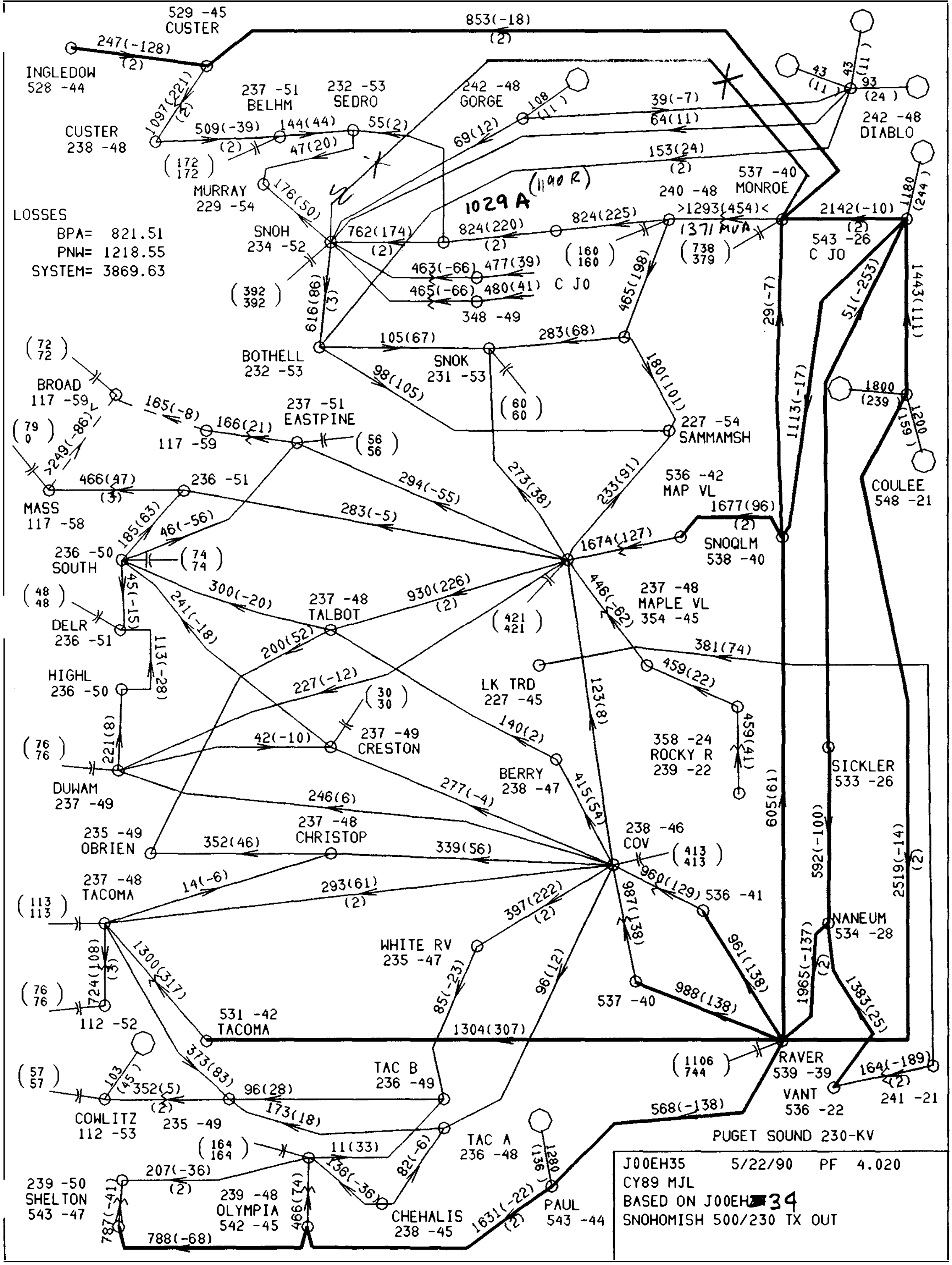


LOSSES
BPA= 799.20
PNW= 1188.98
SYSTEM= 3839.59

PUGET SOUND 230-KV

J00EH34 5/22/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 3 CJ-SNOQ ADDED
SNOHOMISH TX AND MONROE-
SNOHOMISH 500 ADDED

S:PQ R- PLOTTED 22-MAY-90 AT 11:20:09 HOURS

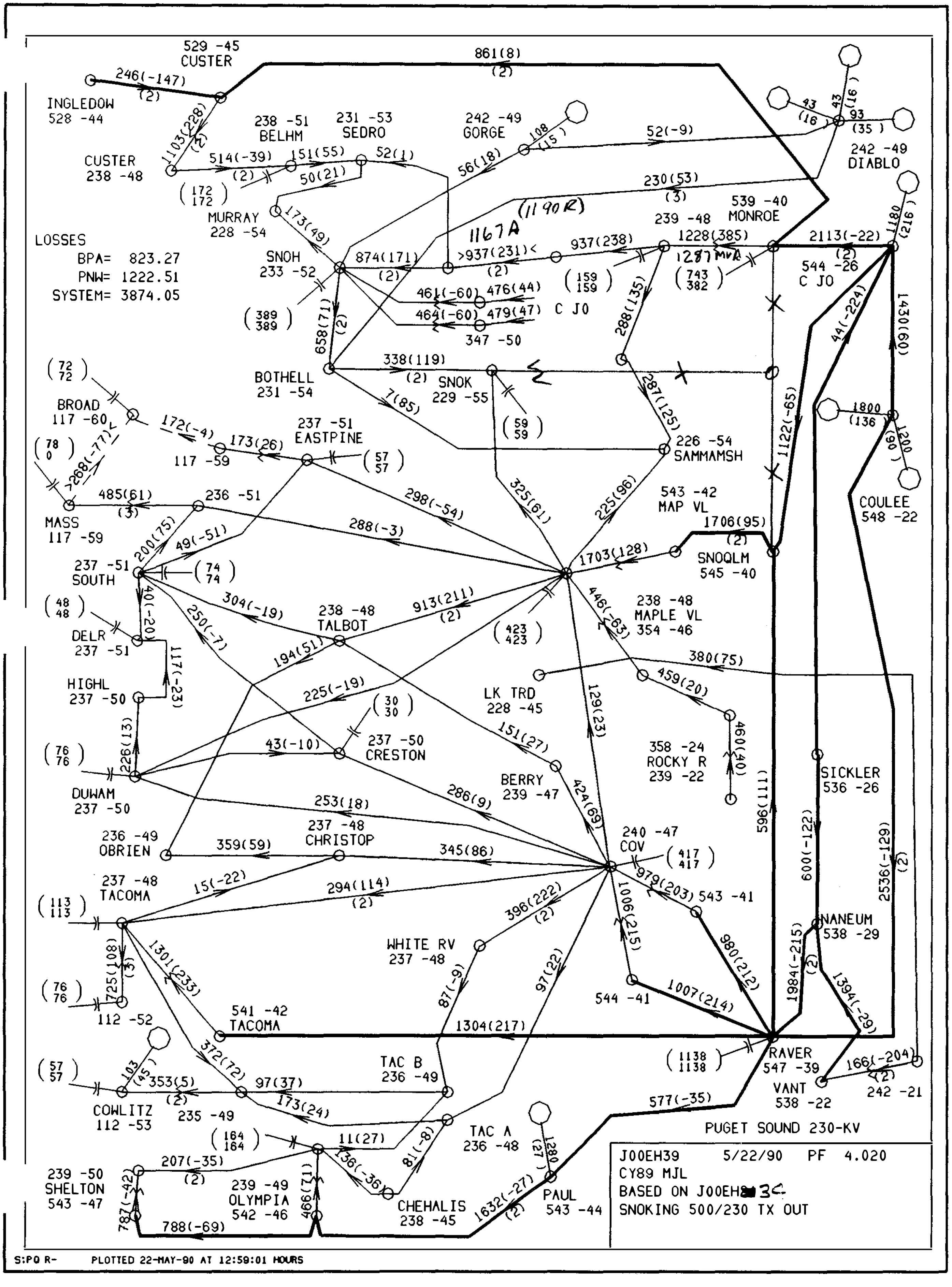


LOSSES
BPA= 821.51
PNW= 1218.55
SYSTEM= 3869.63

PUGET SOUND 230-KV

J00EH35 5/22/90 PF 4.020
CY89 MJL
BASED ON J00EH34
SNOHOMISH 500/230 TX OUT

S:PQ R- PLOTTED 22-MAY-90 AT 12:56:47 HOURS

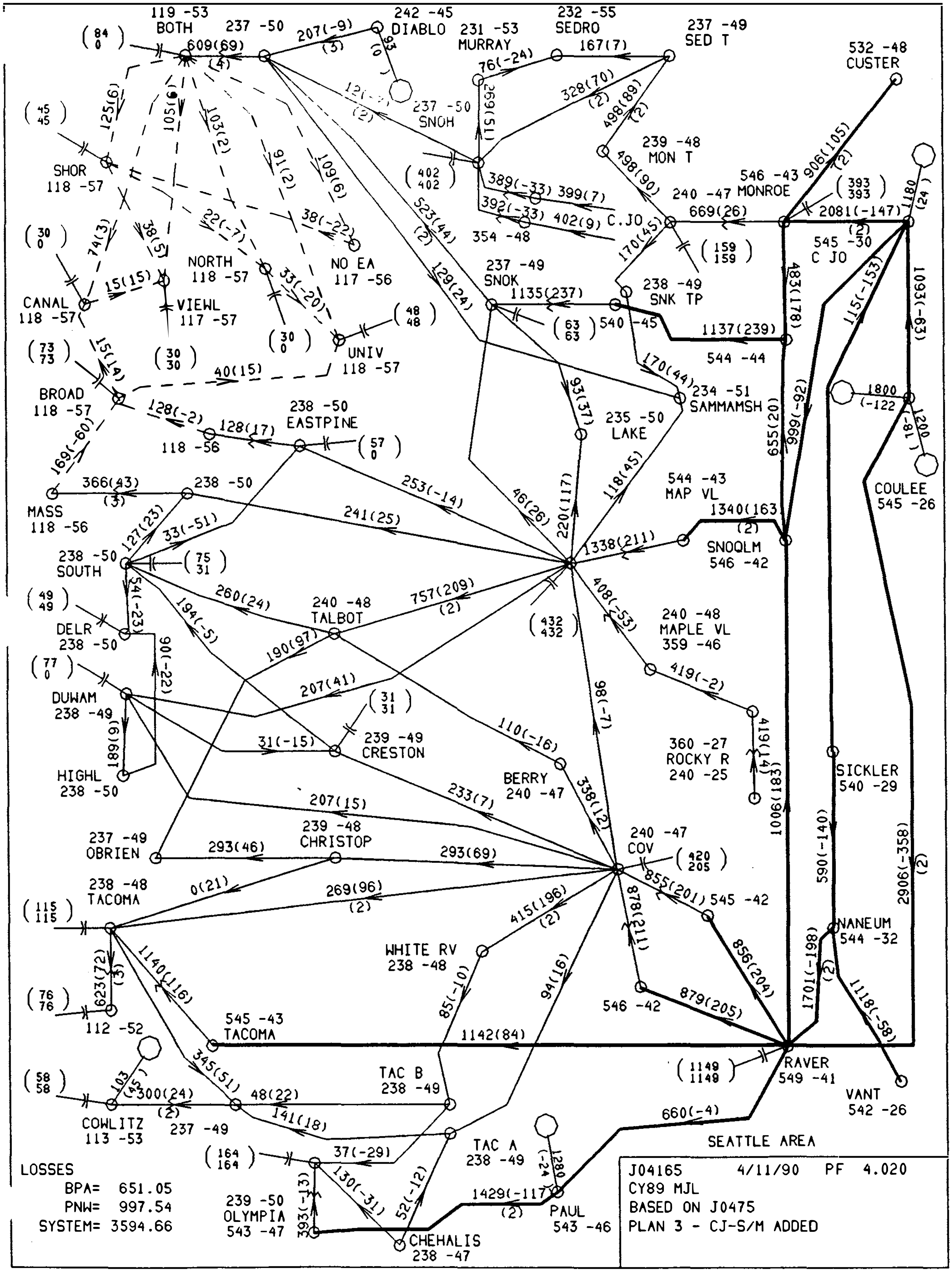


LOSSES
BPA= 823.27
PNW= 1222.51
SYSTEM= 3874.05

PUGET SOUND 230-KV

J00EH39 5/22/90 PF 4.020
CY89 MJL
BASED ON J00EH[illegible]3C
SNOKING 500/230 TX OUT

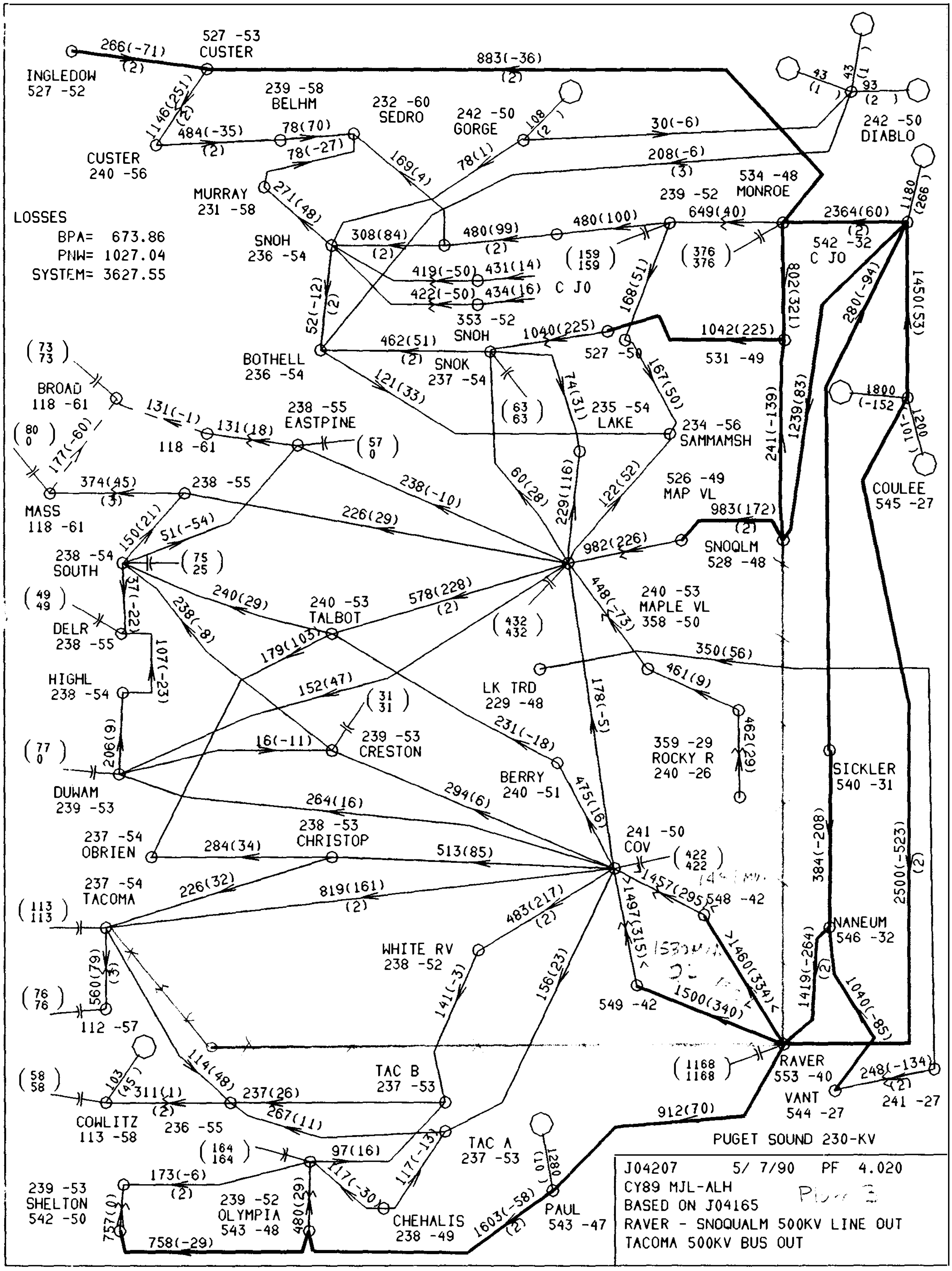
S:PO R- PLOTTED 22-MAY-90 AT 12:59:01 HOURS



LOSSES
BPA= 651.05
PNW= 997.54
SYSTEM= 3594.66

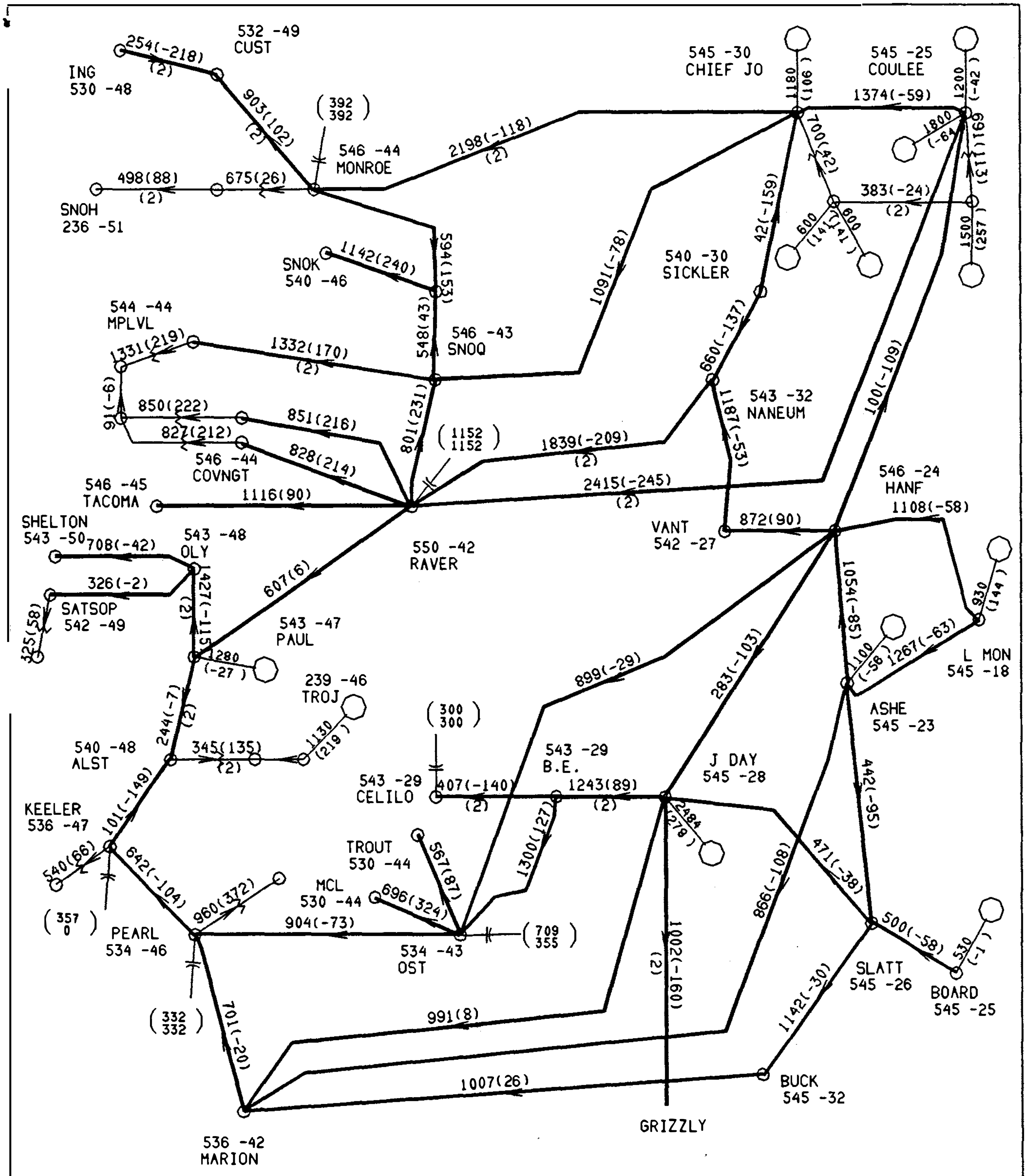
J04165 4/11/90 PF 4.020
CY89 MJL
BASED ON J0475
PLAN 3 - CJ-S/M ADDED

S:PQ R- PLOTTED 11-APR-90 AT 16:01:22 HOURS



J04207 5/ 7/90 PF 4.020
CY89 MJL-ALH
BASED ON J04165
RAVER - SNOQUALM 500KV LINE OUT
TACOMA 500KV BUS OUT

S:PQ R- PLOTTED 7-MAY-90 AT 10:43:09 HOURS



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 400.
DC= 400.

ACTUAL
AC= 76.
DC= 400.

LOSSES
BPA= 652.46
PNW= 1000.63
SYSTEM= 3599.22

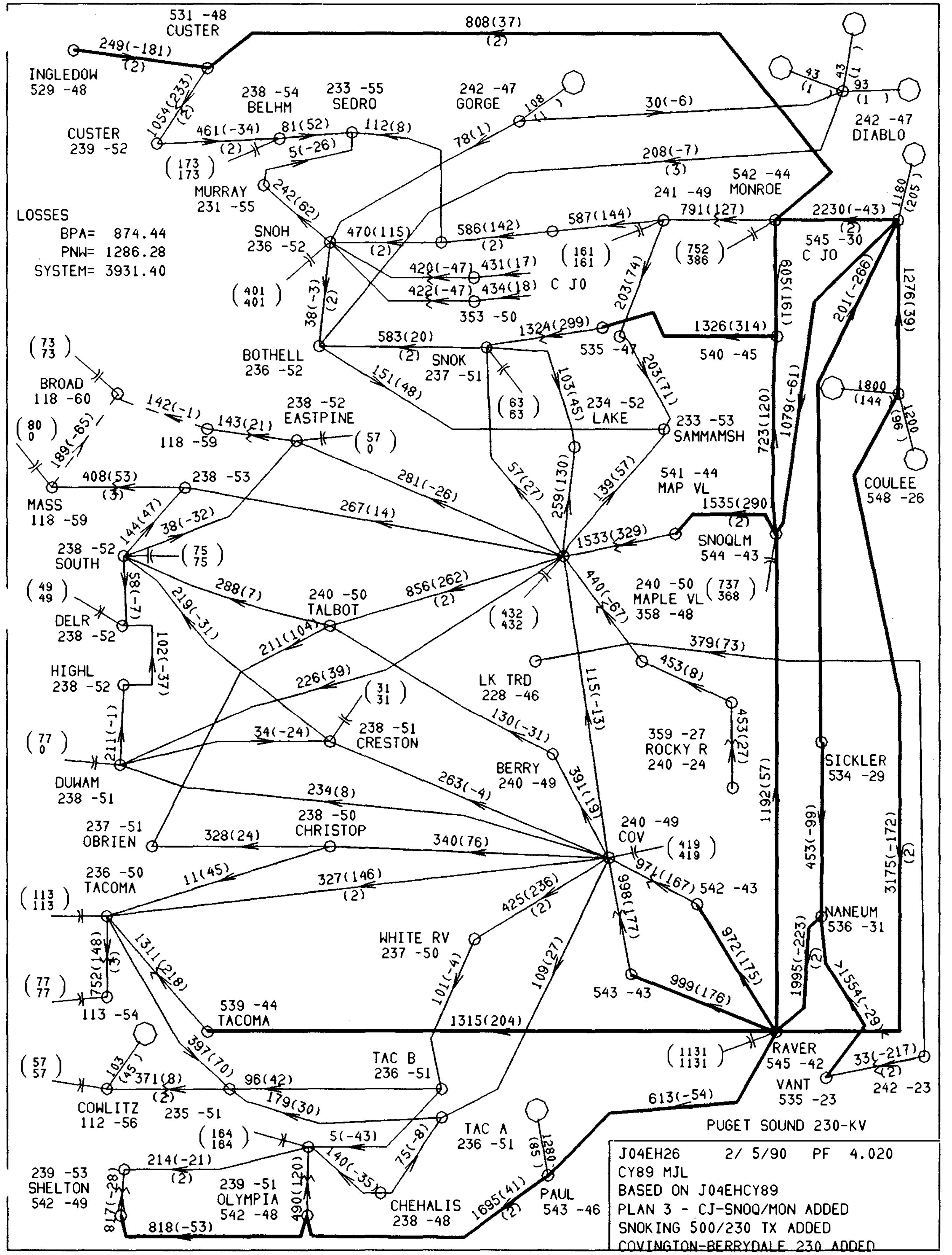
CANADA TO PNW
(BCH & WKOOT)
SI= 850.
AI= 850.

MONT TO PNW
SI= 1250.
AI= 968.

IDAHO TO PNW
SI= 700.
AI= 658.

J04440 7/26/90 PF 4.020
CY89 MJL
BASED ON J0475
PLAN 3 CJ-S/M
C-R COMP CORRECTED

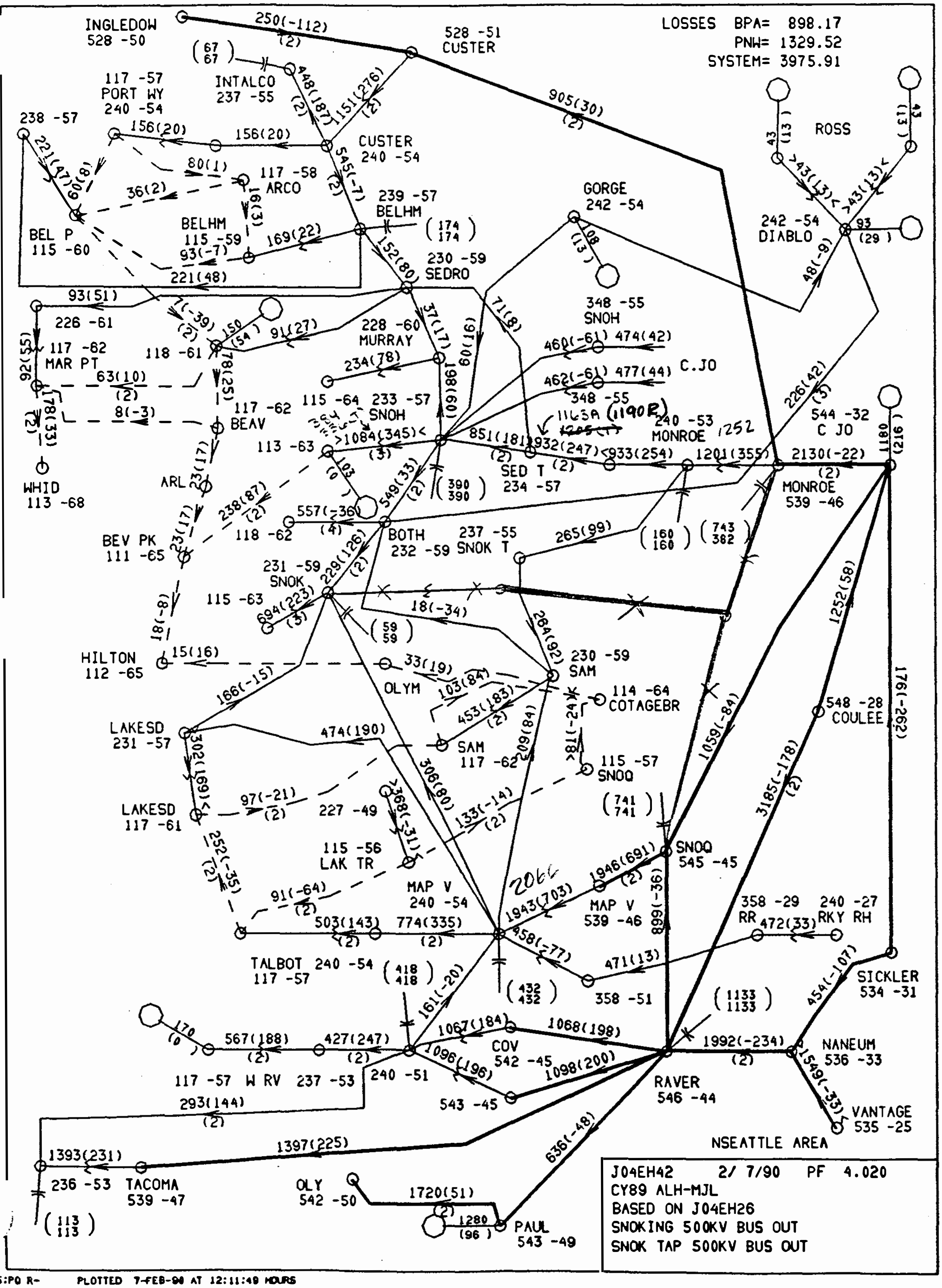
568 STEP K- PLOTTED 26-JUL-90 AT 08:23:46 HOURS



J04EH26 2/ 5/90 PF 4.020
CY89 MJL
BASED ON J04EHCY89
PLAN 3 - CJ-SNOQ/MON ADDED
SNOKING 500/230 TX ADDED
COVINGTON-BERRYDALE 230 ADDED

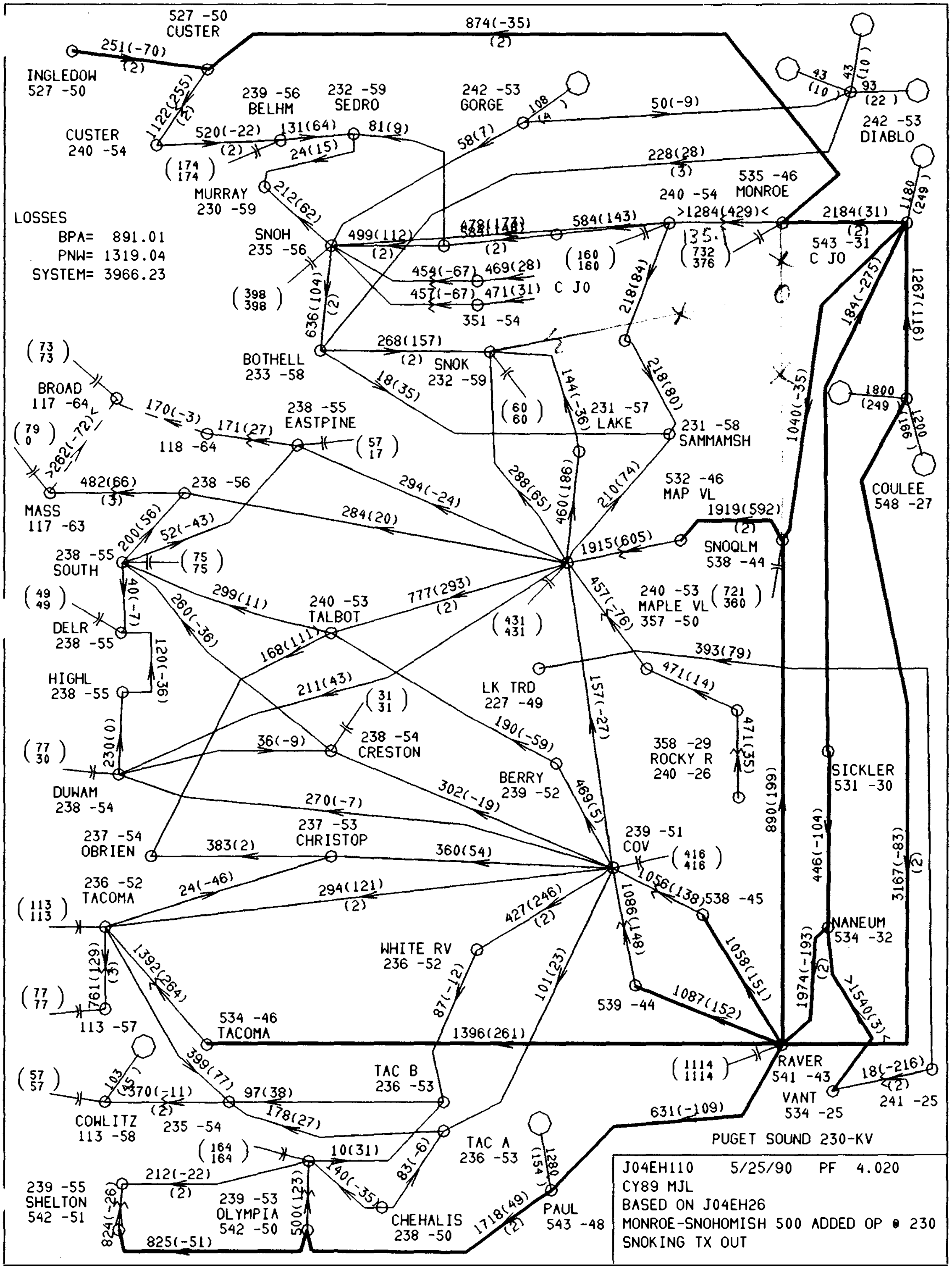
S:PQ R- PLOTTED 5-JUN-90 AT 08:56:45 HOURS

LOSSES BPA= 898.17
PNW= 1329.52
SYSTEM= 3975.91



J04EH42 2/ 7/90 PF 4.020
CY89 ALH-MJL
BASED ON J04EH26
SNOKING 500KV BUS OUT
SNOK TAP 500KV BUS OUT

S:PO R- PLOTTED 7-FEB-90 AT 12:11:49 HOURS



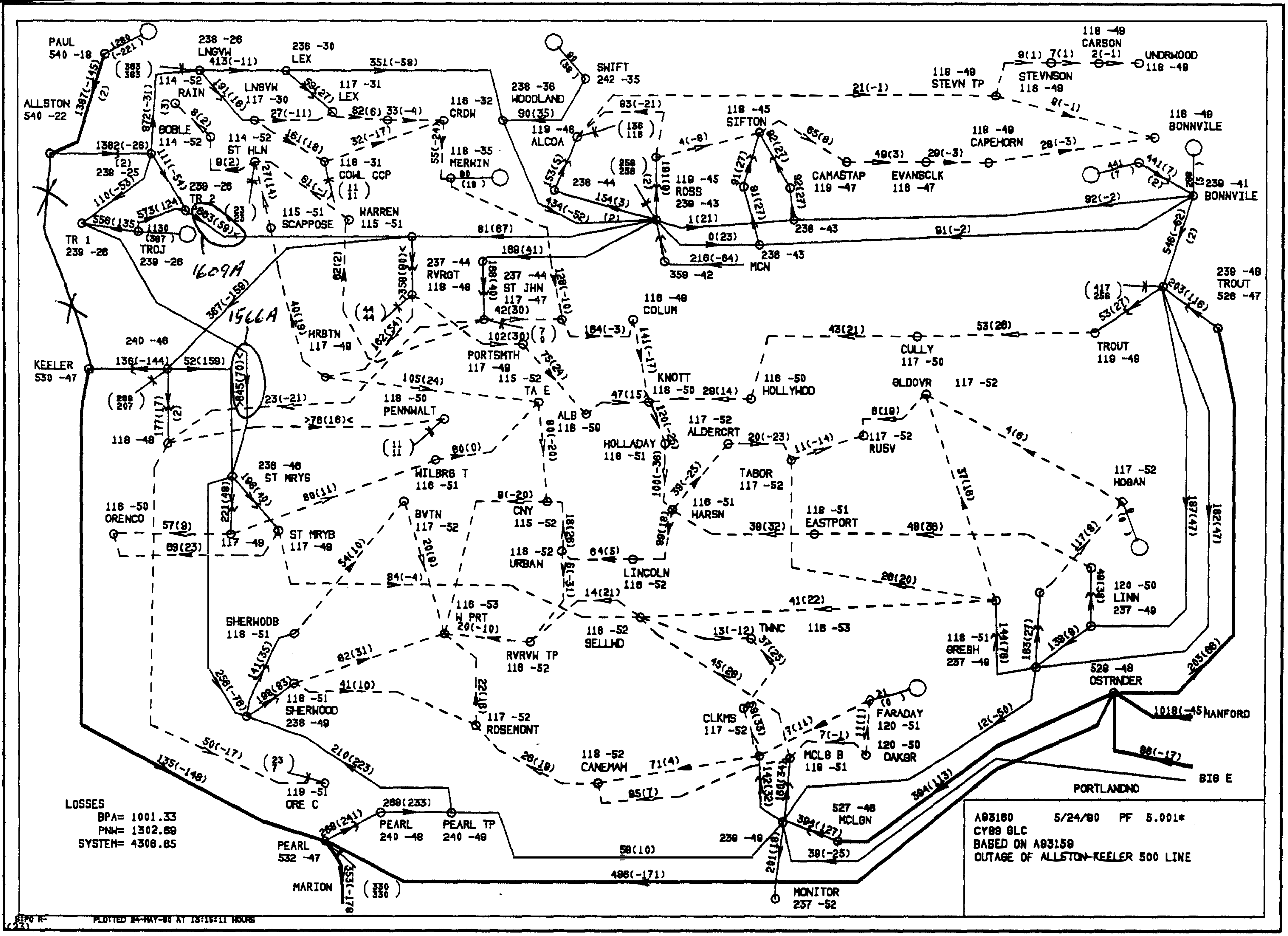
LOSSES
BPA= 891.01
PNW= 1319.04
SYSTEM= 3966.23

PUGET SOUND 230-KV

J04EH110 5/25/90 PF 4.020
CY89 MJL
BASED ON J04EH26
MONROE-SNOHOMISH 500 ADDED OP @ 230
SNOKING TX OUT

S:PQ R- PLOTTED 25-MAY-90 AT 08:10:10 HOURS

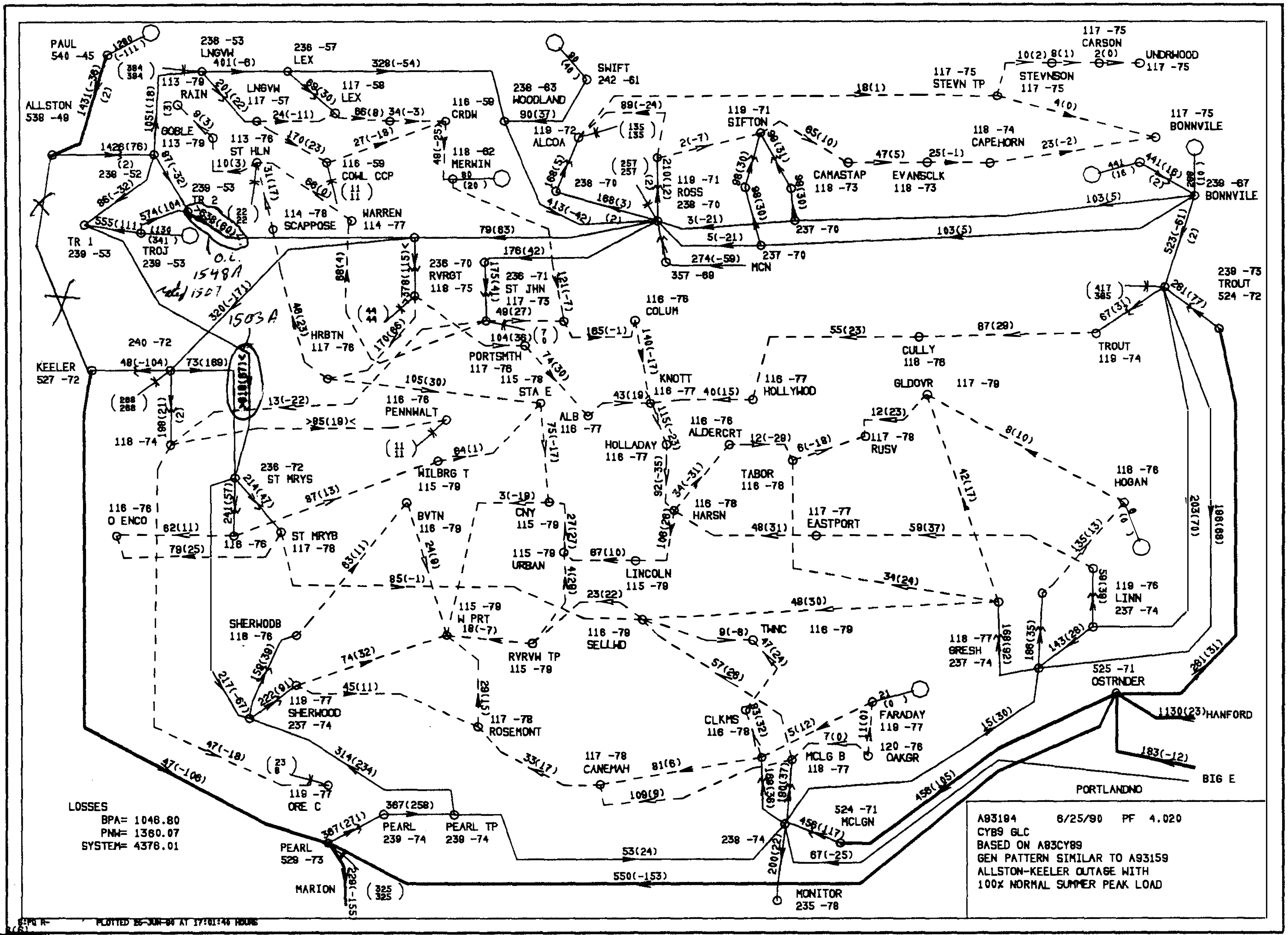
PF - REACTIVE PLAN



LOSSES
BPA= 1001.33
PNW= 1302.69
SYSTEM= 4308.85

A93160 5/24/90 PF 5.001*
CY89 SLC
BASED ON A93159
OUTAGE OF ~~ALLSTON-KEELER~~ 500 LINE

PLOTTED 24-MAY-90 AT 13:15:11 HOURS

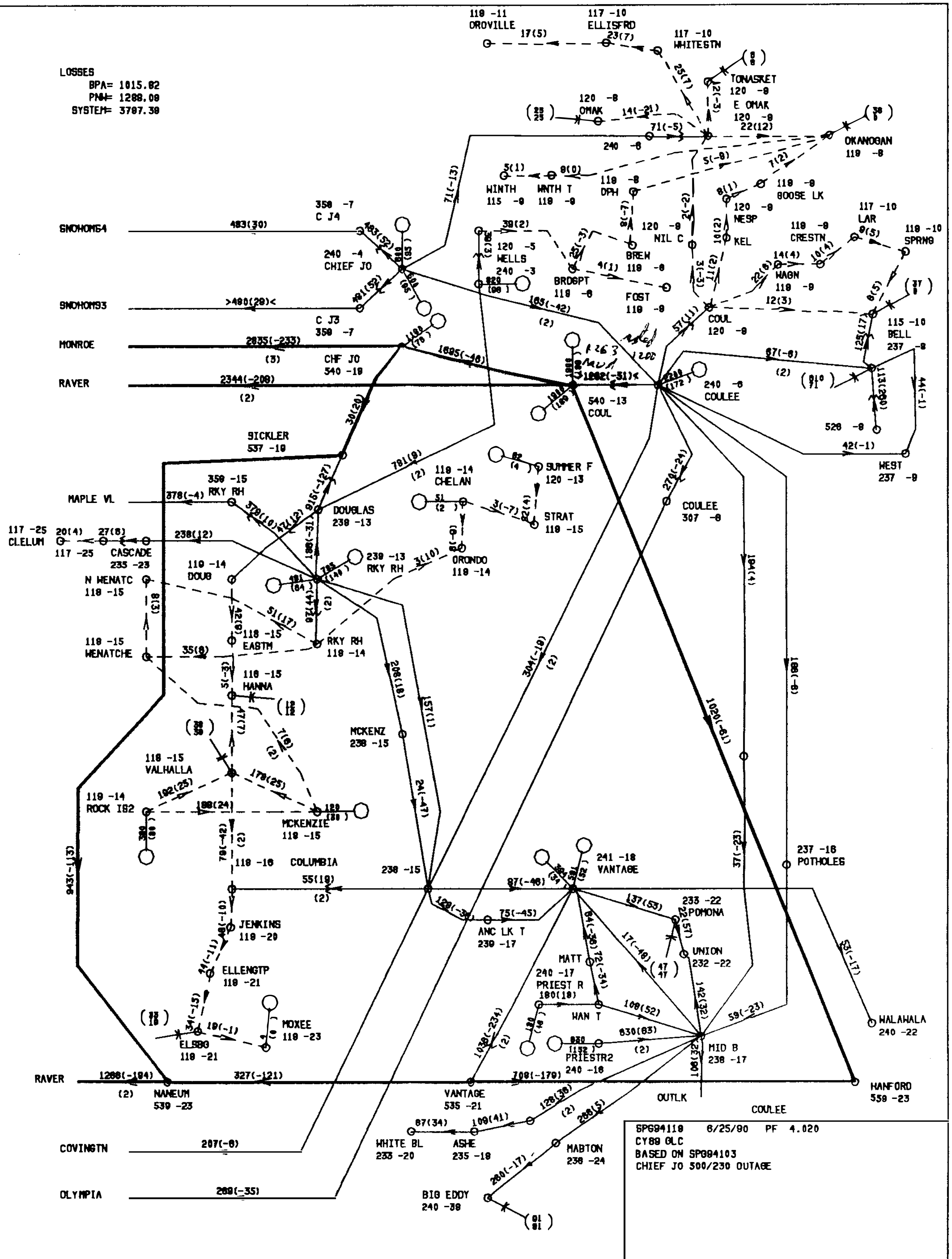


LOSSES
BPA= 1046.80
PNW= 1360.07
SYSTEM= 4376.01

A93194 6/25/90 PF 4.020
CYB9 GLC
BASED ON A83CY89
GEN PATTERN SIMILAR TO A93159
ALLSTON-KEELER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD

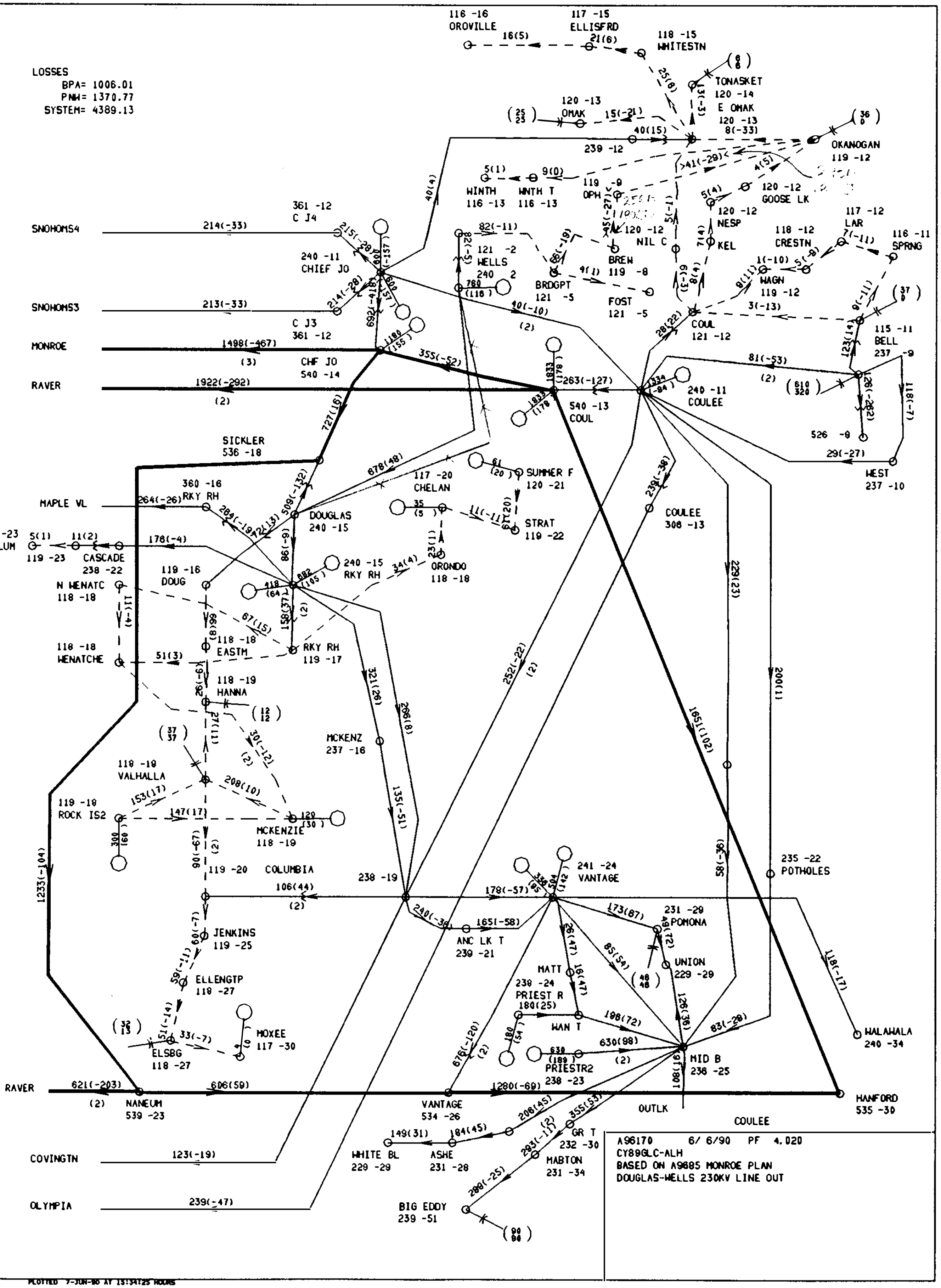
PLOTTED 25-JUN-90 AT 17:01:49 HOURS

LOSSES
BPA= 1015.82
PNW= 1288.09
SYSTEM= 3797.39



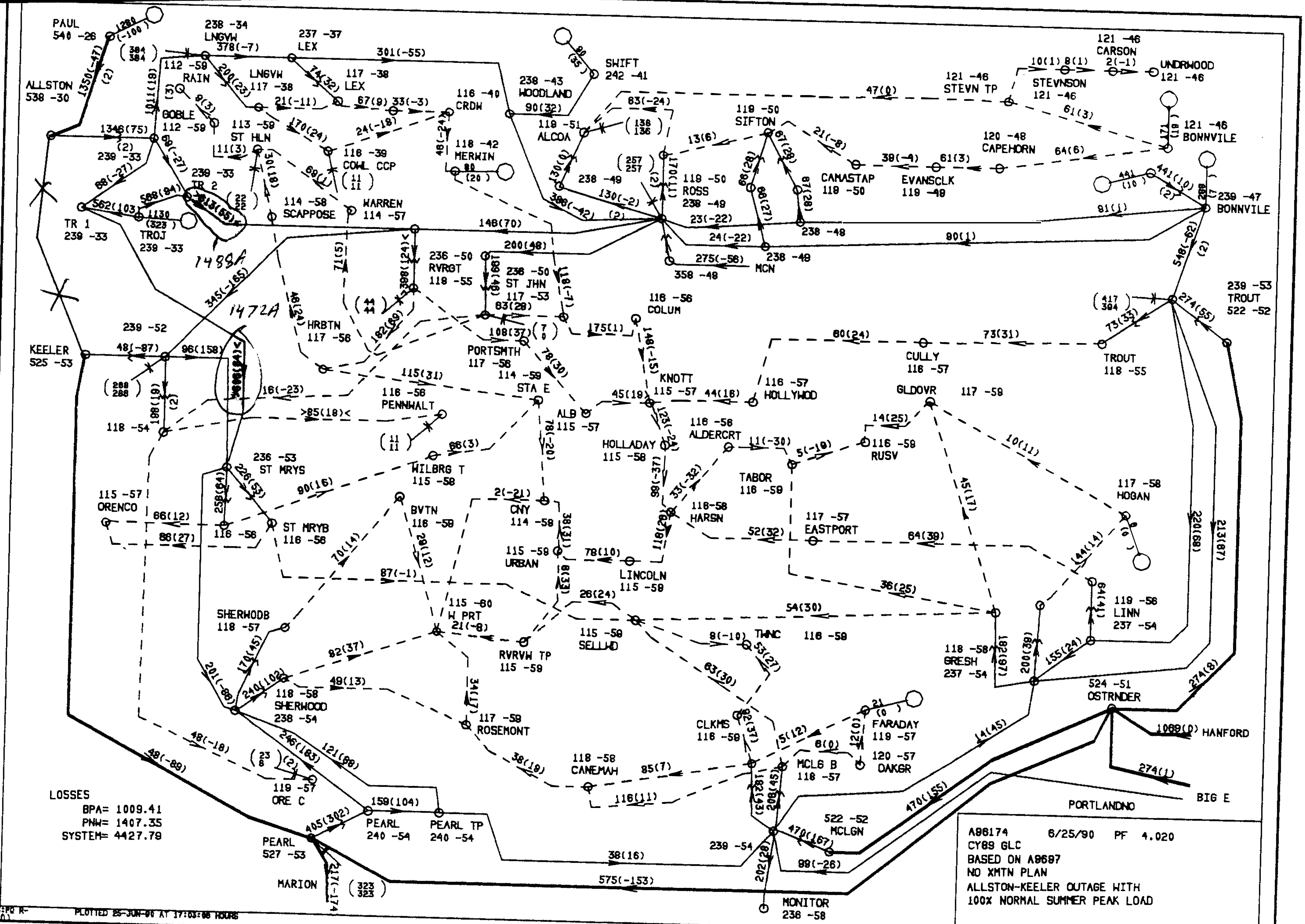
SPG94119 6/25/90 PF 4.020
CY89 GLC
BASED ON SPG94103
CHIEF JO 500/230 OUTAGE

LOSSES
BPA= 1006.01
PNW= 1370.77
SYSTEM= 4389.13



A96170 6/ 6/90 PF 4.020
CY89GLC-ALH
BASED ON A9685 MONROE PLAN
DOUGLAS-WELLS 230KV LINE OUT

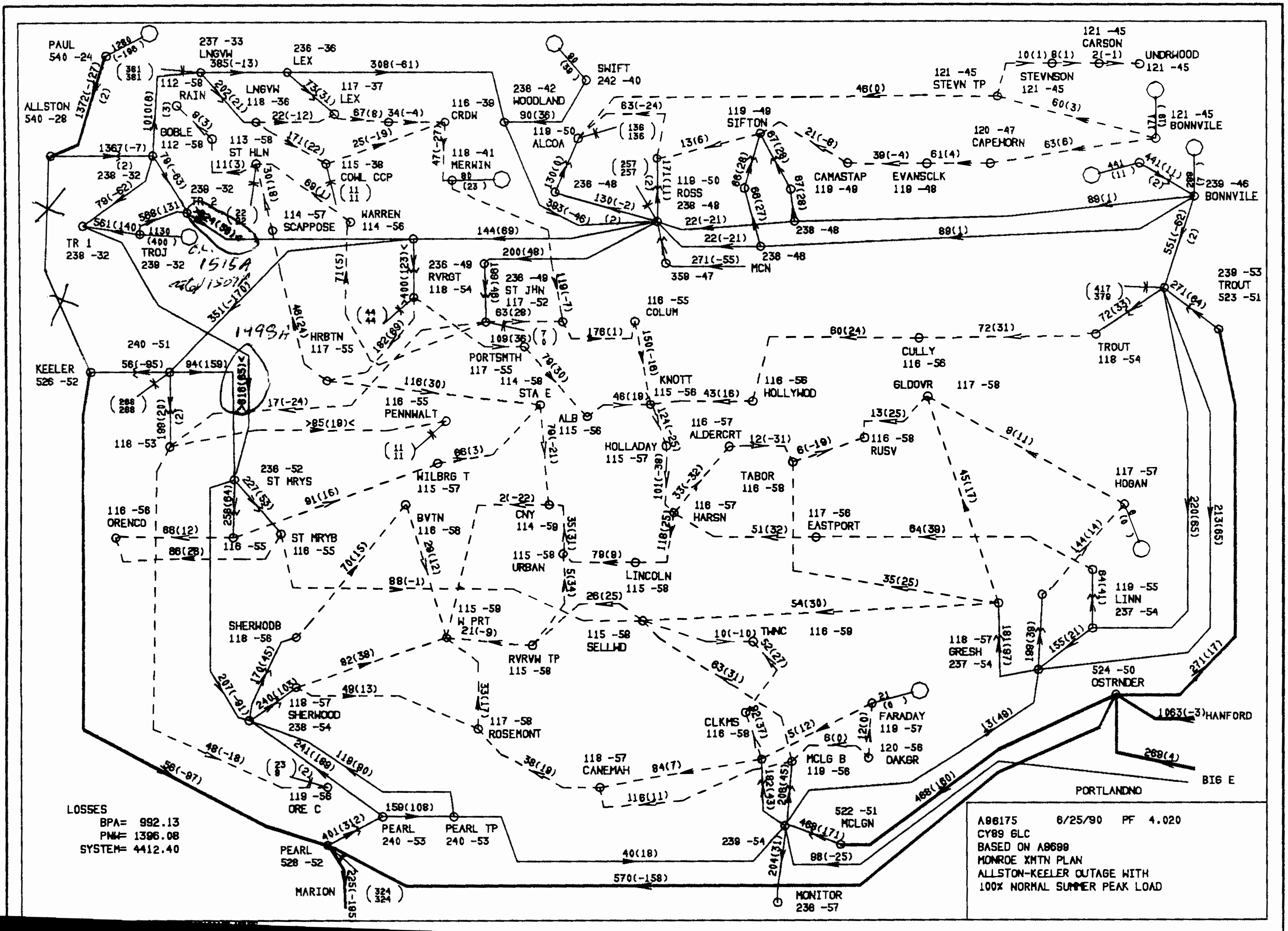
PLOTTED 7-JUN-90 AT 15:34:25 HOURS



LOSSES
BPA= 1009.41
PNW= 1407.35
SYSTEM= 4427.79

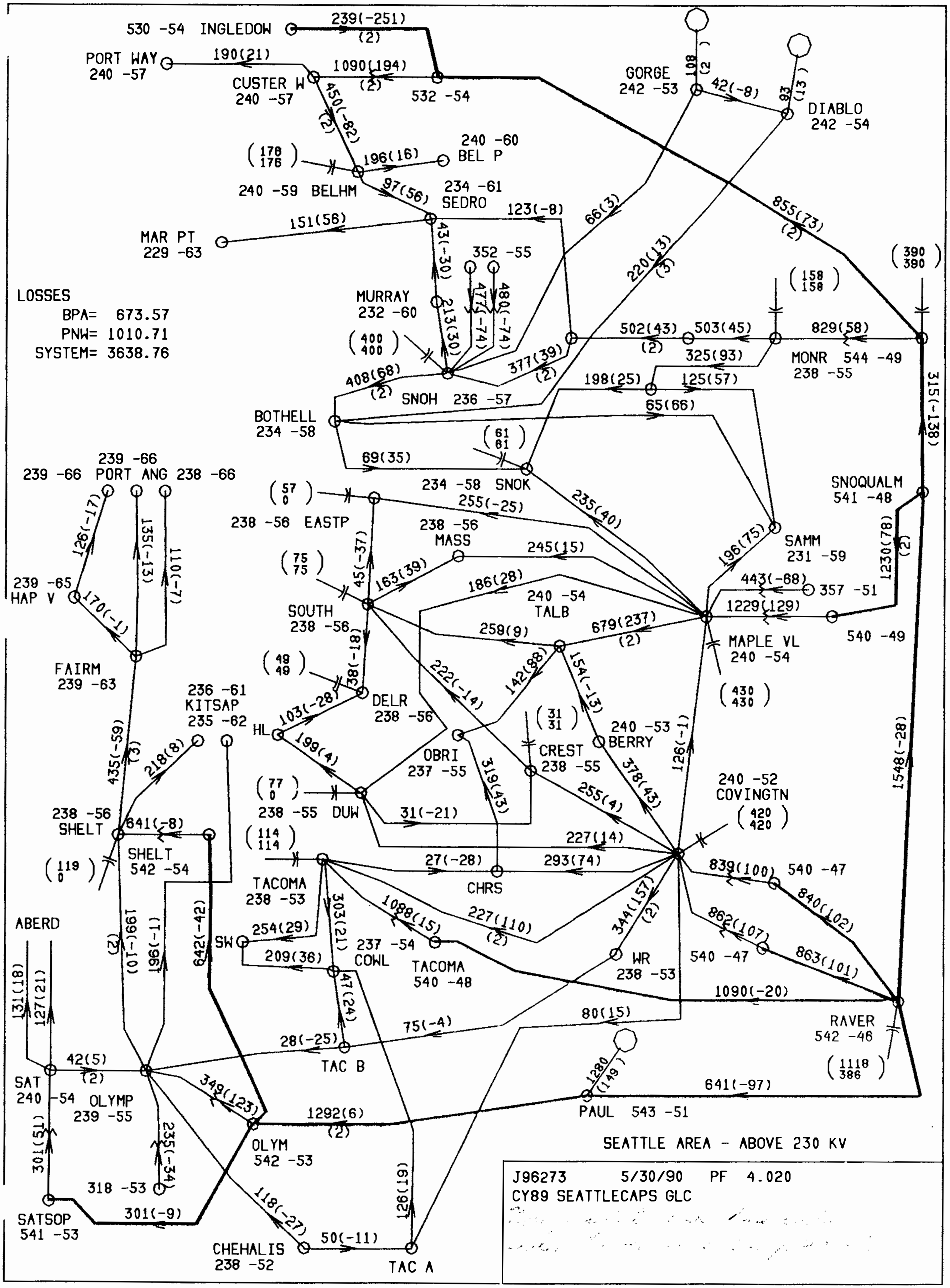
A96174 6/25/90 PF 4.020
CY89 GLC
BASED ON A9697
NO XMTN PLAN
ALLSTON-KEELER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD

PLOTTED 25-JUN-90 AT 17:03:06 HOURS



LOSSES
BPA= 992.13
PNW= 1396.08
SYSTEM= 4412.40

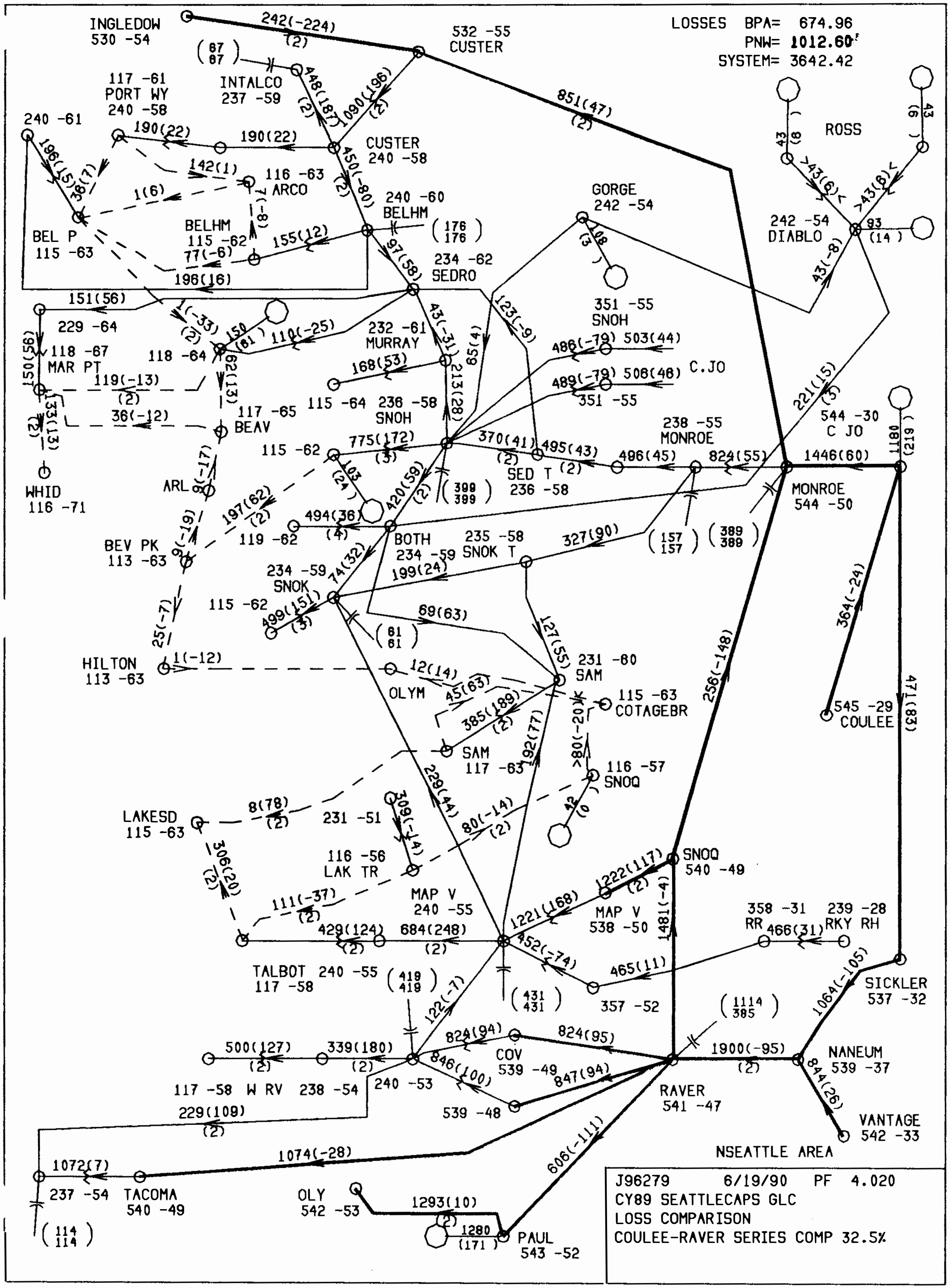
A96175 6/25/90 PF 4.020
CY89 GLC
BASED ON A9699
MONROE XMTN PLAN
ALLSTON-KEELER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD



SEATTLE AREA - ABOVE 230 KV

J96273 5/30/90 PF 4.020
CY89 SEATTLECAPS GLC

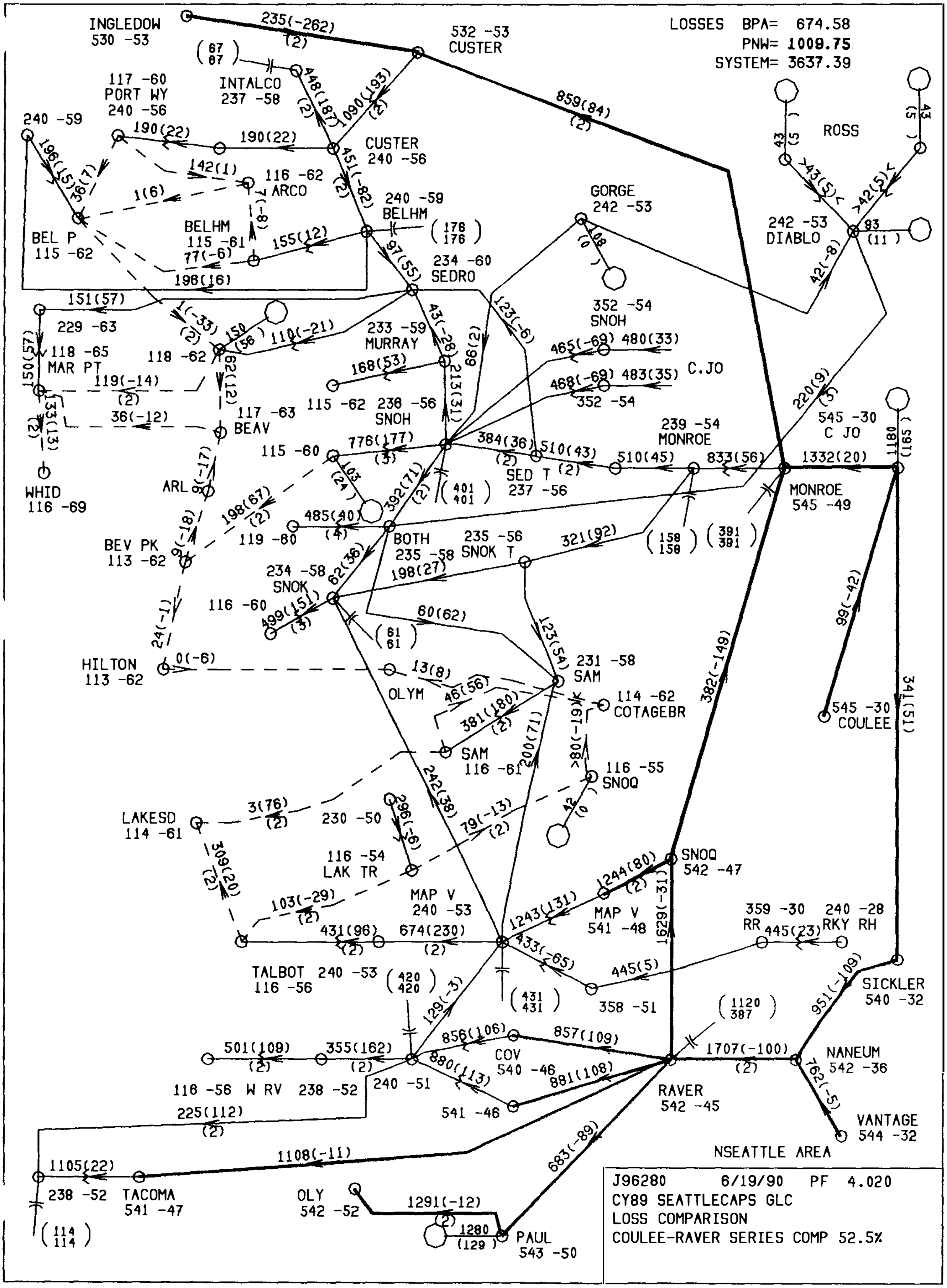
S:PQ R- PLOTTED 3-JUL-90 AT 13:36:09 HOURS



LOSSES BPA= 674.96
PNW= 1012.60
SYSTEM= 3642.42

J96279 6/19/90 PF 4.020
CY89 SEATTLECAPS GLC
LOSS COMPARISON
COULEE-RAVER SERIES COMP 32.5%

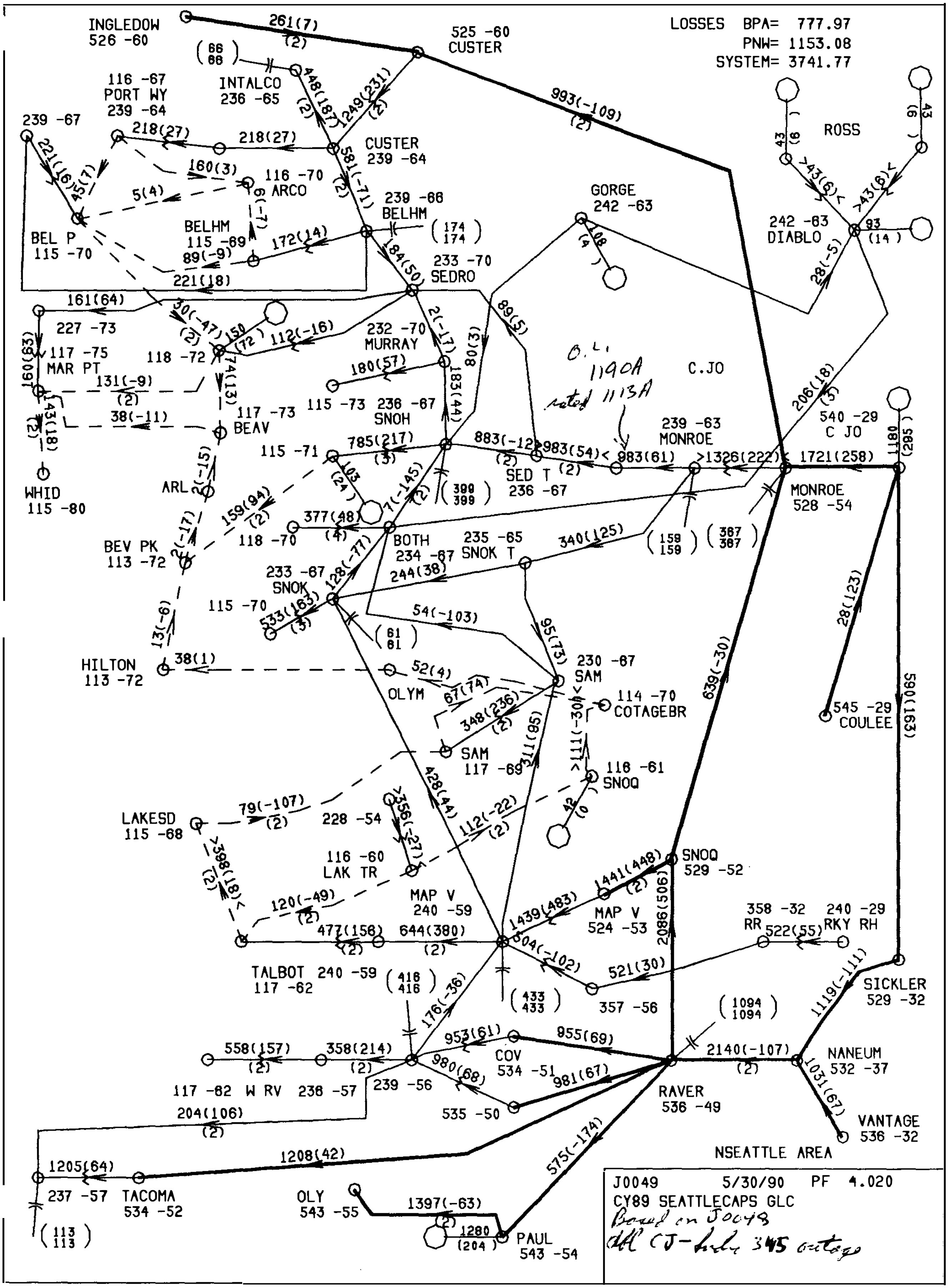
S:PQ R- PLOTTED 19-JUN-90 AT 18:15:58 HOURS



LOSSES BPA= 674.58
PNW= 1009.75
SYSTEM= 3637.39

J96280 6/19/90 PF 4.020
CY89 SEATTLECAPS GLC
LOSS COMPARISON
COULEE-RAVER SERIES COMP 52.5%

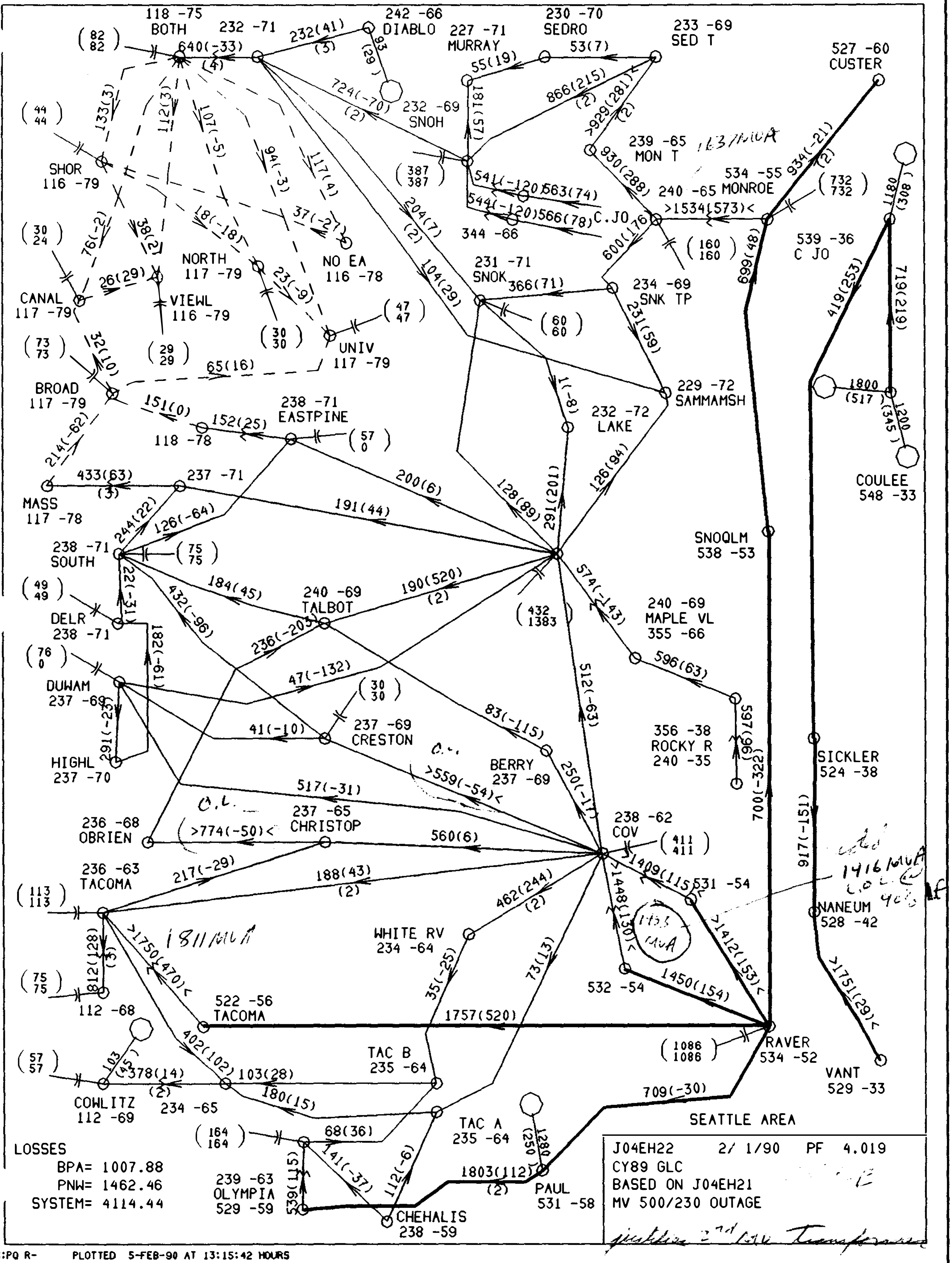
S:PQ R- PLOTTED 19-JUN-90 AT 16:16:53 HOURS



O. L.
1190A
rated 1113A

J0049 5/30/90 PF 4.020
CY89 SEATTLECAPS GLC
Based on J0048
dbl CJ-[illegible] 345 outage

S:PQ R- PLOTTED 30-MAY-90 AT 13:51:55 HOURS



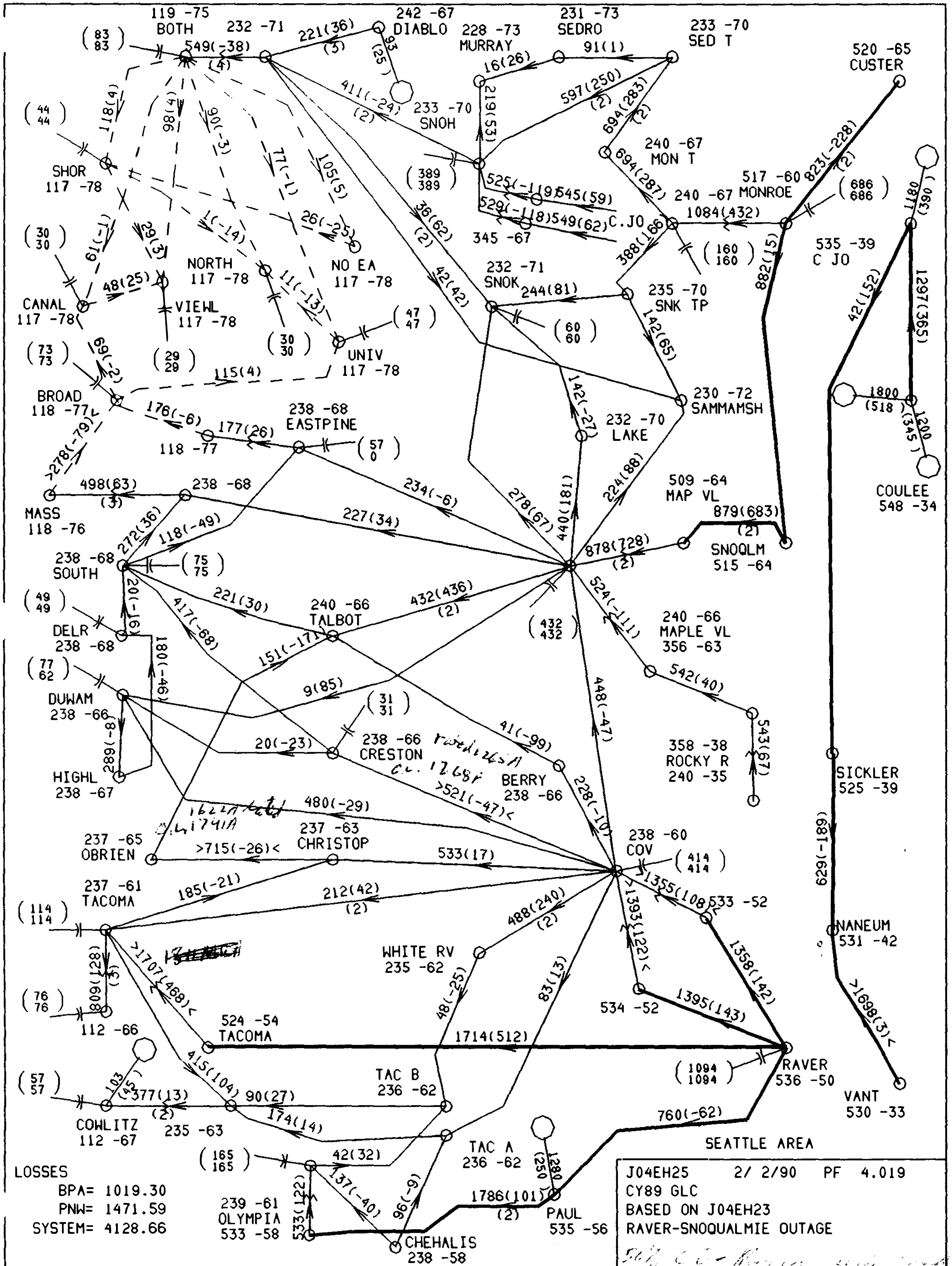
SEATTLE AREA

LOSSES
BPA= 1007.88
PNW= 1462.46
SYSTEM= 4114.44

J04EH22   2/ 1/90   PF 4.019
CY89 GLC
BASED ON J04EH21
MV 500/230 OUTAGE

justifies 2nd MV Transformer

S:PQ R-   PLOTTED 5-FEB-90 AT 13:15:42 HOURS



SEATTLE AREA

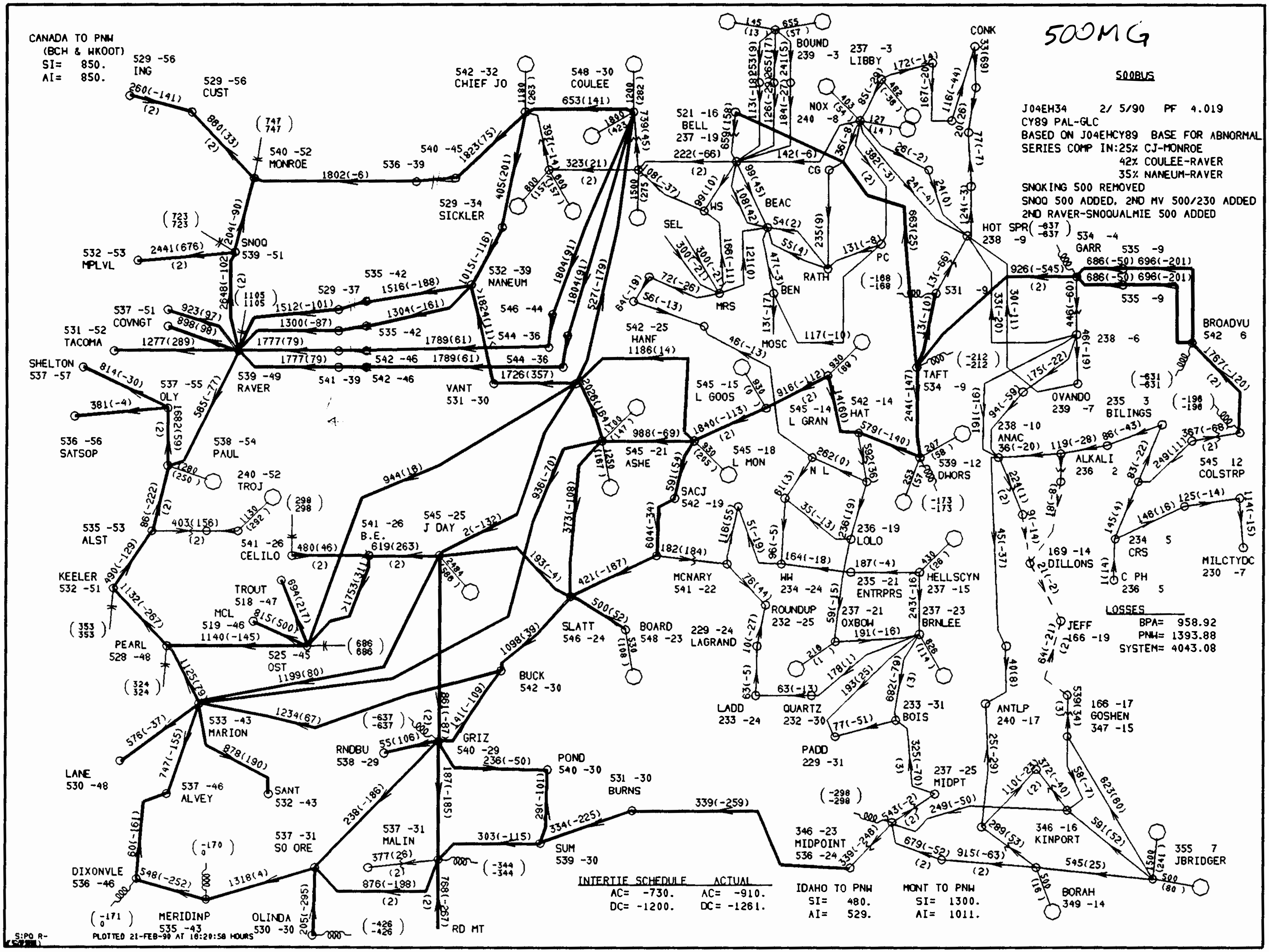
J04EH25 2/ 2/90 PF 4.019
CY89 GLC
BASED ON J04EH23
RAVER-SNOQUALMIE OUTAGE

LOSSES
BPA= 1019.30
PNW= 1471.59
SYSTEM= 4128.66

S:PQ R- PLOTTED 5-FEB-90 AT 13:21:39 HOURS

[illegible] C.C.- Raver [illegible]
to solve
justifies 2nd Raver-Frog 500 k

500MG



CANADA TO PNW
(BCH & WKOOT)
SI= 850.
AI= 850.

500BUS

J04EH34 2/ 5/90 PF 4.019
CY89 PAL-GLC
BASED ON J04EHCY89 BASE FOR ABNORMAL CO
SERIES COMP IN:25% CJ-MONROE
42% COULEE-RAVER
35% NANEUM-RAVER
SNOKING 500 REMOVED
SNOQ 500 ADDED. 2ND MV 500/230 ADDED
2ND RAVER-SNOQUALMIE 500 ADDED

LOSSES
BPA= 958.92
PNW= 1393.88
SYSTEM= 4043.08

INTERTIE SCHEDULE	ACTUAL
AC= -730.	AC= -910.
DC= -1200.	DC= -1261.

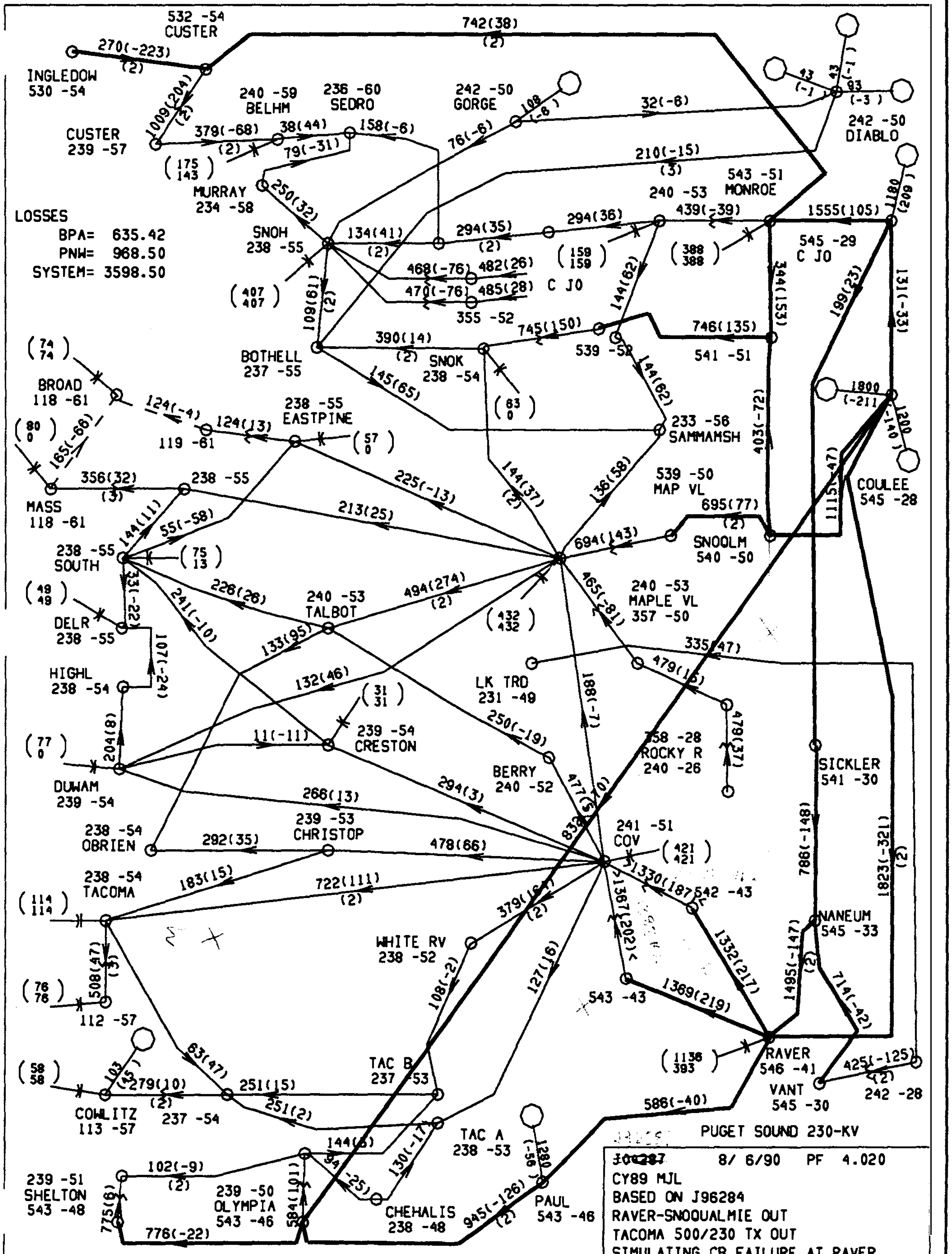
IDAHO TO PNW
SI= 480.
AI= 529.

MONT TO PNW
SI= 1300.
AI= 1011.

S:PO R-

PLOTTED 21-FEB-90 AT 10:20:58 HOURS

PF - PLANS 7 + 8

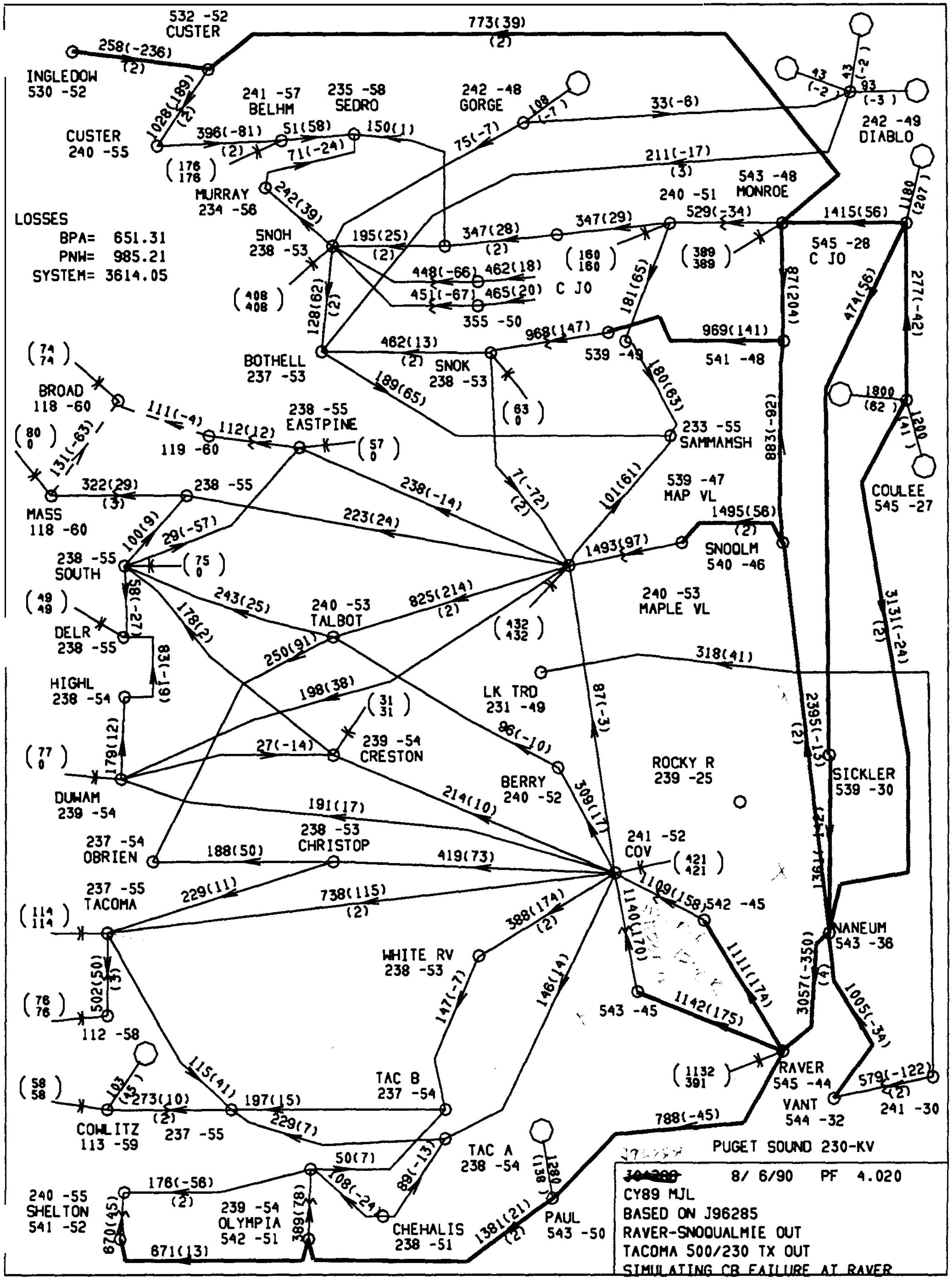


LOSSES
BPA= 635.42
PNW= 968.50
SYSTEM= 3598.50

PUGET SOUND 230-KV

~~J00287~~ 8/ 6/90 PF 4.020
CY89 MJL
BASED ON J96284
RAVER-SNOQUALMIE OUT
TACOMA 500/230 TX OUT
SIMULATING CB FAILURE AT RAVER
PLAN 7

S:PO R- PLOTTED 6-AUG-90 AT 14:53:20 HOURS

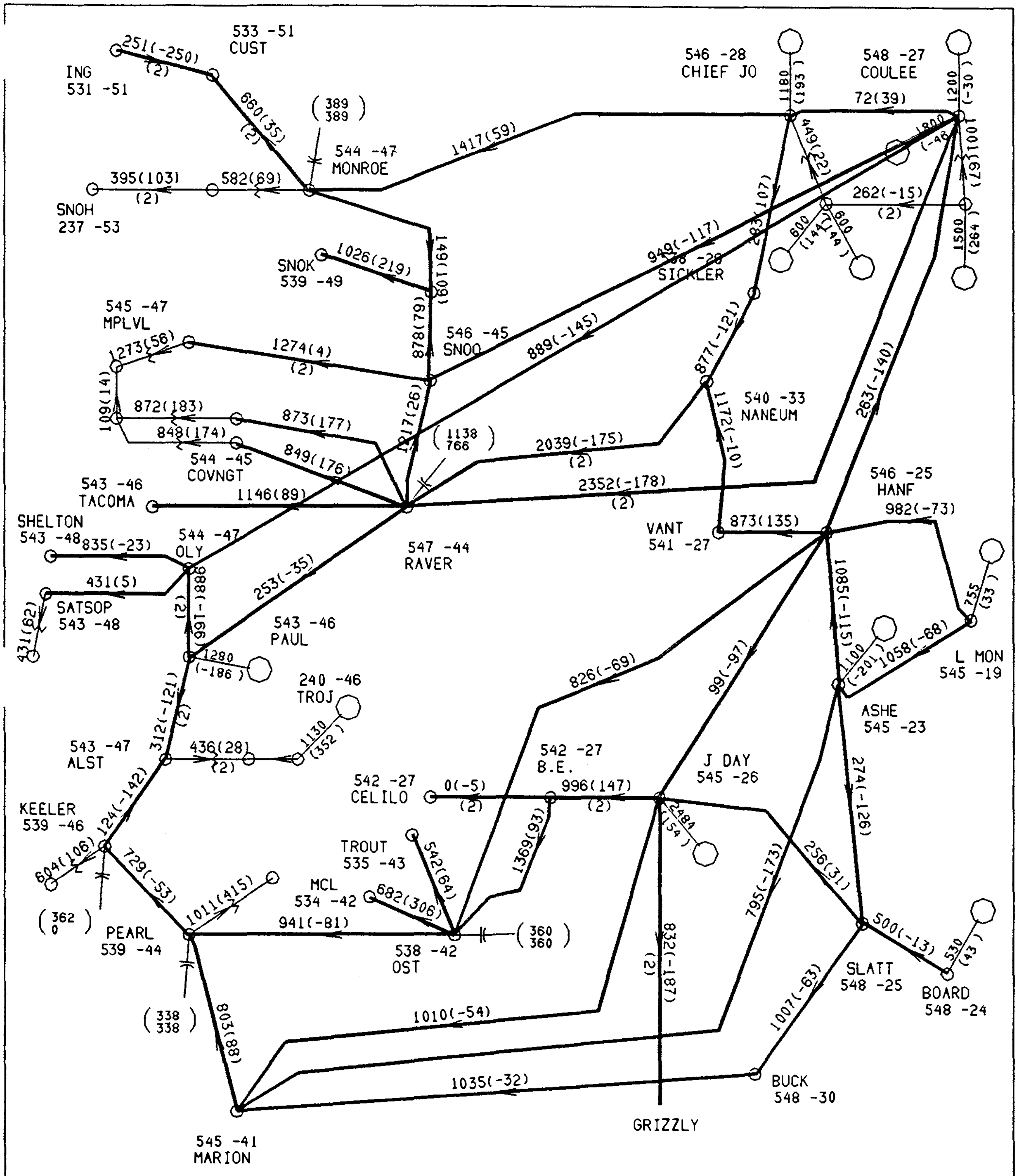


LOSSES
BPA= 651.31
PNW= 985.21
SYSTEM= 3614.05

PUGET SOUND 230-KV

~~J04200~~ 8/ 6/90 PF 4.020
CY89 MJL
BASED ON J96285
RAVER-SNOQUALMIE OUT
TACOMA 500/230 TX OUT
SIMULATING CB FAILURE AT RAVER
PLAN 8

S:PO R- PLOTTED 6-AUG-90 AT 14:52:00 HOURS



500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -370.	BPA= 662.53
DC= 0.	DC= 0.	PNW= 1034.61
		SYSTEM= 3623.36

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 850.	SI= 1310.	SI= 700.
AI= 850.	AI= 994.	AI= 646.

J96EH582 7/24/90 PF 4.020
CY89 MJL
BASED ON J96EH158
PLAN 7 230/287 REBUILD
GC-OLY AND GC-SNOQ 500 ADDED
SNOKING TX ADDED

S:PD R- PLOTTED 25-JUL-90 AT 07:42:19 HOURS
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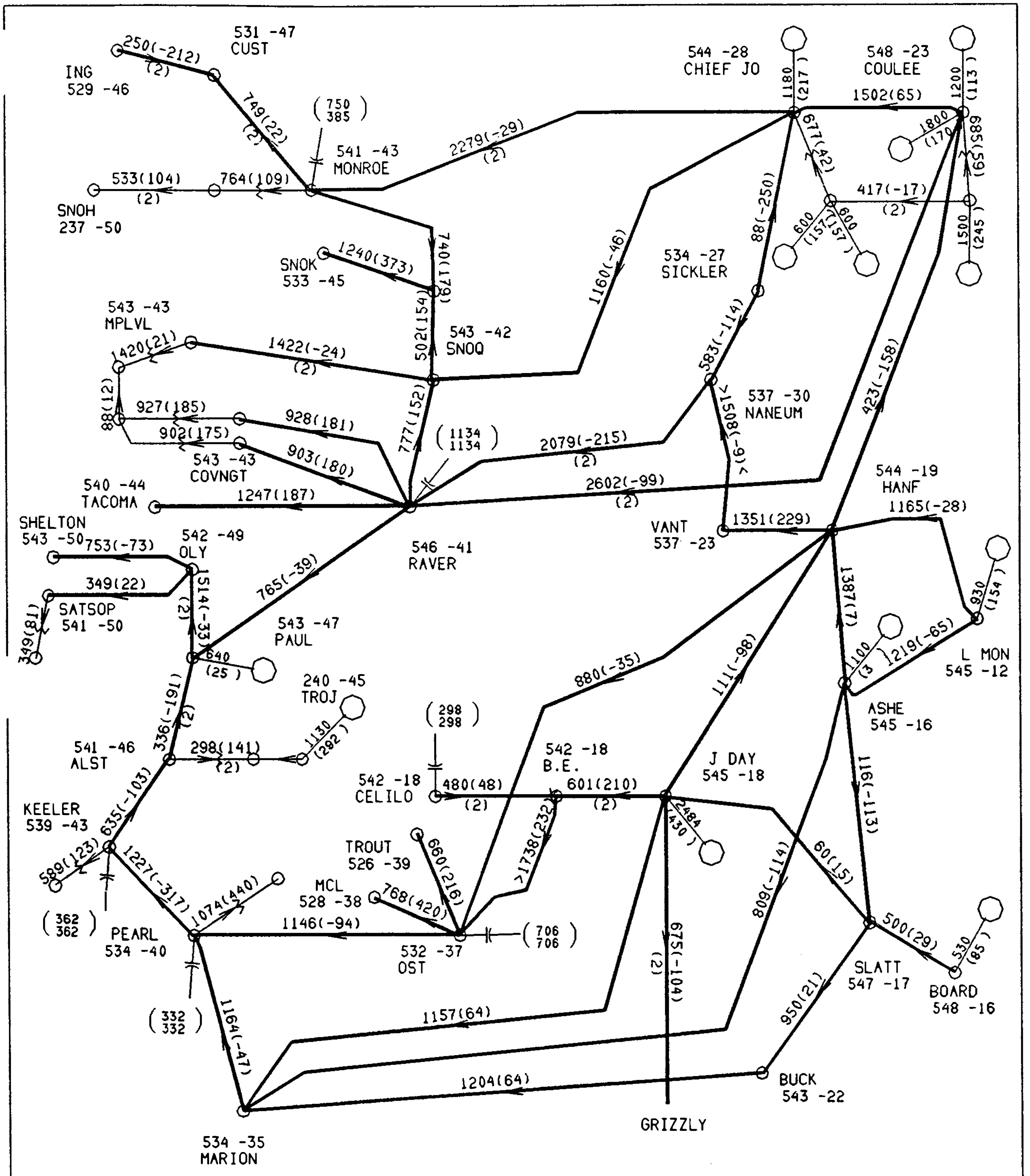

500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -870.	AC= -1137.	BPA= 829.94
DC= -1200.	DC= -1200.	PNW= 1227.15
		SYSTEM= 3865.93

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 850.	SI= 1310.	SI= 630.
AI= 850.	AI= 1042.	AI= 631.

J00EH17 8/ 7/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 3 CJ-S/M
CENTRALIA UNIT DOWN

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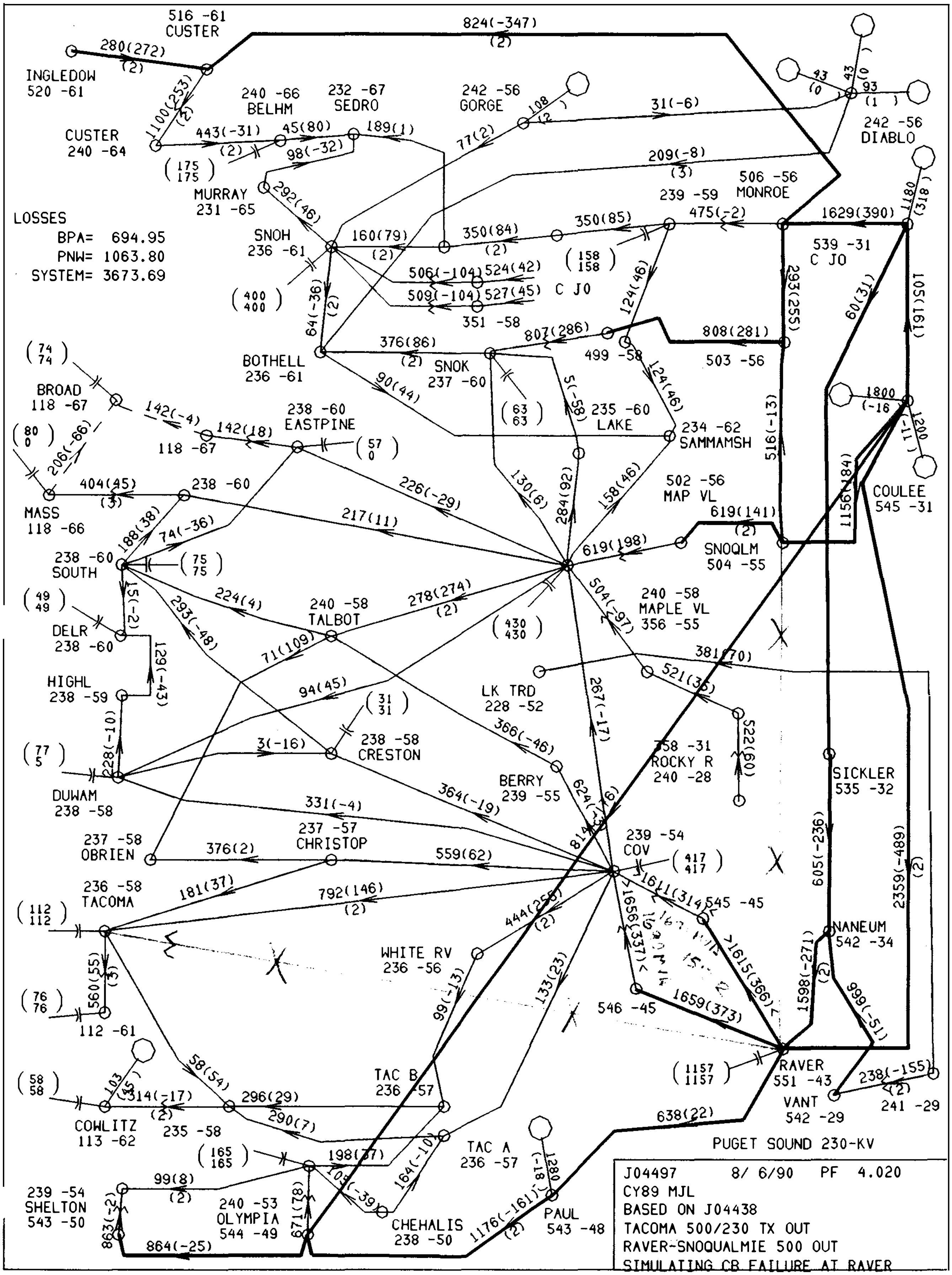
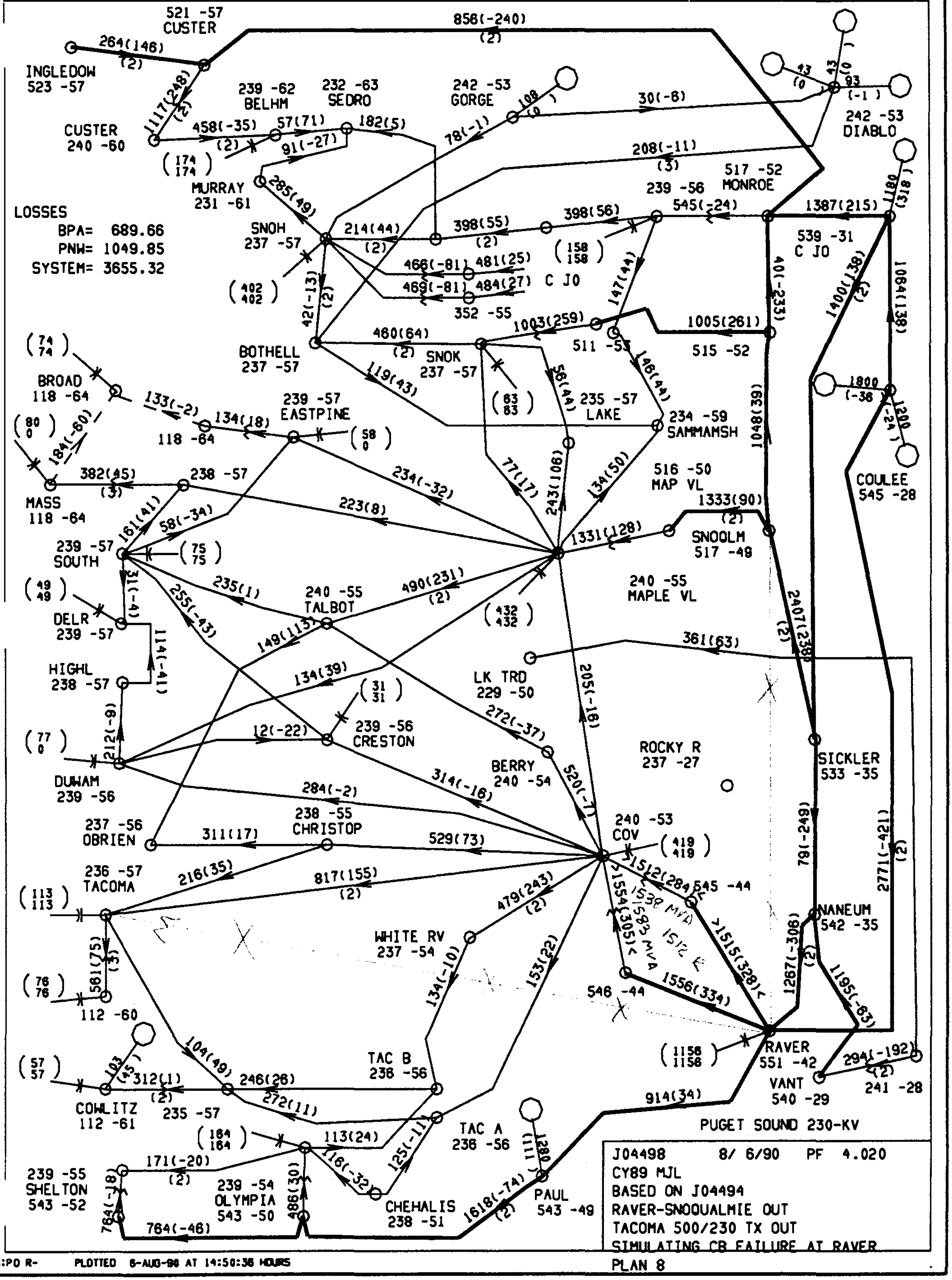


LOSSES
BPA= 694.95
PNW= 1063.80
SYSTEM= 3673.69

J04497 8/ 6/90 PF 4.020
CY89 MJL
BASED ON J04438
TACOMA 500/230 TX OUT
RAVER-SNOQUALMIE 500 OUT
SIMULATING CB FAILURE AT RAVER
PLAN 7

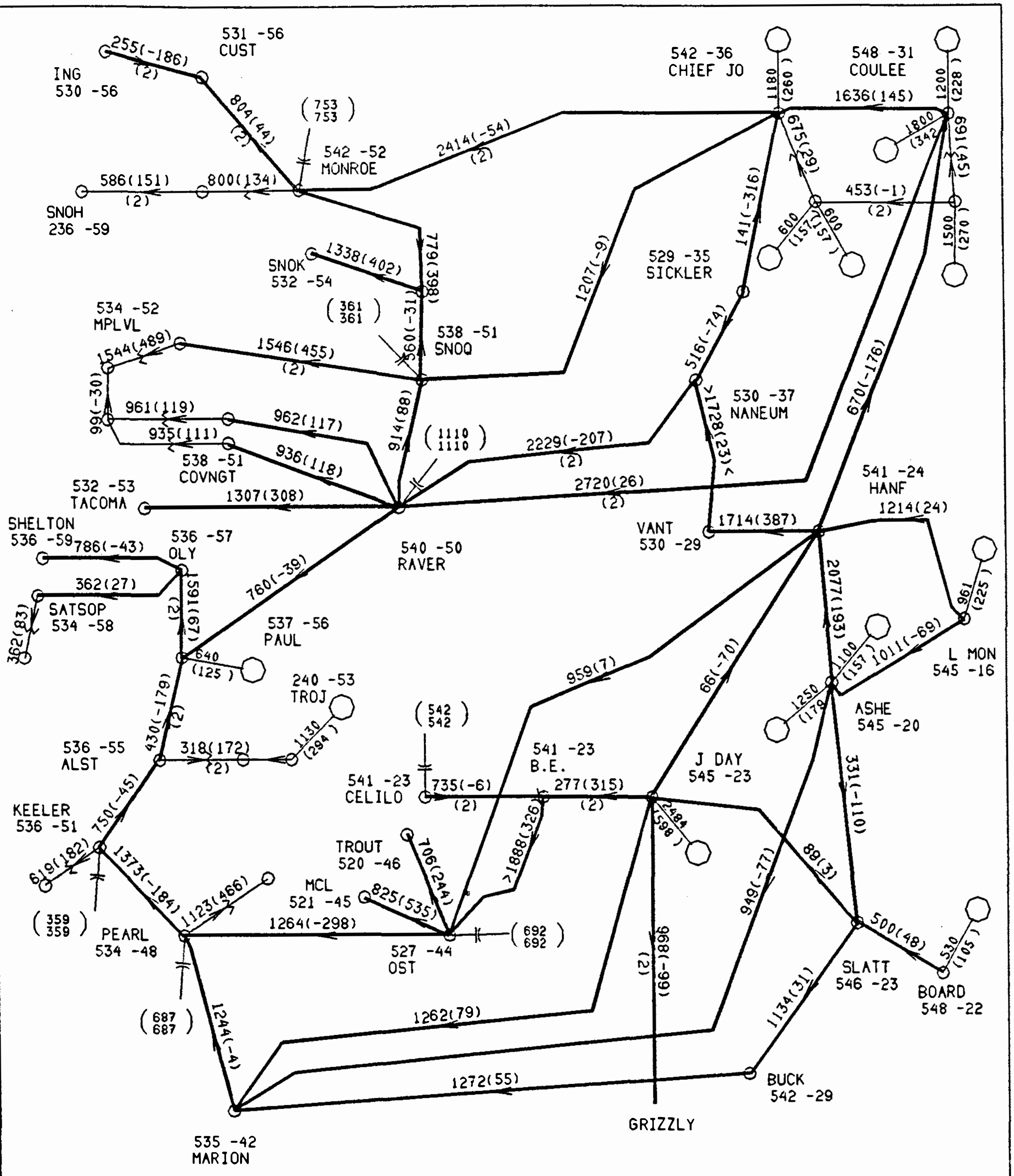
S:PQ R- PLOTTED 6-AUG-90 AT 15:36:41 HOURS



LOSSES
BPA= 689.66
PNW= 1049.85
SYSTEM= 3655.32

PUGET SOUND 230-KV

J04498 8/ 6/90 PF 4.020
CY89 MJL
BASED ON J04494
RAVER-SNOQUALMIE OUT
TACOMA 500/230 TX OUT
SIMULATING CB FAILURE AT RAVER
PLAN 8



500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -815.	BPA= 1052.34
DC= -1840.	DC= -2013.	PNW= 1478.35
		SYSTEM= 4133.36

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 850.	SI= 1300.	SI= 480.
AI= 850.	AI= 1011.	AI= 512.

J04EH160 7/26/90 PF 4.020
CY89 MJL
BASED ON J04EH70
PLAN 3 CJ-S/M
C-R COMP CORRECTED

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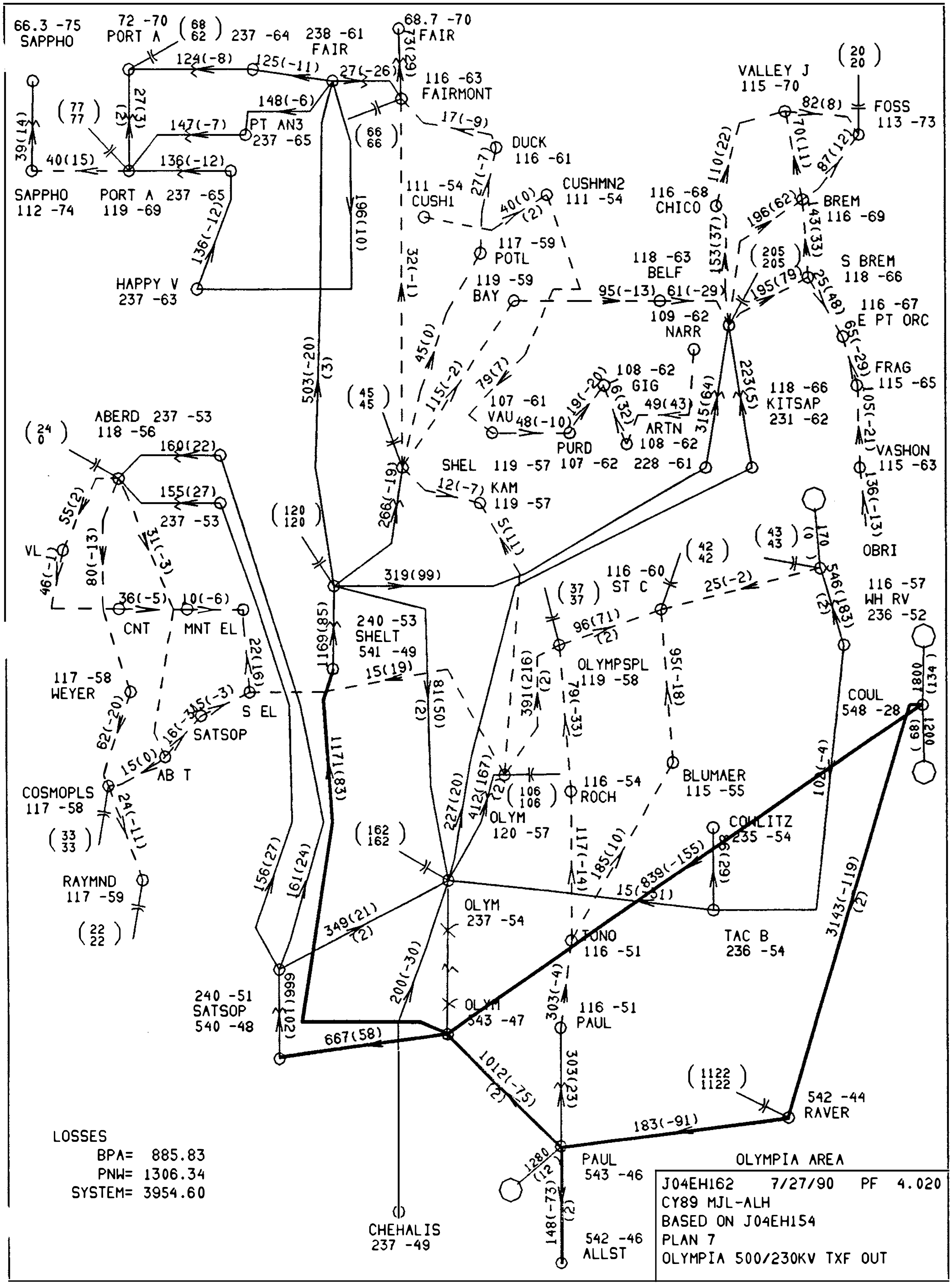
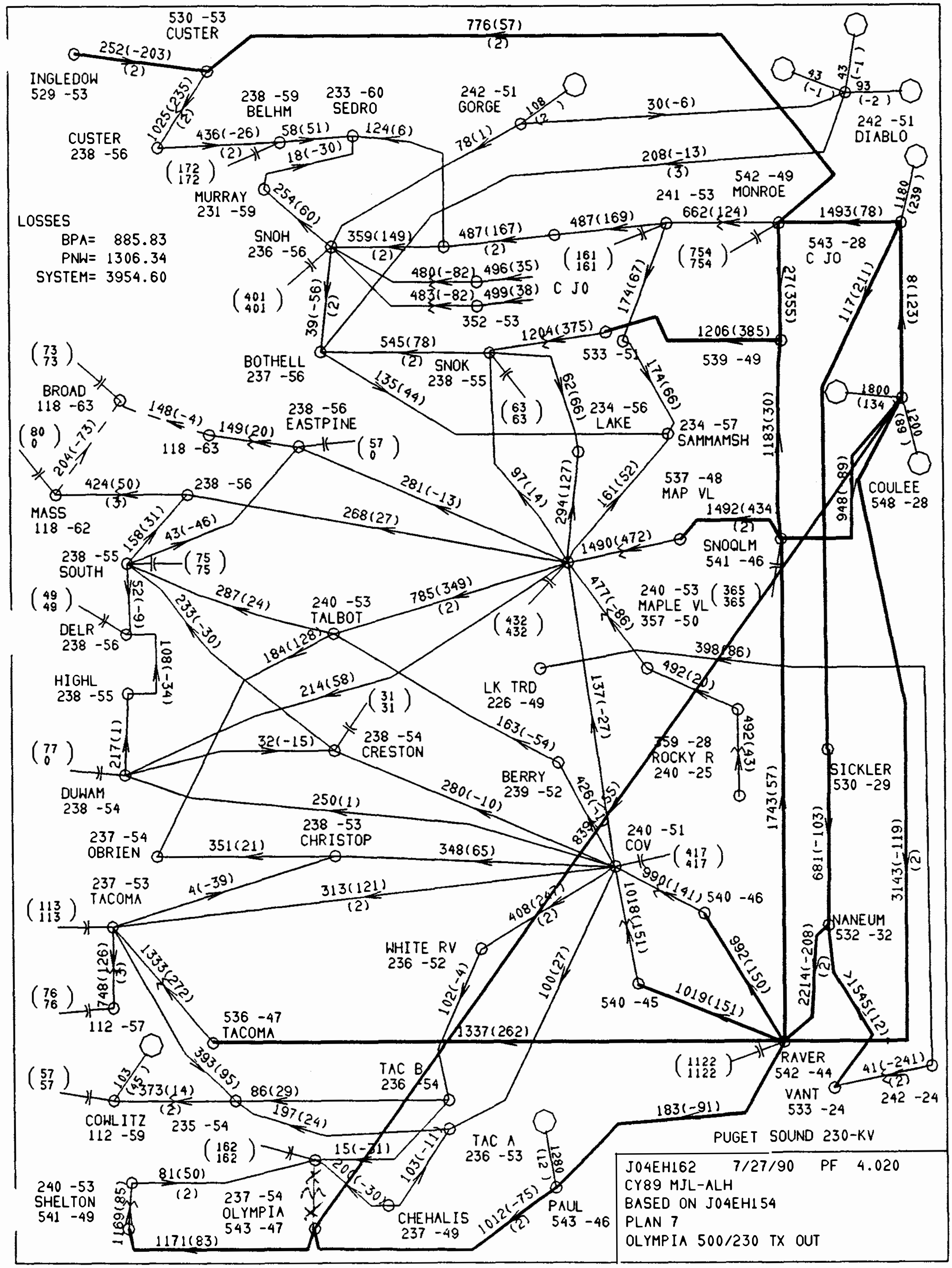


LOSSES
BPA= 885.83
PNW= 1306.34
SYSTEM= 3954.60

OLYMPIA AREA

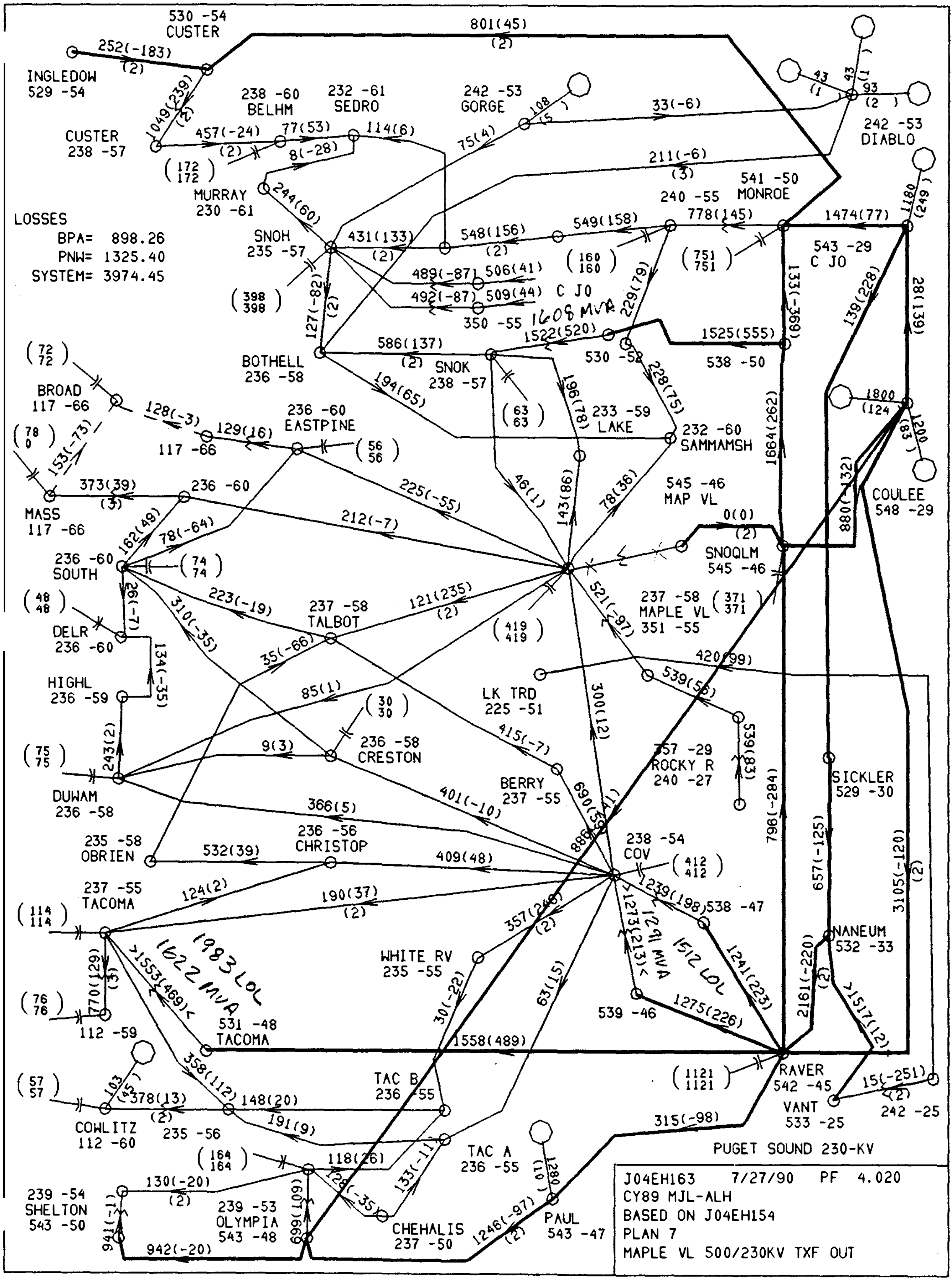
J04EH162 7/27/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH154
PLAN 7
OLYMPIA 500/230KV TXF OUT

S:PQ R- , PLOTTED 27-JUL-90 AT 15:37:42 HOURS



J04EH162 7/27/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH154
PLAN 7
OLYMPIA 500/230 TX OUT

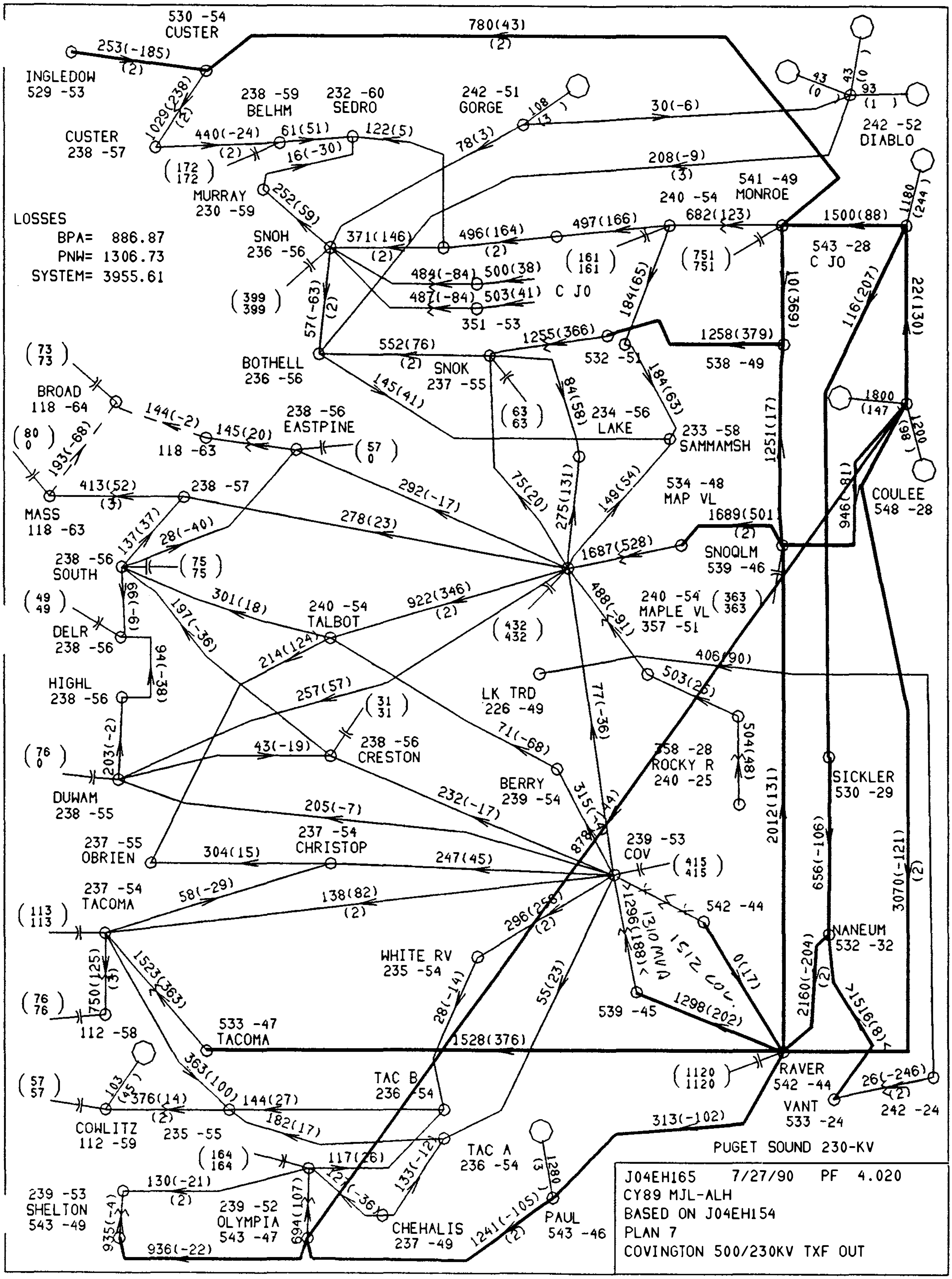
S:PO R- PLOTTED 3-AUG-90 AT 08:52:47 HOURS



LOSSES
BPA= 898.26
PNW= 1325.40
SYSTEM= 3974.45

J04EH163 7/27/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH154
PLAN 7
MAPLE VL 500/230KV TXF OUT

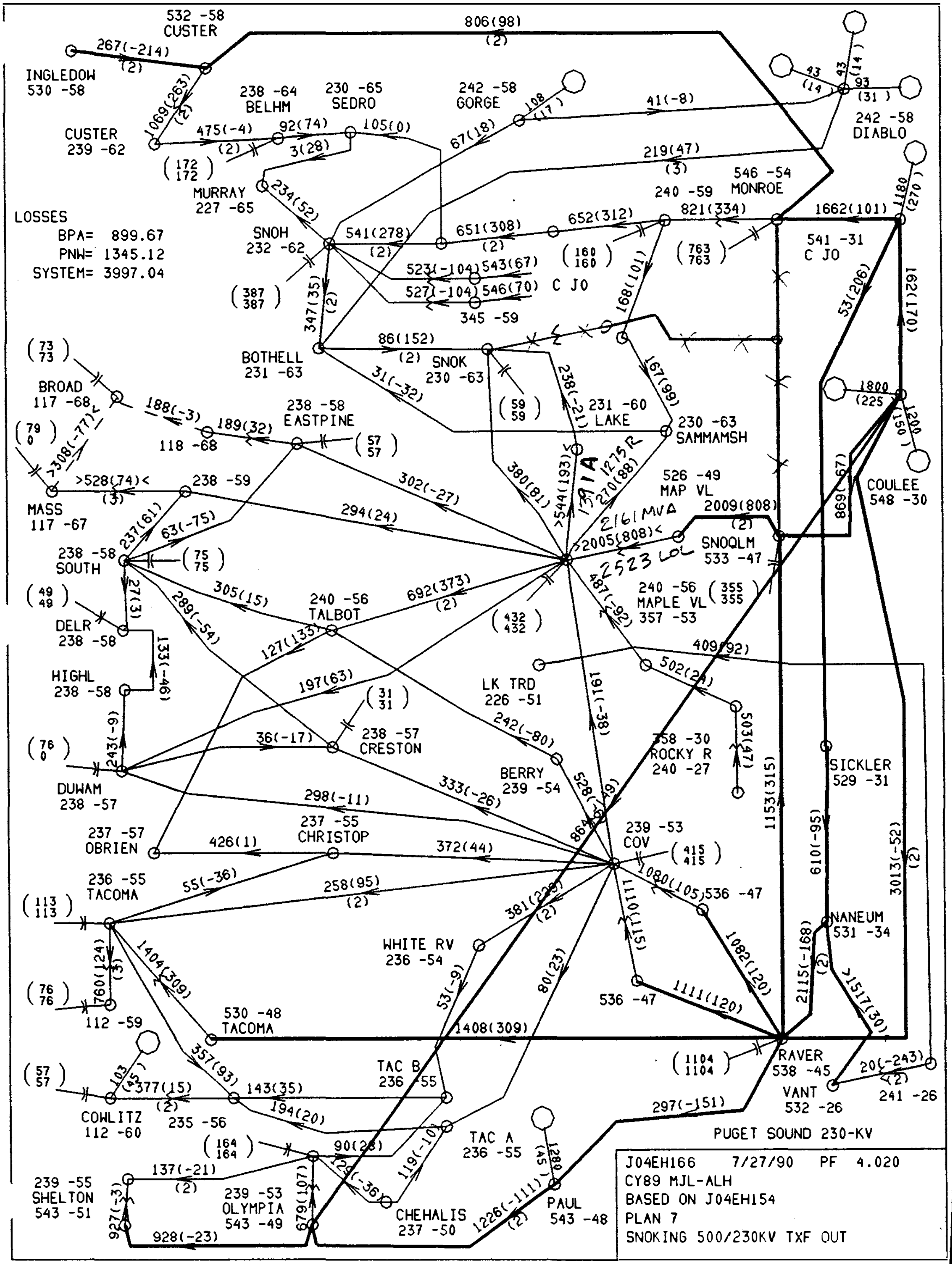
S:PQ R- . PLOTTED 27-JUL-90 AT 15:39:58 HOURS



PUGET SOUND 230-KV

J04EH165 7/27/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH154
PLAN 7
COVINGTON 500/230KV TXF OUT

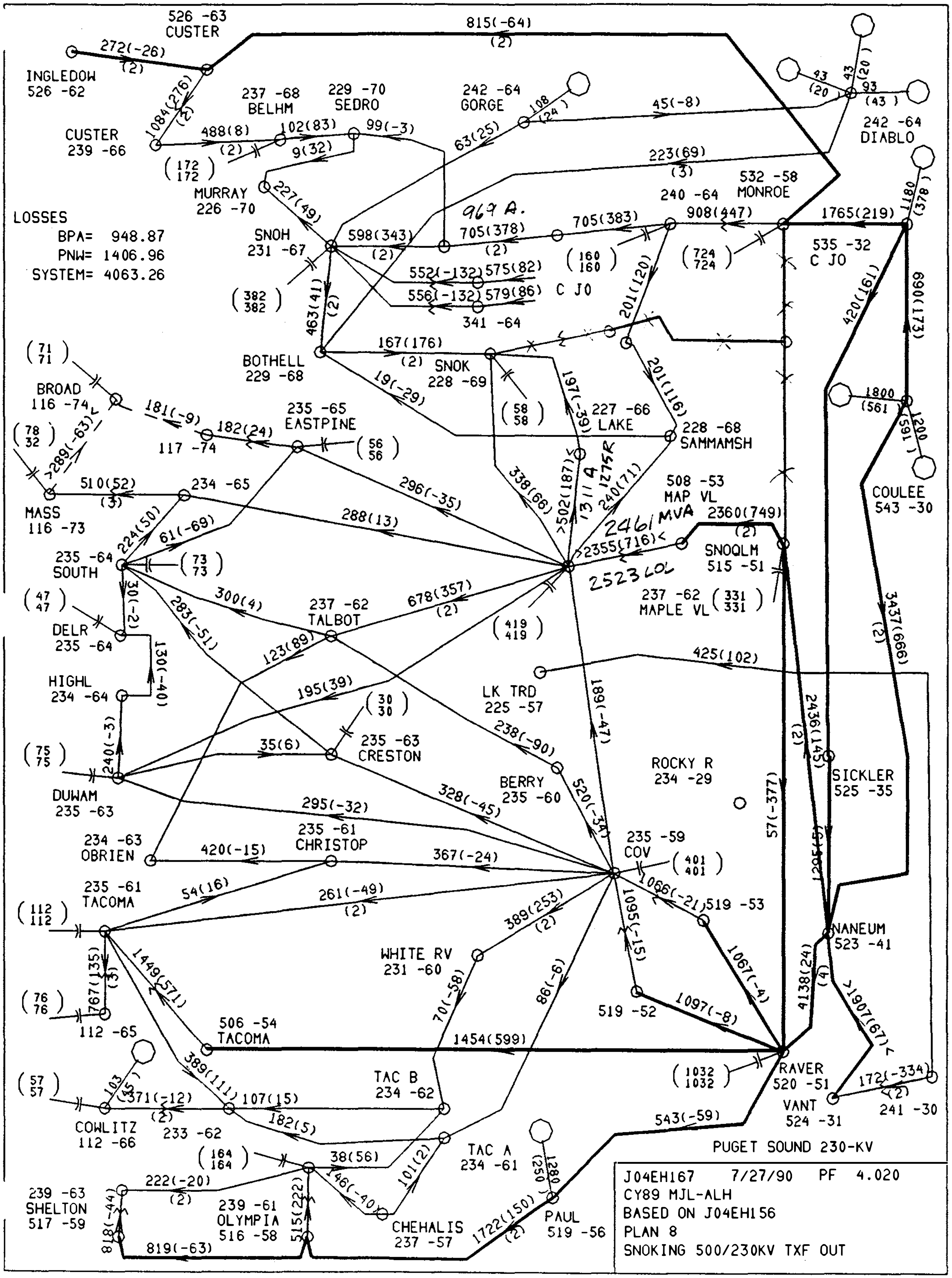
S:PQ R- , PLOTTED 27-JUL-90 AT 15:44:58 HOURS



LOSSES
BPA= 899.67
PNW= 1345.12
SYSTEM= 3997.04

J04EH166 7/27/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH154
PLAN 7
SNOKING 500/230KV TXF OUT

S:PQ R- , PLOTTED 27-JUL-90 AT 15:47:55 HOURS

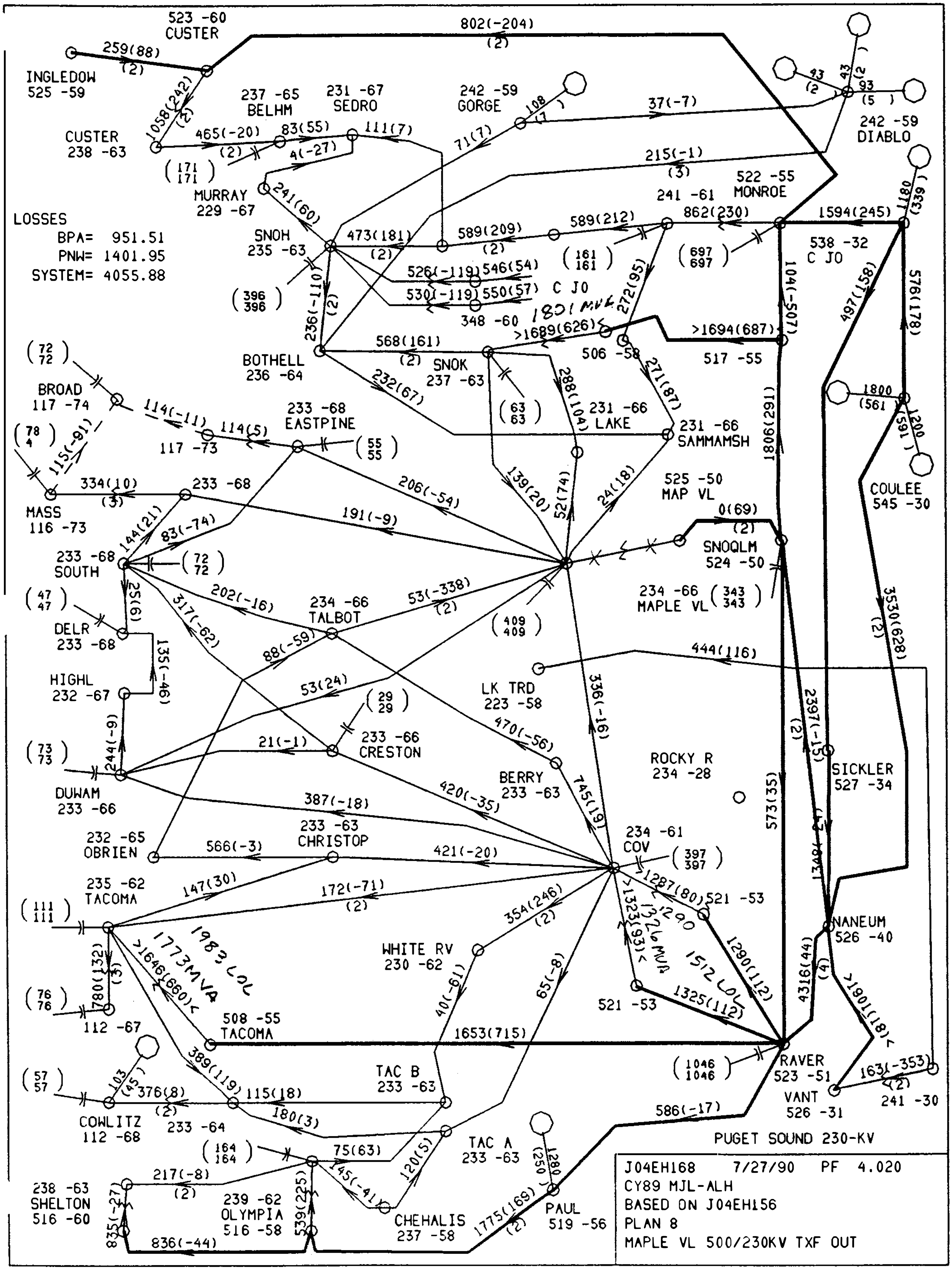


LOSSES
BPA= 948.87
PNW= 1406.96
SYSTEM= 4063.26

PUGET SOUND 230-KV

J04EH167 7/27/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH156
PLAN 8
SNOKING 500/230KV TXF OUT

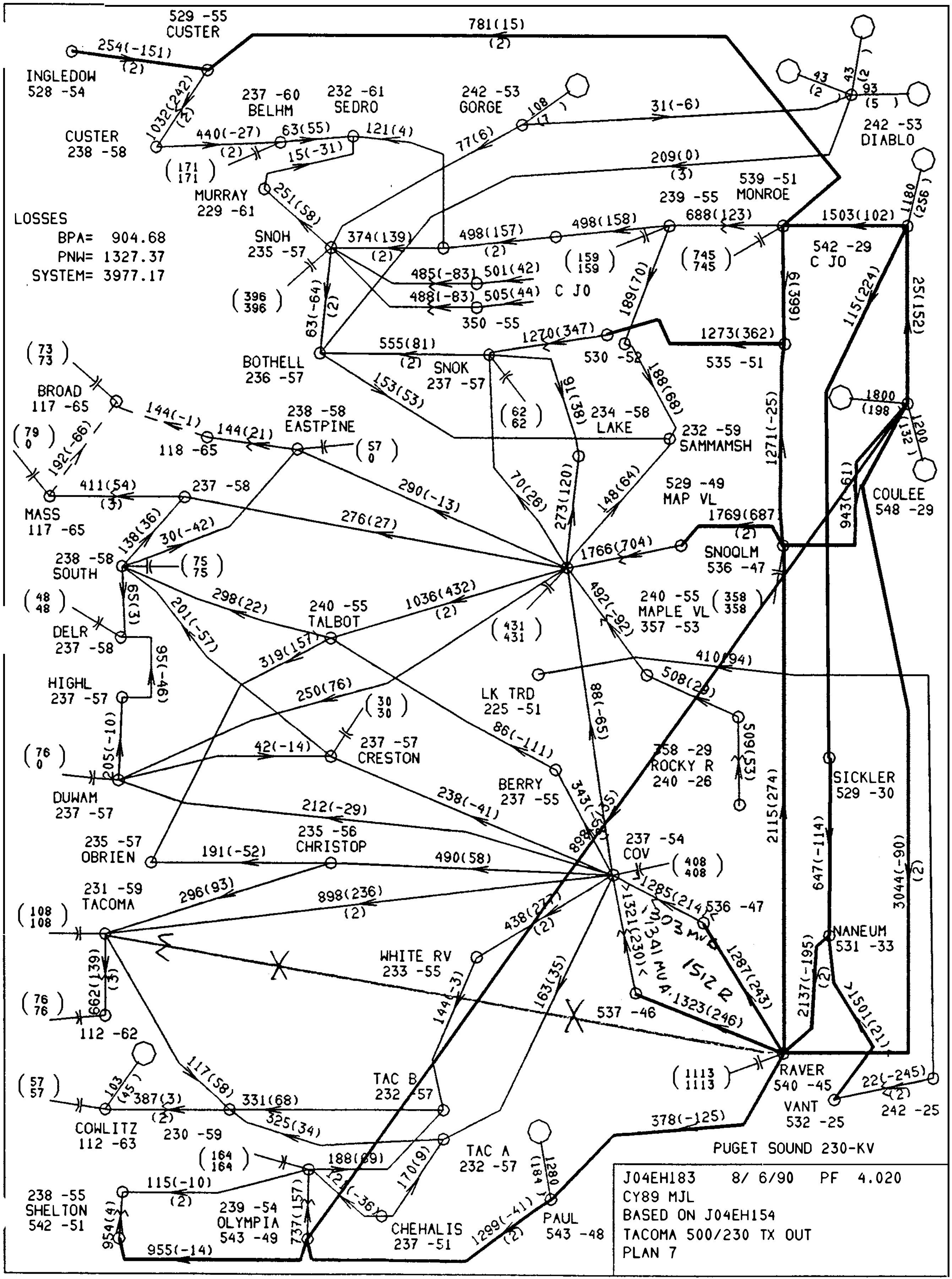
S:PQ R- , PLOTTED 27-JUL-90 AT 15:50:08 HOURS



LOSSES
BPA= 951.51
PNW= 1401.95
SYSTEM= 4055.88

J04EH168 7/27/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH156
PLAN 8
MAPLE VL 500/230KV TXF OUT

S:PQ R- , PLOTTED 27-JUL-90 AT 15:52:18 HOURS



J04EH183 8/ 6/90 PF 4.020
CY89 MJL
BASED ON J04EH154
TACOMA 500/230 TX OUT
PLAN 7

S:PQ R- PLOTTED 6-AUG-90 AT 15:33:52 HOURS

Attachment 2

BPA F 1325.01
(01-89)
(Previously BPA 1100)

U.S. DEPARTMENT OF ENERGY – BONNEVILLE POWER ADMINISTRATION

Memorandum

E : OCT 12 1990

ROM : Marv Landauer, Electrical Engineer
Project Studies Section - EOFB

Marv

SUBJECT: New Cross Mountain Transmission Line Alternative

ATTACHMENT 2

TO : Dennis Porter, Assistant Director
Division of System Planning - EO

I have recently been studying a new cross mountain transmission line alternative for the Puget Sound Area Electric Reliability Project that shows some promise. This alternative consists of rebuilding the double-circuit Chief Joe-Snohomish 345-kV Line to single-circuit 500-kV, using as much of the existing tower structures and conductor as possible. The new line would be looped into Monroe and terminated at Snohomish with a new 500/230-kV autotransformer. New 500-kV switching stations would be added at Columbia and Mad River (my name for a new station along the Stevens Pass corridor), with a new single circuit 500-kV line connecting these new stations to the existing Sickler switchyard. Refer to Attachment A.

Only 2004 studies of this plan have been run and these are not complete. A step plan between 1996 and 2004 has not been developed. There are also many potential variations to this plan that have not yet been explored.

It is assumed that the addition of the Snohomish 500/230-kV transformer (to replace the existing 345/230-kV transformers) and a Snoking 500/230-kV transformer will provide adequate support to the North Seattle area through 2004. A second Chief Joe 500/230-kV transformer will be needed because of the removal of the 345-230-kV transformers there. 500 MVAR SVCs are assumed at Maple Valley and Keeler in the 2004 studies, as in the other plans.

The addition of the new east side crosstie reduces the severity of the outages that can occur by providing a more integrated transmission system. The post-transient performance of the three worst outages for this alternative is shown in the Q-V curves in Attachment B. These curves can be compared to the three worst outages for the Chief Joe-Snoqualmie/Monroe plan we submitted as the budget plan (Plan 3 shown in Attachment C). This new plan will require additional reinforcement for the single line outage in 2004 to provide the necessary 500 MVAR margin, whereas the budget plan does not require additional reinforcement until 2005. It should be noted that this new plan, like the Reactive Alternative, does not have the same ultimate capacity that the new 500-kV double-circuit Line plans do. The crosstie plan and the Reactive Alternative make better use of existing system capacity, especially during outages.

The loss savings for this plan is lower than the new double circuit line plans in the most recent engineering report. As compared to the Reactive Alternative (since the base system will not solve without reinforcement in later years), this new alternative will save about 57 MW in losses in 2004. For comparison, the Chief Joe-Snoqualmie 500-kV double circuit line alternative saves about 65 MW and the Chief Joe-Snoqualmie/Monroe 500-kV double circuit Line plan saves about 77 MW.

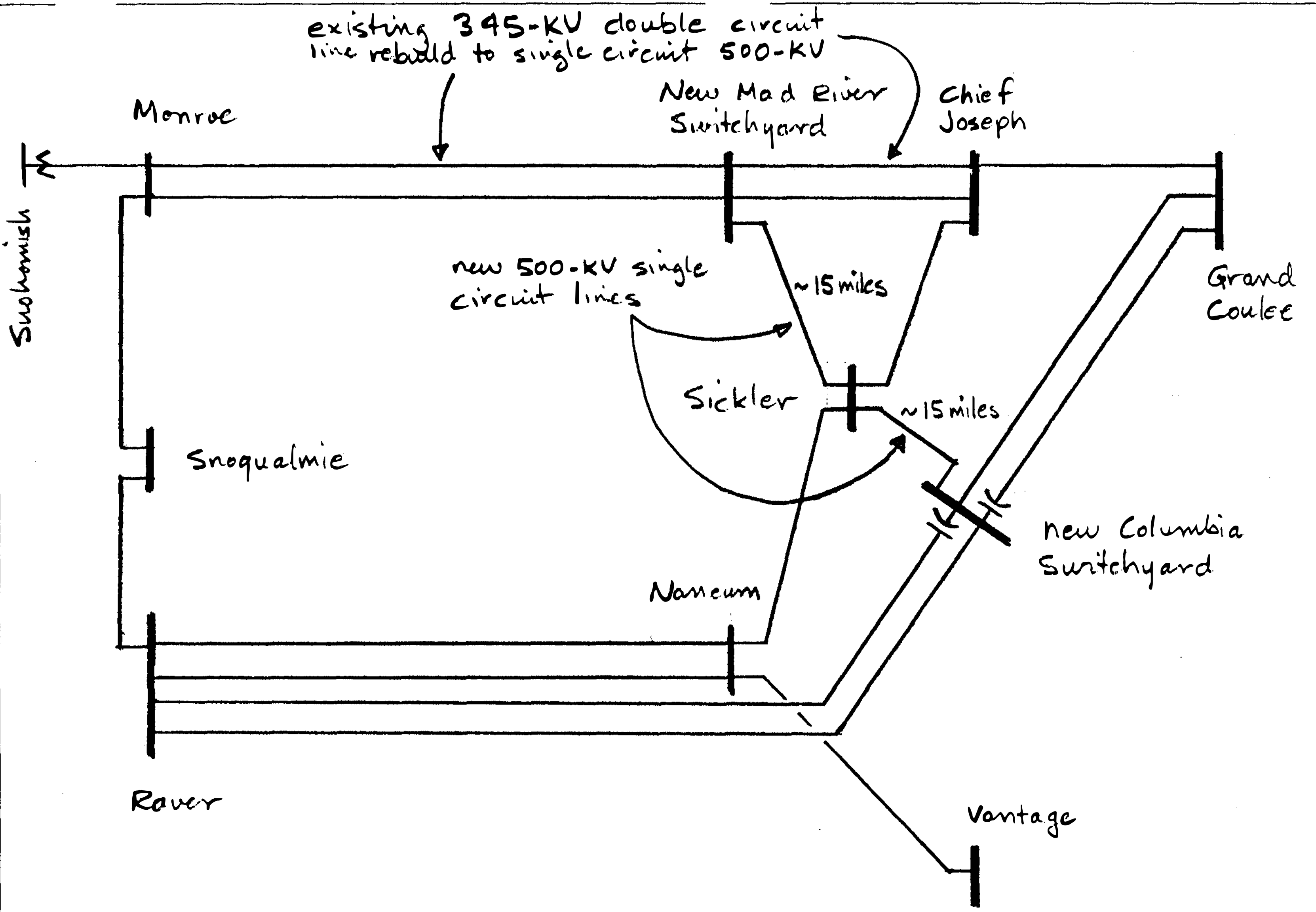
Even though the post-transient performance and loss savings are inferior to the better double-circuit plans, this new plan should be considerably cheaper. The rebuild of the 345-kV line will be less expensive than a new single-circuit line since the conductor and much of the existing towers, can be reused. This savings should more than offset the additional cost of the extra losses, east side line construction and switchyard development at Columbia and Mad River.

This crosstie concept could also be applied to many of the other plans documented in the engineering report. It would also allow for a staged development of these alternatives that could reduce the overall cost.

5 Attachments

MLandauer:zb:3887 (VS16-EOFB-6844L)

cc:
A. Courts - E
M. Raschio - EOF
A. Rodrigues - EOFA
M. Bond - EOFB
G. Comegys - EOFC
Official File - EOF (FY 91 BI 14)
Viles
Taylor

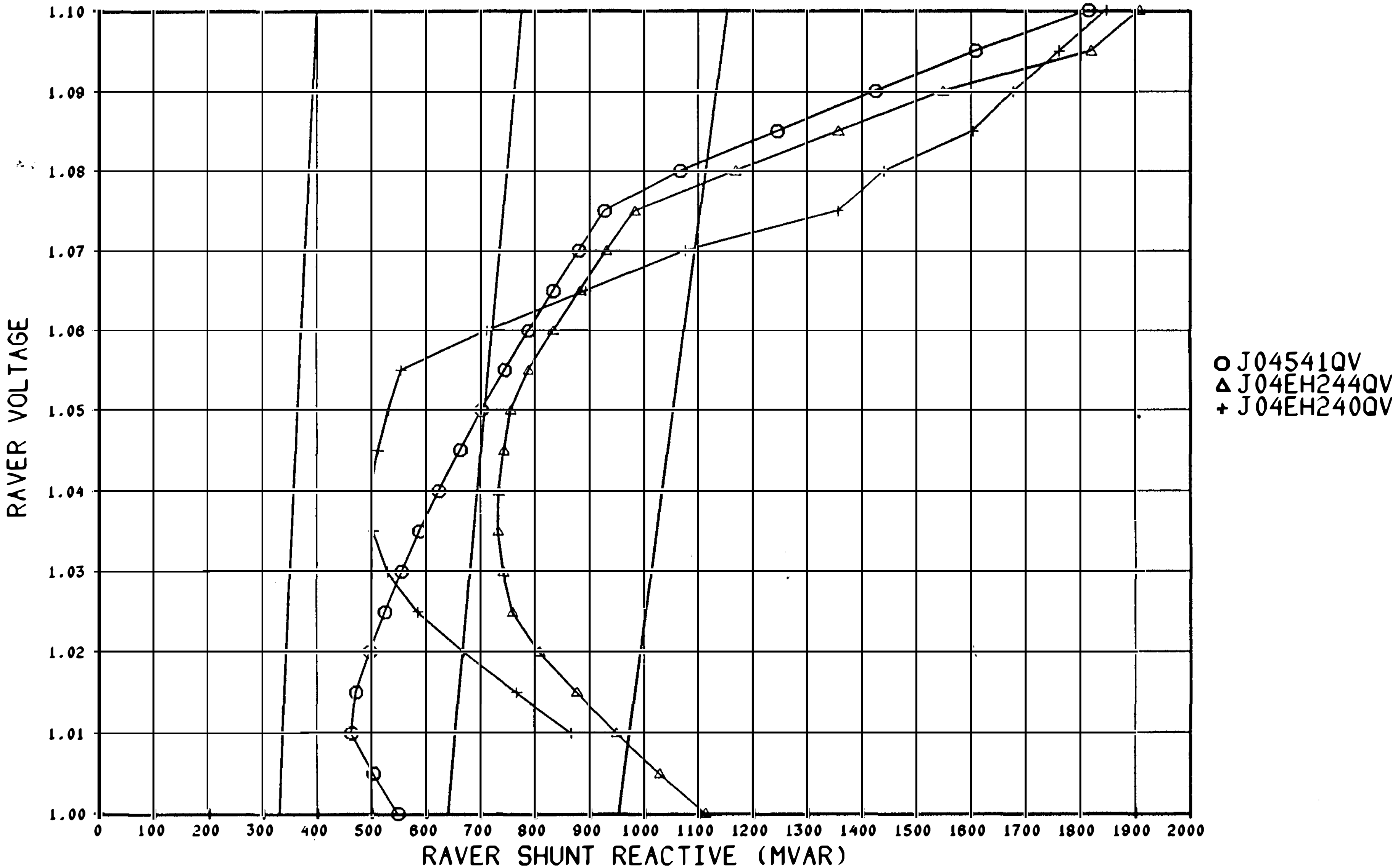


Attachment A: Crosstie Plan

Attachment B

PLAN 10: CROSS TIE COLUMBIA-SICKLER-MADRIVER

CHIEF JO-SNOHOMISH 345 REBUILD TO 500
○J04541 BOTH COLUMBIA-RAVER 500 OUT (J04534)
△J04EH244 MADRIVER-MONROE #2 500 OUT (J04EH238)
+J04EH240 TROJAN SCRAM (J04EH239)



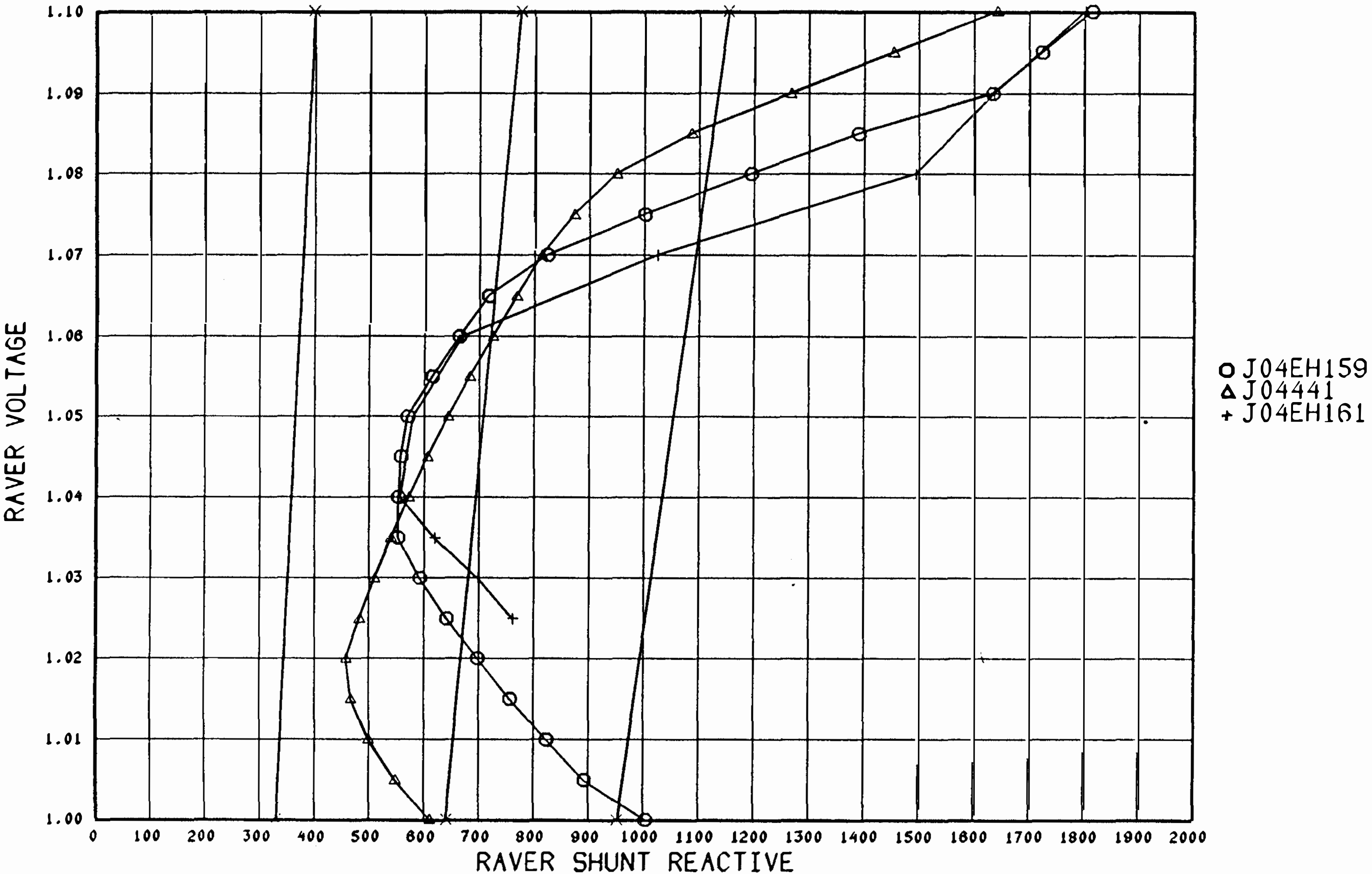
3-OCT-1990

Attachment C

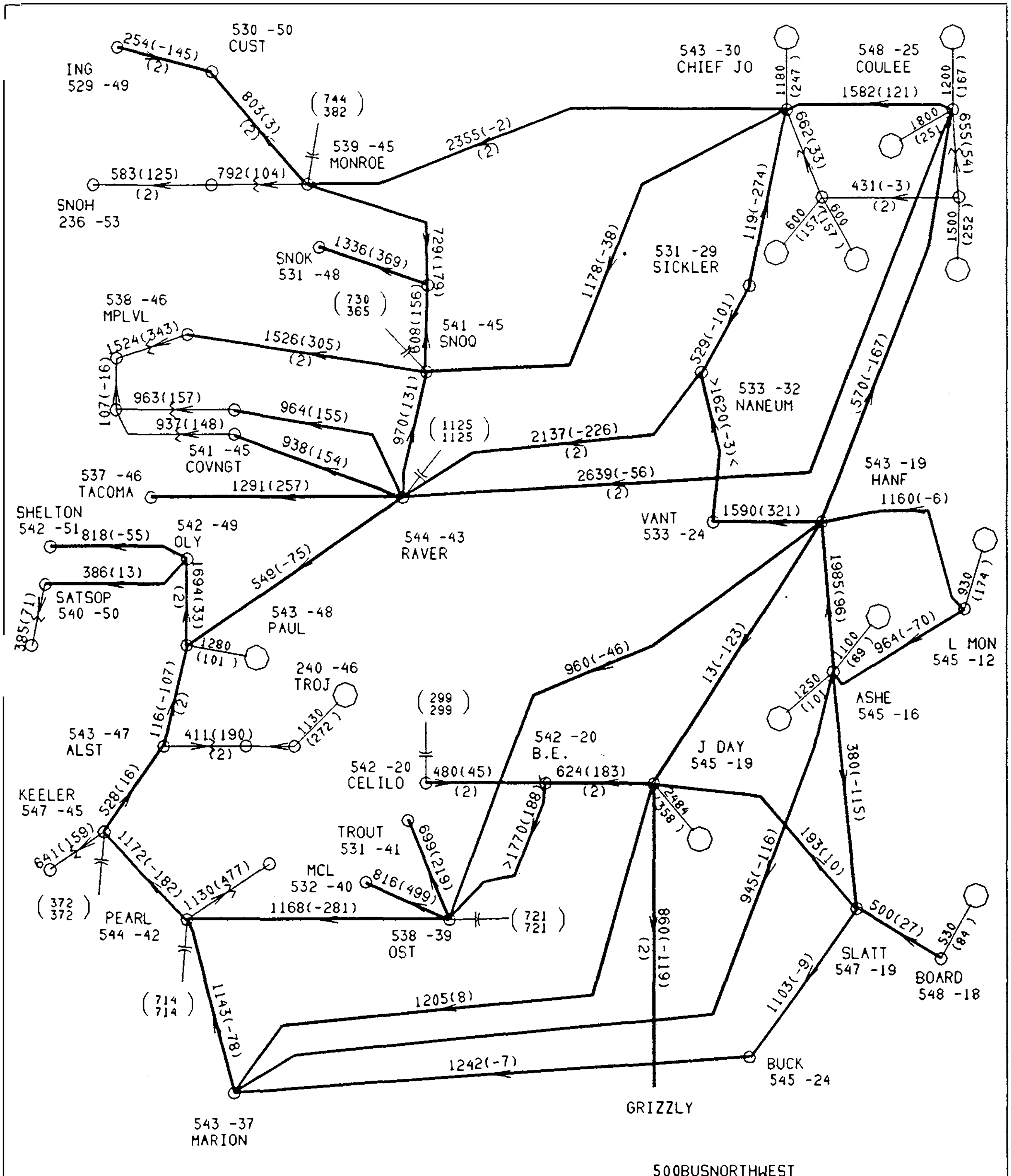
PLAN 3 CHIEF JOE-SNOQ/MON

correct C-R series comp

○ J04EH159: COULEE-RAVER OUT (J04EH158)
△ J04441: BOTH COULEE-RAVER LINES OUT (J04440)
+ J04EH161: TROJAN SCRAM (J04EH160)



4-OCT-1990



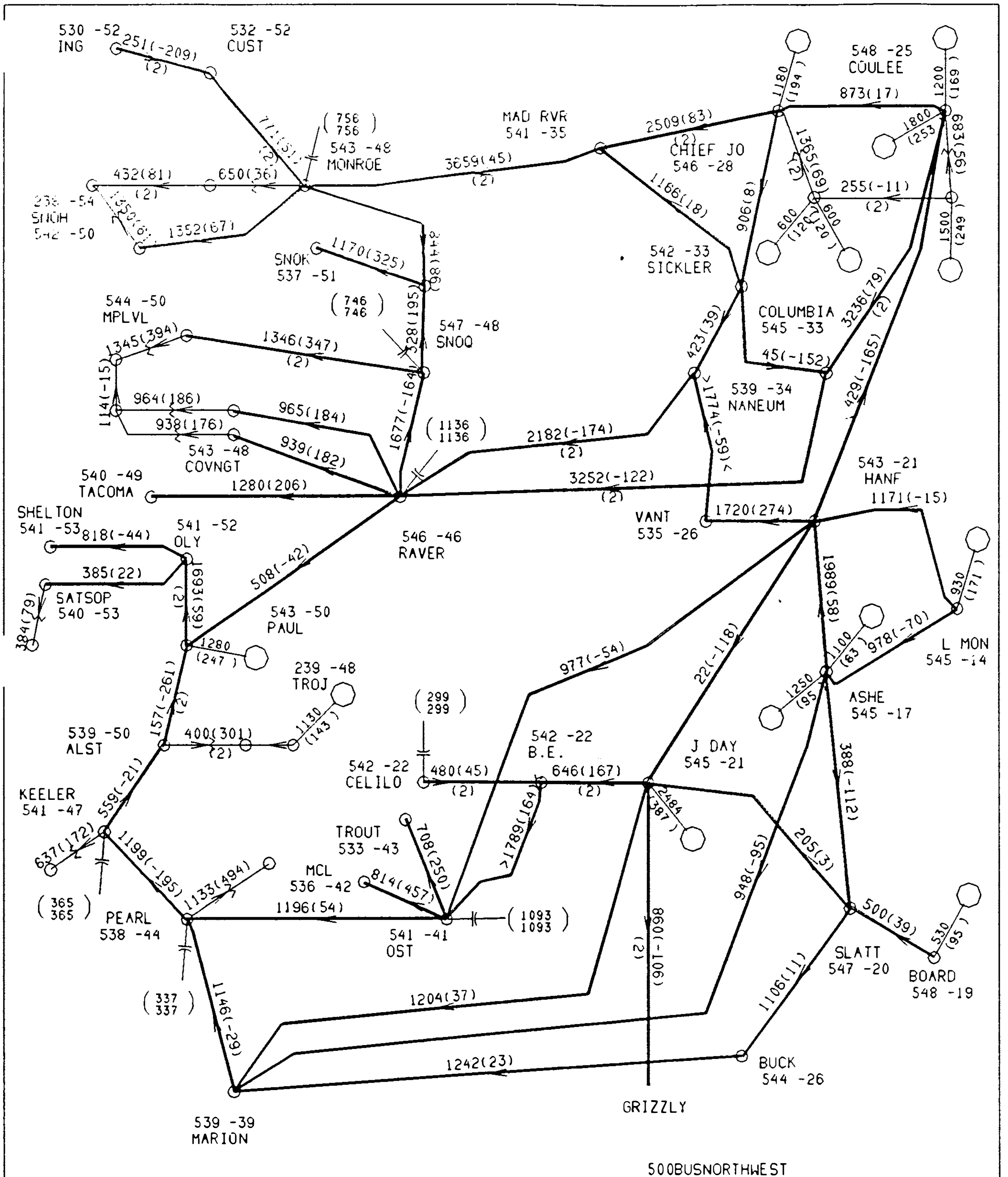
500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -909.	BPA= 876.75
DC= -1200.	DC= -1261.	PNW= 1291.90
		SYSTEM= 3938.84

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 850.	SI= 1300.	SI= 480.
AI= 850.	AI= 1012.	AI= 528.

J04EH158 7/26/90 PF 4.020
CY89 MJL
BASED ON J04EH69
PLAN 3 CJ-S/M
C-R COMP CORRECTED

S.PO R- PLOTTED 26-JUL-90 AT 08:22:51 HOURS



500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -909.	BPA= 893.69
DC= -1200.	DC= -1261.	PNW= 1311.66
		SYSTEM= 3958.77

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 850.	SI= 1300.	SI= 480.
AI= 850.	AI= 1013.	AI= 527.

J04EH238 9/28/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH69
PLAN 10 - CROSSTIE
CJ-SNOH 345 REBUILT TO 500 SSC
COLUMBIA-SICKLER-MAD RIVER 500 SSC ADDED

PLOTTED 12-OCT-90 AT 13:15:44 HOURS

Attachment 3

ATTACHMENT 3: THE REACTIVE PLAN

by Marv Landauer - BPA

3-9-92

The preferred reactive plan is the addition of a new switchyard in the Naneum area that includes series compensation on the Raver side. Initially banks of 19 ohms and 3150 amps will be added to the double circuit lines, followed later by two new banks, one on the Sickler-Raver line (20 ohms and 2200 amps) and one on the Vantage-Raver line (23 ohms and 2000 amps). This plan evolved from the original reactive plan that was described in the Puget Sound Transmission Alternatives Report. This report documents the study work that was done since that time to develop this preferred reactive plan.

Section 1: Assumptions

Plans were designed to provide at least 500 MVAR reactive margin. The studies in this report assume that the following facilities are installed:

To provide reactive support in the Puget Sound Basin through 1996:
- 230-kV, 300 MVAR SVC's at Maple Valley and Keeler,
- 500-Kv Snoqualmie switchyard,
- LDC's added at Coulee, Centralia, John Day, The Dalles, Bonneville.
- additional 500-kV shunt caps at Snoqualmie (625 MVAR) and Monroe (312 MVAR),
- additional 230-kV shunt caps at Snoking, Tacoma and Olympia (153 MVAR each),

These additional shunt capacitors can be used as MSC's.

To provide local reinforcement to the Puget Sound area:
- Raver-Snoqualmie 500-kV line #2
- Maple Valley 500/230-kV transformer #2 and Monroe-Snohomish 230-kV #3 OR Snoking 500/230-kV transformer

These local reinforcement assumptions will be reviewed later in this report.

Some support appears to be needed in the Portland area about 2004, regardless of the reinforcement added in the Puget Sound area. An SVC at Ostrander was proposed in the original reactive plan and would provide this support. However an MSC at Marion is probably sufficient, especially since these studies already include 3 capacitor groups at Ostrander.

Section 2: Evolution of reactive plan

Several reactive options were developed and studied. The more important options are listed below. Other options that were studied and eliminated are included in Table 9 at the end of this report.

System losses and the performance of all option are summarized in Table 1. A diagram of the major cross mountain transmission lines is included in Table 2. QV curves for each option, by plan number, are also attached.

REACTIVE PLAN 3

The Original Reactive Plan consisted of the following additions:

A. 300 MVAR SVC's at Covington, Snohomish and Ostrander,
B. Chief Jo-Monroe series caps, 25% fixed and 25% switched,

C. Naneum-Raver #1 and #2 series caps, 35% fixed and 35% switched,
D. Coulee-Raver #1 and #2 series caps, 20% fixed,
E. Raver-Snoqualmie 500 #2 line, and
F. Maple Valley 500/230 Tx #2 and Monroe-Snohomish 230 #3 line.

This reactive plan appears to have plenty of margin as shown in QV-Curve 3. This is largely due to the MSC's that have been proposed for the Puget Sound Basin since the original engineering report. Overvoltages would occur with the 50% comp on Chief Joe-Monroe line. This would require that the comp be split into two banks, separated by several miles of line impedance.

REACTIVE PLAN 3C

Since the original plan had so much margin, some of the components of that plan could be eliminated. The SVC's are very expensive and the reliability of the switched series is questionable. Therefore this plan was developed with only fixed series caps:

A. 35% series comp on Chief Jo-Monroe line,
B. 60% series comp on Naneum-Raver #1 and #2 line,
C. additional 27.5% series comp on Coulee-Raver #1 and #2 lines,
D. Raver-Snoqualmie 500 #2 line, and
E. Maple Valley 500/230 Tx #2 and Monroe-Snohomish 230 #3 line.

Series comp levels for this plan were selected for optimum loss savings. The Coulee-Raver level was optimized first, Chief Joe-Monroe next, then Naneum-Raver lines (together). Then the sensitivity of these levels were tested against each other and adjusted. The comp levels obtained from this method make the X/R ratios of the five 500-kV lines nearly equal. The loss saving of this plan is slightly better than the original plan as shown in Table 1.

With this plan, there are no series cap terminal overvoltages at operating points. The Chief Joe-Monroe compensation could be added at one site. This plan works through 2003 as shown in QV-Curve 3C.

NANEUM DEVELOPMENT

Large amounts of series compensation are needed in these plans to support the system for the loss of the double circuit Coulee-Raver line. However adding series compensation on the other cross mountain lines is not the most efficient; it is better to load the double circuit lines. One way to improve the system performance without adding excessive amounts of compensations is to develop a switchyard to tie the system together. This would reduce the severity of the double line outage significantly. The switchyard must be developed somewhere along the Coulee-Raver lines, preferably around the midpoint. There are 2 existing stations in this area at Naneum and Columbia. Naneum development would require tying both Coulee-Raver lines, the Vantage-Raver line and the Sickler-Raver line together. Columbia development would require tying both Coulee-Raver lines together near the existing Columbia site and adding a new tie line to Sickler (Rocky Ford on the Coulee-Hanford line is another possibility). This tie line addition would be about 20-25 miles long.

A comparison of the double line outages for these two plans in J97 is shown in QV-Curve 4. If a Naneum Switchyard is developed, the double Coulee-Naneum and double Naneum-Raver line outages are of similar severity and are much better than the existing system without the switchyard. If a Columbia switchyard is developed along with a Sickler-Columbia 500-kV line addition, the double Coulee-Columbia outage is also much better, but the double Columbia-Raver line outage is significantly worse than the Naneum-Raver outage if the Naneum switchyard is developed. However, both of these outages are better than the existing system. The Naneum switchyard performance is better than Columbia.

The loss saving of these two plans and the existing system are very similar. Naneum development should be less expensive to construct since there is no significant line construction. A Naneum Switchyard could also help the line crossing problems in that area.

Either Naneum or Columbia development should fit into the long range planning for the area since they could be the start of a crosstie, which would definitely provide a stronger system, especially if a new line is built in the Stevens Pass (northern) corridor. Also, with a new line addition and no switchyard development, the worst double line outage is still the loss of both Coulee-Raver circuits since they are series compensated. Adding a switchyard along these lines reduces the severity of this worst double line outage and would make the new line options perform much better.

Naneum appears to be the best plan to reduce the severity of the double line outage. If this switchyard is developed, the next problem to solve is the Chief Joe-Monroe outage during abnormal winter since Naneum does little to help that problem. If the problems associated with this line outage is solved, the system should also be acceptable for the Trojan scram. Adding series comp to the new Naneum-Raver line sections (the old Coulee-Raver circuits) would help for both of these outages.

Once a switchyard is added at Naneum, percent compensation levels become confusing. Percent compensation is defined as the terminal-to-terminal impedance of the line in question. For example, an additional 20% compensation on the Coulee-Raver lines is 19 ohms. If Naneum is developed and this same compensation is added on the new Naneum-Raver lines, the percent compensation is 44%. In an attempt for clarity, whenever percent compensation amounts could be confusing, the actual ohms of the bank will also be noted. The impedance of all 500-kV cross mountain lines is summarized in Table 2.

REACTIVE PLAN 3F

This plan consists of the Naneum Switchyard to solve the double line outage and series comp on the new Naneum-Raver lines (26 ohms, 60%) to solve the Chief Joe-Monroe outage and Trojan scram. QV-Curve 3F shows that this plan would perform acceptably through 2004. There is some loss savings due to this plan, however these series comp levels also have not been optimized.

REACTIVE PLAN 3G

The capacitor banks in Plan 3F would need to be extremely large (about 4600 amps to meet the 2004 load). The existing switchgear at Raver is limited to about 4200 amps in winter. Also losses are not optimal for 26 ohm banks.

With the addition of a Naneum switchyard to the existing system, the optimum compensation level for the new Naneum-Raver lines is an additional 20-25% of entire line length (44 to 56% of the Naneum-Raver section). Refer to Graph 5.

With a new cross mountain line added (Chief Joe-Snohomish 345 rebuild to 500-kV double circuit was assumed in this analysis) in addition to the Naneum switchyard, the optimal comp level for loss savings decreases to 15-20% of the entire line length (33 to 44% of the Naneum-Raver section). Refer to Graph 6. An additional 20% (44% of the new Naneum-Raver line section or 19 ohms) is assumed to be optimal for both the existing system and the future system with a new line added.

With 19 ohms compensation added in the double circuit line and a Naneum switchyard in place, the system performance is adequate beyond the year 2000 (refer to QV Curve 3Ga), and even further if a third shunt capacitor is added at Raver or one is added at Naneum. When additional reinforcement is needed, the size of these banks can be increased to 26 ohms (like Plan 3F) or additional comp can be added on the remaining two Naneum-Raver 500-kV lines.

These lines are limited thermally due to sections of 2 1/2 inch conductor. Compensating them too heavily is not efficient. It could also overload these lines and/or cause capacitor terminal overvoltages (this is discussed more later). A workable compensation plan would be to add 19 ohms series capacitors initially on the double circuit Naneum-Raver lines, followed by a 20 ohm (40%) bank on the Sickler-Raver line section and a 23 ohm (40%) bank on the Vantage-Raver line section. This would provide adequate reactive support through 2004 as shown in QV Curve-3G without overvoltages.

Staging the series capacitors has a few advantages. It delays the cost of some of the compensation. It also provides banks with an optimum compensation level that can minimize transmission losses. Depending on the load level, the losses may be lower on the system with the Sickler-Raver and Vantage-Raver capacitors bypassed. These banks could be reserved only for emergency situations by bypassing them during lower load level periods.

REACTIVE PLAN 3J

Because of the heavy loading the caps experience during certain outages and the potential overload problems, it would be beneficial to have adjustable series capacitor banks (Thyristor Controlled Series Capacitors - TCSC) to reduce the effective compensation of the new banks when necessary. This technology is unfortunately in the early stages of development and has not been proven in the field. However, discretely switched capacitor banks could be used to accomplish this objective. This plan was developed with 2-stage caps on the double circuit Naneum-Raver lines.

This plan would add 15 ohm capacitor banks initially in the Coulee-Raver lines at the new Naneum switchyard. In about 2000, an additional 11 ohm capacitor bank would be added in series with the other bank for a total of 26 ohms (60% in 2 switching steps). After Phase II, both banks would be used during EH winter. The comp level could be reduced in lower load periods if the system loss savings would be better. Some or all the capacitors could be bypassed during outages to reduce the loading of the banks as discussed later. The performance of this plan is shown in QV Curve 3Ja (Phase I) and QV Curve 3J (Phase II). QV Curve 3Jb shows the performance of the Phase II system with some caps bypassed.

Section 3: Analysis of favorable options

Of all the reactive plans listed above and in Table 9, only Plans 3F, 3G and 3J will be considered further. Plan 3 would be expensive and complicated. Plan 3C is attractive due to its loss savings and cost, however it requires at least two new stations. The addition of the Naneum switchyard fits better into the long range plans of the addition of a new cross mountain line since it reduces the severity of the loss of both Coulee-Raver lines (which is still the critical outage even after the addition of a new line).

The reactive options will be planned to meet the 2004 load level. Higher load levels would be difficult for the following reasons:

1. The Vantage-Naneum line is near its thermal capacity in 2004. Refer to case J04908 which shows this line, which will be rated at 3000 amps when upgrades are complete, loaded to 2903 amps. This line is limited by the existing 2 1/2 inch conductor (33 miles).

2. This plan is beginning to require excessive amounts of shunt reactive in the load area. The QV curves get much flatter as shunt capacitors are added. All three major 500-kV busses serving the Puget Sound area (Raver, Snoqualmie and Monroe) are all approaching minimum reactive margin.

3. Adding series comp to the Chief Joe-Monroe line will not help the voltage stabilty performance of the system since the loss of this line is a critical outage for the system.

4. The old Vantage-Raver and Sickler-Raver lines could be reconductored, however this is expected to be expensive as compared to the construction of a new line. These rebuilds would save losses but would only provide reactive support for a couple of years until further reinforcement is needed.

5. SVC additions in the Puget Sound Basin could provide adequate reactive support to the system for a few more years, but they would be expensive both in terms of equipment costs and the higher transmission system losses that would result. The line overloads mentioned in (1) above would also have to be corrected.

6. The ampacity of the series capacitor banks needed for these plans are quite high to meet the 2004 load level. Extending this plan beyond 2004 would significantly increase the MVARs that are required (the MVARs are proportional to current squared).

Therefore the series capacitor additions will be sized for 2004 only. Plans 3F, 3G and 3J will be studied further to determine the ampacities required for the series capacitors. Some of the outages required by the Reliability Criteria cause very high capacitor loading.

All the series capacitors in these plans are needed for the voltage stability of the Chief Joe-Monroe and Trojan outages in EH winter. The Naneum switchyard is needed for the voltage stability of the double line outages in normal winter. However, the heaviest series capacitor loading does not occur for the critical outages for voltage stability, but it occurs during the less probable double line outages in normal winter (same corridor, bus or CB). The series caps are not necessarily needed for the voltage stability of these outages.

Two options exist to reduce the series capacitor loadings during double line outages. One is to run the CT's in the load area and the other is to bypass the overloaded series capacitors as long as the system is still voltage stable without the capacitors.

Regardless of capacitor loadings, the CT's in the load area would probably be started during winter peakload conditions if any permanent Cross Mountain line outage occurred (they are only assumed on in EH winter basecases). This could reduce the size of the new series capacitor banks. The capacitor banks have a 30 minute overload capability of 135% that can be used while the CT's are started. These studies assume that the same CT's are used as is assumed in the EH winter cases. But as it turns out, the CT's only decrease the capacitor bank loadings by about 5% as shown in the cases discussed later.

Since the new series capacitors are not necessarily needed for the voltage stability for the low probability double line outages that cause high capacitor loading, they can be bypassed after these outages occur. This would reduce the maximum loading of the capacitor banks significantly.

The reason that these caps are not needed for the voltage stability of the system for these outages is as follows. The Plan 3F system is voltage stable for the outage of the two high-capacity Naneum-Raver #3 and #4 lines which removes both capacitor banks and leaves only the two old Naneum-Raver lines in service. The performance of the system will be better for the outage of the #1 and #3 lines (a critical outage for the sizing of the capacitors) even if the remaining capacitors are bypassed since this leaves one old Naneum-Raver line and one of the circuits from the stronger double-circuit lines. The same reasoning applies to outages of the Coulee-Naneum lines.

The ampacity of the capacitors required in each of these three plans is discussed below. As it turns out, bypassing capacitors is the only measure to significantly reduce the size of the series cap banks.

PLAN 3F
Naneum switchyard and 60% comp on double circuit Naneum-Raver lines

With only two large capacitor groups added, the current rating would need to be very high; 4620 amps at Naneum and 3286 at Columbia as shown in Table 15. This Naneum cap rating would cause switchgear overloads at Raver (the 3000 amp switchgear is capable of only about 4200 amps in cold weather). The Columbia caps are only designed for uprates to 3000 amps. Use of CT's alone will not reduce these loadings below these limits (4375 amps and 3110 amps respectively). Bypassing the caps whenever they overload (for two line, voltage stable outages) will reduce the loading to below the amperage needed for single line outage during EH winter. The worst single line outage will require ratings of 4120 amps for Naneum and upgrade of the Columbia caps to 2620 amps. The 2 line outage loadings would be within the 135%, 30 minute ratings of the series capacitors to allow time for manually bypassing the caps.

PLAN 3G
Naneum switchyard, 44% comp on double circuit Naneum-Raver lines, 40% comp on Sickler-Raver line and 40% on the Vantage-Raver lines.

This plan includes the addition of 19 ohm cap banks on the double-circuit Naneum Raver lines initially with the addition of the switchyard (Phase I). In about 2001, aditional banks will be needed on the Sickler-Raver and the Vantage-Raver lines, also at the Naneum Switchyard (Phase II). Since the 19 ohm banks are adequate to meet the voltage stability requirements of the system through 2001, these banks need only to be sized for the worst outage in this timeframe. The addition of the cap banks on the other two Naneum-Raver lines decreases the maximum loading that the double-circuit banks experience. A complete table of all outages run for this analysis is included in Table 16.

With this capacitor plan, the Phase I capacitor banks need to be about 3700 amps and the Columbia banks upgraded to 3060 amps (slightly above the 3000 amp design limit). Running CT's after these outages occur will only reduce these ratings to 3500 and 2900 amps respectively. Bypassing overloaded series capacitors for voltage stable, low probability two-line outages will reduce these ratings to 3120 and 2700 amps respectively. The Phase II capacitor additions would need to be 3000 amps for the Sickler-Raver line and 2600 amps for the Vantage-Raver line for the parallel double-circuit line outage. With the Phase II additions, the Phase I Naneum bank loadings will still be within its 3120 amps limit (only 2700 amps is needed in 2004).

It should also be noted that the Phase II caps are also not needed for the loss of the parallel double circuit lines (Plan 3F is voltage stable for this outage without them). These capacitor bank sizes could be reduced to 2200 and 2000 amps respectively for the Sickler-Raver and Vantage-Raver banks by bypassing them for this outage. These ratings are determined by the loss of one of the double circuit Naneum-Raver lines during EH winter.

PLAN 3J

Naneum switchyard and 60% comp on double circuit Naneum-Raver lines in two steps, 35% and 25%.

Plan 3J utilizes two-step series capacitors that can be bypassed partially or completely during non-critical double line outages and during light load periods. A complete table of all outages run for this analysis is included in Table 17.

Phase I of this capacitor plan includes 15 ohm capacitors in the double circuit Naneum-Raver lines. These caps would be adequate until 2000 as shown in QV Curve 3Ja. Bypassing overloaded Naneum series capacitors for voltage stable, low probability two-line outages will require ratings of less than the 3120 amps needed for Plan 3G (15 ohms is used here instead of 19 ohms). For Phase II, an additional 11 ohms series comp is needed on the same Naneum-Raver lines, for a total of 26 ohms. This 11 ohm bank will need to be bypassed to keep the bank from loading beyond 3100 amp during the EH outage of a single Naneum-Raver line. At least 15 ohms is needed for voltage stability of this outage as shown in QV Curve 3Jb. The Columbia series capacitors in Phase II need to be rated for 2700 amps, which also assumes that these capacitors will be bypassed for the low probability, two-line outages in normal winter.

COMPARISON OF 3 OPTIONS

Very rough cost estimates of each of these plans were included in Table 18. These estimates assume that all facilities are installed at the same time. Plan 3J is the least expensive, followed closely by Plan 3G. The capacitors for Plan 3F would be 1324 MVARs each. Capacitors of this size, besides being expensive, have never been built. Smaller banks sizes would be much easier to design and construct.

Plan 3G requires that capacitors be bypassed for double line outages during normal winter. Plan 3J is further complicated by the factor that the caps may need to be bypassed for some outages during EH winter load conditions. This could be very confusing to the operators.

Plan 3J requires the Phase II capacitor additions one year earlier than Plan 3G. Plan 3G could be modified into a plan similar to 3J in the future by adding parallel capacitor cans to upgrade the Phase I capacitors to about 3300 amps and 18 ohms and adding an 8 ohm bank in series. Plan 3G also has a benefit to reliability of spreading the compensation among more lines.

Plans 3G is the favored Reactive Option. It fits in well with the long range plans for the area. The compensation is optimally sized for the existing system and the system with the addition of a new cross mountain transmission line. The additions are confined to one new substation. It provides the most flexibility for the Phase II capacitor additions.

Provisions should be added to upgrade all these capacitors to 4200 amps (CB limitations) to allow for possible upgrading if lines are reconductored. Before the comp levels for Phase II of these plans are finalized, reconductoring options on the Sickler-Raver and Vantage-Raver lines should be explored. This should not affect the comp level on the Coulee-Raver lines significantly. Also, as discussed later, FACTS technology should be considered for the Phase II banks.

Section 4: Local Reinforcement

LOCAL REINFORCEMENT NEEDS FOR THE REACTIVE OPTION

All reactive plans would have similar local reinforcememt requirements. Plan 3F was used for study purposes in this section.

MAIN GRID TRANSFORMER NEEDS OF PUGET SOUND BASIN

Case J00EH55 shows the Monroe transformer just below the emergency rating for a Maple Valley 500/230-kV transformer outage (1506 MVA, 1512 mva limit). The Covington and Tacoma banks are also heavily loaded for this outage. Case J04EH508 shows Monroe transformer loaded 8% above emergency rating for this same outage. Additional transformation will be needed by October, 2000. The Covington-Creston 230-kV line is close to overload in these cases also. Previous studies showed another load area problem where the Monroe-Snohomish 230 kV lines overloaded for the double loss of the Chief Joe-Snohomish 345-kV lines. Therefore a new 500/230-kV transformer at Snoking is proposed to take care of these problems. This transformer addition would be accomplished by converting the existing Snoking Tap-Snoking line to 500-kV operation, tapping the existing Monroe-Snoqualmie 500-kV line. A second Maple Valley 500/230 transformer and Monroe-Snohomish 230 line #3 would also solve these problems.

THERMAL PROBLEMS BETWEEN RAVER AND SNOQUALMIE

Case J04EH515 shows the loss of the Raver-Snoqualmie line during abnormal winter. The Covington-Creston 230-KV line overloads (107%) along with the Covington (100% and 102%) and Tacoma (101%) 500/230-kV transformers. This same outage in J00EH71 shows the loading on the Covington-Creston line at 97% of its thermal rating. This line would overload in about 2002. As mentioned in the next section, there are reactive problems for this outage also.

The overloads shown in case J04EH515 are caused by the amount of power flowing into Raver. This could be decreased by bypassing the series capacitors at the new Naneum switching station whenever this outage occurs. Case J04EH774 shows that the overloads can be deferred until 2004 if this is done. Although bypassing the caps will defer the overloads, it would also jeopardize the cross mountain transmission into the Puget Sound Basin while the caps are bypassed.

Adding series compensation in the Chief Joe-Monroe line would also help the thermal overload problems, reduce system losses and not weaken the cross mountain transmission system (as bypassing the capacitors would).

If a second Raver-Snoqualmie line is added to correct this problem, the Reliability Criteria then requires that the system withstand the loss of both Raver-Snoqualmie circuits during normal winter peak conditions. J04760 shows the outage of both Raver-Snoqualmie 500kV lines. The Covington-Creston 230-kV line overloads (103%) for this outage. The Covington-Duwamish 230-kV line and the Tacoma and Covington transformers are heavily loaded for this outage also. An additional line will need to be added about 2003, just one year later. This Reliability Criteria requirement should be reviewed for this case since these lines are so short and the probability of this outage is low. The series capacitors at Naneum could be bypassed whenever this double line outage occurred. Also, if a new cross mountain line is terminated at Snoqualmie or Monroe, the need for additional transmission between Raver and Snoqualmie for winter conditions would be reduced.

REACTIVE ANALYSIS OF THE PUGET SOUND BASIN

Comparing QV Curves 3F and 11, the Raver-Snoqualmie #2 and Maple Valley transformer #2 provide about 300 MVARs reactive support for the Chief Joe-Monroe outage. This is probably equivalent to about one year load growth.

Both Monroe and Snoqualmie have adequate reactive margin for loss of Raver-Snoqualmie in normal winter. QV Curve 12 shows 600-700 MVAR margin for both busses for this outage.

However, QV Curve-13 shows that there is a slight reactive deficit in 2004 for the loss of this line in addition to the overloads shown above. Reinforcement is also needed in this area by about 2002 to provide sufficient reactive margin for this outage. A second Raver-Snoqualmie line would obviously help this problem, but, as mentioned above, a third line between these stations would be needed soon after that to meet the Reliability Criteria for the double line outage during normal winter peak load periods.

Other options could also correct the system problems for the Raver-Snoqualmie outage. Series comp in the Chief Joe-Monroe line would correct both the thermal and the reactive problems caused by this outage by increasing the flow in the northern corridor. Additional MSC's in the Monroe/Snoqualmie area would help the reactive deficit, but not the thermal problems. Any conservation and/or local generation added north of Snoqualmie would help both the reactive and thermal problems caused by the Raver-Snoqualmie outage.

Some reinforcement is needed in 2002 to correct both the thermal problems and provide reactive margins for the Raver-Snoqualmie outage. A Raver-Snoqualmie 500-kV line #2 is proposed here but this problem will require further study at a later date.

The FY92 reactive study assumed that the PCB capacitor group at Raver would be retired when the second Monroe capacitor bank was added in 1994. QV Curve 3Ga and QV Curve 3G show that a third Raver shunt cap group is again needed between

2001 and 2004. The actual date of the cap bank is tied to the addition of Phase II caps and will need to be studied further. Naneum and Snoqualmie are also possible sites for this MSC.

Section 5: Other Items of Interest

QV PERFORMANCE OF PORTLAND BUSSES FOR TROJAN SCRAM

The QV performance of the critical busses in the Portland area for the Trojan scram is shown in QV Curve 10 for reactive Plan 3F. A 312 MVAR MSC was added at Marion for these outages. The three busses tested all have at least 500 MVAR margin.

NANEUM SPLIT BUS

Development at Naneum could either be a full bus tying the 4 lines together or a split bus where one Coulee-Raver line is tied to the Sickler-Raver line and the other tied to the Vantage-Raver line. Earlier loss saving studies show that the losses of both plans are nearly identical. Case J93787 which had a split Naneum bus had essentially the same losses as J93799 which had the full Naneum bus. The QV performance is also very similar as shown in a comparison on QV-Curve 3F-Split and QV-Curve 3F (full bus). The split bus would be cheaper and it was originally thought that this arrangement would be better for conditions of summer export to California. However as shown in the analysis of this problem (below), the split bus makes some outages better, but others get worse. The summer problems with either switchyard development plan were not as bad as originally thought also. Therefore it was decided not to pursue the split bus further since the full bus provided much additional operational flexibility.

The earlier Naneum studies that assumed only the split bus should still be adequate for comparison purposes.

SUMMER STUDIES WITH NANEUM SWITCHYARD

The effect of the new Naneum Switchyard (both full and split bus) on high-export summer conditions on problems in the Vantage-Richland area was investigated. These results are summarized in Table 14. The addition of the new switchyard does not affect this area significantly.

STATION LOCATION

Although all the studies in this report assume that the location of the new switchyard in the reactive plans is at Naneum, that site is not adequate for much development due to its slope. The voltage stability performance of other sites west of the existing site were investigated. As the site moves west, the loss of both Coulee-Naneum lines becomes worse (the lines become longer) while the double Naneum-Raver outage becomes better. However, the double Naneum-Raver outage is most critical if the switchyard is at Naneum. The Coulee-Naneum line outage would not become the critical case unless the site were located more than 10 miles west of the existing Naneum site. This is shown in QV Curve 7. However, due to the terrain, no sites more than 10 miles west of Naneum were investigated.

The losses also increase as the site moves west. This is because it is beneficial to shift the power off the old Vantage-Raver and Sickler-Raver lines and onto the Coulee-Raver lines as soon as possible. Graph 8 shows the loss changes at several locations west of Naneum. The 2 best locations from a siting standpoint are 2 miles and 8 miles west. The difference in losses between these two points is about 2 MW. These studies assumed new 26 ohm cap banks on the Coulee-Raver lines. They also included a new large generator at Ashe (1200 MW) which would tend to inflate these loss savings somewhat.

OVERVOLTAGES ON CAPS ON OLD NANEUM-RAVER LINES

When adding series compensation on the old Naneum-Raver lines an interesting phenomenum was noted. If the comp level was above 40%, the voltages on the west capacitor terminal would rise during the parallel double circuit outage, even as the system voltage dropped while the QV-curve was defined. The higher the comp level, the higher the overvoltages (in the 560-kV range). The voltage at these terminals would not start to drop until the reactive limits were reached at Coulee, which usually signifies the total collapse of the transmission system. This phenomenum is probably due to the low impedance of this point with respect to its source and the phase angle of the power that is going through the series capacitors. The final comp level on these lines is slightly lower than these problem levels so it is not anticipated that this phenomenum will cause any problems.

MOVING SERIES CAPS TO RAVER

Case J04787QV was run to show the affect of moving the new series caps on the old Naneum-Raver lines to the Raver end of those lines. Very high overvoltages resulted on the capacitor terminals at Raver (around 600-kV) for the double circuit Naneum-Raver line outage. The cause of these high voltages is apparently the reactive current from the shunt capacitors at Raver flowing into the remaining Naneum-Raver lines through the series compensation. Raver is not a viable location for the series capacitors because of the shunt compensation there.

FACTS TECHNOLOGY

Phase II series capacitor additions would probably be good candidates for FACTS (Flexible AC Transmission System) technology. Since these are lossy lines, it would be desirable to bypass all or most of these capacitors normally for loss savings. The optimum amount of compensation would increase as loads grow. Although some compensation is needed for various outages, overvoltages and high currents somewhat limit the total ohms that can be put into service. By the time these banks are needed (around 2000), FACTS technology may be mature enough for possible implementation.

Section 6: Recommended Plan

Plan 3G is the preferred reactive option. It has favorable loss savings, cost and flexibility. The plan consists of:

PHASE I

1) Naneum switchyard

2) 19 ohm, 3150 amp series cap banks on both Coulee-Raver lines west of Naneum

PHASE II (around 2001)

3) 20 ohm, 2200 amp series cap bank on Sickler-Raver line west of Naneum

4) 23 ohm, 2000 amp series cap bank on Vantage-Raver line west of Naneum

5) upgrade Columbia series caps to 2700 amps (reduces ohms from 21 to 19)

6) third 500-kV shunt capacitor group in the vicinity of Raver

Local Reinforcement requirements

7) Snoking 500/230-kV transformer (2001)

8) Raver-Snoqualmie 500-kV #2 line or Chief Joe-Monroe series comp (2002)

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TABLE 1: LOSS SAVINGS AND PERFORMANCE OF REACTIVE OPTIONS

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	DESCRIPTION	BPA LOSSES	PNW LOSSES	CASE #	REACTIVE MARGINS 2-L/1-L/TROJAN INCL UNUSED MSC
	BASE	755	1148	J04706	
	RAVER-SNOQ #2, MV TX #2	745	1135	J04705	
PLAN 1	CJ-MON/SNOQ - STEVENS PASS	669	1040	J04662	1100/900/900
PLAN 3	REACTIVE - FIXED PLUS SWITCHED SERIES CAPS AND SVC'S 25+25%(CJ-M),35+35%(N-R),20%(C-R)	736	1117	J04660	900/1100/1400
PLAN 3A	REACTIVE - FIXED PLUS SWITCHED SERIES CAPS 25+25%(CJ-M),35+35%(N-R),20%(C-R)	736	1117	J04660	500/500/700
PLAN 3B	SERIES CAPS PLUS SVC	736	1117	J04660	700/900/1100
PLAN 3C	SERIES CAPS 35%(CJ-M),60%(N-R),20%(C-R)	734	1112	J04714	300/600/700
PLAN 3D	NANEUM SERIES PLUS CAPS 35%(CJ-M),60%(C-R)	737	1117	J04723	700/400/700
PLAN 3E	NANEUM SERIES PLUS CAPS 35%(CJ-M),60%(C-R),NANEUM MSC	737	1117	J04723	700+/700/900
PLAN 3F	NANEUM PLUS SERIES CAPS 60%(C-R)	741	1124	J04767	500/450/500
PLANS 3C&1	REACTIVE AND CJ-MON/SNOQ	666	1031		
PLAN 3G	NANEUM PLUS SERIES CAPS 44%(C-R),40%(S-R), 40%(V-R)	737	1121	J04905	700/400/550
PLAN 3Ga	NANEUM PLUS SERIES CAPS 44%(C-R) - Phase 1 only	739	1125	J04910	
PLAN 3H	NANEUM PLUS SERIES CAPS 44%(C-R),30%(S-R), 39%(V-R)	739	1123	J04829	650/350/450
PLAN 3J	NANEUM PLUS SERIES CAPS 35%+25%(C-R)	741	1128	J04960 (15 ohms)	500+/400/500+
PLAN 3K	NANEUM PLUS SERIES CAPS 44%+16%(C-R)	739	1125	J04910 (19 ohms)	500+/450/500+

NOTE:
The addition of the Raver-Snoqualmie #2 and the Maple Valley transformer #2 account for about half the loss savings of the reactive plans.

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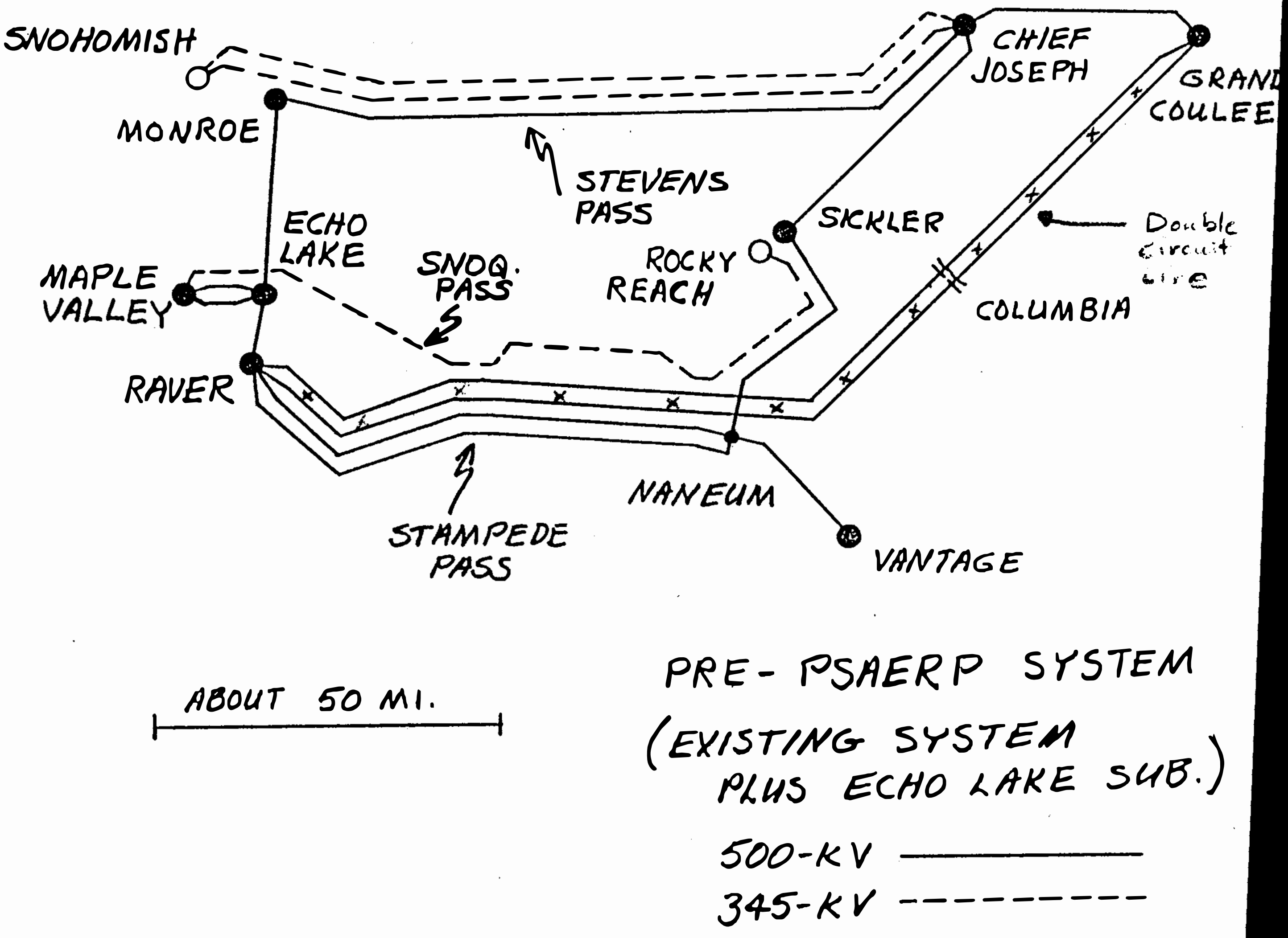
TABLE 2: IMPEDANCES OF 500-KV CROSS MOUNTAIN TRANSMISSION

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

Line	ohms impedance		
Coulee-Naneum-Raver	51.64 + 43.04 = 94.68 ohms		
Columbia series caps	originally	30%	28.4 ohms
	with upgrade	22.5%	21 ohms
Sickler-Naneum-Raver*	21.93 + 51.38 = 73.31 ohms		
Vantage-Naneum-Raver*	24.39 + 59.55 = 83.94 ohms		
Chief Joe-Monroe	72.14 ohms		

* If these lines are compensated in any of the plans, the percentage comp is based on the Naneum-Raver sections only



PRE- PSAERP SYSTEM
(EXISTING SYSTEM PLUS ECHO LAKE SUB.)

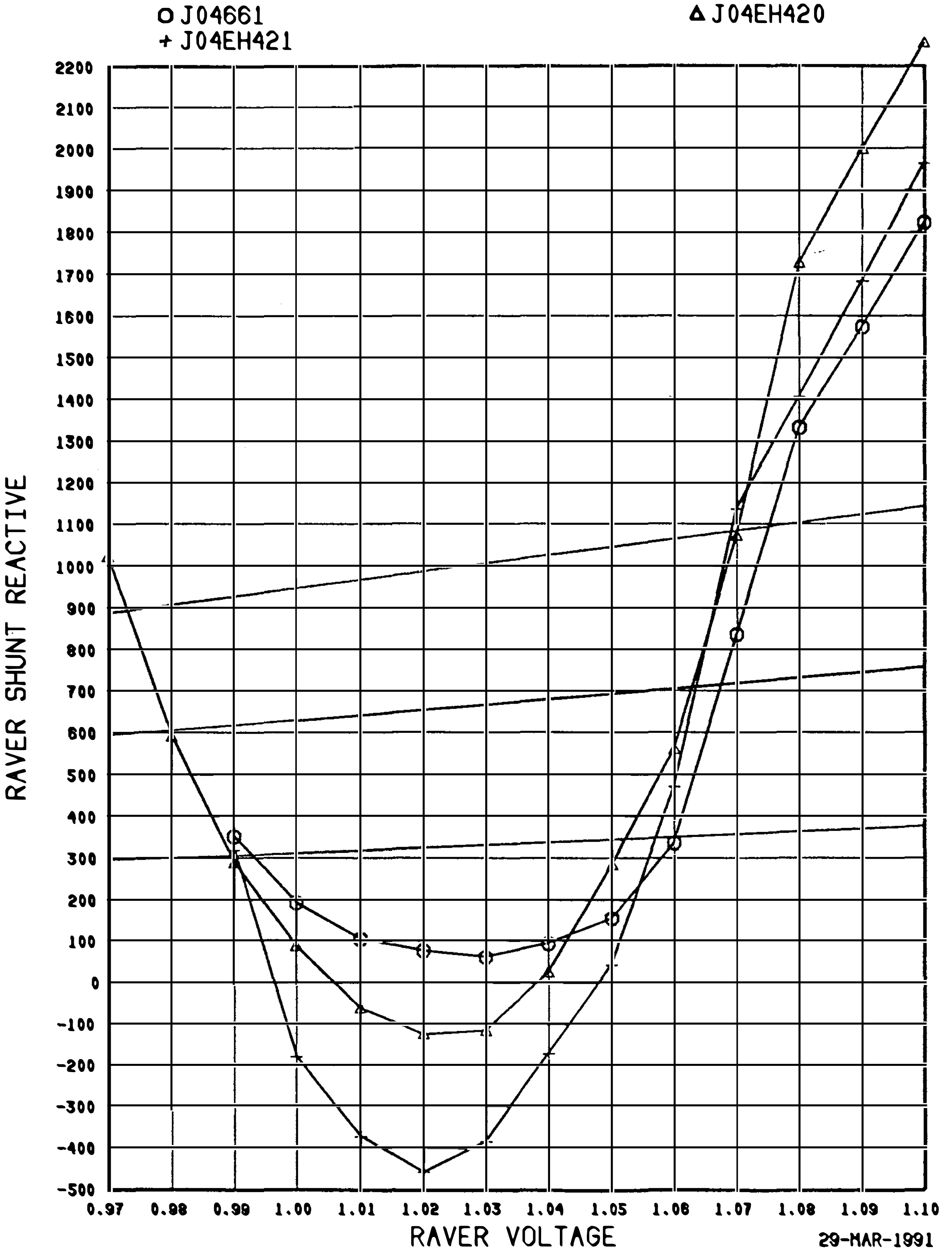
QV-Curve - 3

SVC's @ K, MV, Snoh, Cov, Ostr.
Switched series caps

PLAN 3

J04661:DOUBLE COULEE-RAVER 500 OUT (J04660) MSC AT SNOQ (1)
J04EH420:CHIEF JO-MONROE 500 OUT (J04EH418) NO MSC ADDED
J04EH421:TROJAN SCRAM(J04EH419) NO MSC ADDED

MSC avail.
Rav(1), Mon(1), Oly(1)
Oly(1)
Oly(1)



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J04661QV.SETUP

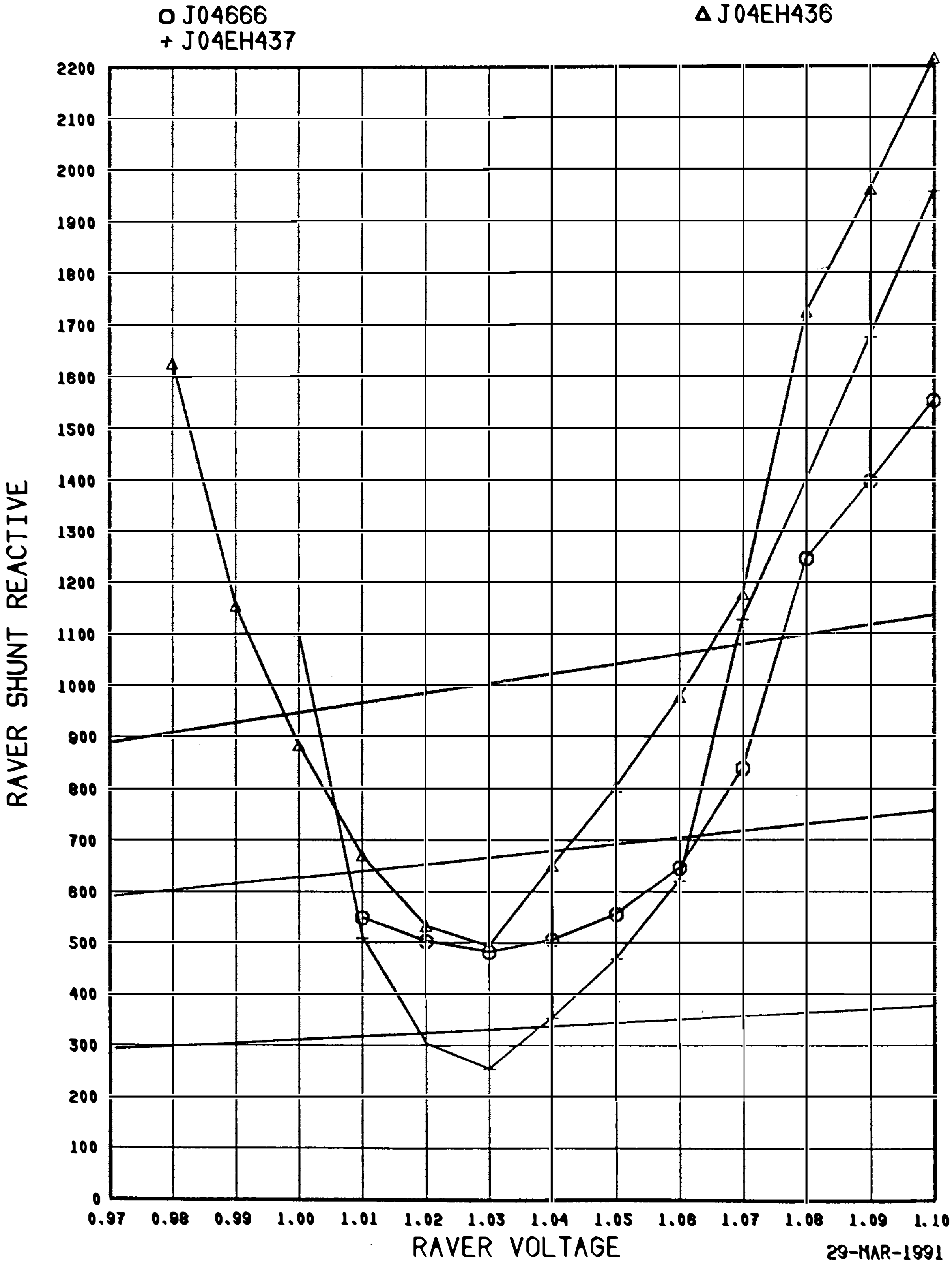
QU Curve-3A

SVC's @ Keeler & MV
switched series caps

MSC avail

PLAN 3A

○J04666:DOUBLE COULEE-RAVER 500 OUT (J04660)
MSC AT SNOQ (1), MSC AT MON (1) Rav(1), Oly(1)
△J04EH436:CHIEF JO-MONROE 500 OUT (J04EH418) none.
MSC AT OLYMPIA (1)
+J04EH437:TROJAN SCRAM(J04EH419)MSC AT MARION(1) Oly(1)



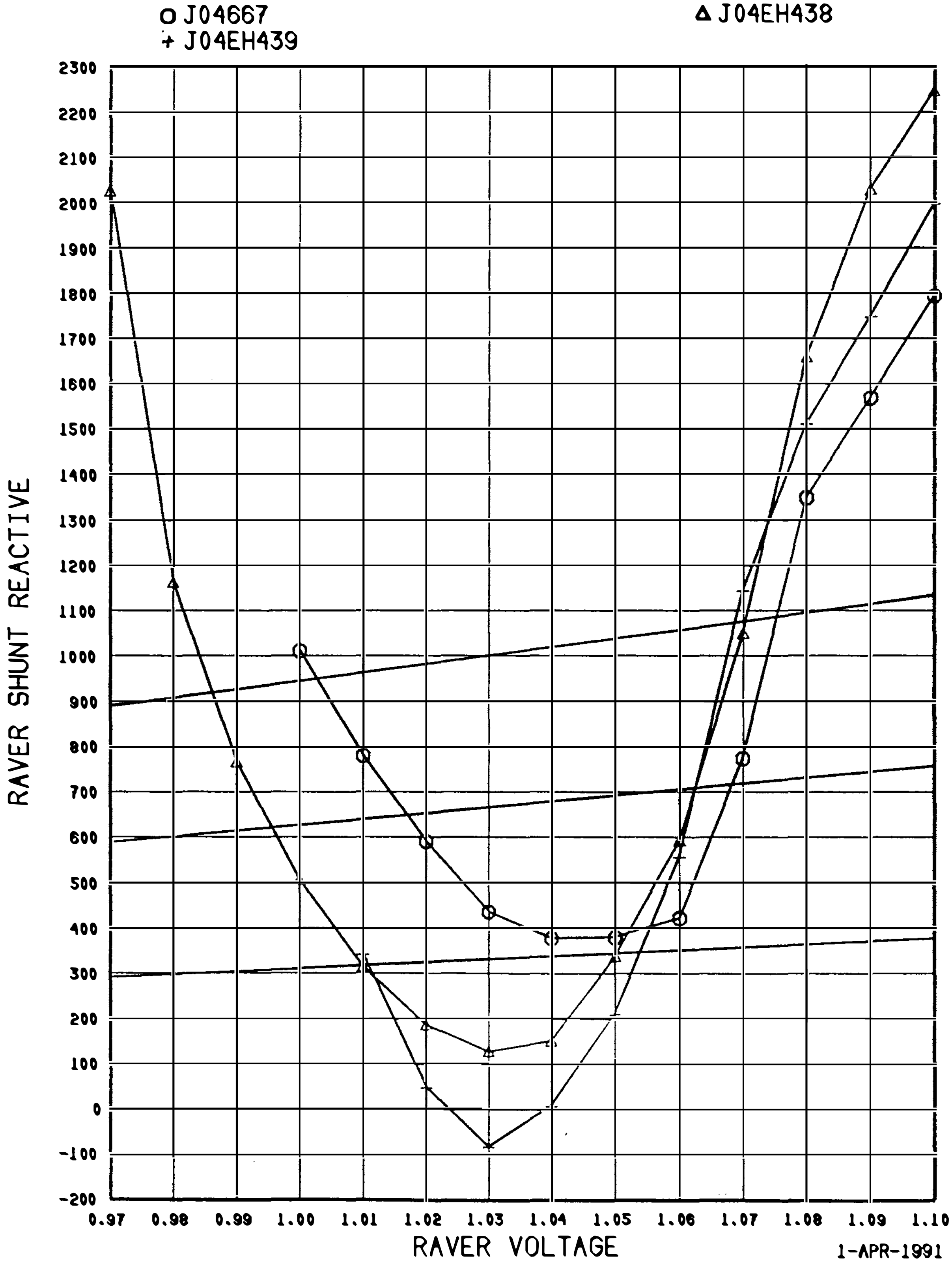
29-MAR-1991
J04EH436QV.SETUP

QV Curve - 3B

SVC @ K, MV, Snoh, Cov
No switched series caps.
MSC avail.

PLAN 3B

J04667:DOUBLE COULEE-RAVER 500 OUT (J04660) Rav(1) Oly(1)
MSC AT SNOQ (1), MONROE (1)
J04EH438:CHIEF JO-MONROE 500 OUT (J04EH418) Oly(1)
NO MSC ADDED
J04EH439:TROJAN SCRAM(J04EH419)MSC AT MARION (1) Oly(1)



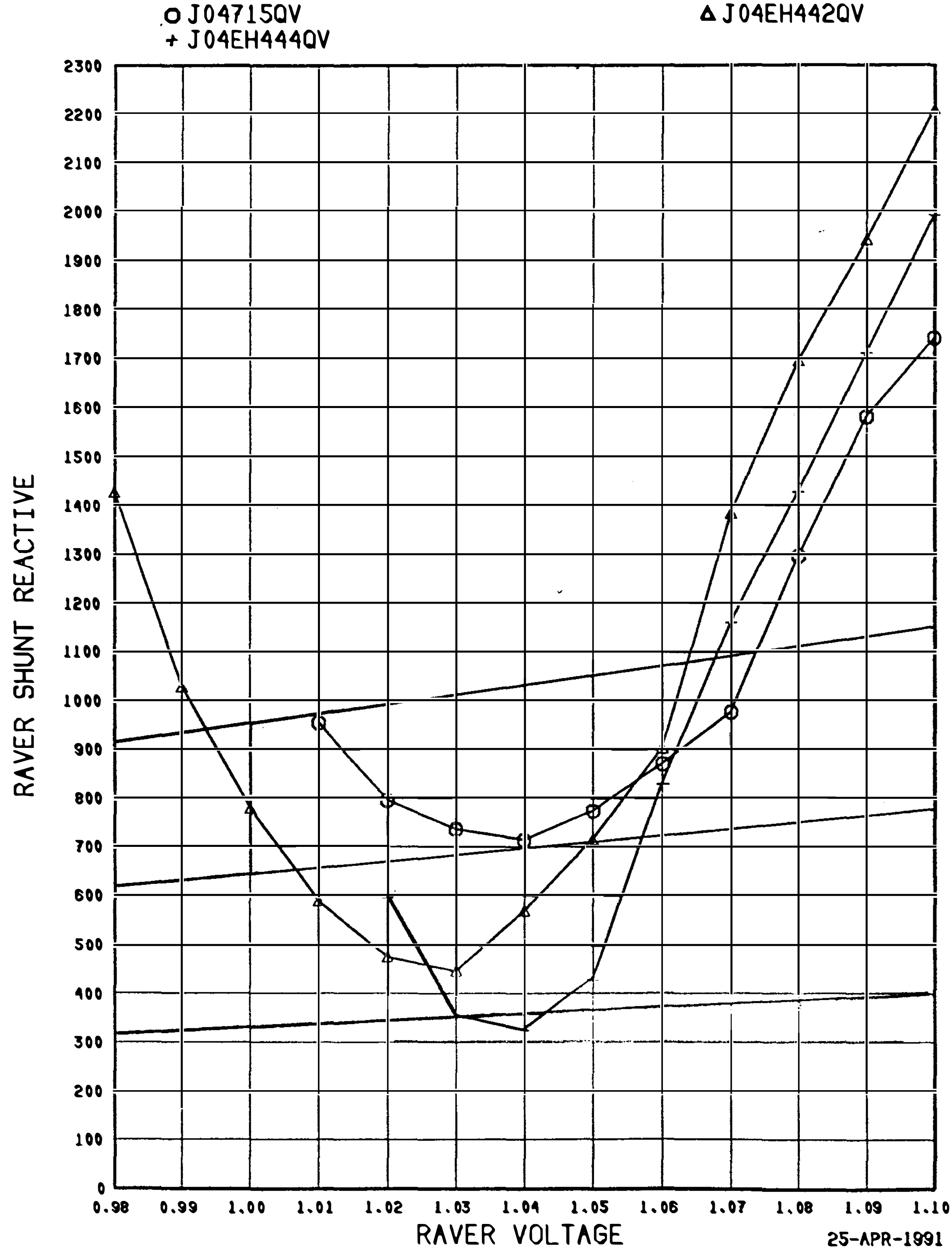
1-APR-1991
J04667QV.SETUP

QV Curve-3C

ALL SERIES REACTIVE PLAN - FIXED

Plan 3C

50% C-R COMP, 35% CJ-M COMP, 60% N-R COMP
○J04715: DOUBLE COULEE-RAVER OUTAGE, MSC
AT SNOQ(1),MON(1),OLY; (J04714)
△J04EH442: CJ-MONROE OUT (J04EH440) NO MSC
+J04EH444:TROJAN SCRAM (J04EH441) NO MSC



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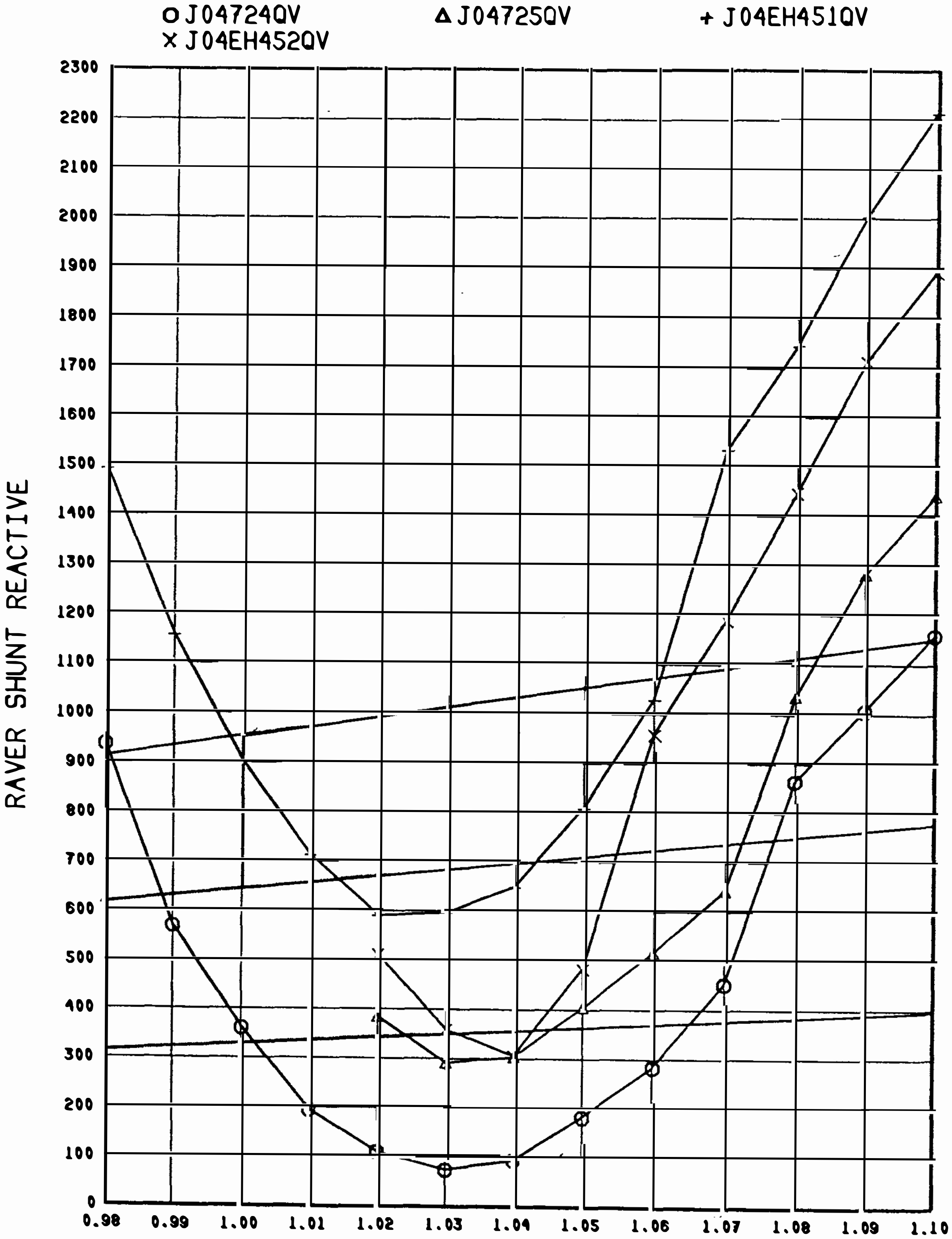
PLAN3SER.SETUP

QV Curve - 3D

Plan 3D

FIXED SERIES REACTIVE PLAN WITH NANEUM SWITCHYARD

50% C-R COMP, 35% CJ-M COMP, SPLIT NANEUM BUSSES
J04724: 2 COUL-NAN OUT, MSC @SNOQ,MON,OLY(J04723)
J04725: 2 NAN-RAV OUT, MSC @SNOQ,MON,OLY(J04723)
J04EH451: CJ-MONROE OUT (J04EH449) MSC @ OLY
J04EH452:TROJAN SCRAM (J04EH450) MSC @ OLY



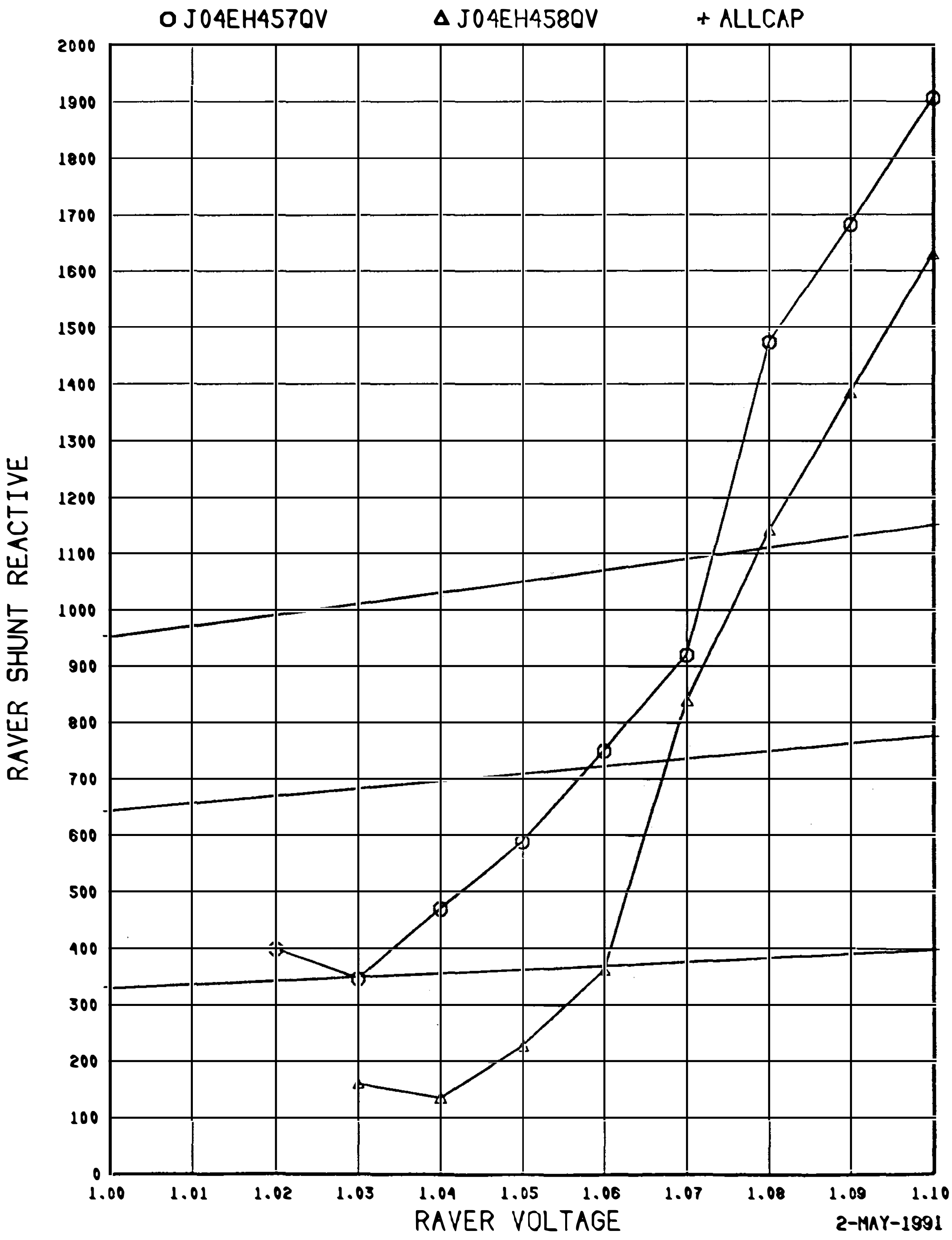
8-MAY-1991
PLAN3D.SETUP

QV Curve -3E

PLAN 3E

FIXED SERIES REACTIVE PLAN WITH NANEUM SWYD & CAPS

50% C-R COMP, 35% CJ-M COMP, SPLIT NANEUM BUSSES
200 MVAR ON EACH NANEUM BUS
○ J04EH457: CJ-MONROE OUT (J04EH447) MSC @ OLY
△ J04EH458: TROJAN SCRAM (J04EH448) MSC @ OLY



2-MAY-1991

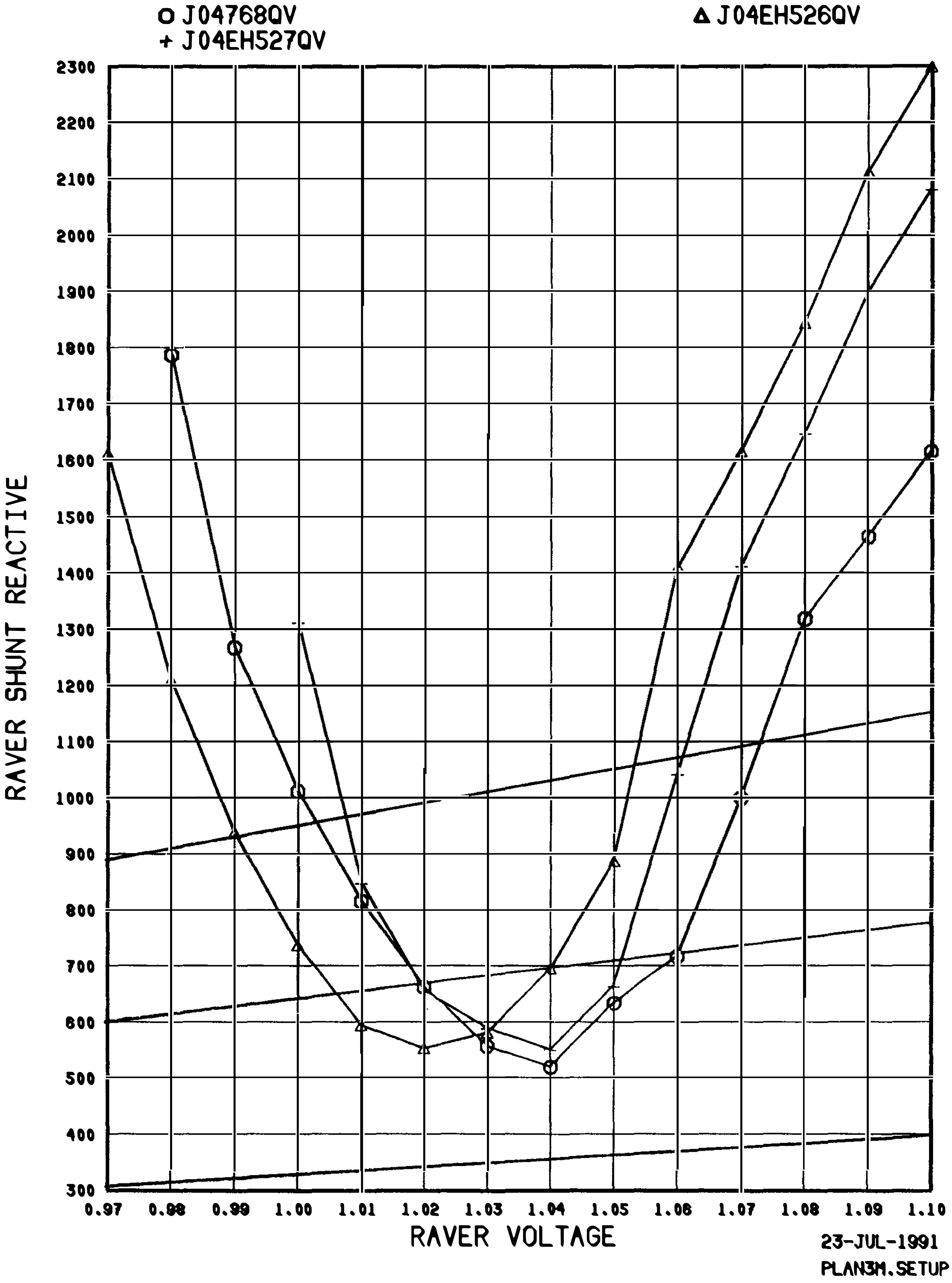
PLAN3NANEUMCAPS.SETUP

QV Curve 3F

PLAN 3F VOLTAGE SUPPORT 2

ADDITIONAL 27.5% SERIES COMP ON COULEE-RAVER LINES AT NEW NANEUM SWITCHYARD - ALL MSC USED

J04768:NAN-RAV OUT, MSC @ SNQ,MON,OLY,RAV (J04767)
J04EH526:CJ-MONROE OUT, MSC @ OLY,RAV (J04EH524)
J04EH527:TROJAN SCRAM, MSC @ OLY,MARION (J04EH525)

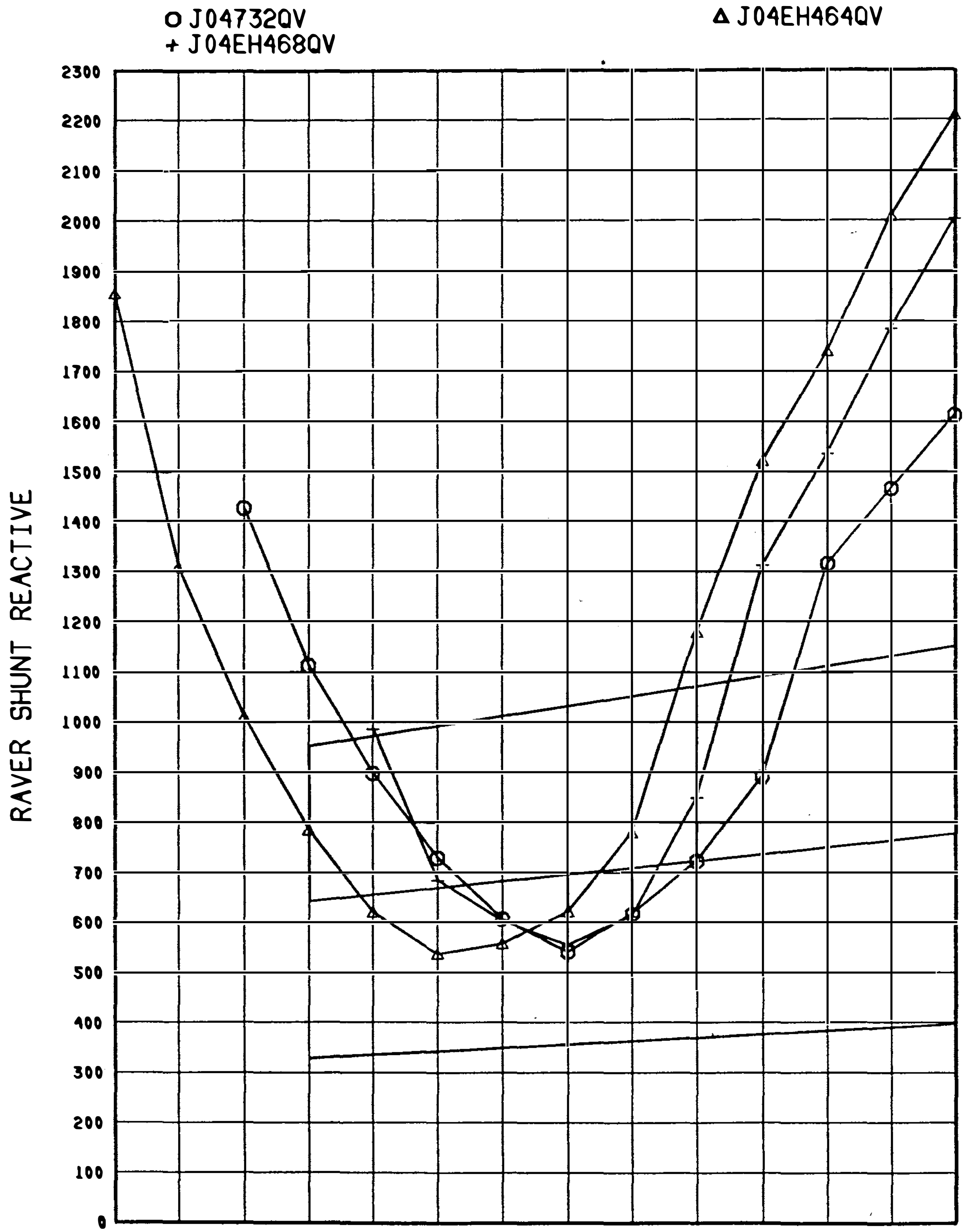


23-JUL-1991
PLAN3M.SETUP

QU Curve -3F - Split PLAN 3F - Split

FIXED SERIES REACTIVE PLAN WITH NANEUM SWITCHYARD

50% C-R COMP, SPLIT NANEUM BUSSES
J04732: 2 NAN-RAV OUT, MSC @SNOQ,MON,OLY(J04731) MSC RAV
J04EH464: CJ-MONROE OUT, MSC @OLY(J04EH462) MSC RAV
J04EH468:TROJAN SCRAM MSC @OLY & MARION (J04EH463)

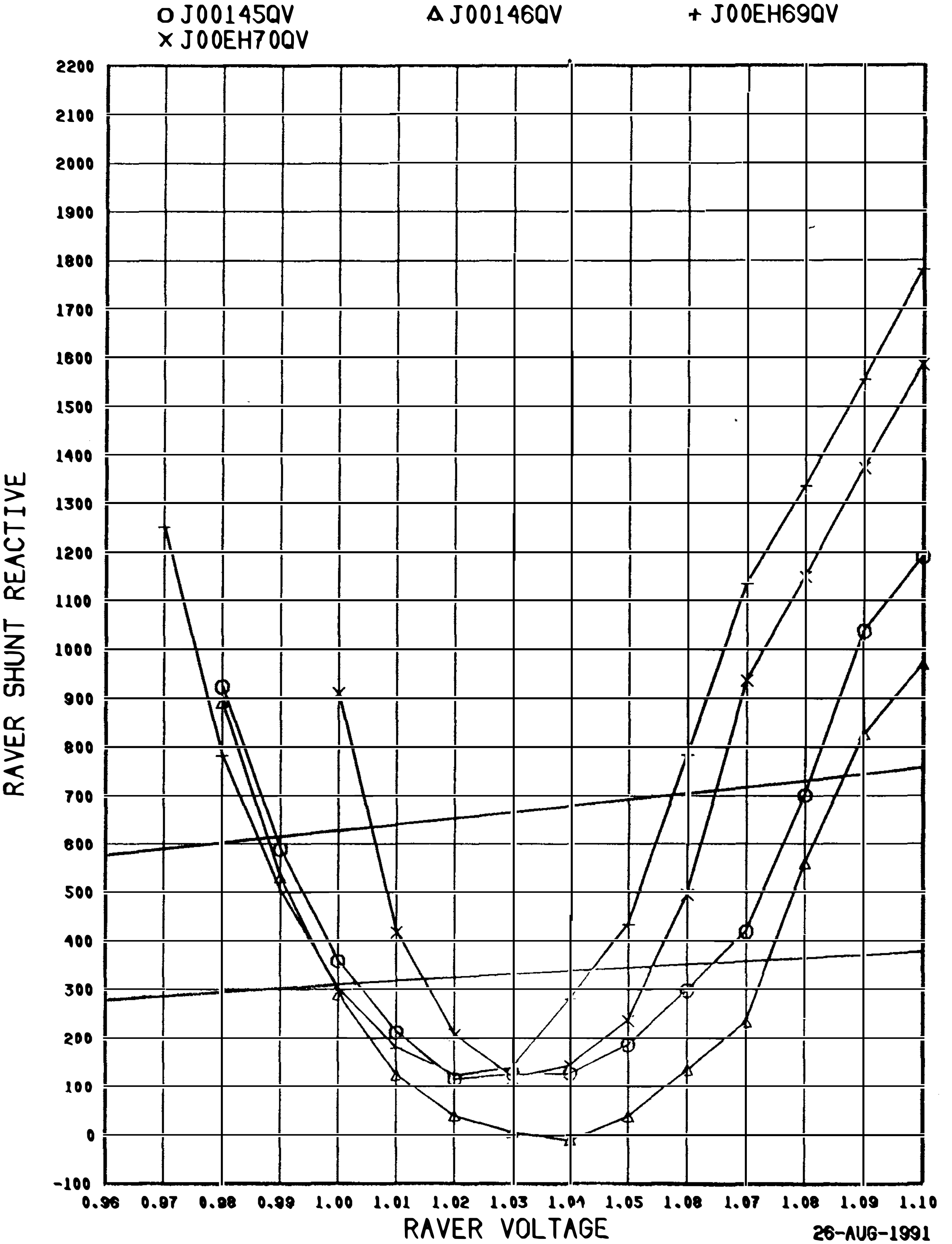


8-MAY-1991
PLAN3NANEUM.SETUP

QV Curve 3Ga

REACTIVE PLAN 3.2:NANEUM SWYD.42% COMP ON COUL-RAV

oJ00145:NAN-RAV 3&4 OUT. MSC @SNOQ. MON(J00144) }
▲J00146:GC-NAN 1&2 OUT. MSC @SNOQ. MON(J00144) } OLY Avail.
+J00EH69:CJ-MON. MSC @MON. OLY(J00EH67)
J00EH70:TROJAN SCRAM. MSC @ OLY (J00EH68)



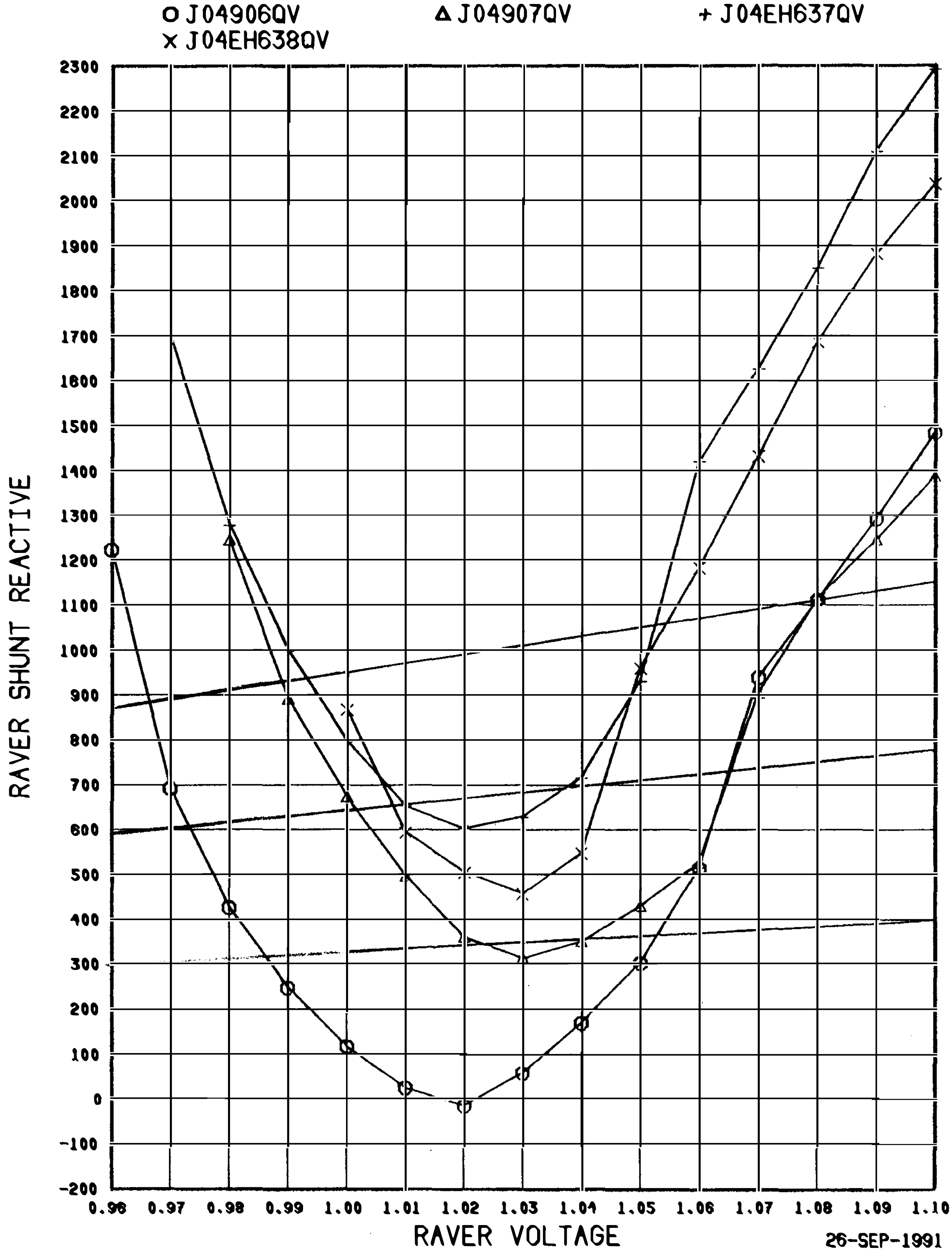
26-AUG-1991
J00145QV.SETUP

QV Curve 3G

PLAN 3: NANEUM SWYD, SERIES COMP ALL NAN-RAV LINES

42% ON COULEE-RAVER, 40% ON OLD NANEUM-RAVER LINES
oJ04906:NAN-RAV 3&4 OUT,MSC @OL,SNQ,MON,RAV(J04905)
ΔJ04907:GC-NAN 1&2 OUT,MSC @OL,SNQ,MON,RAV(J04905)
+J04EH637:CJ-MON, MSC @ OLY (J04EH635)
J04EH638:TROJAN SCRAM, MSC @ OLY,MARION (J04EH636)

ALL MSC's USED



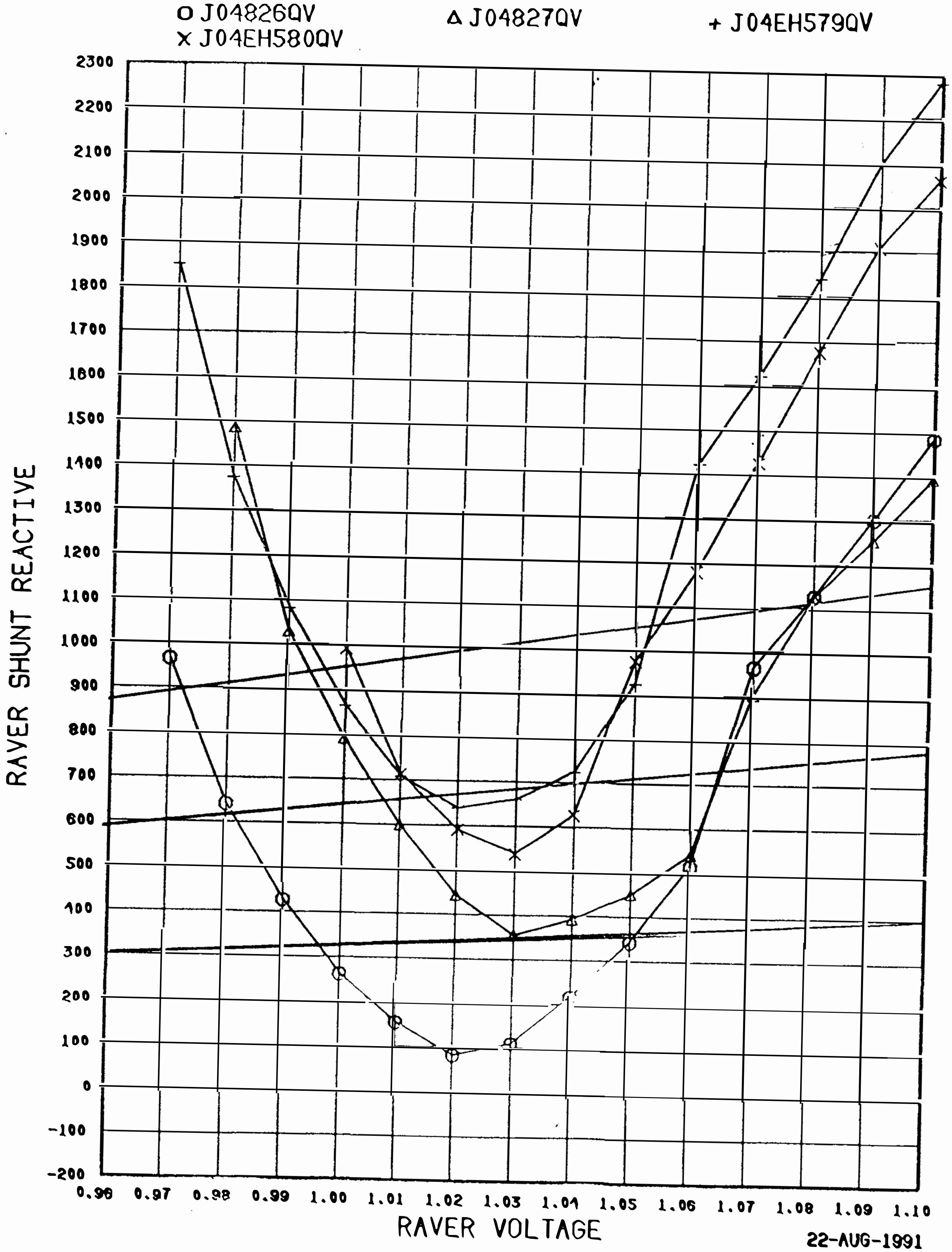
26-SEP-1991
J04PLAN3-3.SETUP

QV Curve 3H

ALL MSC's USED

PLAN 3H:NANEUM SWYD

20% ON COULE-RAV,30% ON SICK-RAV, 39% ON VANT-RAV
○ J04826:NAN-RAV 3&4 OUT,MSC @OL,SNQ,MON,RAV(J04825)
△ J04827:GC-NAN 1&2 OUT,MSC @OL,SNQ,MON,RAV(J04825)
+ J04EH579:CJ-MON, MSC @ OLY (J04EH577) MSC RAV
× J04EH580:TROJAN SCRAM, MSC @ OLY,MARION (J04EH578) MSC RAV

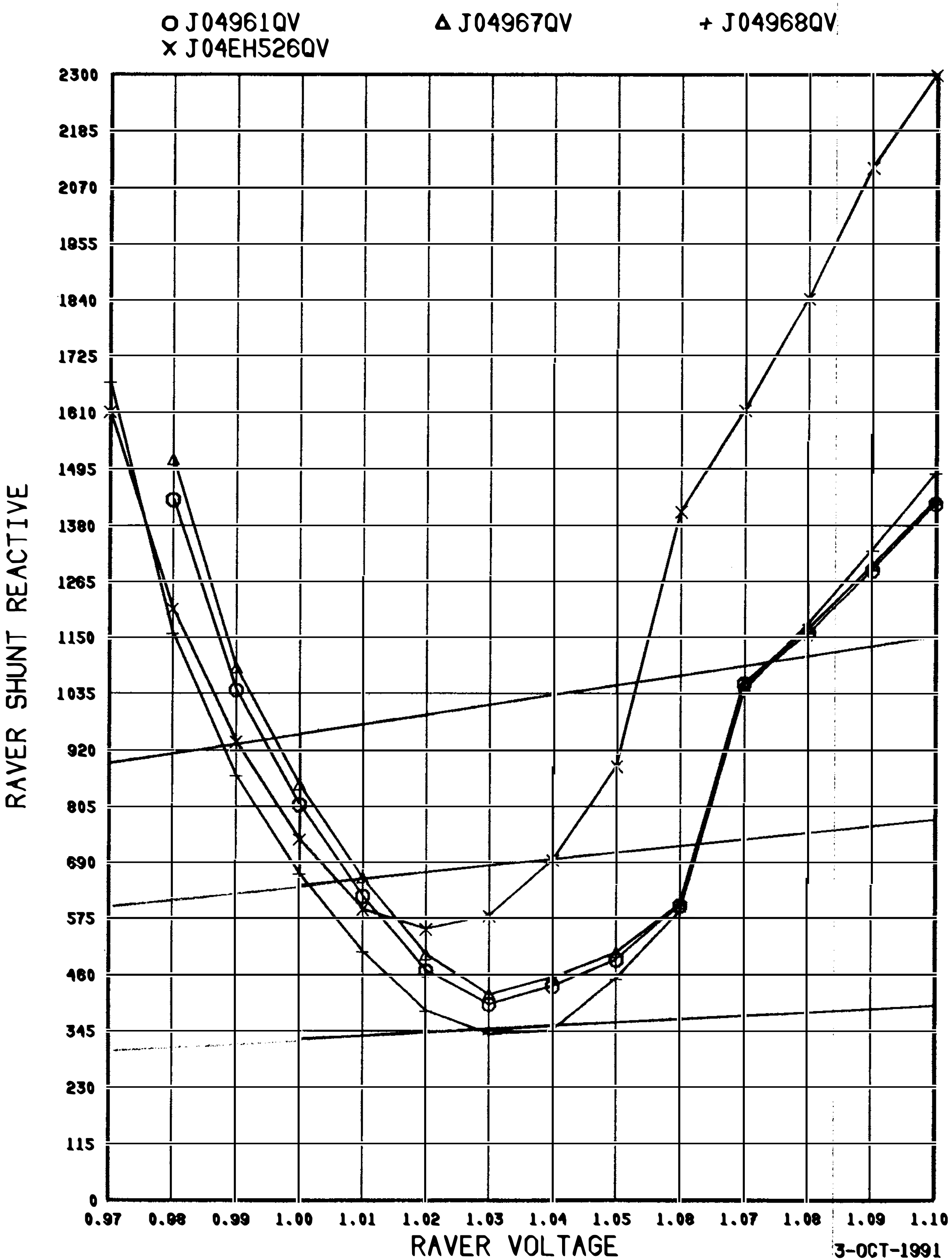


22-AUG-1991
J04PLAN3-4.SETUP

QV Curve 3J

PLAN 3J: NANEUM SWYD, 11+15 OHM COMP ON COUL-RAV

ALL MSC'S USED
o J04961:GC-NAN 1&2 OUT, 15 OHMS IN NAN-RAV (J04960)
Δ J04967:GC-NAN 1&2 OUT, 11 OHMS IN NAN-RAV (J04960)
+ J04968:NAN-RAV 1&3 OUT, 0 OHMS IN NAN-RAV (J04960)
x J04EH526:CJ-MON, 26 OHMS IN NAN-RAV (J04EH624)

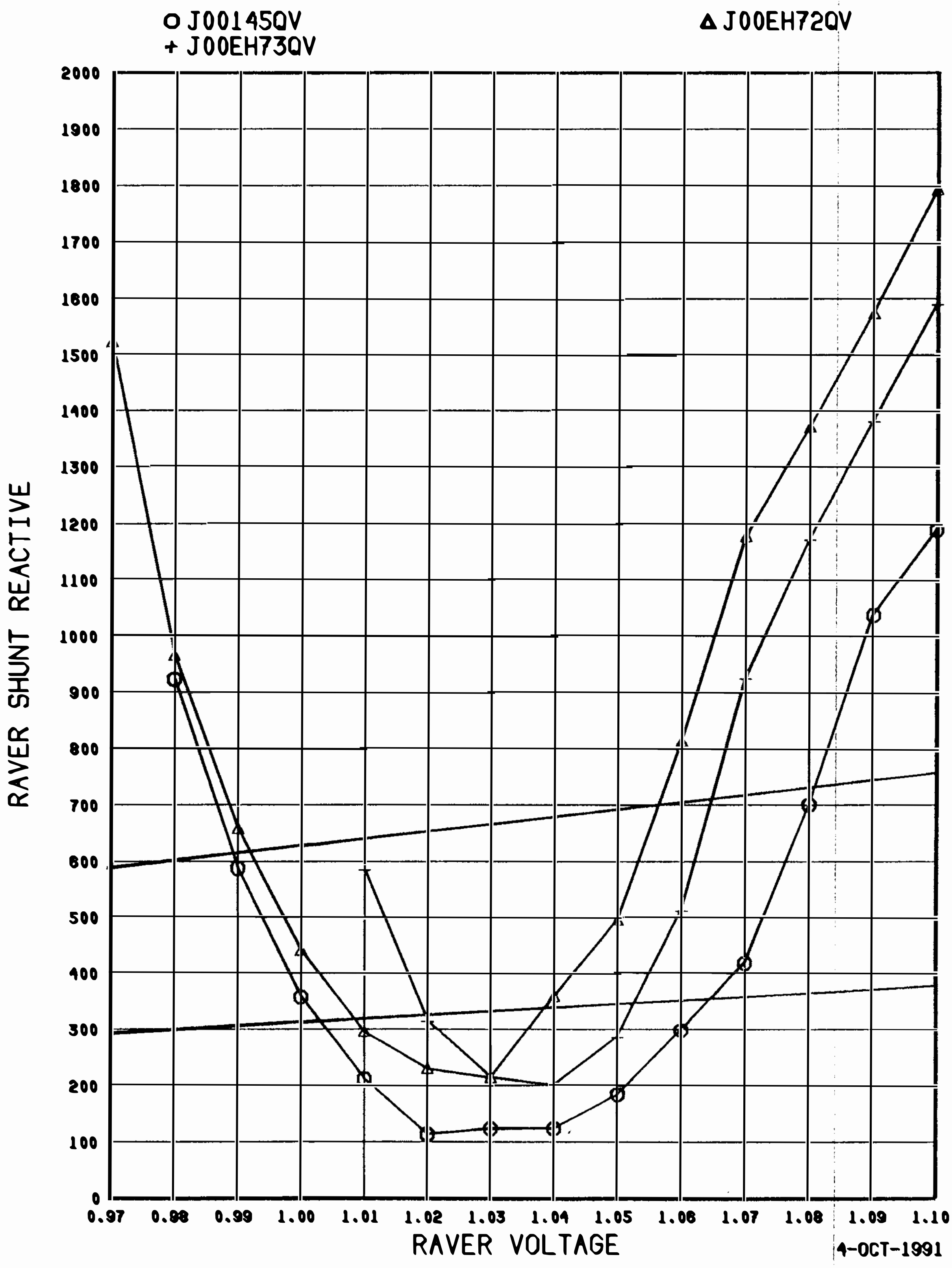


3-OCT-1991
J04PLAN3J.SETUP

QV Curve 3Ja

REACTIVE PLAN 3J:NANEUM SWYD & 15 OHMS ON COUL-RAV

O J00145:NAN-RAV 3&4 OUT, MSC @SNOQ, MON(J00144)
△J00EH72:CJ-MON, MSC @MON, OLY (J00EH67)
+J00EH73:TROJAN SCRAM, MSC @ OLY (J00EH68)

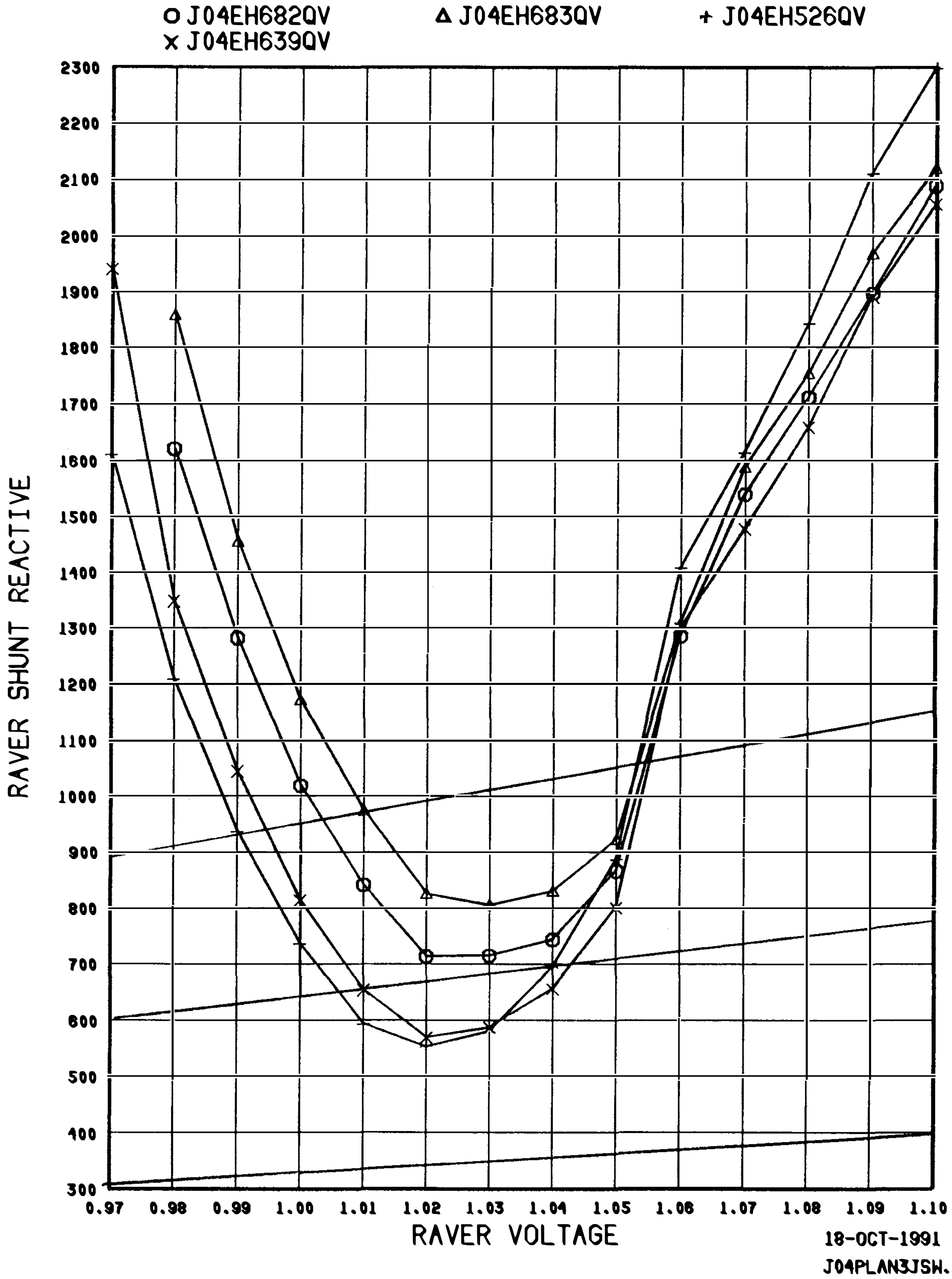


4-OCT-1991
J00plan3J.SETUP

QV Curve 3Jb

PLAN 3J: NANEUM SWYD, SWITCHABLE COMP ON COUL-RAV

BASED ON J04EH524, ALL MSC'S USED
J04EH526:CHIEF JO-MONROE OUT, 26 OHMS IN NAN-RAV
J04EH682:NANEUM-RAVER OUT, 7 OHMS IN NAN-RAV
J04EH683:NANEUM-RAVER OUT, 0 OHMS IN NAN-RAV
J04EH639:NANEUM-RAVER OUT, 15 OHMS IN NAN-RAV

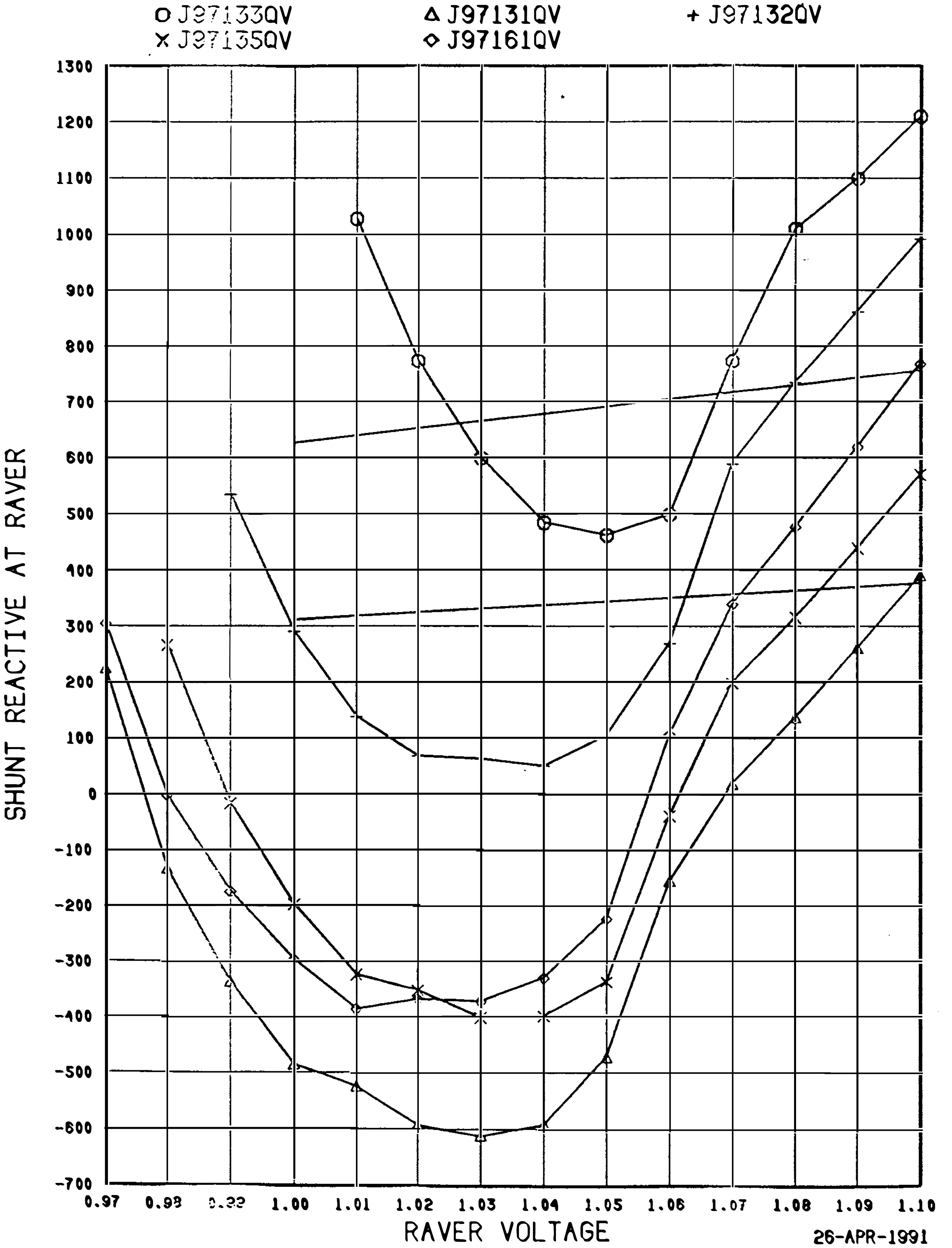


18-OCT-1991
J04PLAN3JSH.SETUP

QV Curve 4

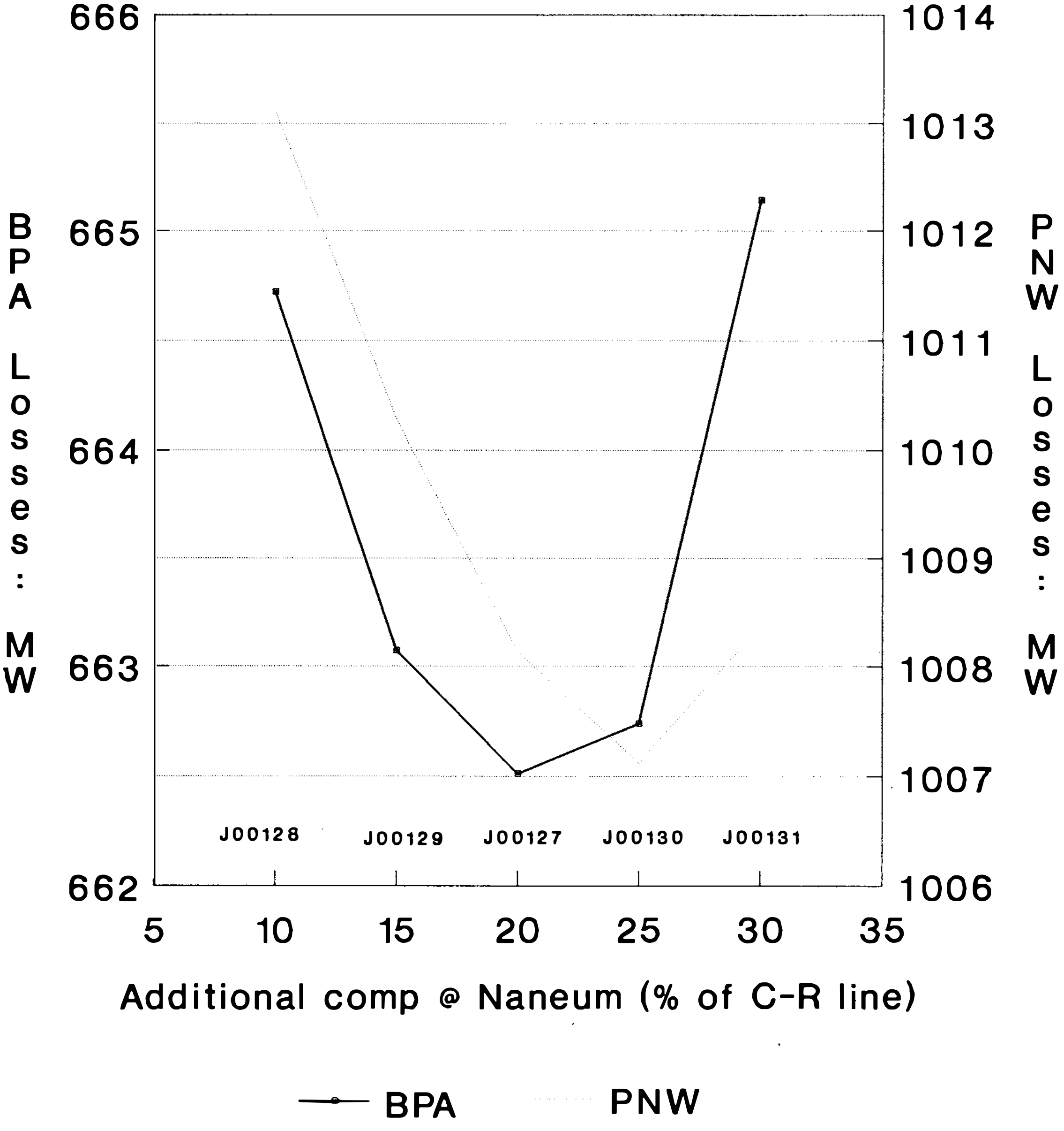
WORST DOUBLE LINE OUTAGE - ALL MSC'S USED

○J97133:NO ADDITIONS, 2COUL-RAV OUT (J9782)
△J97131:SICKLER-COL, 2COUL-COL OUT (J97130)
+J97132:SICKLER-COL, 2RAVER-COL OUT (J97130)
×J97135:NANEUM SY, 2COUL-NANEUM OUT (J97134)
◇J97161:NANEUM SY, 2NANEUM-RAVER OUT (J97134)



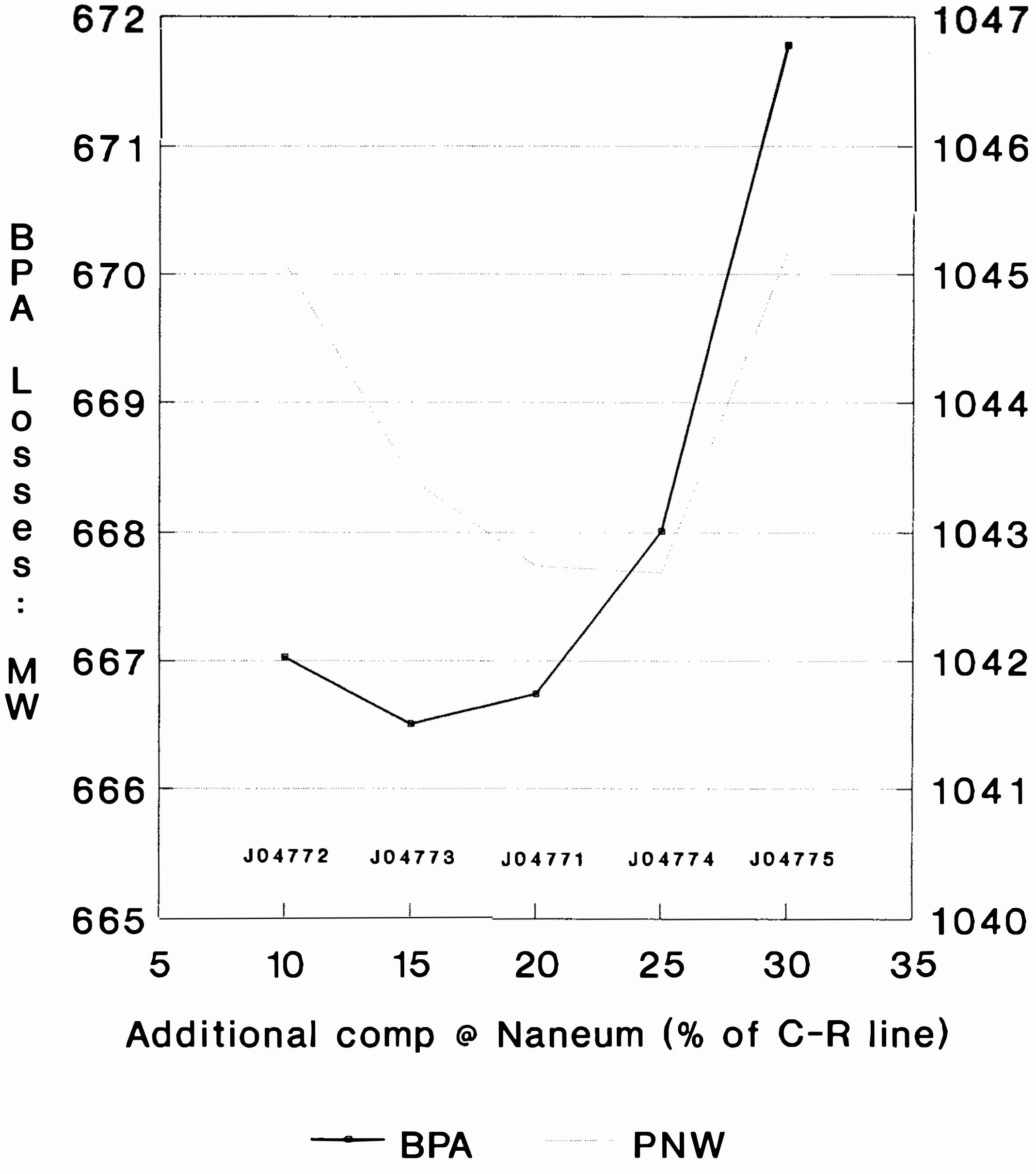
26-APR-1991
J97TRANS.SETUP

Graph 5
Loss Savings vs. Coulee-Raver comp level with Naneum Switchyard



11-4-91

Graph 6
Loss Savings vs. Coulee-Raver comp level with Naneum SWYD and CJ-Snoh 345 rebuild

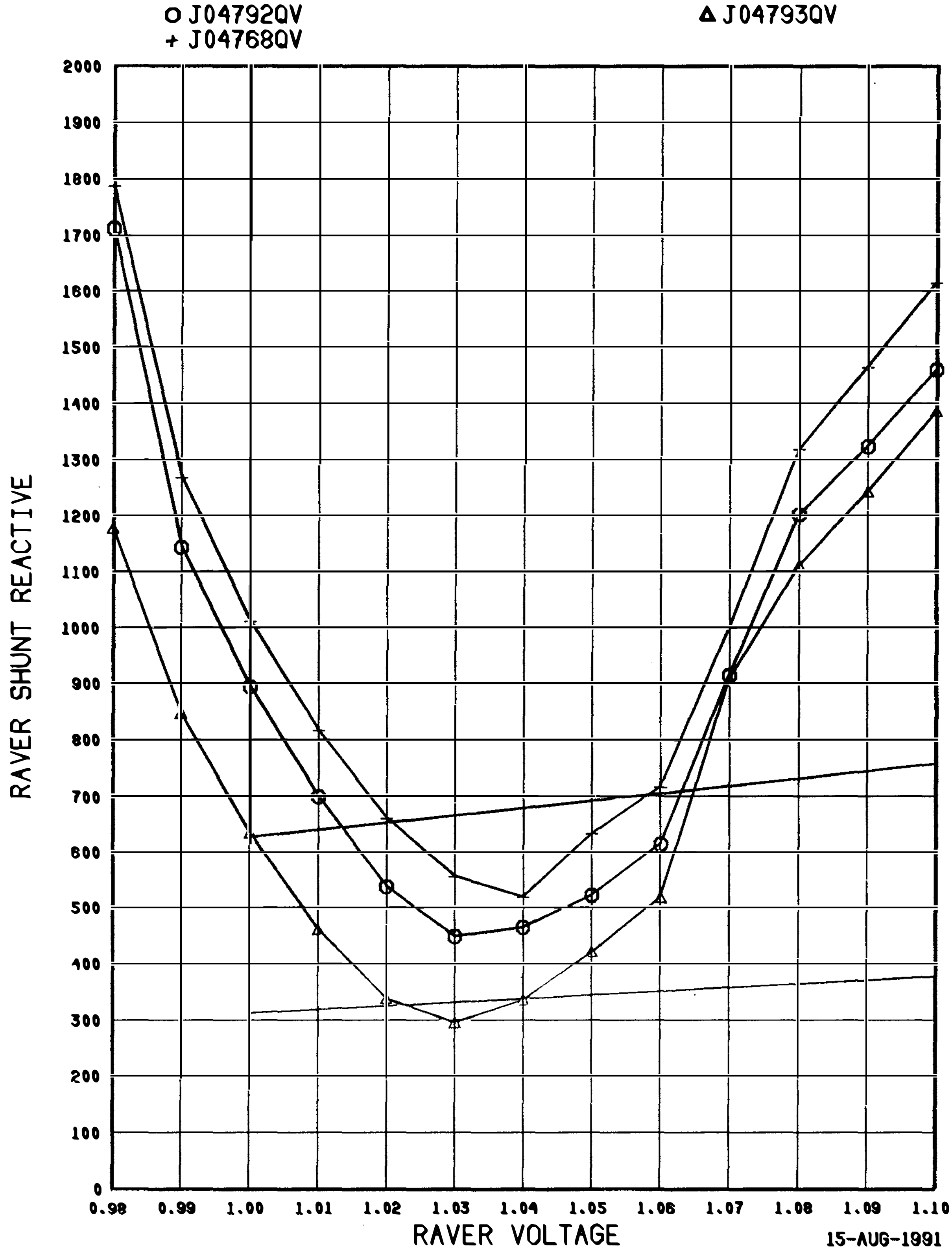


11-4-91

QV Curve - 7

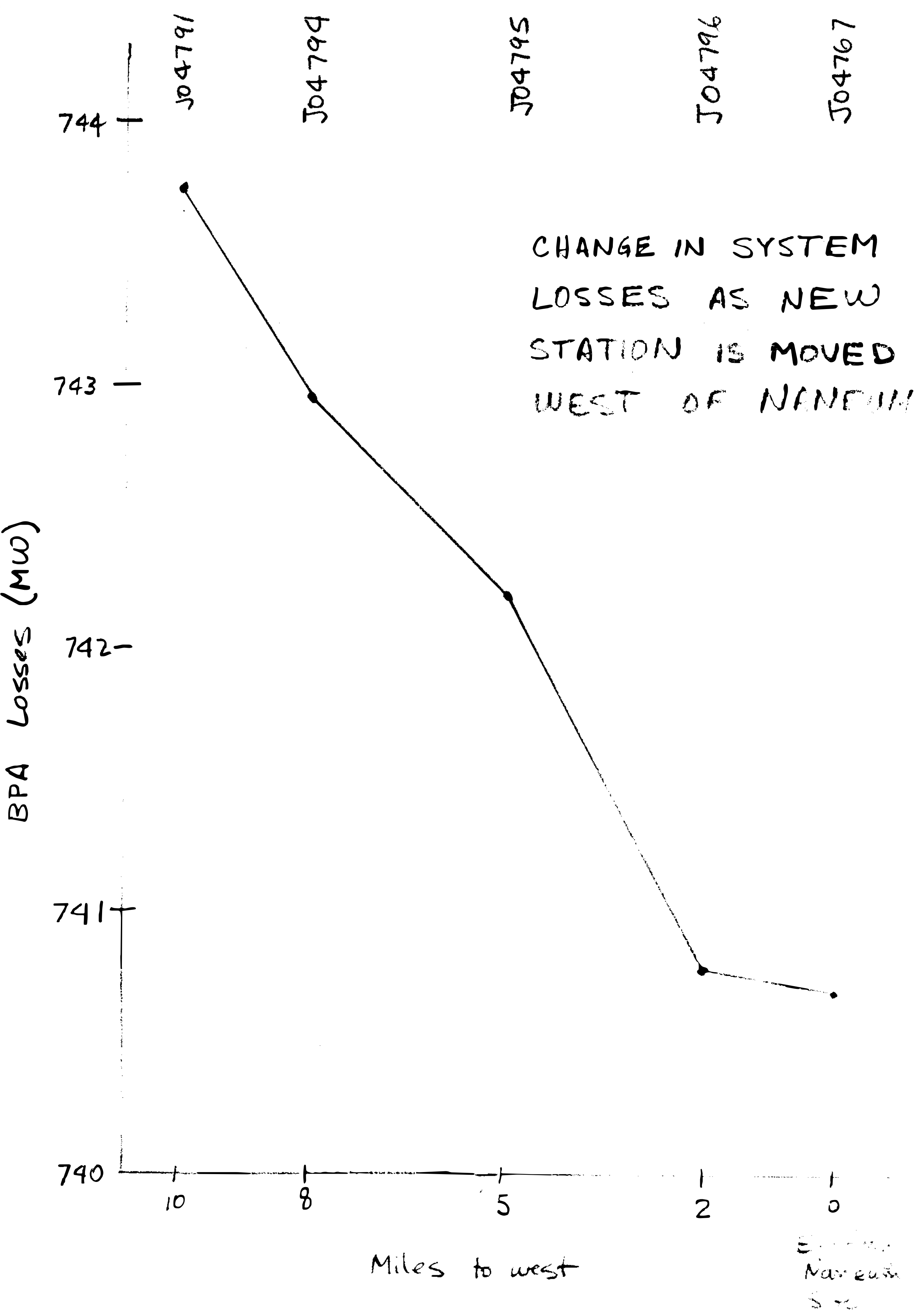
EFFECT OF MOVING NEW STATION WEST OF NANEUM

J04767: NEW STATION AT NANEUM
J04791: NEW STATION AT KITTITAS, 10 MILES WEST
○J04792QV:GC-KITT 1&2 OUT,MSC ⊗SNQ,MON,OLY(J04791)
Δ J04793QV:GC-NAN 1&2 OUT, MSC ⊗SNQ,MON,OLY(J04767)
+ J04768QV:NAN-RAV OUT,MSC ⊗ SNQ,MON,OLY,RAV(J04767)



15-AUG-1991
KITTMOVE.SETUP

GRAPH - 8



CHANGE IN SYSTEM LOSSES AS NEW STATION IS MOVED WEST OF NANEUM xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

TABLE 9: OTHER REACTIVE PLANS STUDIED

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These reactive plans were also studied but for various reasons were eliminated from further study. QV Curves are attached for each. Performance and losses are also summarized in Table 1.

REACTIVE PLAN 3A

This plan is the same as Plan 3 except that the SVC's at Covington and Snohomish are eliminated. Even without these 2 SVC's, the system performance is still acceptable through 2004. Refer to QV-Curve 3A. There are also overvoltage problems with 50% comp on Chief Joe-Monroe line; therefore the two 25% comp groups would need to be separated.

REACTIVE PLAN 3B

This plan is the same as Plan 3 except that the switched series caps are eliminated. This plan would probably work through 2005 as shown in QV-Curve 3B. It has slightly better margins than Plan 3A. There are no overvoltage problems on the Chief Joe-Monroe line since there are no switched capacitors.

REACTIVE PLAN 3D

This plan consists of:

A. Naneum switchyard (2-4 CB rings or full development of 12 CB's),
B. 35% comp on Chief Jo-Monroe and
C. 60% comp (26 ohms) on Naneum-Raver #3 and #4 (double circuit line)

With the addition of a Naneum Switchyard, the Chief Jo-Monroe outage becomes the critical outage. This plan will meet the 500 MVAR margin through 2003 as shown in QV-Curve 3D.

The transmission losses for this plan are slightly higher than the above plans (see Table 1), however the series comp levels have not yet been optimized with a Naneum switchyard in place. The same comp levels as Plan 3C were assumed. As will be shown later, the series capacitors at Naneum load very heavily during outages. An advantage to this plan is that the Chief Joe-Monroe comp would help reduce the loading of the series capacitors at Naneum during multiple outages. Cases J04916 (25% comp) and J04917 (35%) were run to test this concept against case J04910 (no comp) which depicts one of the worst outages for capacitor loading. The 25% comp addition reduces the loading on the Naneum capacitors by only 5%, while the 35% comp reduced it 8%. This 35% comp station would need to be at least 2600 amps. This ampacity reduction benefit is not significant enough to warrant the addition of a new capacitor bank on the Chief Joe-Monroe line. Compensation levels above 35% would need to be added in this line to be effective and line overvoltages would surely result.

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TABLE 9: OTHER REACTIVE PLANS STUDIED CONT.
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REACTIVE PLAN 3E

This plan is the same as Plan 3D except that two 200 MVAR shunt capacitor banks were added at Naneum (split bus) for additional voltage support. Larger banks caused overvoltages.

This plan would have the required margins through 2004 as shown in QV-Curve 3E. The loss saving of this plan is also slightly less than the above plans (Table 1), however the series comp levels have not been optimized with a Naneum switchyard in place.

REACTIVE PLAN 3H

This plan is similar to Plan 3G. With 40% comp added on each of the Sickler-Raver and Vantage-Raver lines, the loading for the double Naneum-Raver outage is not equal as shown in J04824 for the outage of the double circuit Naneum-Raver lines. In fact the Sickler-Raver line is at its thermal capacity while the Vantage-Raver line is well below. This contingency appears to be the limiting outage for Plan 3G. These two lines can be more equally loaded by reducing the Sickler-Raver comp to 30% (15.4 ohms). The corresponding outage for this condition is shown in J04828. The outage performance of this plan is slightly degraded by this lower comp level.

REACTIVE PLAN 3K

This plan is very similar to Plan 3J except that the capacitor bank step sizes would be 19 and 7 ohms. The 19 ohm bank size is slightly better than 15 ohms for loss savings. The 19 and 7 ohm sizes gives a wider range of cap bank sizes than the 15 and 11 ohm plan. The 19 ohm step size also provides better reactive margins for the loss of the parallel circuit in the EH winter. But it will also require larger cap bank sizes as was shown in the analysis for Plan 3J.

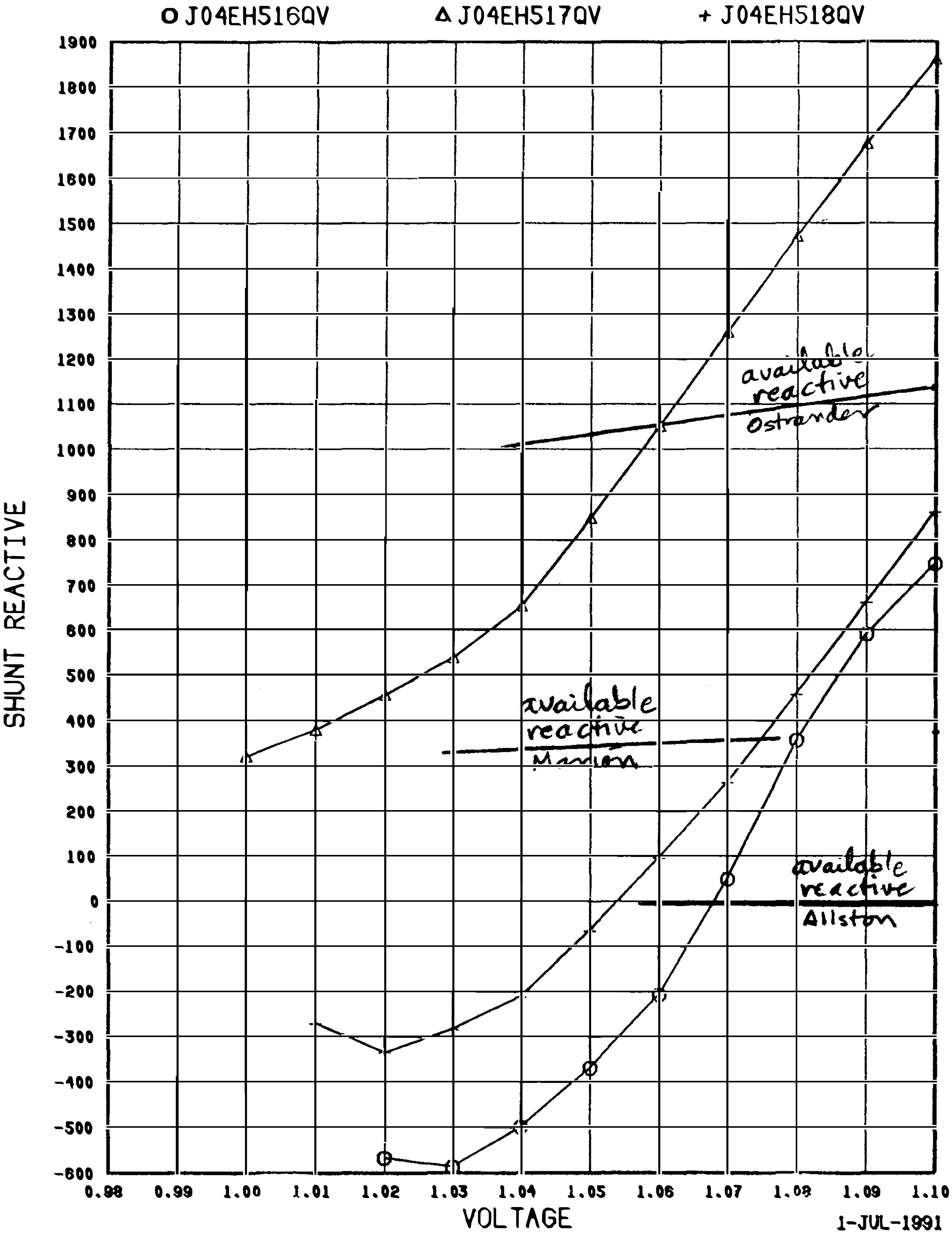
QV-10

Plan 3F

Portland Reactive
Requirements

TROJAN SCRAM

BASED ON J04EH493
○ J04EH516: MSC @OLY & MARION, HOLD ALLSTON
△ J04EH517: MSC @OLY & MARION, HOLD OSTRANDER
+ J04EH518: MSC @OLY, HOLD MARION



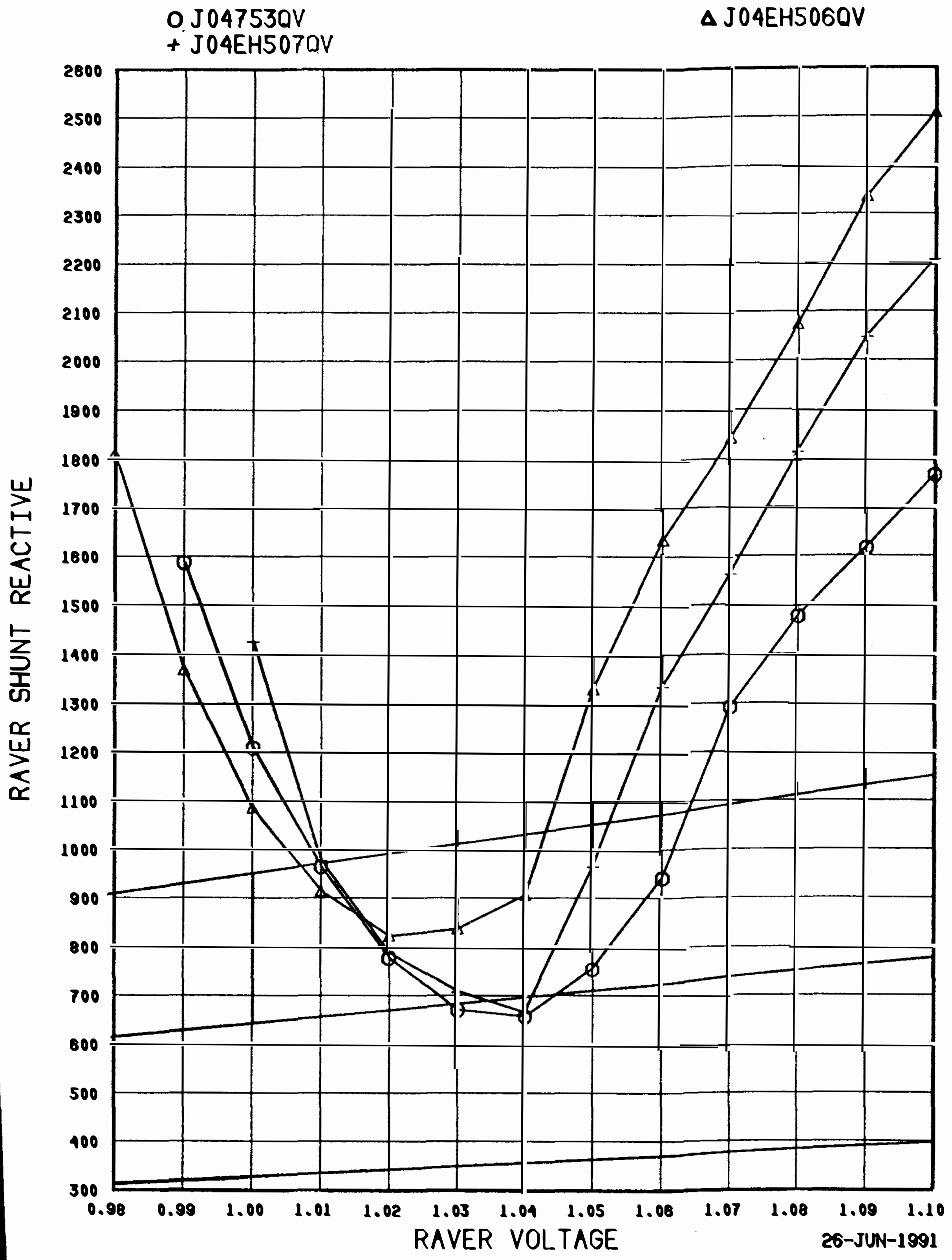
1-JUL-1991
J04EH516QV.SETUP

QV Curve 11

w/o Raver-Snoq #2
and MV Tx #2

FIXED SERIES REACTIVE PLAN WITH NANEUM SWITCHYARD

oJ04753:NAN-RAV OUT,MSC @SNQ,MON,OLY(J04752)
ΔJ04EH506:CJ-MONROE OUT,MSC @OLY(J04EH504)
+J04EH507:TROJAN SCRAM,MSC @OLY,MARION(J04EH505)



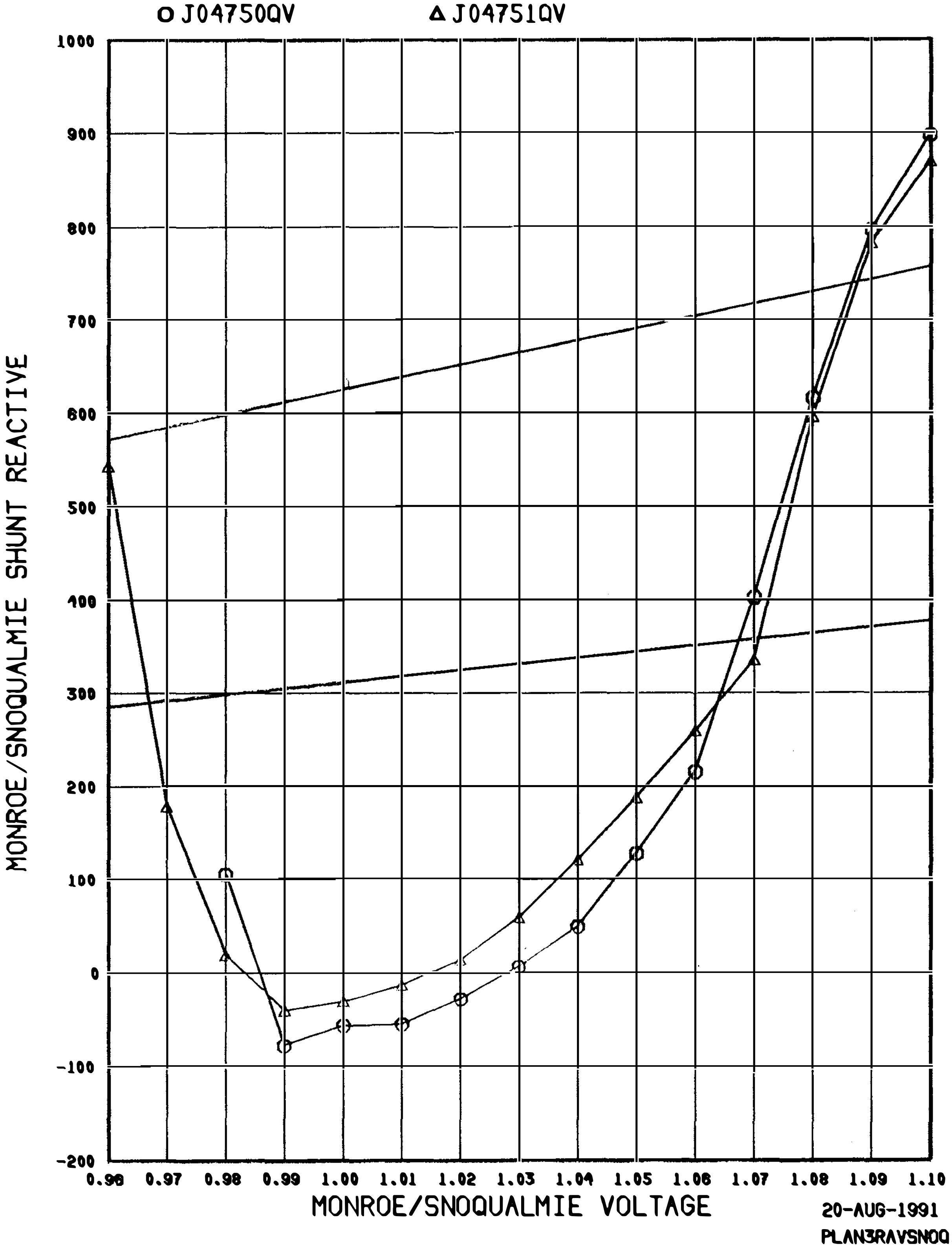
26-JUN-1991
plan3naneum.SETUP

QV-Curve 12

PLAN 3 - LOSS OF RAVER-SNOQUALMIE LINE

RAVER-SNOQUALMIE OUT - BASE J04741

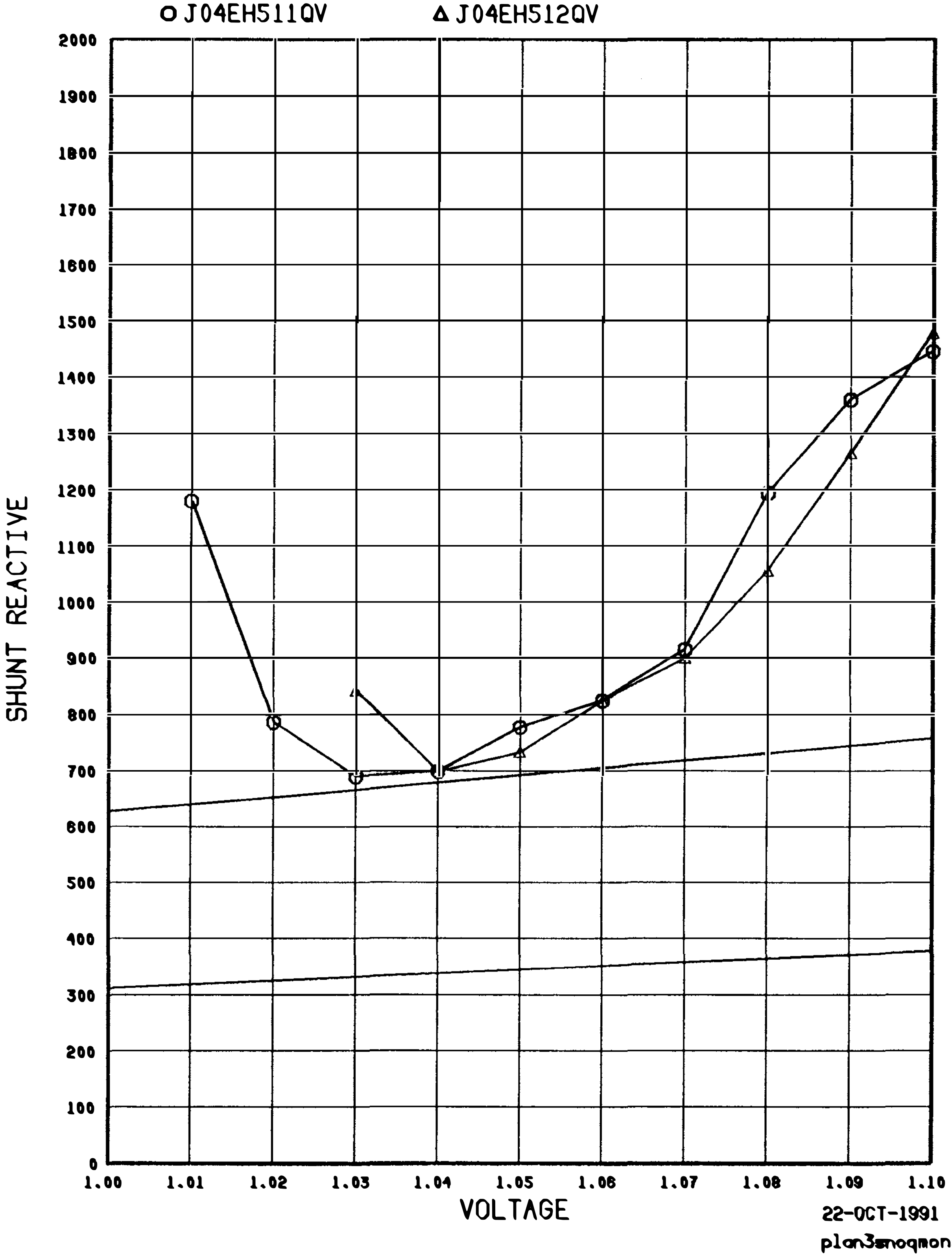
○J04750: MONROE BUS, MSC @SNOQ,MON,OLY,RAV
ΔJ04751: SNOQUALMIE BUS, MSC @SNOQ,MON,OLY,RAV



20-AUG-1991
PLAN3RAVSNOQ.SETUP

QV Curve 13

FIXED SERIES REACTIVE PLAN WITH NANEUM SWITCHYARD
LOSS OF RAVER-SNOQUALMIE 500: BASED ON J04EH491
MSC AT OLYMPIA AND RAVER
J04EH511:SNOQUALMIE CHARACTERISTICS
J04EH512:MONROE CHARACTERISTICS



22-OCT-1991
plan3snoqmon.SETUP

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TABLE 14: NANEUM SUMMER STUDIES OF RICHLAND/VANTAGE PROBLEMS

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The effect of adding a new Naneum switchyard (both full bus and split) was investigated for summer problems with heavy export to SW. The following is a summary of these studies. The base case used for these studies contained some very pessimistic assumptions which resulted in loadings that would be heavier than should actually occur. However, the data can be used as a comparison to show the differences between the system configurations. None of the changes in loading were felt to be significant. The Vantage-Hanford overload for the Coulee-Hanford outage is probably the most significant with a 3.6% increase with the addition of a full bus.

NANEUM SUMMER STUDY ASSUMPTIONS

1. Coulee gen increased from 5400 to 6000
2. Chief Jo gen increased from 2100 to 2380
3. Lower Snake decreased from 650 to 500 each
4. BCH intertie increased from 1200 to 2200
5. Wanapum left at 840
6. Rocky Reach gen increased from 1100 to 1250
7. Boardman and Ashe gen removed
8. PNW/PSW interties left at 4900 scheduled/3900 actual and 2734 DC
9. Trojan and Centralia on
10. WWP/BCH intertie removed
11. Run from Budget basecases

			CASE # AND LOADING			
OUTAGE	HEAVILY LOADED LINES	RATING*	EXISTING	SPLIT BUS	FULL BUS	
Base: No outage			A96179	A96180	A96181	
	Rocky Rh-Columbia	1200	748	815	752	
	Coulee-Potholes	900	559	553	536	
Coulee-Hanford			A96182	A96186	A96190	
	Coulee-Potholes	900	752	714	685	
	Naneum-Vantage	2590	1827	1892	2129	
	Vantage-Hanford	2900 (80)	3130	3154	3243	XX
	Columbia-Vantage	950	884	907	808	
	Douglas-Rocky Rh	2120	452	1116	545	
	Rocky RH-Columbia	1200	874	972	883	
Vantage-Hanford			A96183	A96187	A96191	
	Coulee-Potholes	900	466	484	476	
	Coulee-Hanford	3420	2890	2884	2878	
	Midway-Grandview T	1200	1146	1125	1133	
2 Coulee-Raver			A96185	A96189	A96193	
or	Coulee-Hanford	3420	2895	2998	2899	
2 Coulee-Naneum	Sickler-Naneum	2900	2242	2292	2587	
	Coulee-Potholes	900	727	753	729	
	Naneum-Vantage	2590	520			

* Includes planned uprates

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TABLE 14: NANEUM SUMMER STUDIES CONT

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			CASE # AND LOADING			
OUTAGE	HEAVILY LOADED LINES	RATING*	EXISTING	SPLIT BUS	FULL BUS	
2 Naneum-Raver			A96185	A96194	A96195	
	Naneum-Vantage	2590	520	1111	1452	
Stevens-Thayer			A96184	A96188	A96192	
	Horn R-HRT	330	440	440	440	
Naneum-Sickler			A96196	A96200	A96204	
	Rocky RH-Mckenzie	1190	1251	1186	1179	
	Rocky RH-Columbia	1200(80)	1105	1040	1033	
	Coulee-Potholes	900	612	555	551	
	Columbia-Vantage	950	890	780	767	
	Hanna-Eastmt	260	260	255	253	
Midway-Wanapum			A96197	A96201	A96205	
	Coulee-Potholes	900	586	580	564	
Mckenzie-Rocky R			A96198	A96202	A96206	
	Rocky RH-Columbia	1200	1126	1226	1139	XX
	Hanna-Eastmt	260	258	286	262	
Douglas-Rocky Rh			A96199	A96203	A96207	
	Hanna-Eastmt	260	223	300	235	XX

Vantage-Midway-Outlook loadings decrease with Naneum development (base)

Slatt-John Day loading increases only slightly with Naneum development (base)

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TABLE 15:SUMMARY OF OUTAGES RUN FOR PLAN 3F
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WORST SINGLE LINE OUTAGE IN EH WINTER:

Outage	Case #	Naneum cap loading	Columbia cap loading
Parallel 500 line	J04EH510	4121 amps	
	J04EH509		2616 amps

WORST DOUBLE LINE OUTAGE DURING NORMAL WINTER

Outage	Case #	Naneum cap loading	Naneum cap loadg w CT	Columbia cap loading	Columb cap loadg w CT
Vantage-Naneum and Coulee-Naneum #1 or #2	J04757			3286 amps*	3110 A est.*
Naneum-Raver #1 and Naneum-Raver #3 or #4	J04755	4620 amps**	4375 A est**		

* Exceeds maximum upgrade capability of existing Columbia series capacitor banks (3000 amps).

** Exceeds Switchgear limitations of existing equipment at Raver.

Load reductions due to the CT's is estimated from actual cases run in Table 16 and 17. Loading is reduced by about 5% when CT's were run. The same CT's were run here as in the EH winter cases.

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TABLE 16:SUMMARY OF OUTAGES RUN FOR PLAN 3G

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WORST SINGLE LINE OUTAGE IN EH WINTER, PHASE I:

Parallel 500 line	J00EH65	3073 amps	
	J00EH66		2495 amps
	J04EH560	3233 amps	
	J04EH561		2594 amps
Estimated J01 loading		3113 amps	2520 amps

WORST DOUBLE LINE OUTAGE DURING NORMAL WINTER, PHASE I:

Outage	Case #	Naneum loading	Naneum loading with CT	Columbia loading	Columbia loading with CT
Vantage-Naneum and	J00149			2995 amps	
Coulee-Naneum #1 or #2	J04913			3242 amps	
	J04919				3076 amps
Estimated J01 loading				3057 amps	2900 amps
Naneum-Raver #1 and	J00150	3611 amps			
Naneum-Raver #3 or #4	J00152		3418 amps		
	J04914	3942 amps			
	J04918		3735 amps		
Estimated J01 loading		3694 amps	3497 amps		
Naneum-Raver #1 and #2	J00147	2770 amps			
	J04911	3023 amps			
Sickler-Naneum and	J00148			3041 amps	
Coulee-Naneum #1 or #2	J04912			3197 amps	
Naneum-Raver #2 and	J00151	3492 amps			
Naneum-Raver #3 or #4	J04915	3812 amps			

Phase II caps: 20 ohms on Sickler-Raver line
23 ohms on Vantage-Raver line

WORST SINGLE LINE OUTAGE IN EH WINTER, PHASE II:

Outage	Case #	Naneum cap loading	Columbia cap loading	S-R caps	V-R caps
Parallel 500 line	J04EH563	2706 amps		2110 amps	1816 amps
	J04EH562		2704 amps		

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TABLE 16:SUMMARY OF OUTAGES RUN FOR PLAN 3G cont.

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DOUBLE CIRCUIT LINE OUTAGES DURING NORMAL WINTER, PHASE II:

Outage	Case #	Sickler-Raver cap loading	Vantage-Raver cap loading
Naneum-Raver #3 and #4 double circuit	J04824	2999 amps	2581 amps

Outage	Case #	Naneum cap loading	Columbia cap loading	S-R caps loading	V-R caps loading
Vantage-Naneum and Coulee-Naneum #1 or #2	J04814 J04919 w CT		3294 amps 3076 amps		
Naneum-Raver #1 and Naneum-Raver #3 or #4	J04815	3457 amps			2322 amps
Naneum-Raver #1 and #2	J04909	3023 amps			
Sickler-Naneum and Coulee-Naneum #1 or #2	J04813		3283 amps		
Naneum-Raver #2 and Naneum-Raver #3 or #4	J04816	3295 amps		2574 amps	

Series caps are not needed for voltage stability of the double line outages on this page.

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TABLE 17:SUMMARY OF OUTAGES RUN FOR PLAN 3J

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Phase I: 15 ohms in Naneum-Raver double circuit
Phase II: 15 + 11 ohms in Naneum-Raver double circuit

SINGLE LINE OUTAGE IN EH WINTER: PHASE I CAPS

These outages are similar to Plan 3G in Table 16.
Caps will need to be bypassed for most 2 line outages

DOUBLE LINE OUTAGE DURING NORMAL WINTER: PHASE I CAPS

These outages are similar to Plan 3G in Table 16.
Caps will need to be bypassed for most 2 line outages

SINGLE LINE OUTAGE IN EH WINTER: PHASE II CAPS

Outage	Case #	Comp Level	Naneum cap loading	Columbia cap loading
Parallel 500 line	J04EH640	26 ohms	4039 amps	
	J04EH641	26 ohms		2700 amps
	J04EH639	15 ohms	3071 amps*	
		19 ohms	3425 amps est.	
Chief Joe-Monroe	J04EH526	26 ohms	3041 amps	

DOUBLE LINE OUTAGE DURING NORMAL WINTER: PHASE II CAPS

Outage	Case #	Comp Level	Naneum cap loading	Columbia cap loading
Vantage-Naneum and Coulee-Naneum #1 or #2	J04963	15 ohms		3207 amps
	J04965	11 ohms		3175 amps
	J04969	15 ohms + CT		3043 amps
Naneum-Raver #1 and Naneum-Raver #3 or #4	J04962	15 ohms	3661 amps	
	J04964	11 ohms	3410 amps	
	J04966	11 ohms + CT	3228 amps	

* A minimum of 15 ohms is needed to meet voltage stability margins for the outage of one Naneum-Raver compensated line during EH winter.

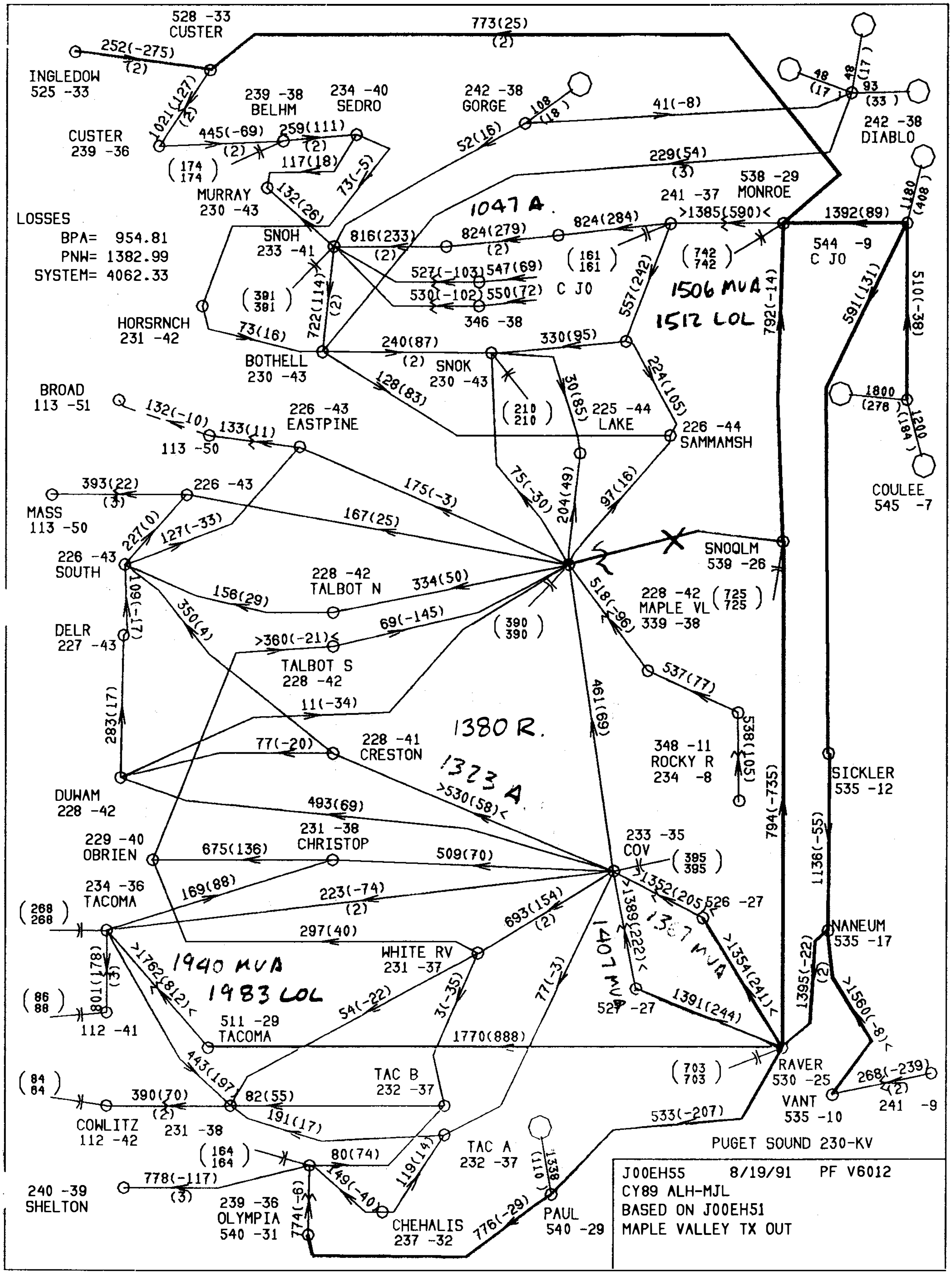
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

TABLE 18: ROUGH COMPARISON OF COST ASSOCIATED WITH PLANS 3F, 3G AND 3J

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

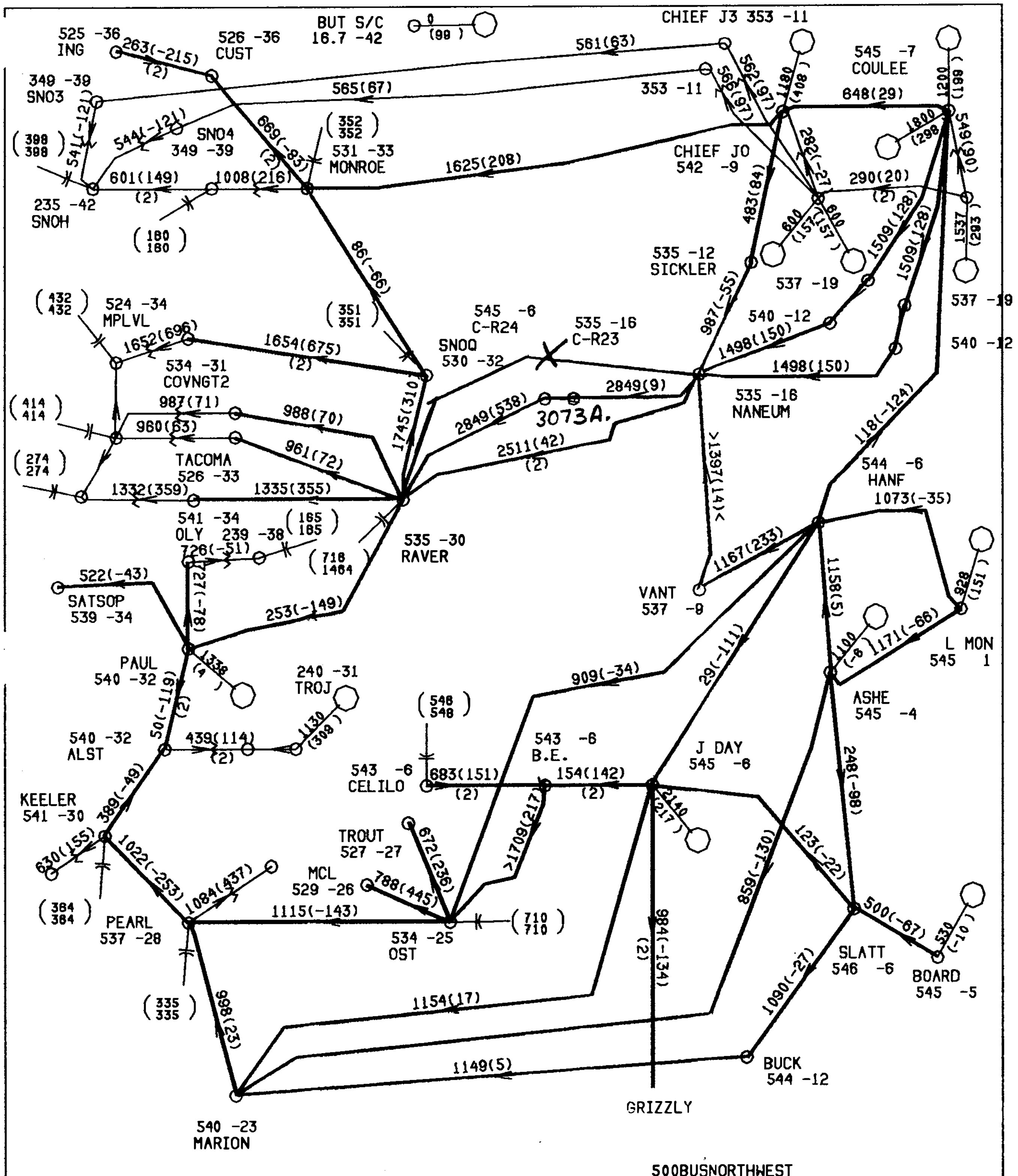
Plan	MVARs	Losses (MW)	Total Cost
Plan 3F			
4120 amps, 26 ohms at Naneum	1324 ea	4 MW	$36 million
uprate Columbia to 2700 amps	92 ea		
Plan 3G			
3150 amps, 19 ohms at Naneum	566 ea	0 MW	$29 million
uprate Columbia to 2700 amps	92 ea		
2200 amps, 20 ohms on S-R	290		
2000 amps, 23 ohms on V-R	276		
Plan 3J			
3100 amps, 15 ohms at Naneum	432 ea	2 MW	$28 million
uprate Columbia to 2700 amps	92 ea		
additional 3100 amps, 11 ohms at Naneum (in series with 15 ohms)	317 ea		

Losses are evaluated at a present worth of $1 million per MW
Series capacitor costs are $2.95 million plus $9.23 per KVAR per bank
Naneum switchyard (12 CBs) is common in all plans - no cost added in comparison



S:PQ R- , PLOTTED 19-AUG-91 AT 11:03:35 HOURS

PFPLOT PFP334 : REVISED 10/11/80



500BUSNORTHWEST

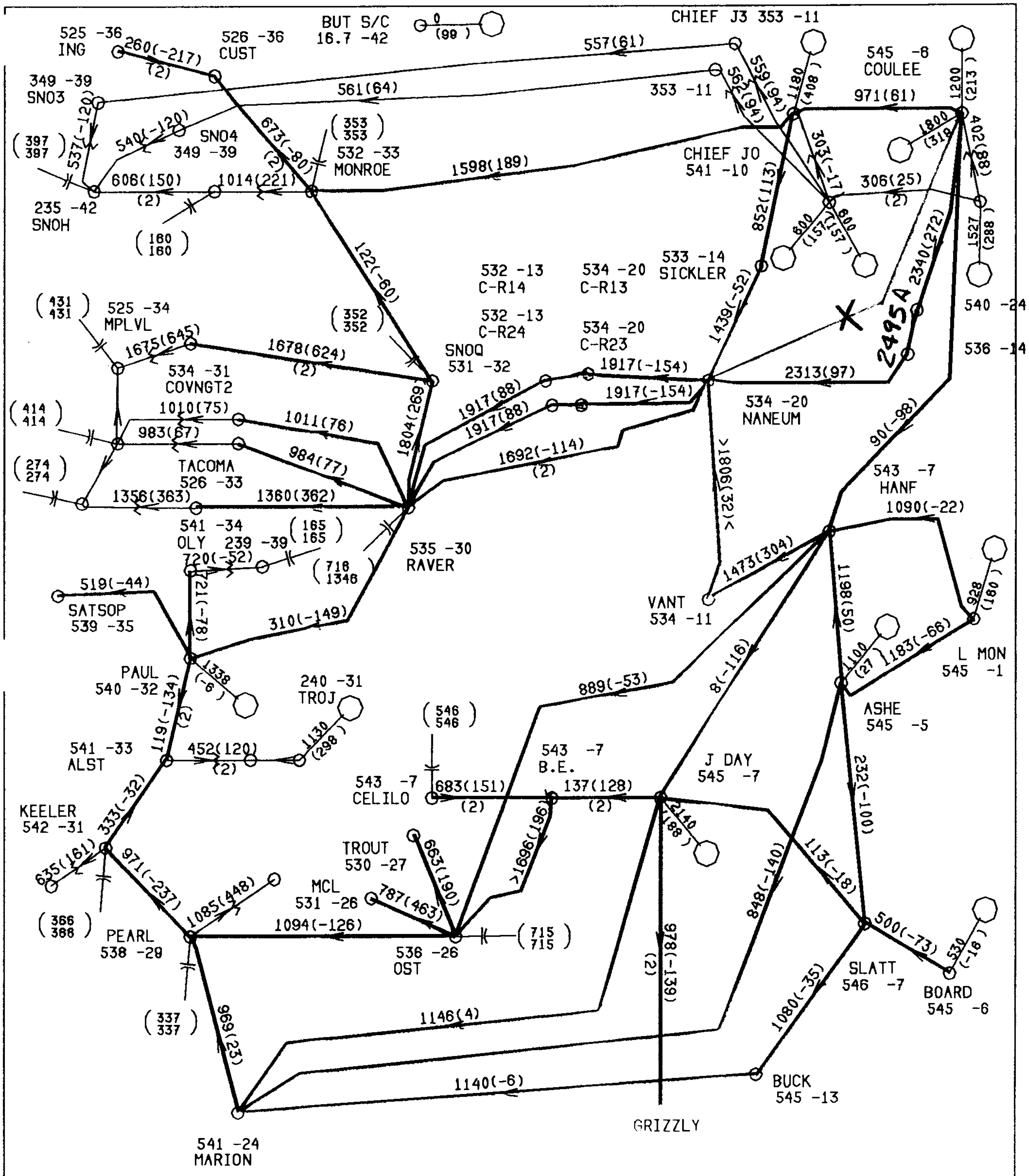
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -84.	AC= -434.	BPA= 951.88
DC= -1710.	DC= -1710.	PNW= 1370.84
		SYSTEM= 4054.31

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1310.	SI= 630.
AI= 450.	AI= 1014.	AI= 575.

J00EH65 8/14/91 PF V6012
CY89 MJL
BASED ON J00EH64
NANEUM-RAVER #3 OUT

S:PQ R- , PLOTTED 14-AUG-91 AT 14:40:00 HOURS

PFPLOT PFP334 : REVISED 10/11/90

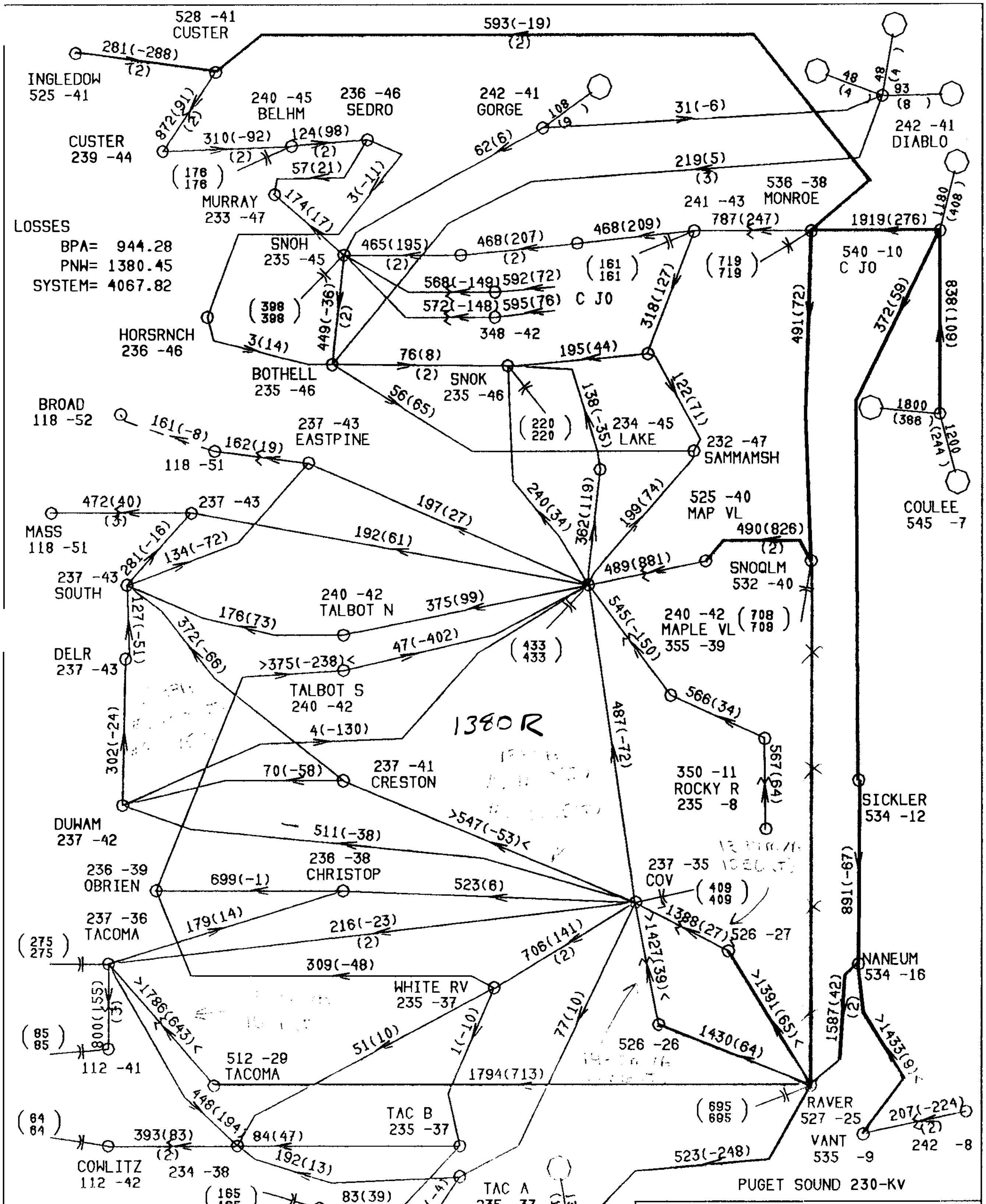


500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -84.	AC= -435.	BPA= 944.13
DC= -1710.	DC= -1710.	PNW= 1361.51
		SYSTEM= 4043.71

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1310.	SI= 630.
AI= 450.	AI= 1012.	AI= 577.

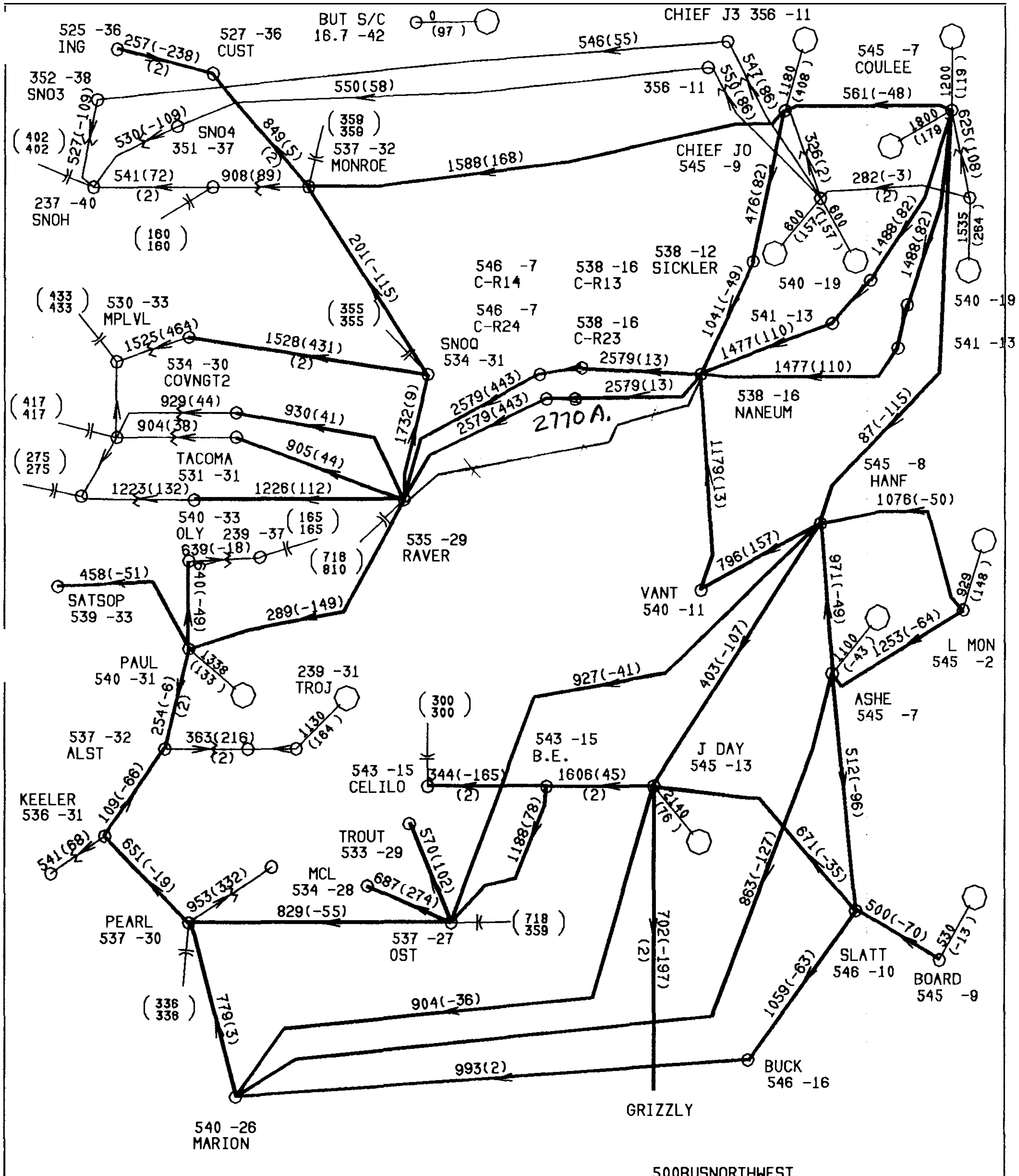
J00EH66 8/14/91 PF V6012
CY89 ALH-MJL
BASED ON J00EH6~~6~~4
COULEE-NANEUM #1 OUT



J00EH71 8/26/91 PF V6010
CY89 ALH-MJL
BASED ON J00EH87
RAVER-SNOQUALMIE 500KV OUTAGE

S:PQ R- , PLOTTED 26-AUG-91 AT 15:18:42 HOURS

PFPLOT PFP334 : REVISED 10/11/80



500BUSNORTHWEST

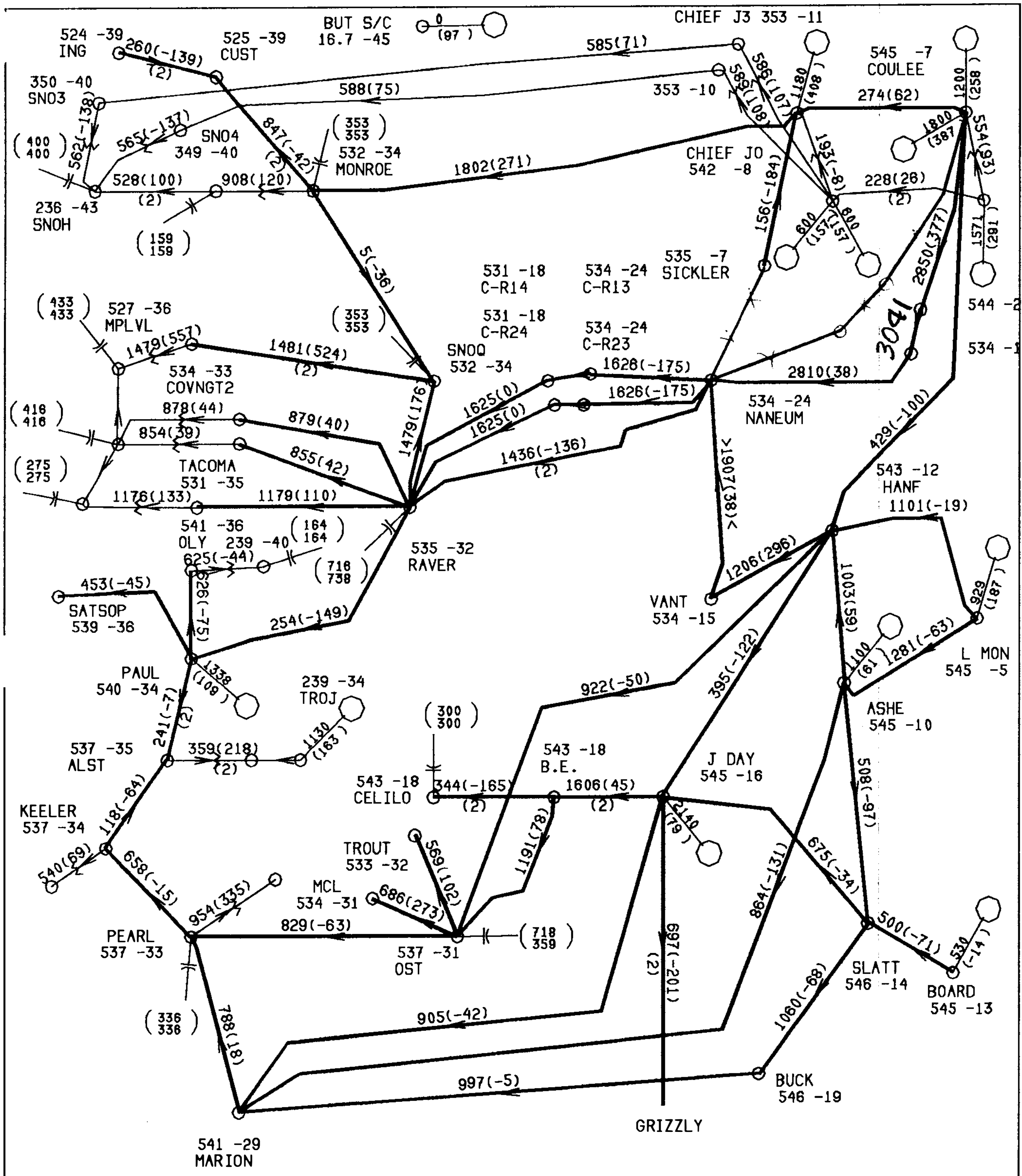
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -284.	BPA= 734.50
DC= 832.	DC= 832.	PNW= 1095.62
		SYSTEM= 3644.71

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 982.	AI= 684.

J00147 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J00144
NANEUM - RAVER 1&2 500KV LINES OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:12:06 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

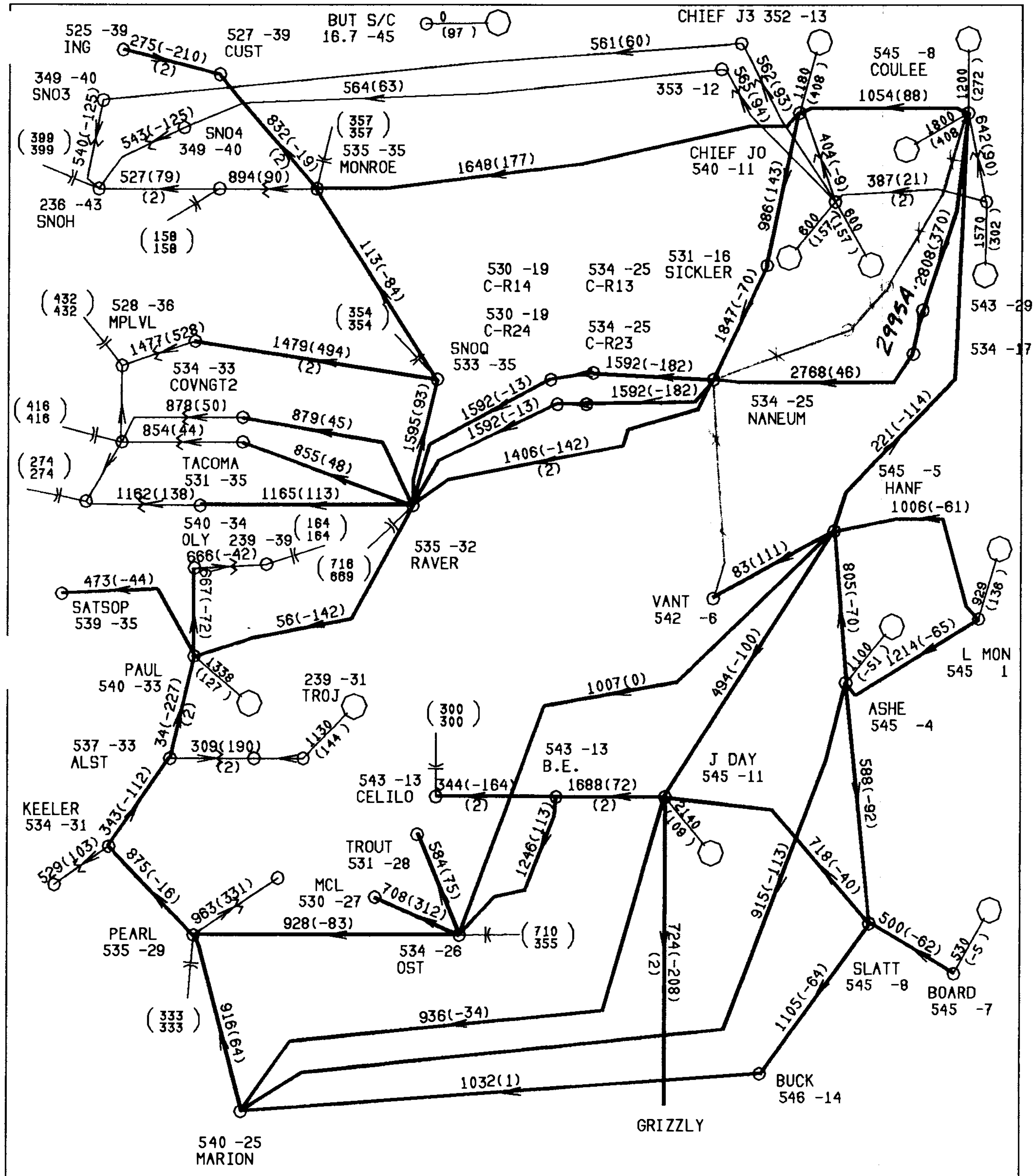
J00148 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J00144
SICKLER - NANEUM 500KV LINE OUT
COULEE - NANEUM 1 500KV LINE OUT

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -288.	BPA= 759.87
DC= 832.	DC= 832.	PNW= 1131.81
		SYSTEM= 3683.67

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 973.	AI= 689.

S:PQ R- , PLOTTED 1-OCT-91 AT 15:13:51 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= 832.

ACTUAL
AC= -284.
DC= 832.

LOSSES
BPA= 762.59
PNW= 1130.77
SYSTEM= 3684.51

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

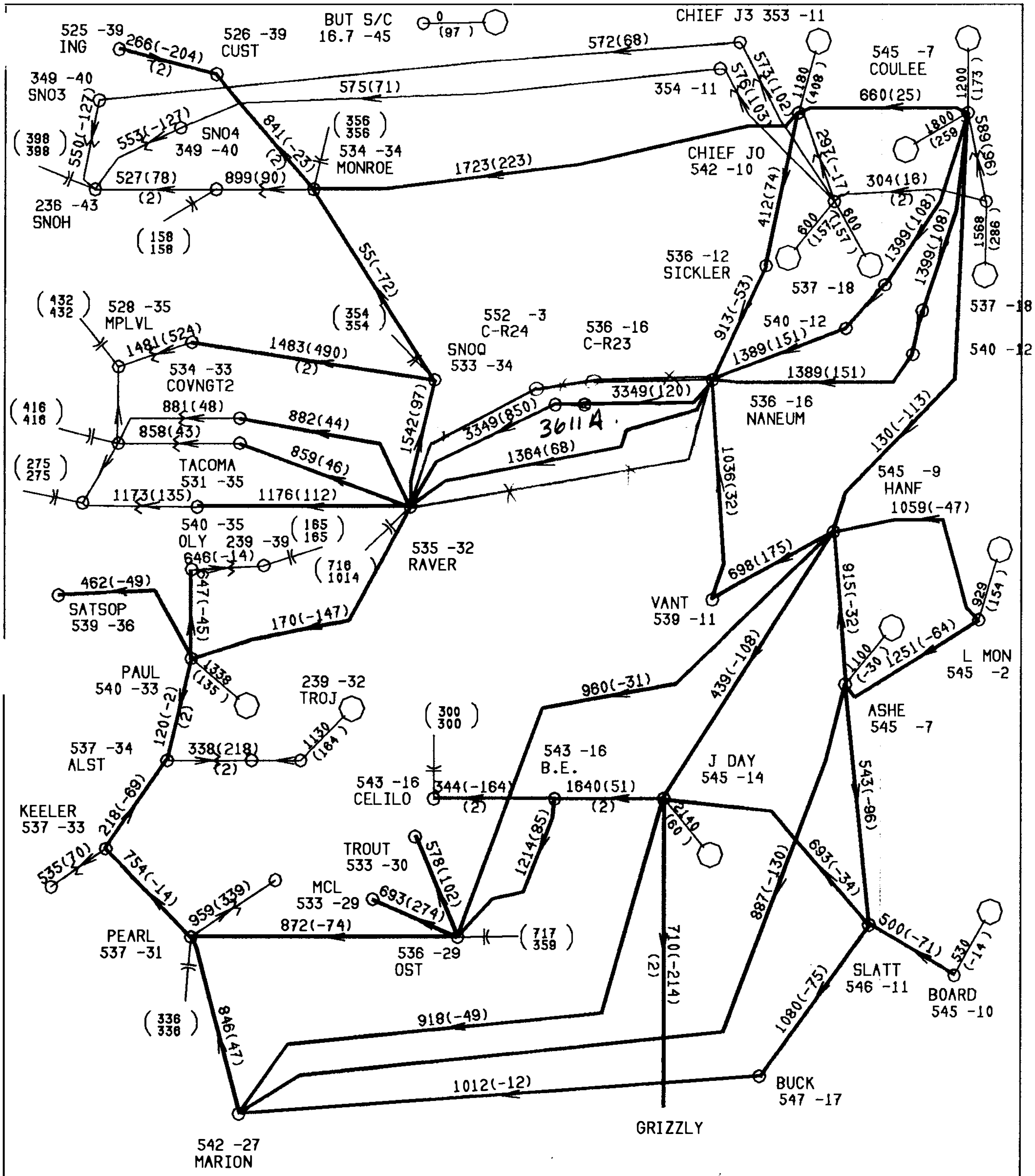
MONT TO PNW
SI= 1250.
AI= 985.

IDAHO TO PNW
SI= 700.
AI= 681.

J00149 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J00144
VANTAGE - NANEUM 500KV LINE OUT
COULEE - NANEUM 1 500KV LINE OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:10:24 HOURS

PFPLOT PFP334 : REVISED 10/11/90



INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -286.	BPA= 762.29
DC= 832.	DC= 832.	PNW= 1128.75
		SYSTEM= 3681.09

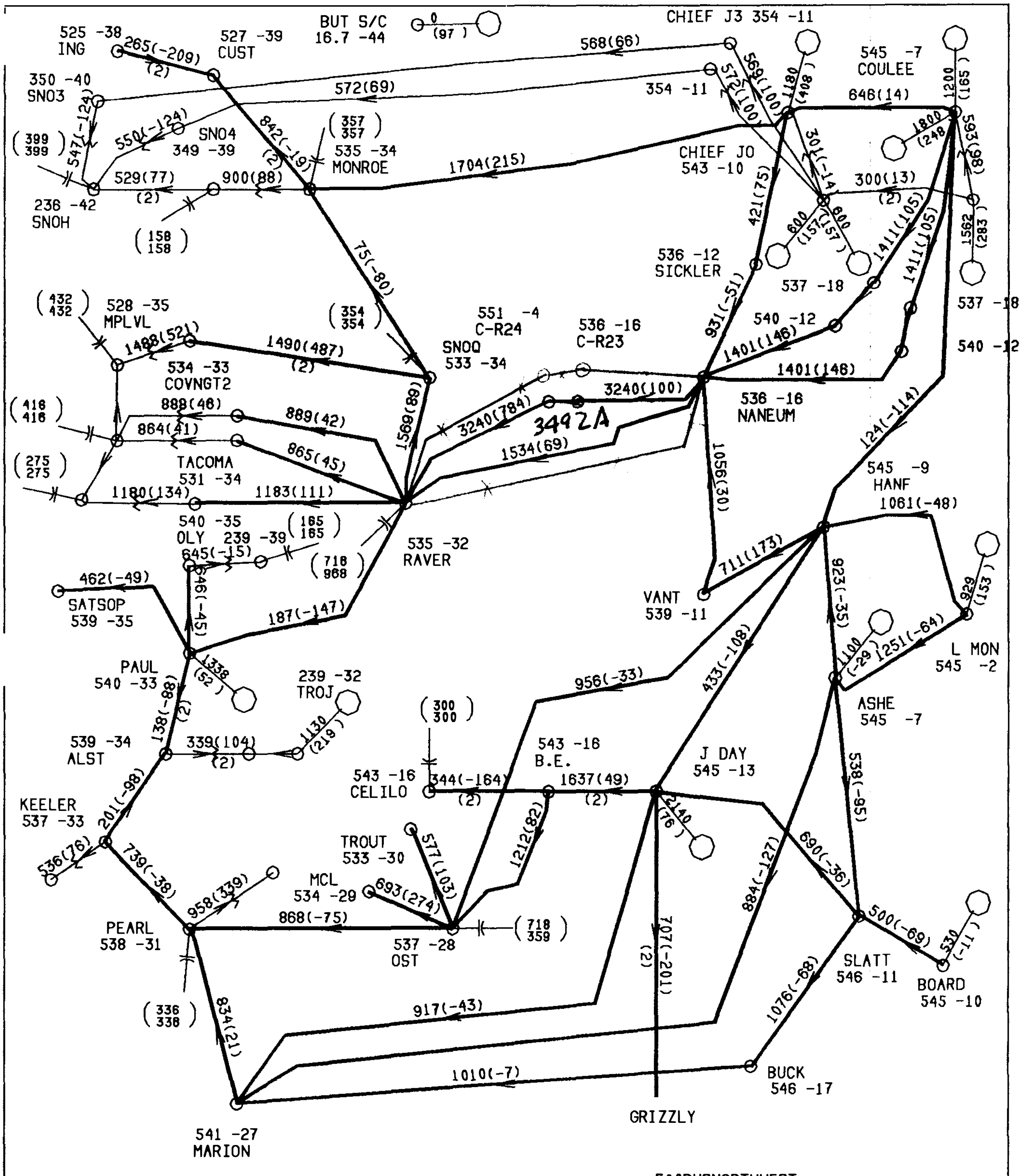
CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 979.	AI= 685.

500BUSNORTHWEST

J00150 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J00144
NANEUM - RAVER 1&3 500KV LINES OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:11:14 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

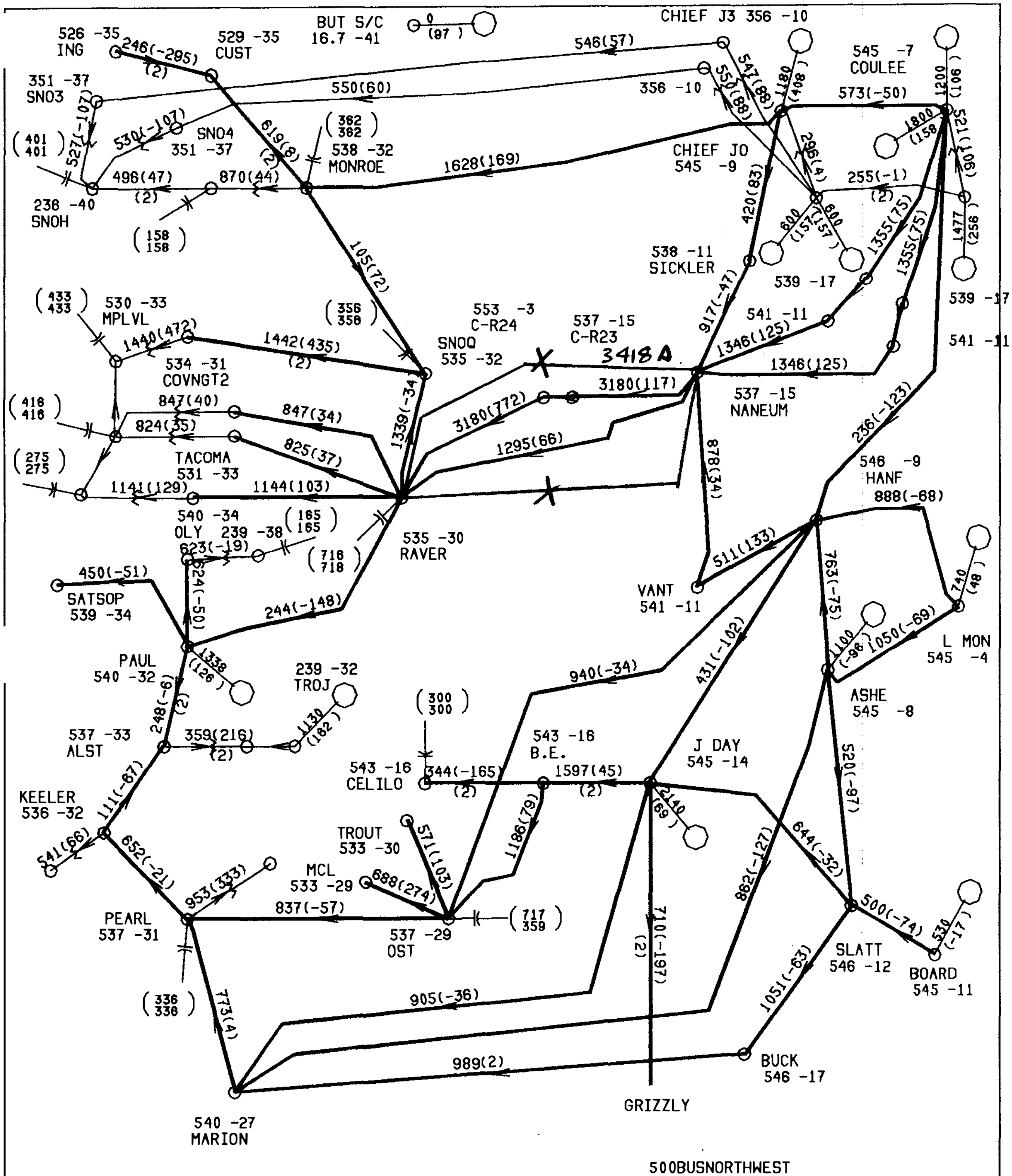
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -285.	BPA= 756.80
DC= 832.	DC= 832.	PNW= 1122.51
		SYSTEM= 3674.30

J00151 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J00144
NANEUM - RAVER 2&3 500KV LINES OUT

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 980.	AI= 685.

S:PQ R- , PLOTTED 1-OCT-91 AT 15:14:49 HOURS

PFPLOT PFP334 : REVISED 10/11/90

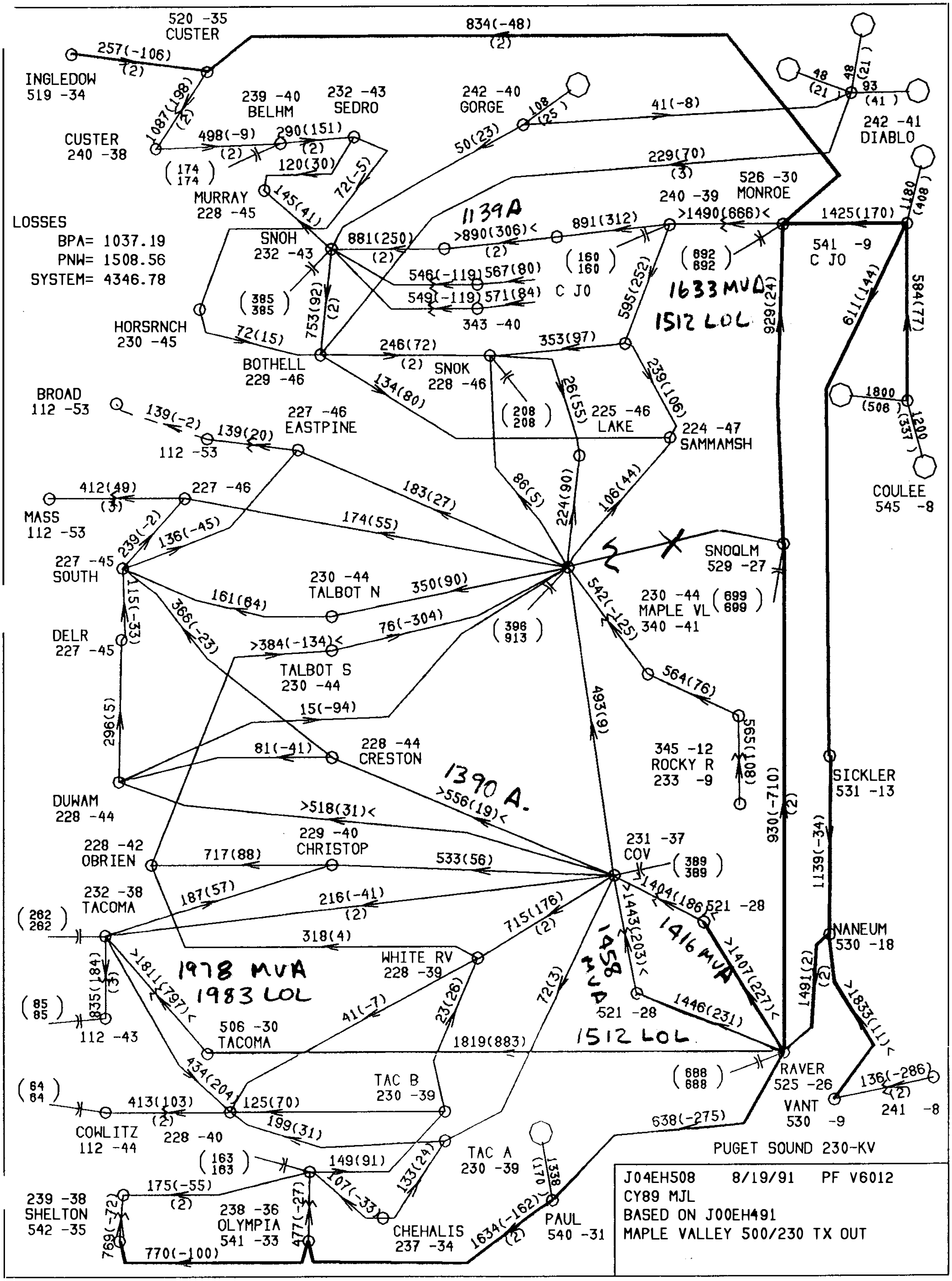


500BUSNORTHWEST

J00152 10/ 1/91 PF V6012
CY89 ALH-MJL
BASED ON J00144
NANEUM-RAVER #1 AND #3 OUT
604 MW CT'S ADDED IN PUGET SOUND

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -281.	BPA= 713.80
DC= 832.	DC= 832.	PNW= 1073.99
		SYSTEM= 3620.63

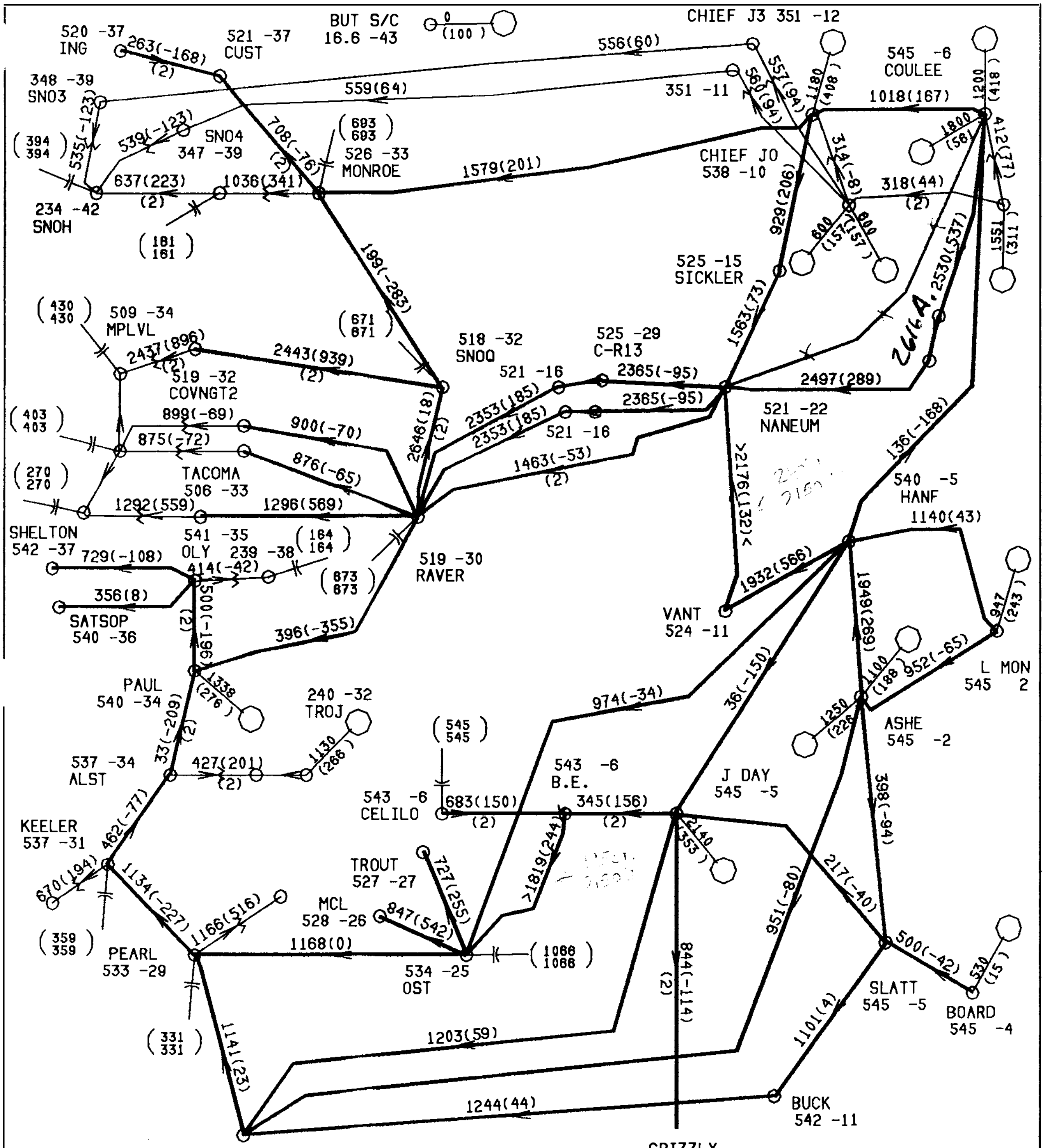
CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 985.	AI= 684.



PUGET SOUND 230-KV

J04EH508 8/19/91 PF V6012
CY89 MJL
BASED ON J00EH491
MAPLE VALLEY 500/230 TX OUT

S:PQ R- , PLOTTED 19-AUG-91 AT 10:58:25 HOURS PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -953.	BPA= 1024.89
DC= -1710.	DC= -1710.	PNW= 1481.04
		SYSTEM= 4320.96

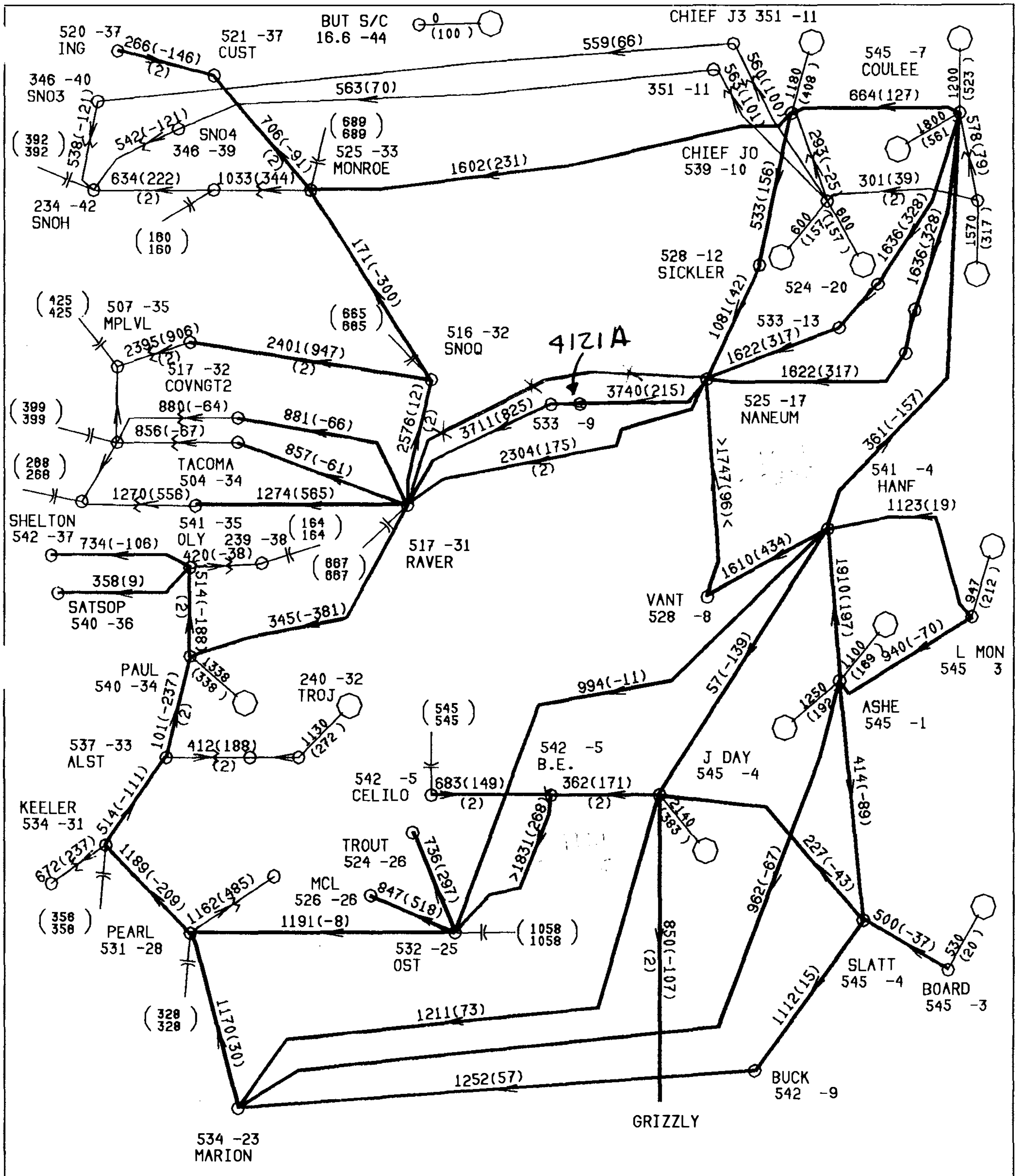
CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1021.	AI= 536.

J04EH509 6/25/91 PF V6010
CY89 ALH-MJL
BASED ON J04EH491
COULEE - NANEUM 1 500 OUT

Full

S:PQ R- , PLOTTED 25-JUN-91 AT 12:09:06 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -952.	BPA= 1041.05
DC= -1710.	DC= -1710.	PNW= 1500.15
		SYSTEM= 4339.84

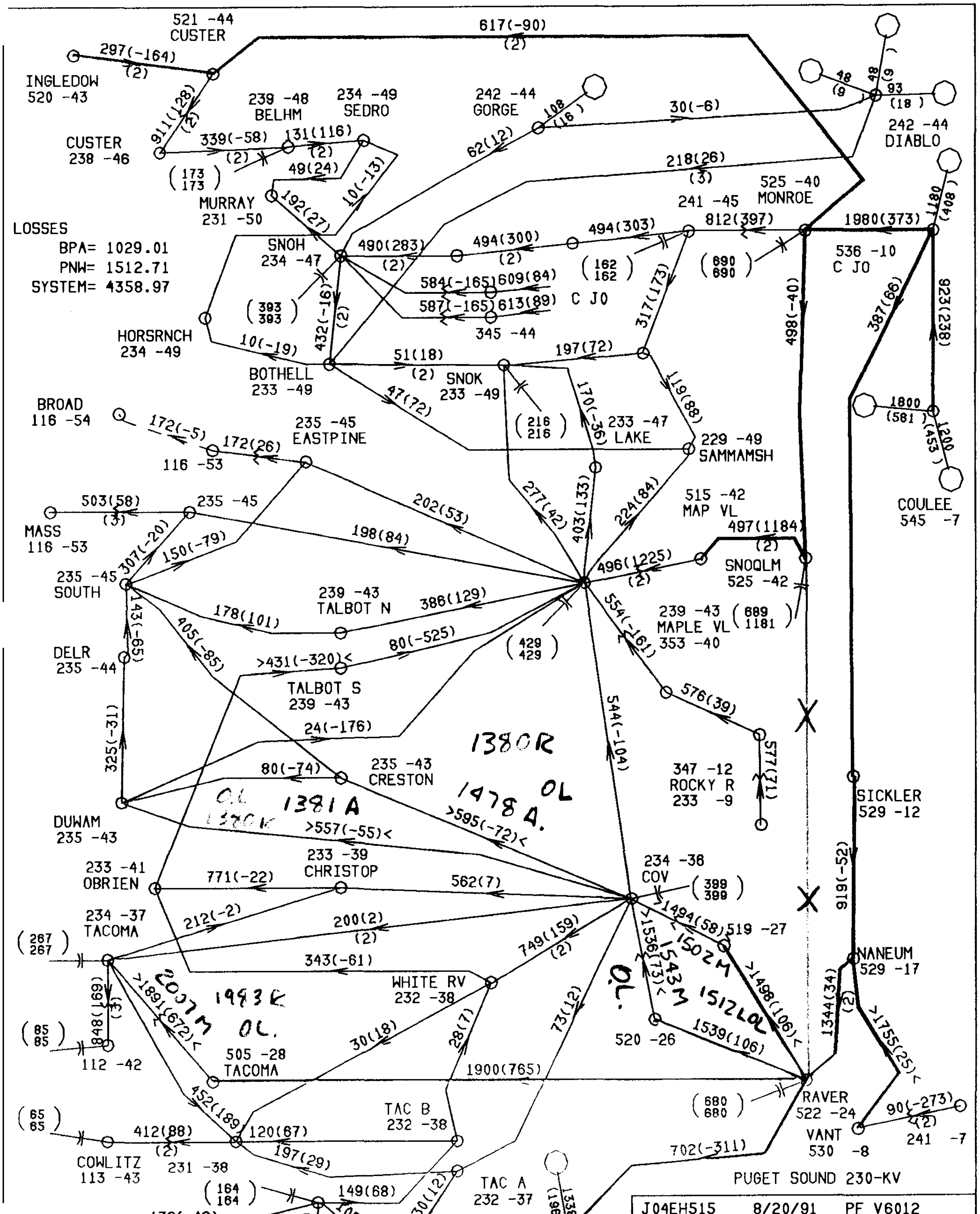
CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1023.	AI= 534.

J04EH510 6/25/91 PF V6010
CY89 ALH-MJL
BASED ON J04EH491
NANEUM - RAVER 3 500 OUT

Full

S:PQ R- , PLOTTED 25-JUN-91 AT 12:14:19 HOURS

PFPLOT PFP334 : REVISED 10/11/90



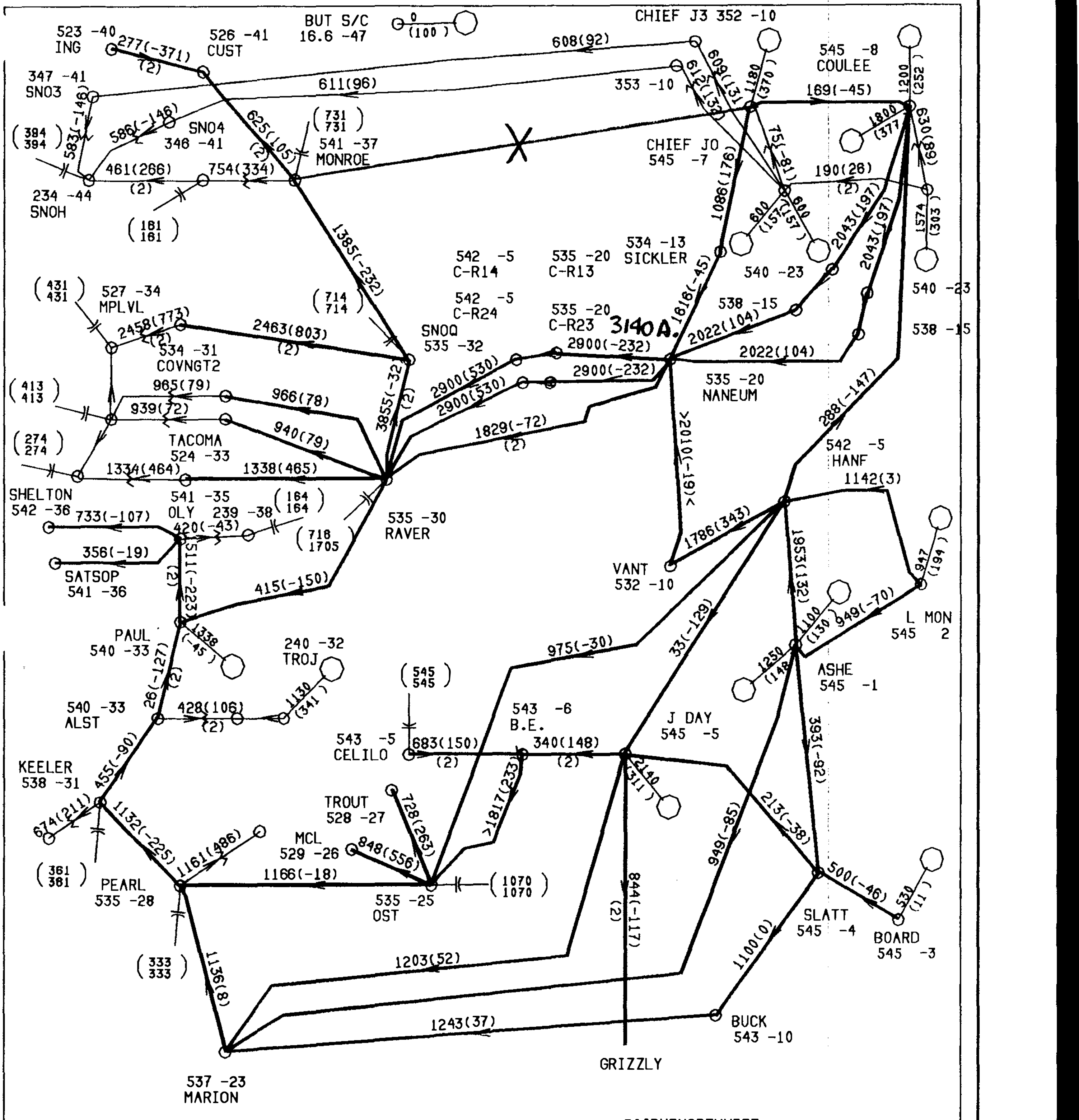
LOSSES
BPA= 1029.01
PNW= 1512.71
SYSTEM= 4358.97

PUGET SOUND 230-KV

J04EH515 8/20/91 PF V6012
CY89 MJL
BASED ON J04EH491
RAVER-SNOQUALMIE OUT

S:PQ R- , PLOTTED 20-AUG-91 AT 16:14:28 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -730.
DC= -1710.

ACTUAL
AC= -952.
DC= -1710.

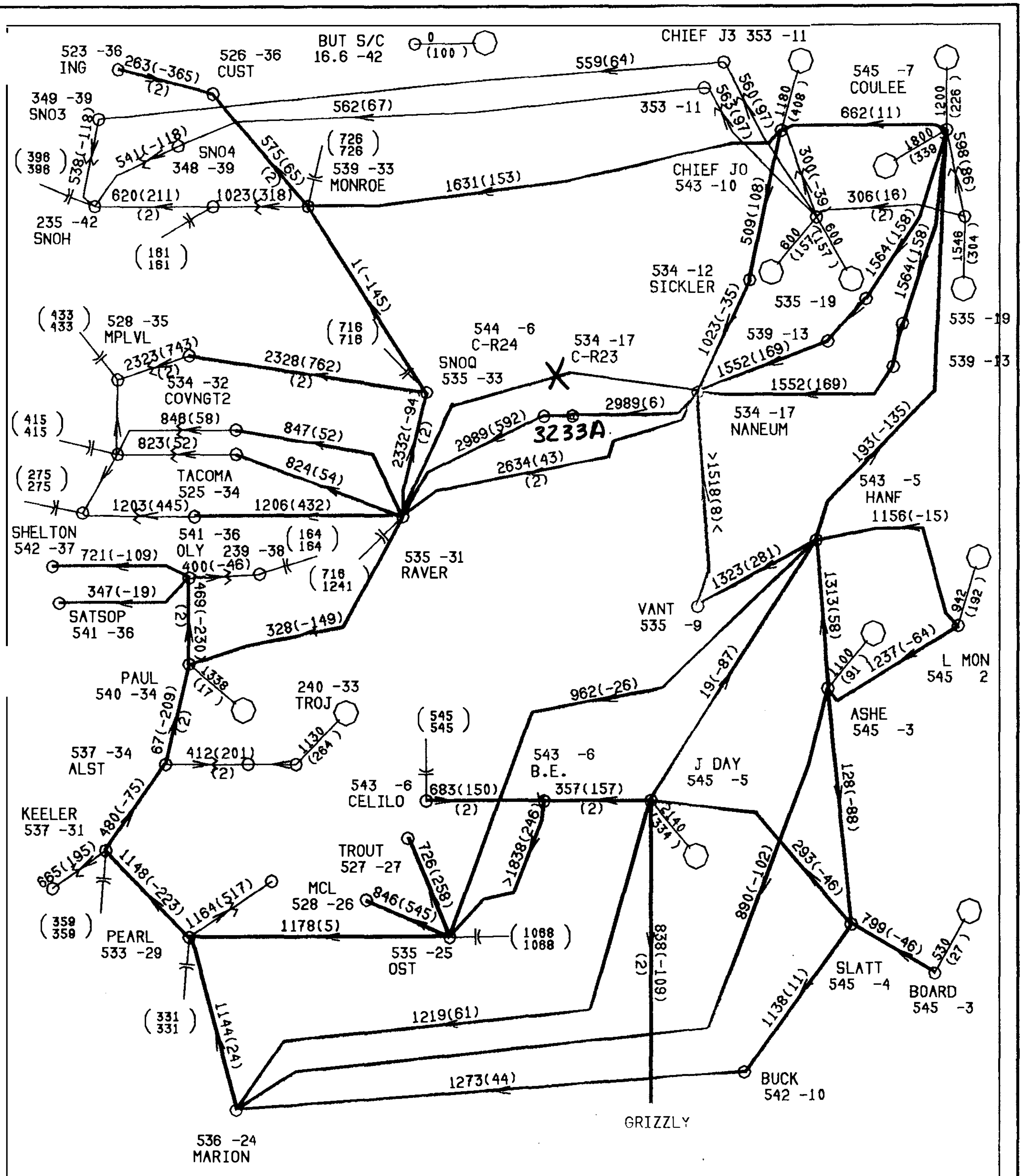
LOSSES
BPA= 1041.99
PNW= 1504.42
SYSTEM= 4345.77

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1023.

IDAHO TO PNW
SI= 480.
AI= 535.

J04EH526 10/ 3/91 PF V6012
CY89 MJL
BASED ON J04EH524
CHIEF JOE-MONROE OUT
26 Ω on Naneum - Raver 3 + 4



500BUSNORTHWEST

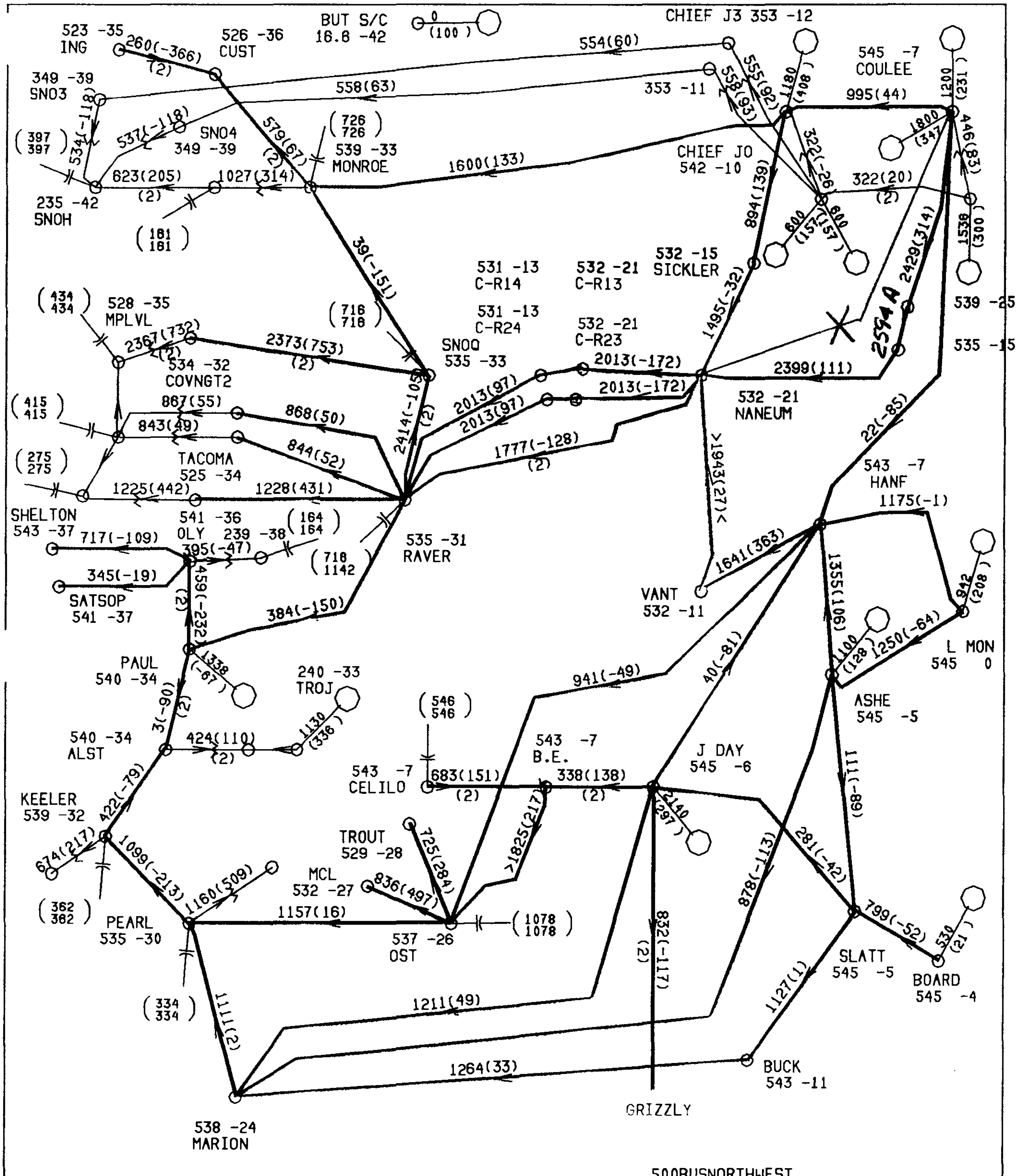
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -956.	BPA= 996.90
DC= -1710.	DC= -1710.	PNW= 1451.38
		SYSTEM= 4290.89

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1014.	AI= 539.

J04EH560 8/14/91 PF V6012
CY89 MJL
BASED ON J04EH559
NANEUM-RAVER #3 OUT

S:PQ R- , PLOTTED 14-AUG-91 AT 14:40:20 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

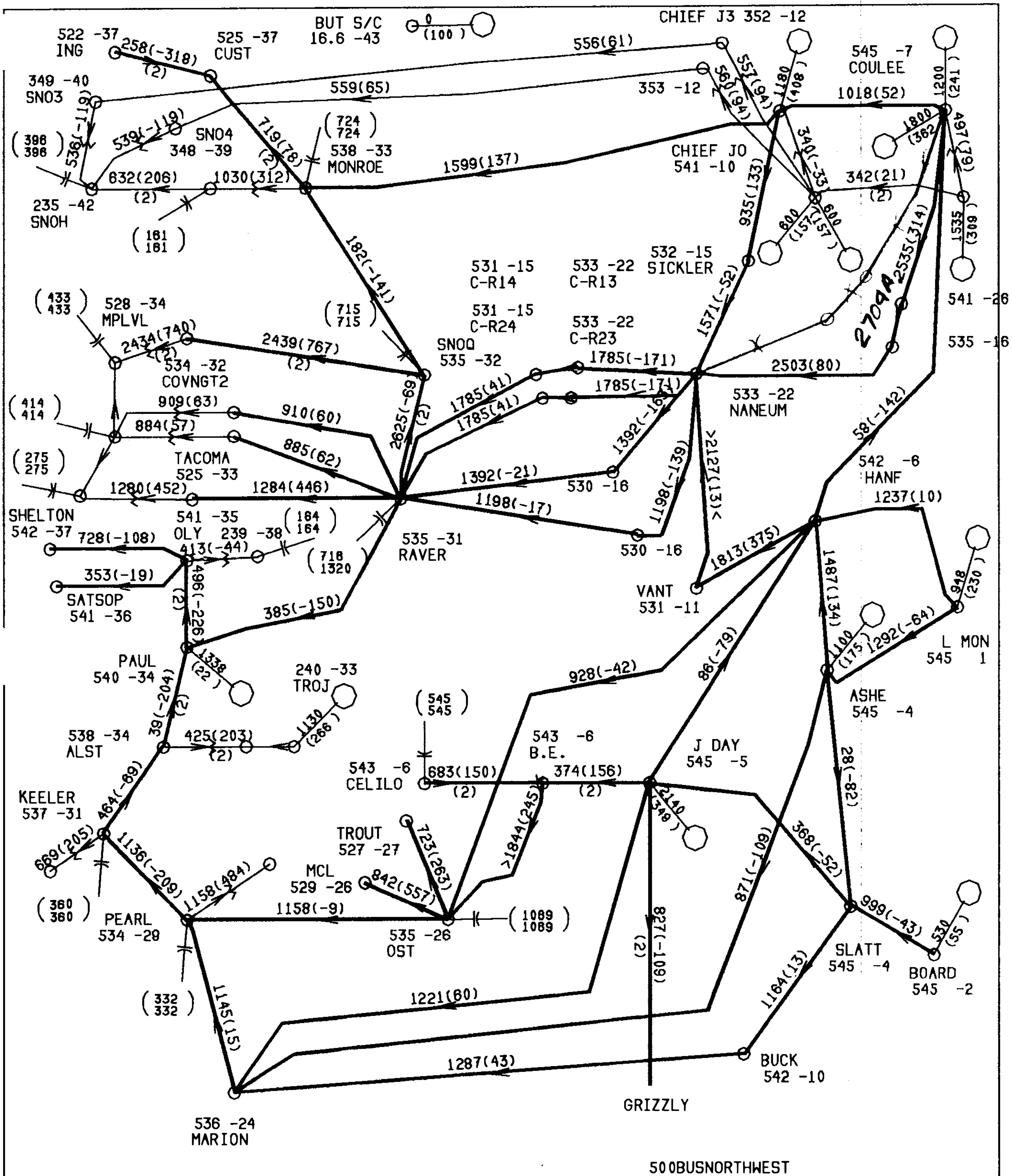
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -957.	BPA= 988.10
DC= -1710.	DC= -1710.	PNW= 1440.22
		SYSTEM= 4279.11

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1300.	SI= 480.
AI= 450.	AI= 1012.	AI= 541.

J04EH561 8/14/91 PF V6012
CY89 MJL
BASED ON J04EH559
COULEE-NANEUM #1 OUT

S:PQ R- , PLOTTED 14-AUG-91 AT 14:42:00 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -730.
DC= -1710.

ACTUAL
AC= -959.
DC= -1710.

LOSSES
BPA= 1018.88
PNW= 1477.67
SYSTEM= 4319.15

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

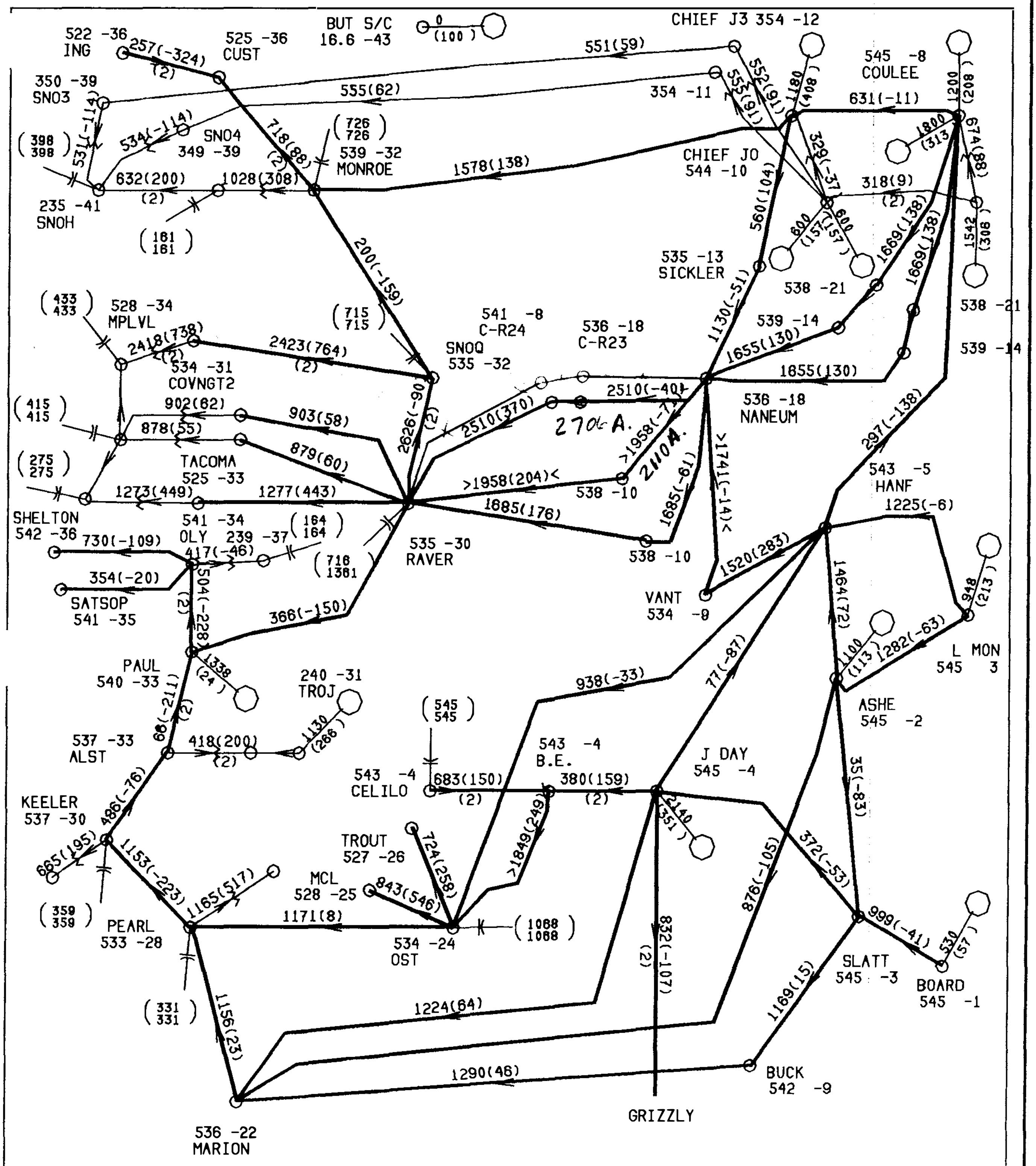
MONT TO PNW
SI= 1300.
AI= 1008.

IDAHO TO PNW
SI= 480.
AI= 543.

J04EH562 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04EH543
COULEE - NANEUM 1 500KV LINE OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:16:44 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -730.
DC= -1710.

ACTUAL
AC= -956.
DC= -1710.

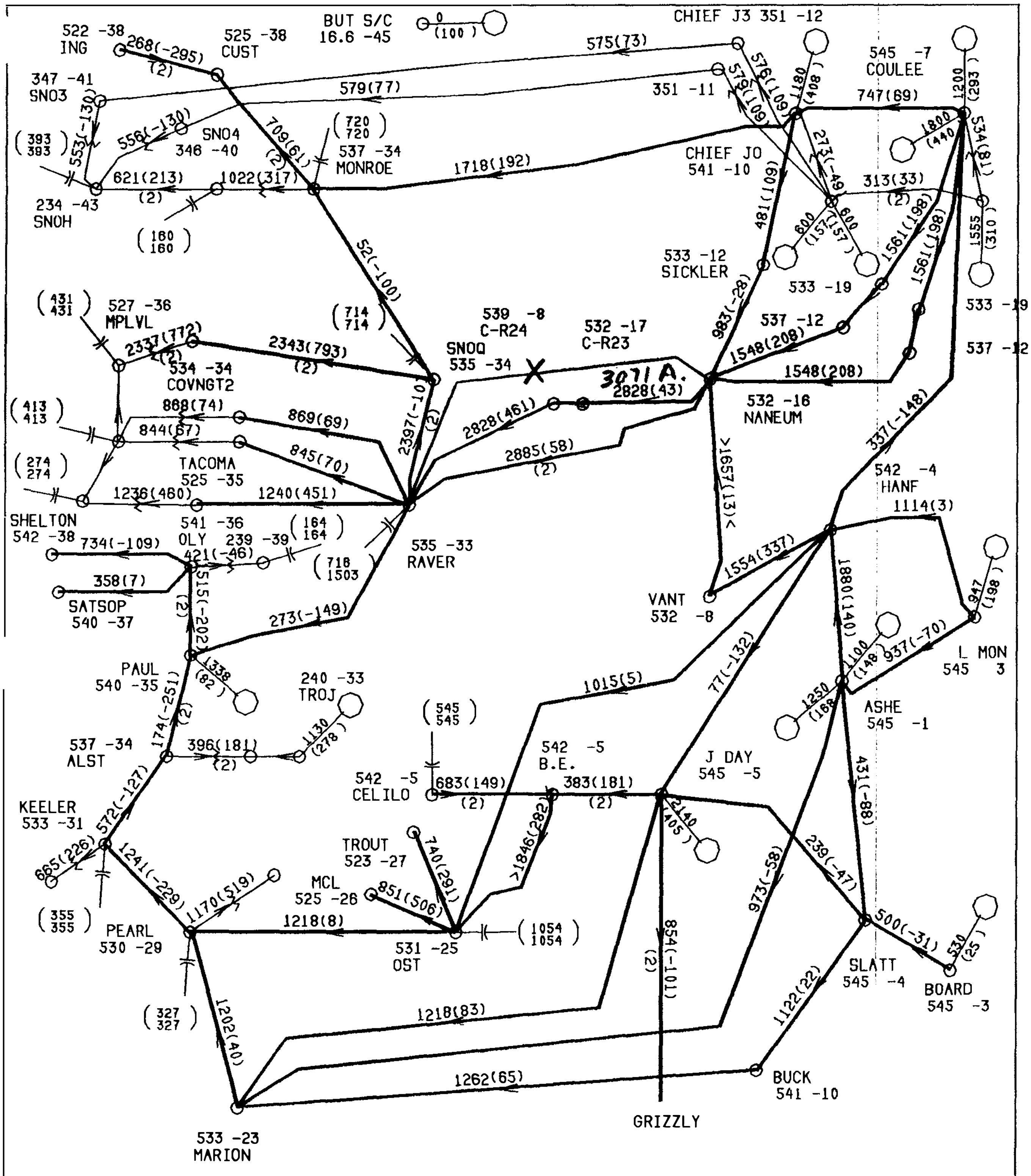
LOSSES
BPA= 1026.14
PNW= 1484.83
SYSTEM= 4324.99

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1014.

IDAHO TO PNW
SI= 480.
AI= 540.

J04EH563 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04EH542
NANEUM - RAVER 3 500KV LINE OUT



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -730.
DC= -1710.

ACTUAL
AC= -953.
DC= -1710.

LOSSES
BPA= 1024.49
PNW= 1485.30
SYSTEM= 4324.90

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

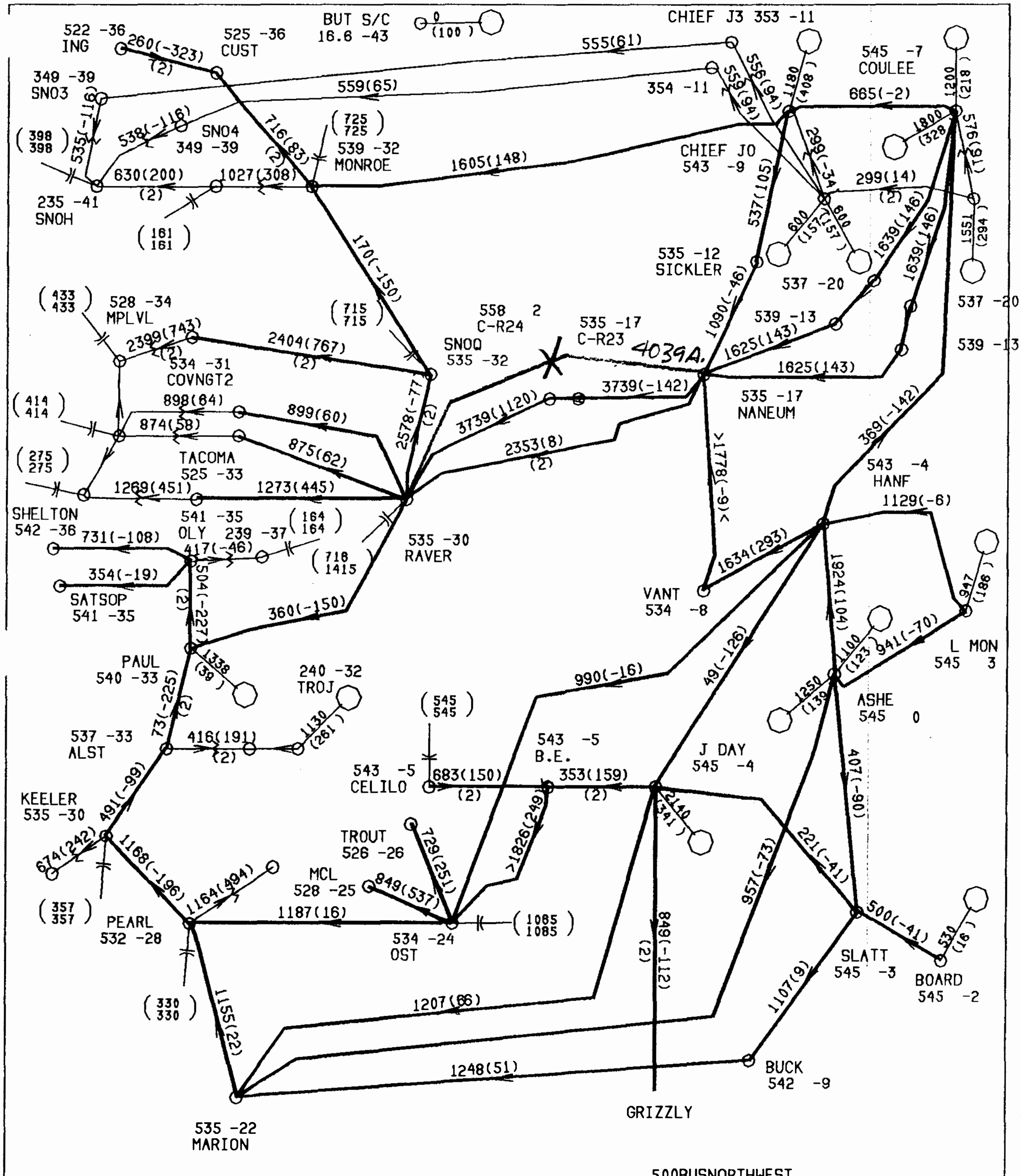
MONT TO PNW
SI= 1300.
AI= 1022.

IDAHO TO PNW
SI= 480.
AI= 535.

J04EH639 10/ 3/91 PF V6012
CY89 MJL
BASED ON J04EH524
NANEUM-RAVER #3 OUT
15 OHMS COMP IN OTHER NANEUM-RAVER LINE

S:PQ R- , PLOTTED 3-OCT-91 AT 11:16:48 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= -730.
DC= -1710.

ACTUAL
AC= -951.
DC= -1710.

LOSSES
BPA= 1026.00
PNW= 1480.20
SYSTEM= 4317.75

J04EH640 10/ 3/91 PF V6012
CY89 MJL
BASED ON J04EH524
NANEUM-RAVER #3 OUT
26 OHMS COMP IN OTHER NANEUM-RAVER LINE

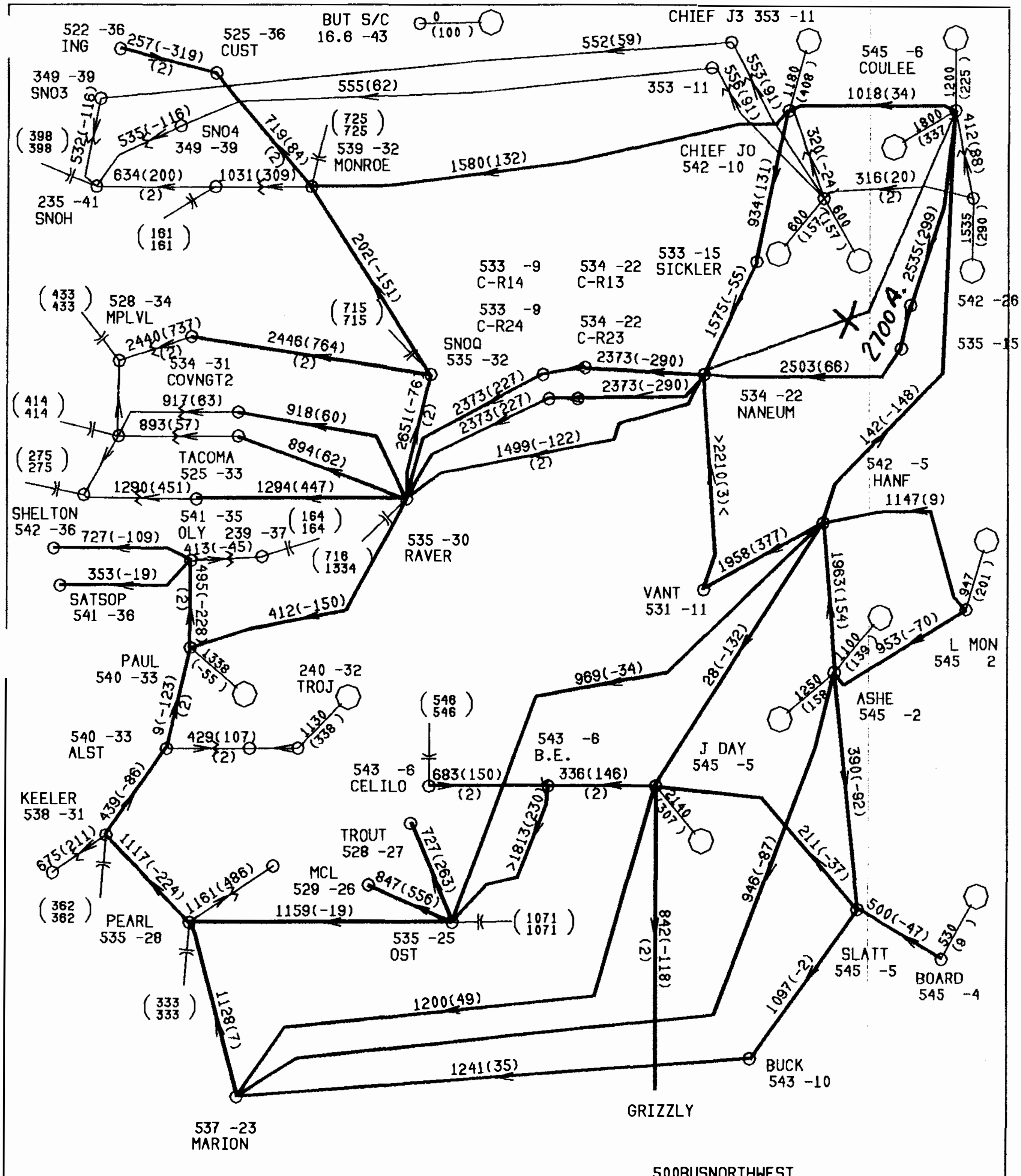
CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1027.

IDAHO TO PNW
SI= 480.
AI= 533.

S:PQ R- , PLOTTED 3-OCT-91 AT 11:15:55 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE   ACTUAL   LOSSES
AC= -730.   AC= -952.   BPA= 1012.15
DC= -1710.   DC= -1710.   PNW= 1465.17
SYSTEM= 4302.49

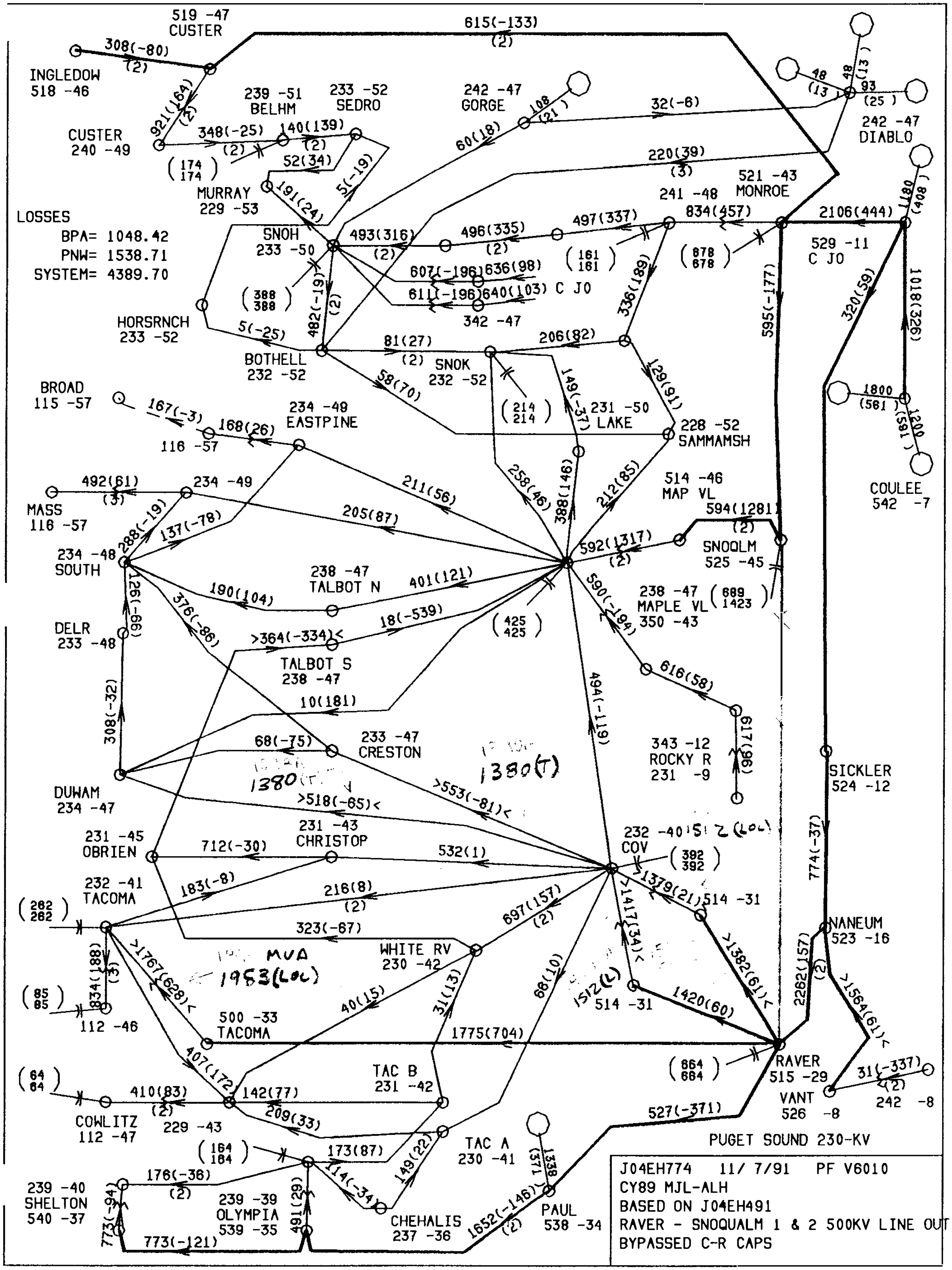
CANADA TO PNW (BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1021.

IDAHO TO PNW
SI= 480.
AI= 536.

J04EH641 10/ 3/91 PF V6012
CY89 MJL
BASED ON J04EH524
COULEE--NANEUM #1 OUT
26 OHMS COMP IN NANEUM-RAVER LINES

S:PQ R- , PLOTTED 3-OCT-91 AT 11:14:52 HOURS   PFPLOT PFP334 : REVISED 10/11/90

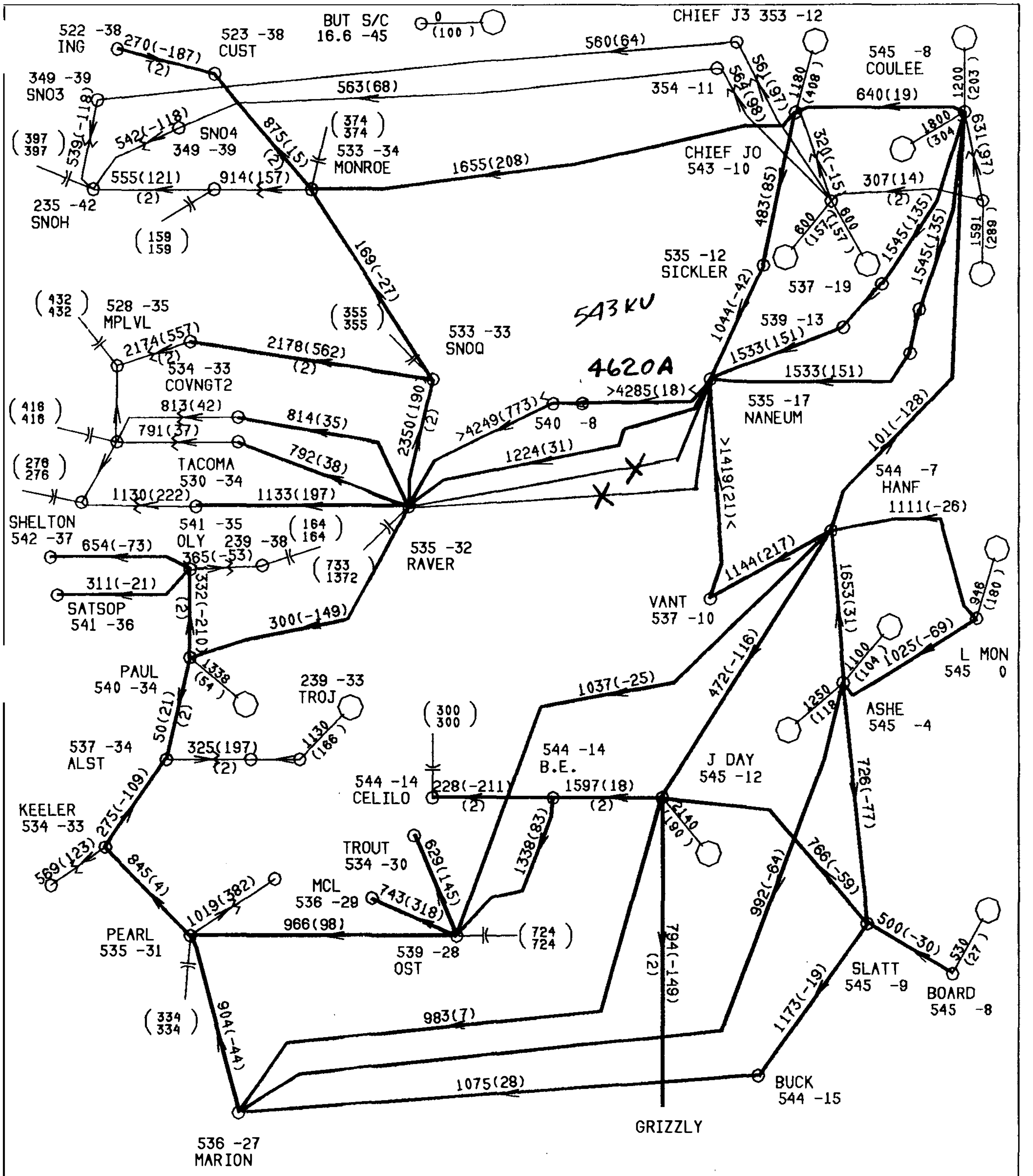


LOSSES
BPA= 1048.42
PNW= 1538.71
SYSTEM= 4389.70

PUGET SOUND 230-KV

J04EH774 11/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH491
RAVER - SNOQUALM 1 & 2 500KV LINE OUT
BYPASSED C-R CAPS

S:PQ R- , PLOTTED 7-NOV-91 AT 12:35:55 HOURS PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE ACTUAL LOSSES
AC= 0. AC= -282. BPA= 815.24
DC= 557. DC= 557. PNW= 1206.60
SYSTEM= 3941.40

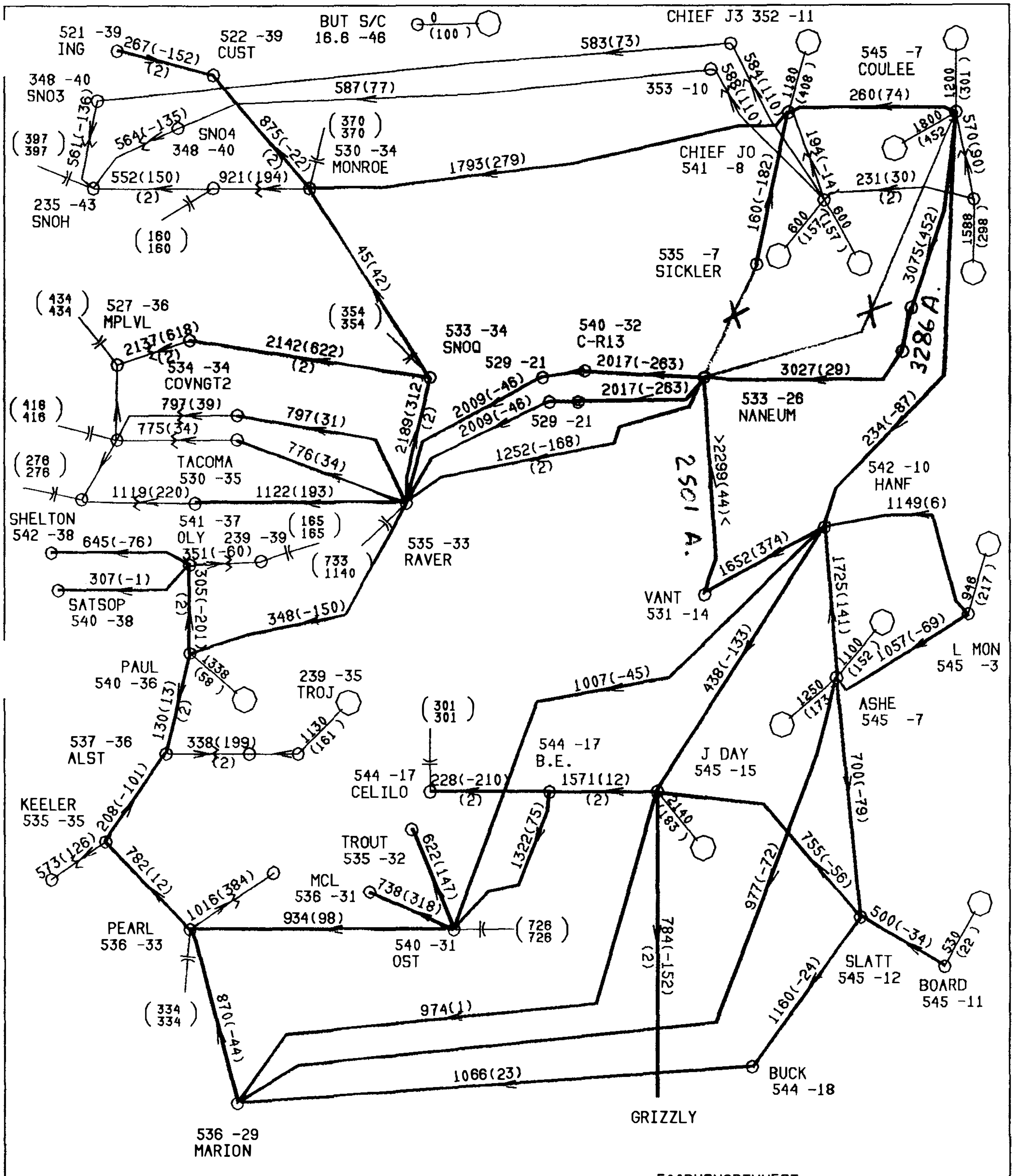
CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 988.

IDAHO TO PNW
SI= 700.
AI= 680.

J04755 6/25/91 PF V6010
CY89 ALH-MJL
BASED ON J04741
NANEUM-RAVER 1 AND 3 LINES OUT

Full Naneum Bus



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= 557.

ACTUAL
AC= -285.
DC= 557.

LOSSES
BPA= 803.12
PNW= 1203.79
SYSTEM= 3938.20

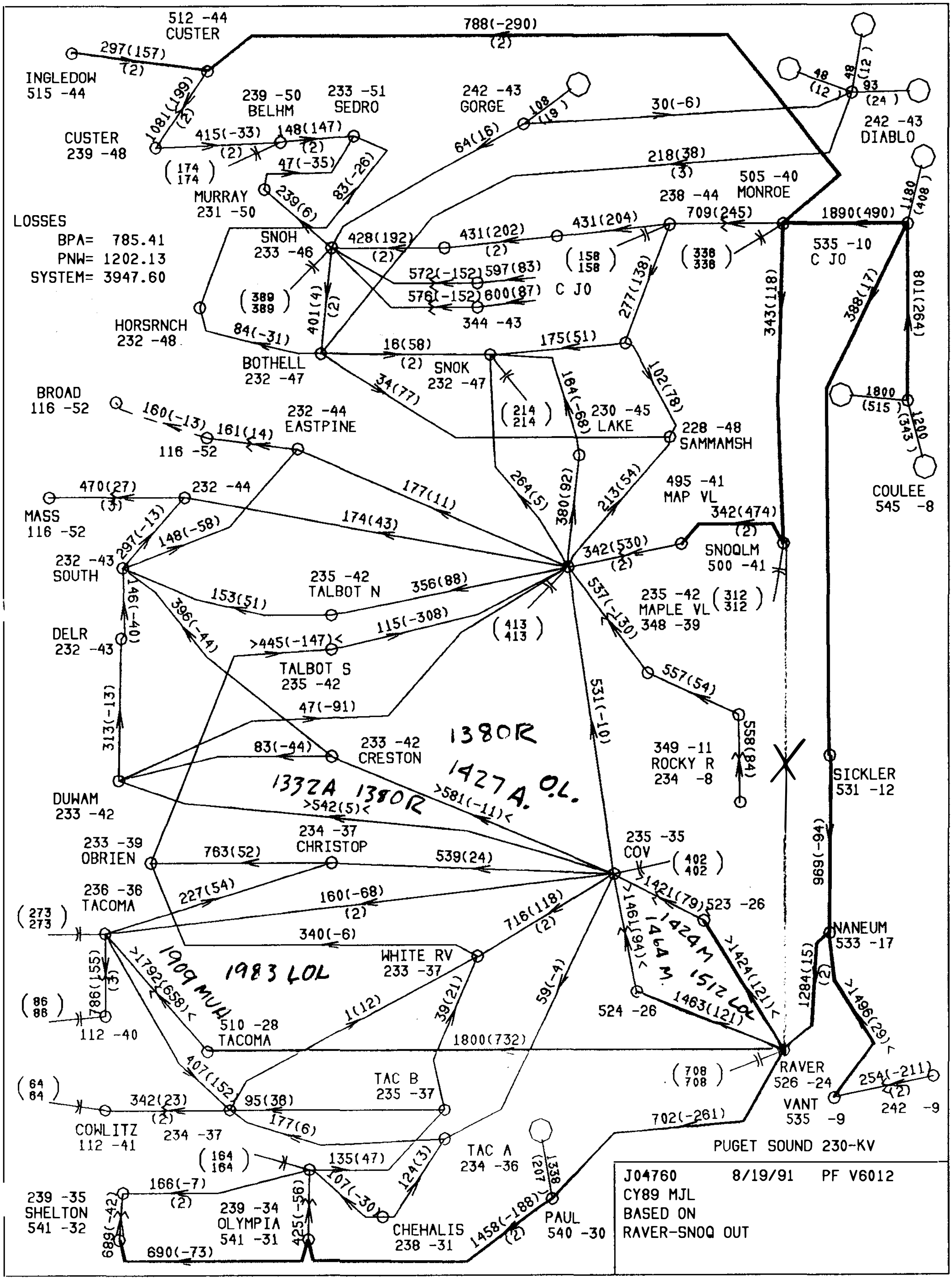
CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 980.

IDAHO TO PNW
SI= 700.
AI= 684.

J04757 6/27/91 PF V6012
CY89 ALH-MJL
BASED ON J04741
SICKLER-NANEUM AND COULEE-NANEUM OUT
CR11, CR12

Full Bus

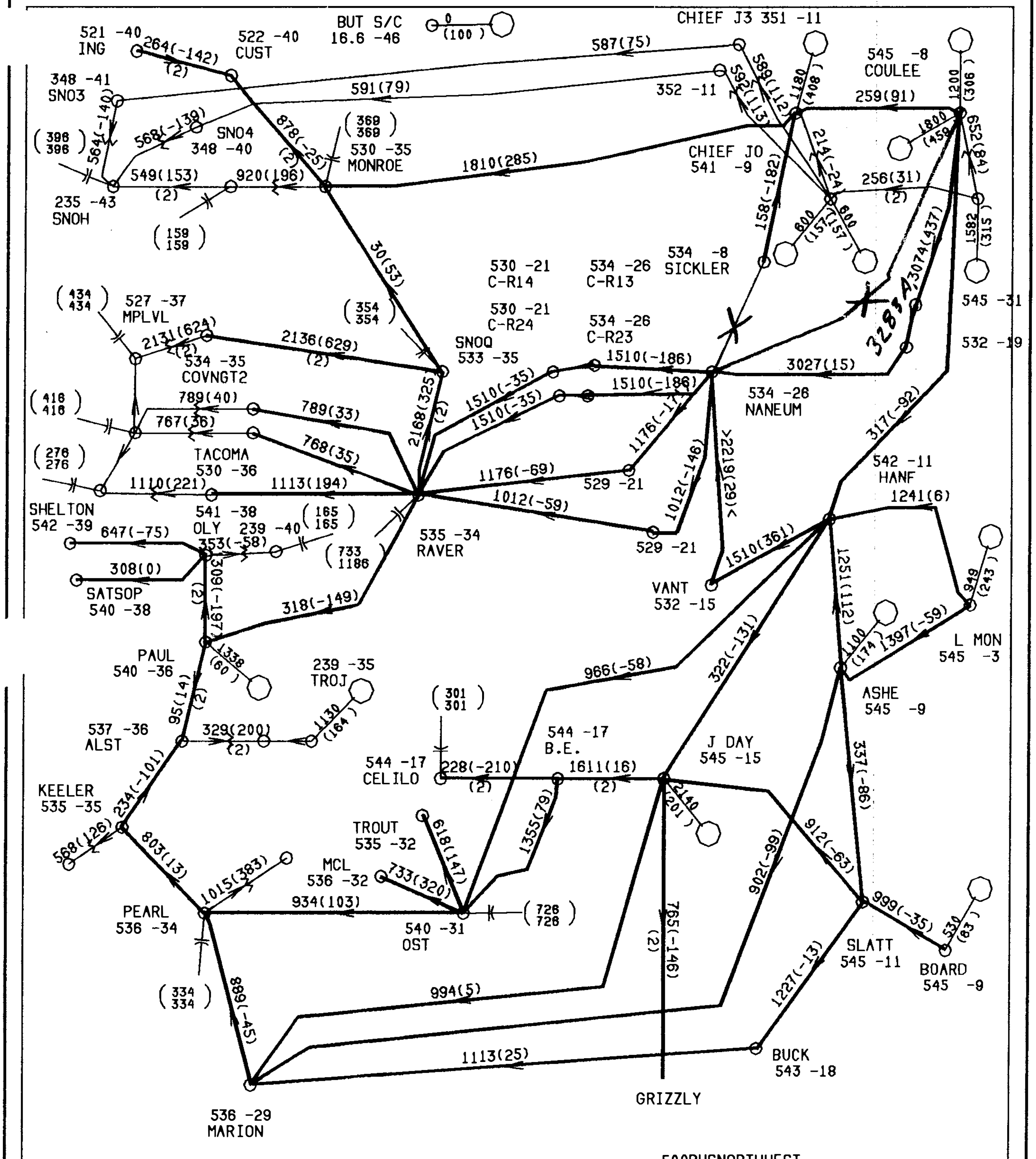


LOSSES
BPA= 785.41
PNW= 1202.13
SYSTEM= 3947.60

PUGET SOUND 230-KV

J04760 8/19/91 PF V6012
CY89 MJL
BASED ON
RAVER-SNOQ OUT

S:PQ R- , PLOTTED 19-AUG-91 AT 15:50:57 HOURS PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

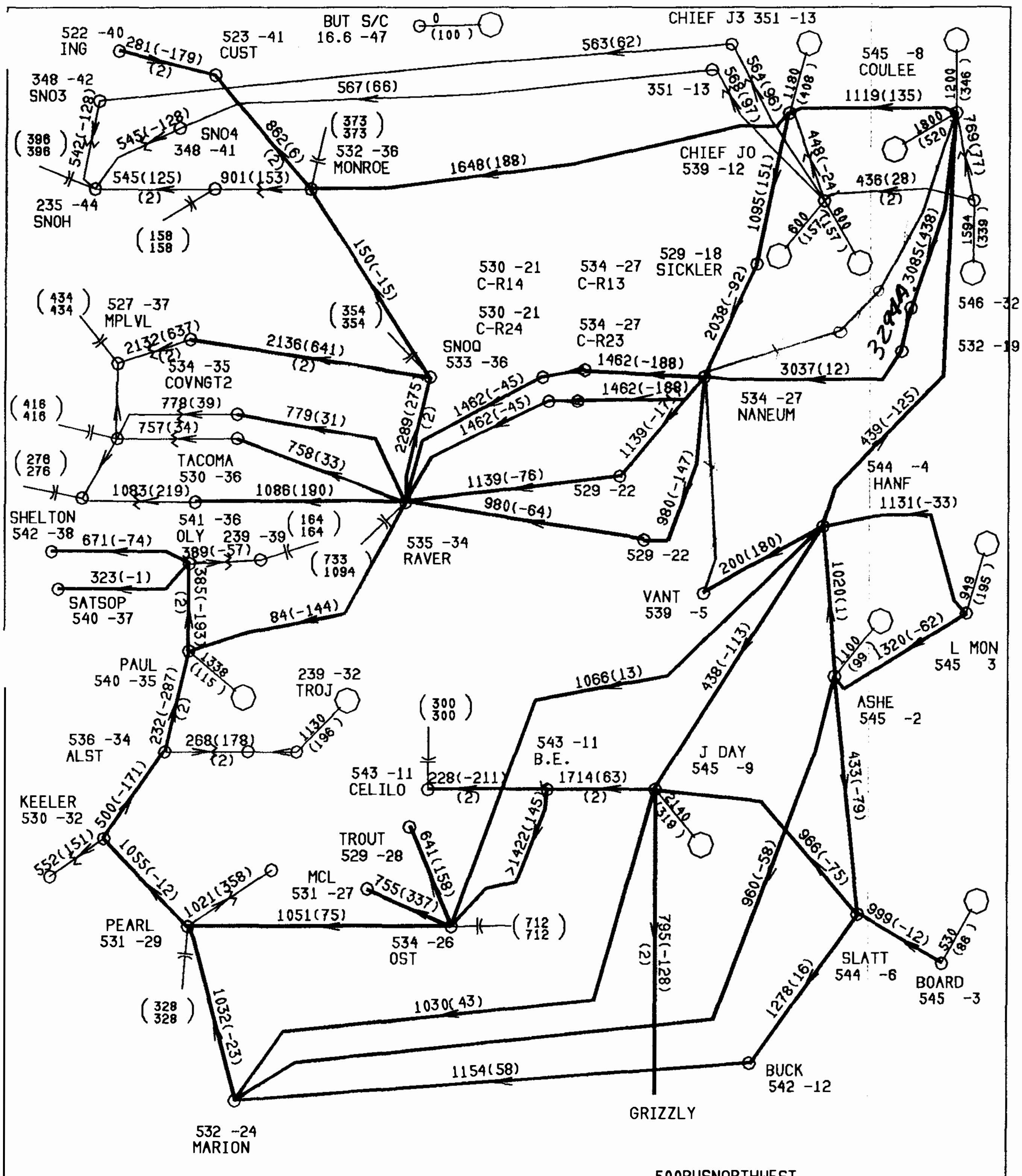
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -295.	BPA= 810.49
DC= 557.	DC= 557.	PNW= 1216.94
		SYSTEM= 3957.48

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 958.	AI= 696.

J04813 10/ 2/91 PF V6012
CY89 ALH-MJL
BASED ON J04788
SICKLER-NANEUM OUT
COULEE-NANEUM #1 OUT

S:PQ R- , PLOTTED 2-OCT-91 AT 14:11:49 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

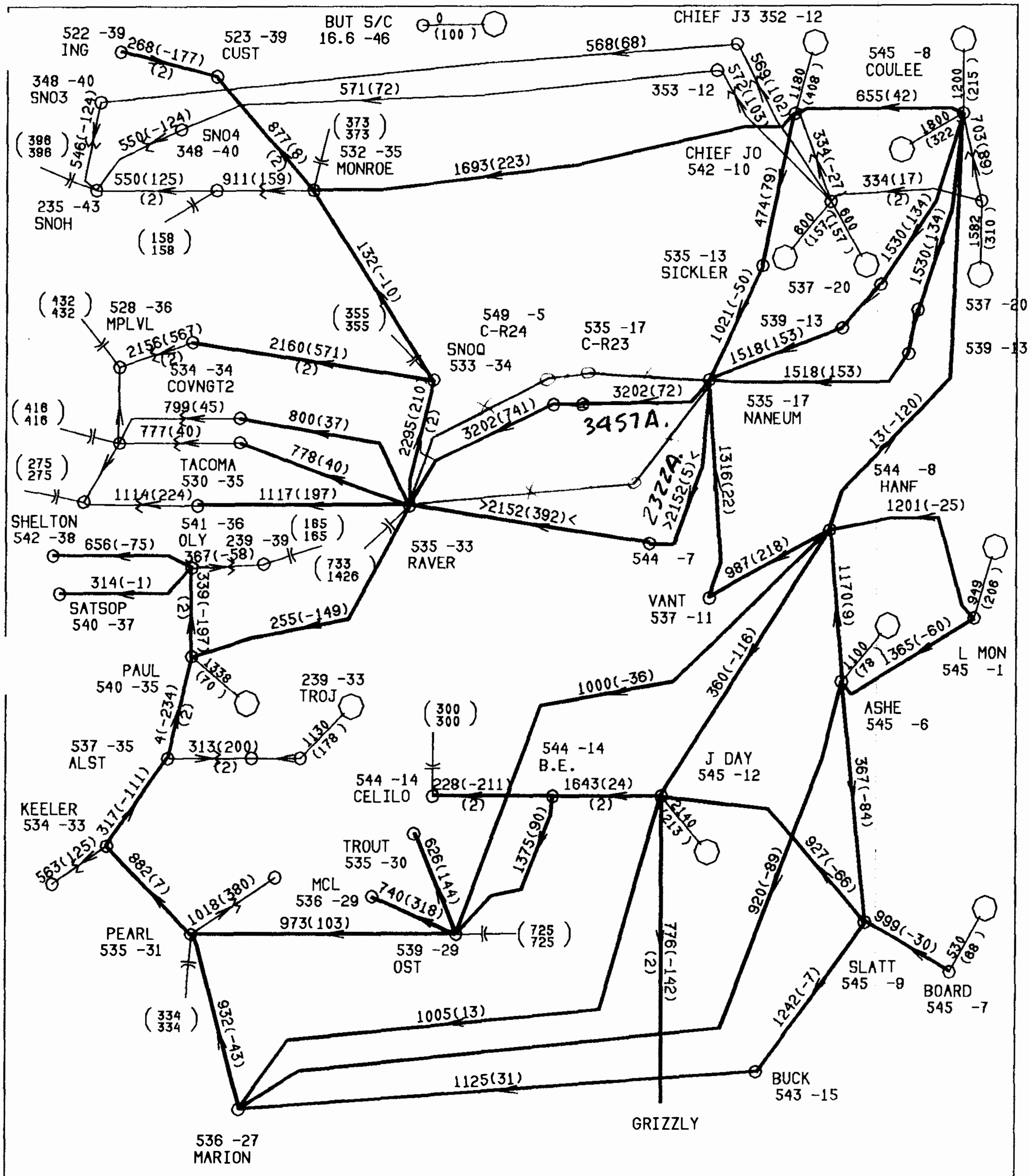
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -291.	BPA= 824.76
DC= 557.	DC= 557.	PNW= 1228.84
		SYSTEM= 3972.32

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 972.	AI= 687.

J04814 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04788
VANTAGE - NANEUM 500KV LINE OUT
COULEE - NANEUM 1 500KV LINE OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:34:37 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= 557.

ACTUAL
AC= -293.
DC= 557.

LOSSES
BPA= 817.80
PNW= 1216.78
SYSTEM= 3956.65

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

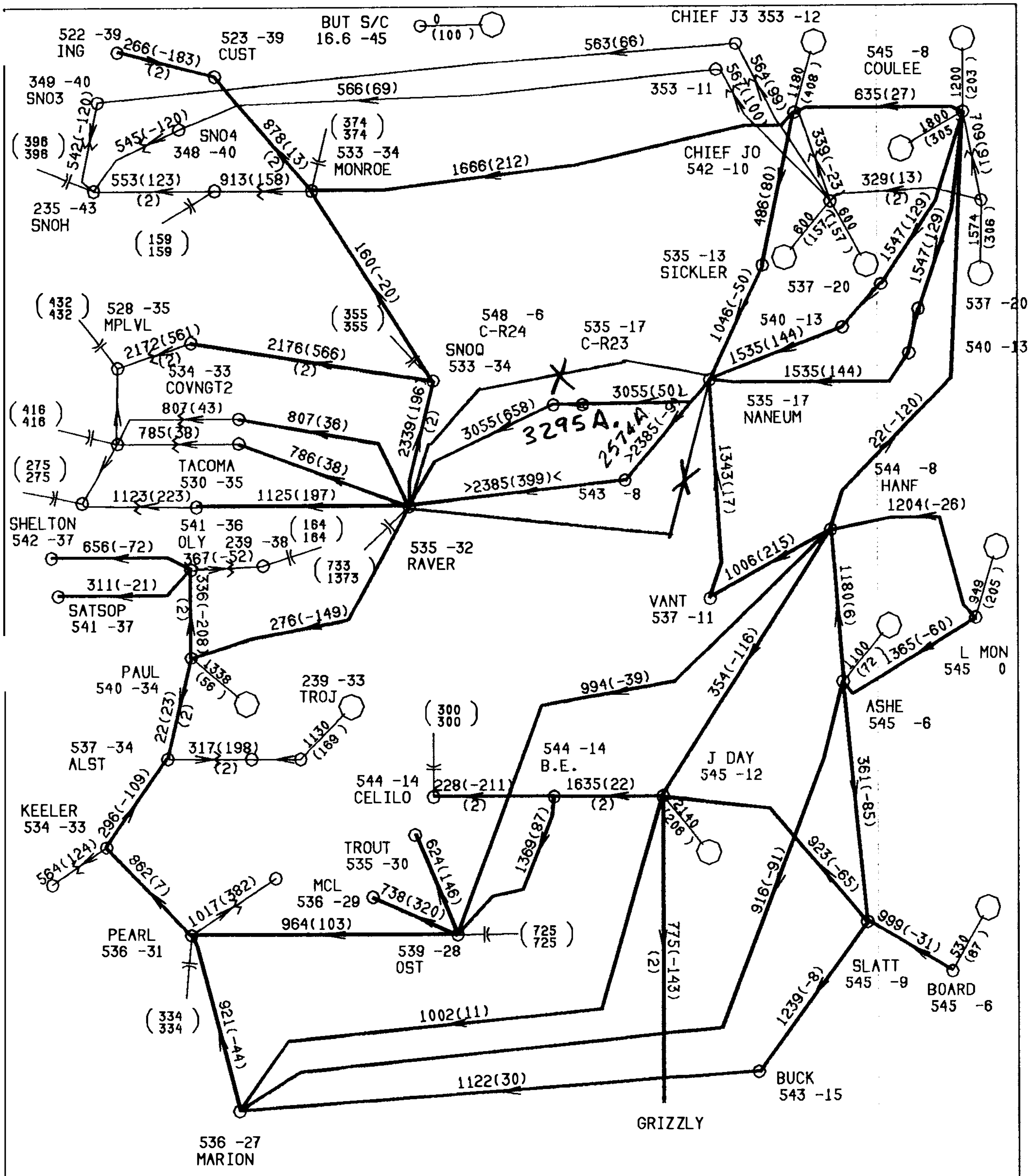
MONT TO PNW
SI= 1250.
AI= 966.

IDAHO TO PNW
SI= 700.
AI= 692.

J04815 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04788
NANEUM - RAVER 1 500KV LINE OUT
NANEUM - RAVER 3 500KV LINE OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:35:32 HOURS

PFPLOT PFP334 : REVISED 10/11/90

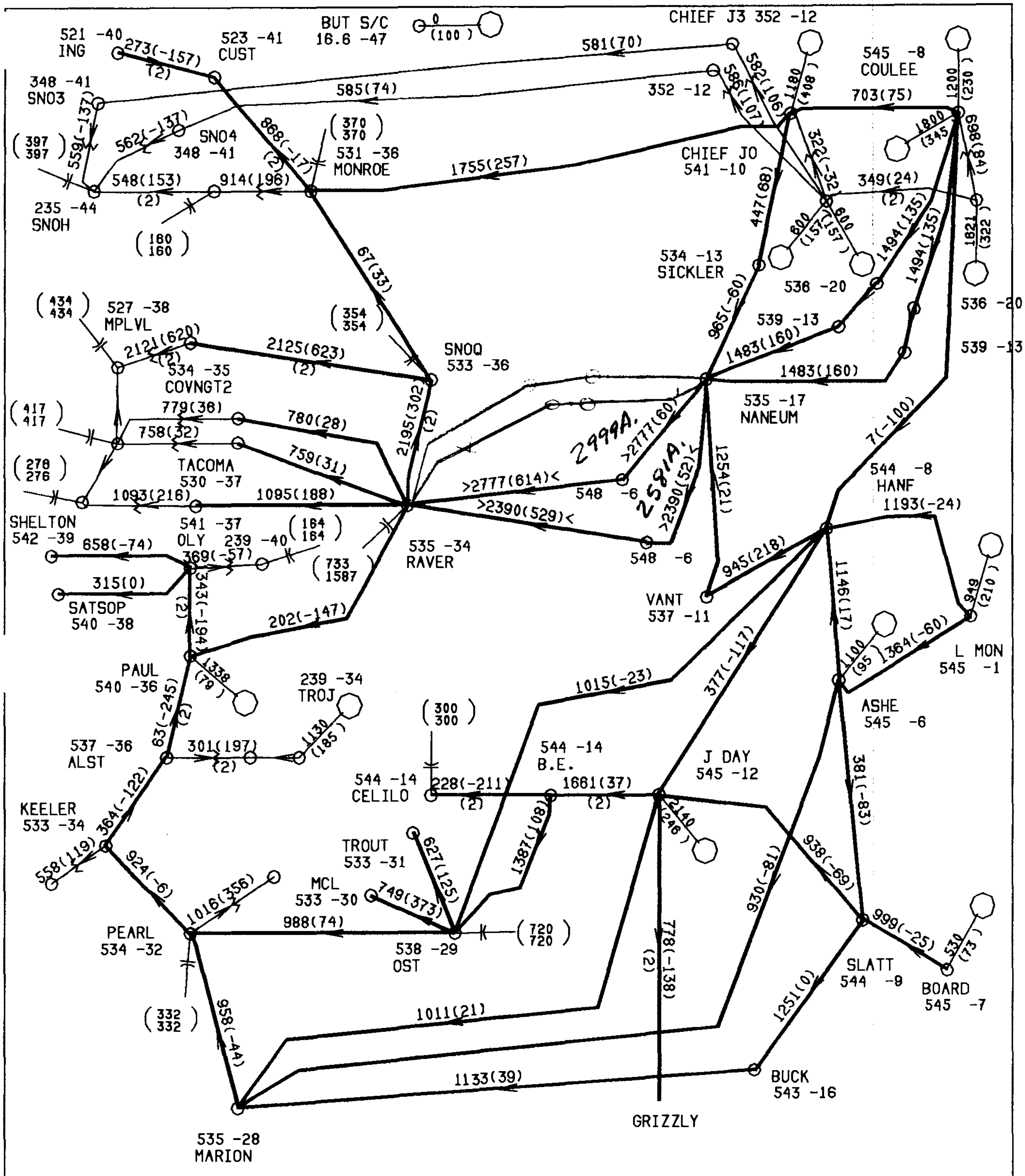


500BUSNORTHWEST

INTERTIE	SCHEDULE	ACTUAL	LOSSES
AC=	0.	AC= -292.	BPA= 811.06
DC=	557.	DC= 557.	PNW= 1208.79
			SYSTEM= 3948.87

J04816 10/ 2/91 PF V6012
CY89 ALH-MJL
BASED ON J04788
NANEUM-RAVER #2 AND #3 OUT

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 966.	AI= 692.



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= 557.

ACTUAL
AC= -294.
DC= 557.

LOSSES
BPA= 854.31
PNW= 1256.02
SYSTEM= 3997.45

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

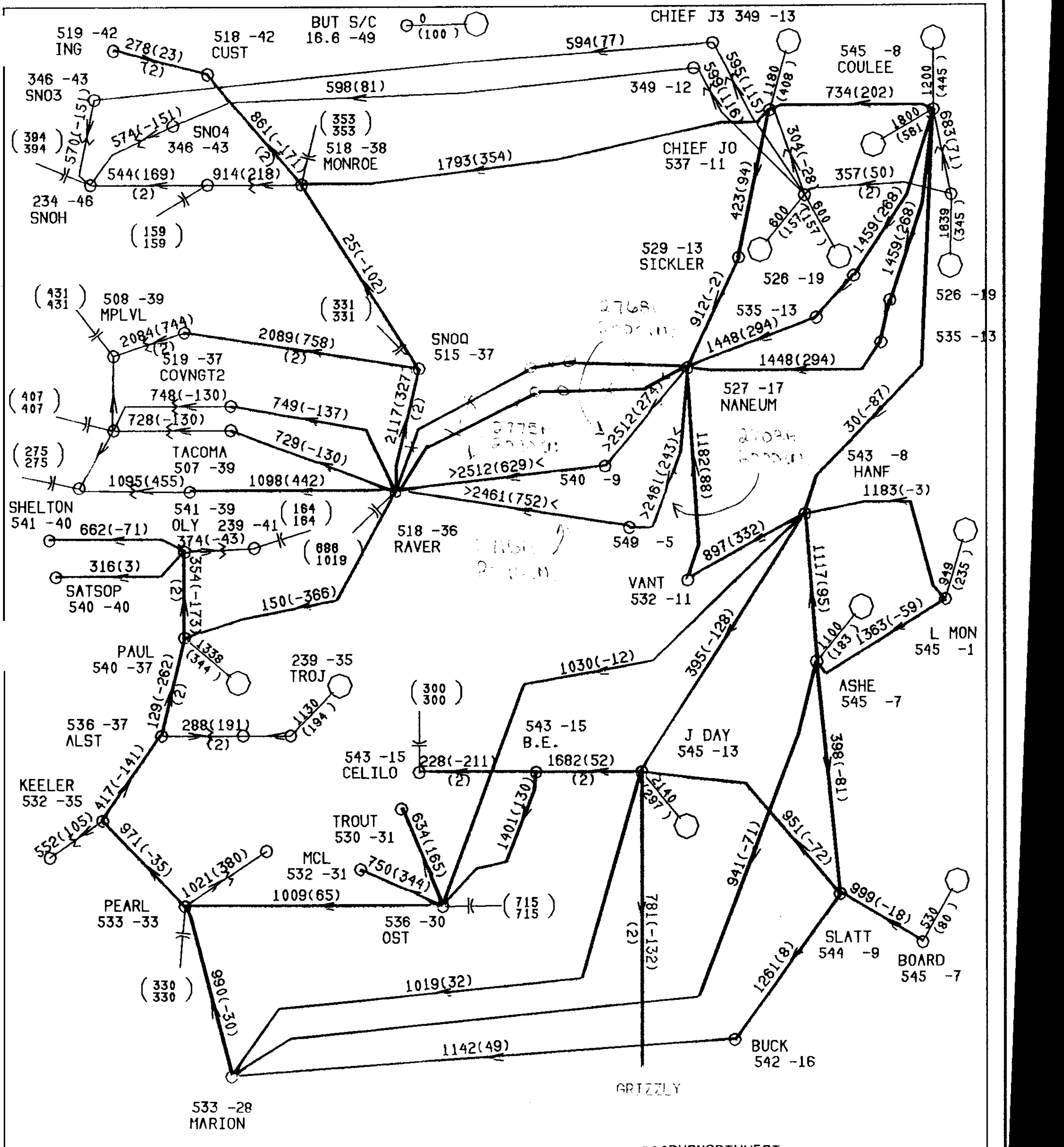
MONT TO PNW
SI= 1250.
AI= 964.

IDAHO TO PNW
SI= 700.
AI= 692.

J04824 10/ 1/91 PF V6010
CY89 MJL
BASED ON J04788
NANEUM - RAVER 3&4 500KV LINES OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:33:43 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= 557.

ACTUAL
AC= -295.
DC= 557.

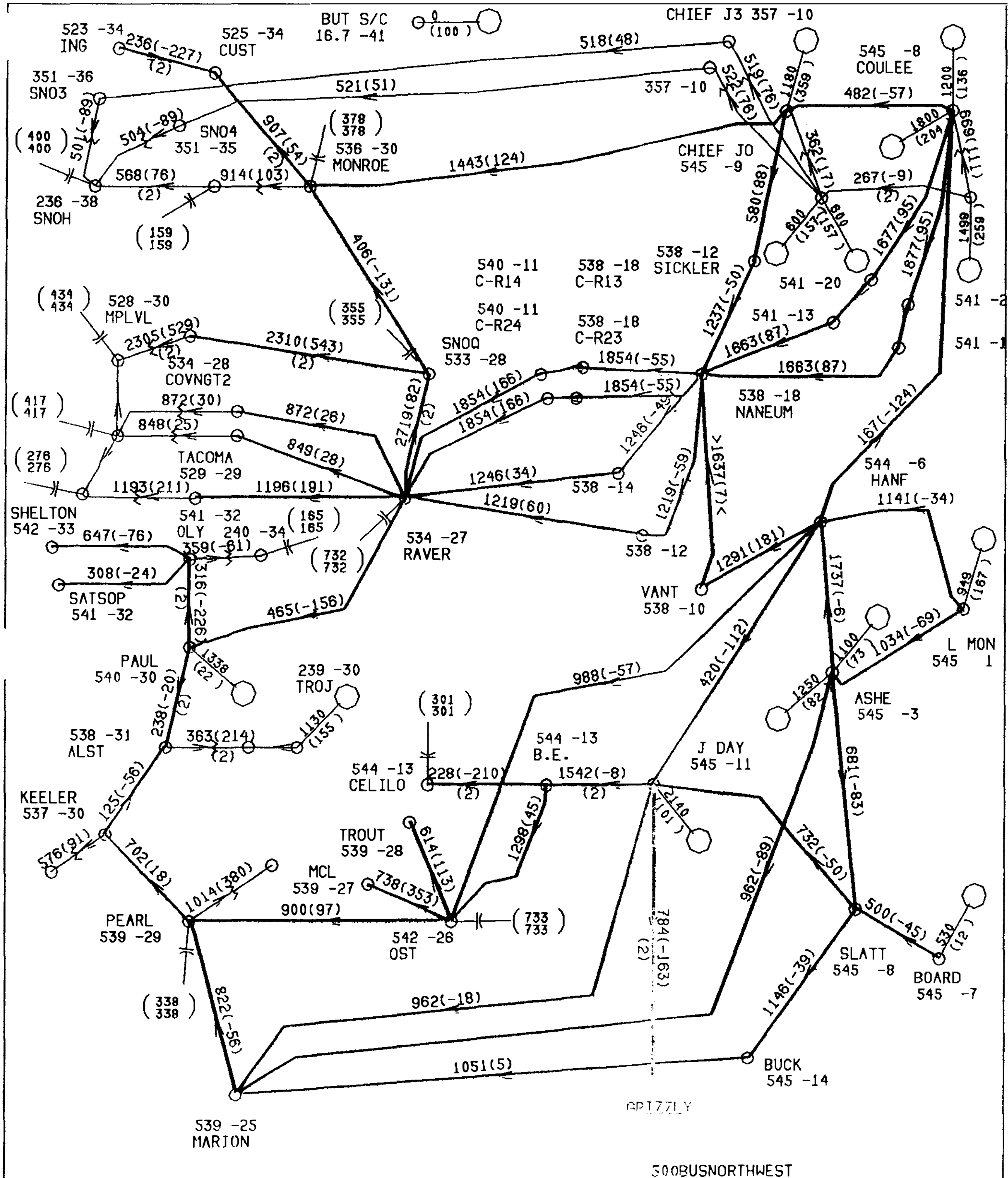
LOSSES
BPA= 867.41
PNW= 1273.53
SYSTEM= 4019.89

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 962.

IDAHO TO PNW
SI= 700.
AI= 692.

J04828 8/26/91 PF V6010
CY89 ALH-MJL
BASED ON J04825
NANEUM - RAVER 3&4 OUT



500BUSNORTHWEST

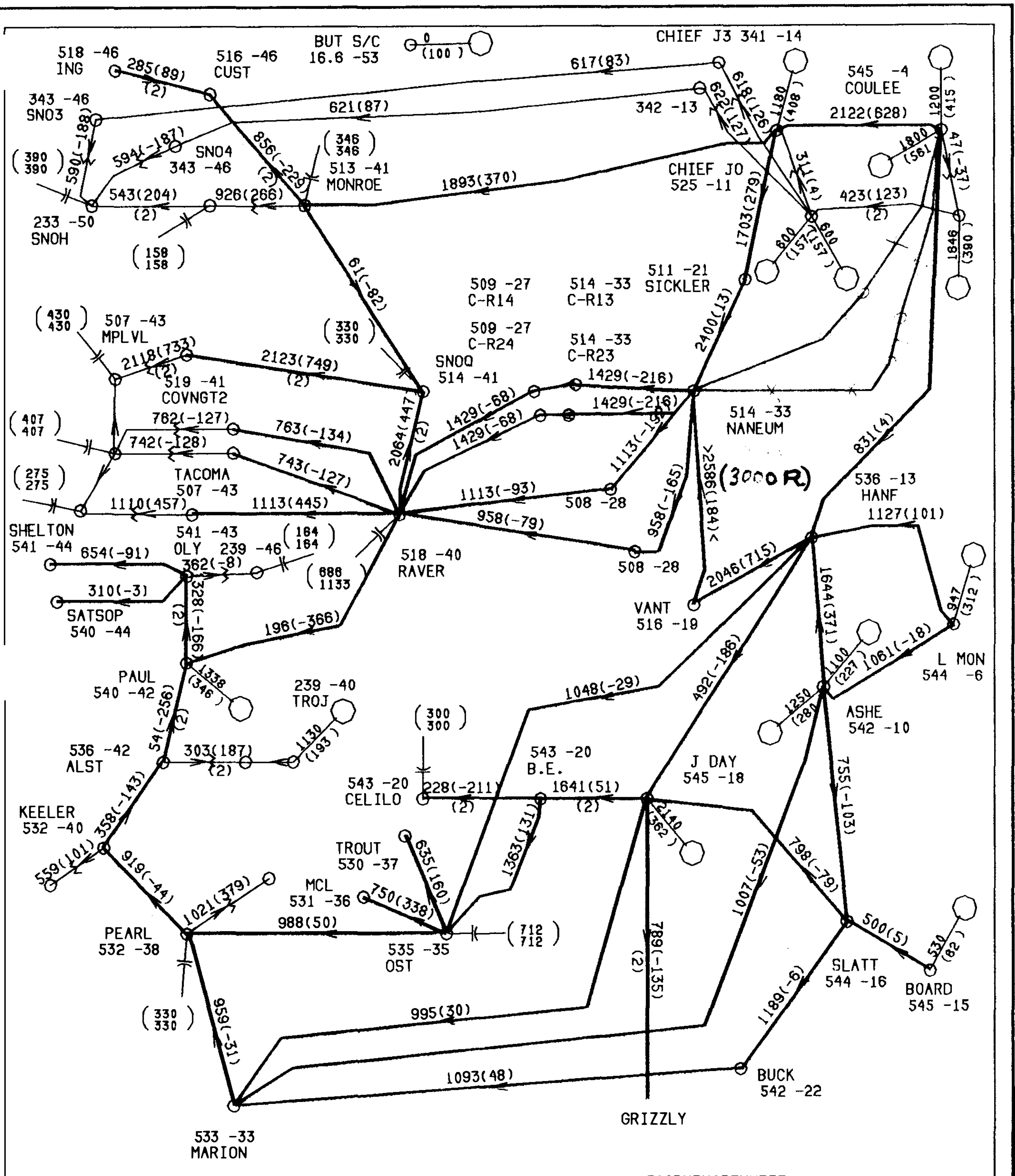
INTERTIE SCHEDULE		ACTUAL		LOSSES	
AC=	0.	AC=	-279.	BPA=	738.58
DC=	557.	DC=	557.	PNW=	1123.21
				SYSTEM=	3852.06

CANADA TO PNW (BCH & WKOOT)		MONT TO PNW		IDAHO TO PNW	
SI=	450.	SI=	1250.	SI=	700.
AI=	450.	AI=	991.	AI=	680.

J04829 8/26/91 PF V6010
CY89 ALH-MJL
BASED ON J04632
NANEUM SWITCHYARD
30% COMP ON SICKLER-RAVER
20% COMP ON COULEE-RAVER
39% COMP ON VANTAGE-RAVER

S:PQ R- , PLOTTED 26-AUG-91 AT 16:23:20 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= 557.

ACTUAL
AC= -292.
DC= 557.

LOSSES
BPA= 859.25
PNW= 1264.47
SYSTEM= 4009.09

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

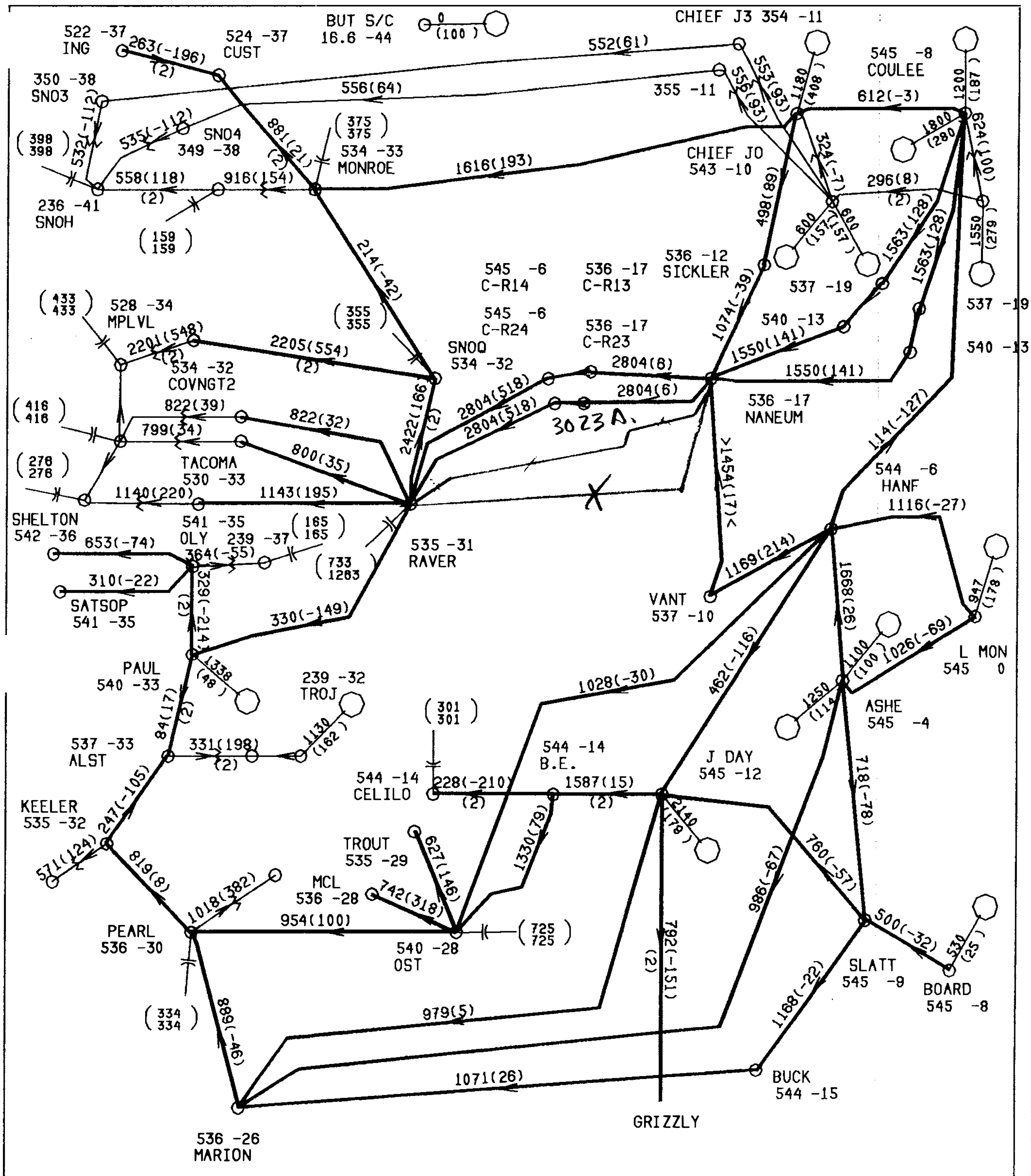
MONT TO PNW
SI= 1250.
AI= 969.

IDAHO TO PNW
SI= 700.
AI= 689.

J04908 9/26/91 PF V6010
CY89 ALH-MJL
BASED ON J04905
BOTH COULEE-NANEUM LINES OUT

S:PQ R- , PLOTTED 26-SEP-91 AT 13:27:12 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE   ACTUAL   LOSSES
AC= 0.   AC= -282.   BPA= 778.56
DC= 557.   DC= 557.   PNW= 1168.41
SYSTEM= 3901.17

CANADA TO PNW (BCH & WKOOT)
SI= 450.
AI= 450.

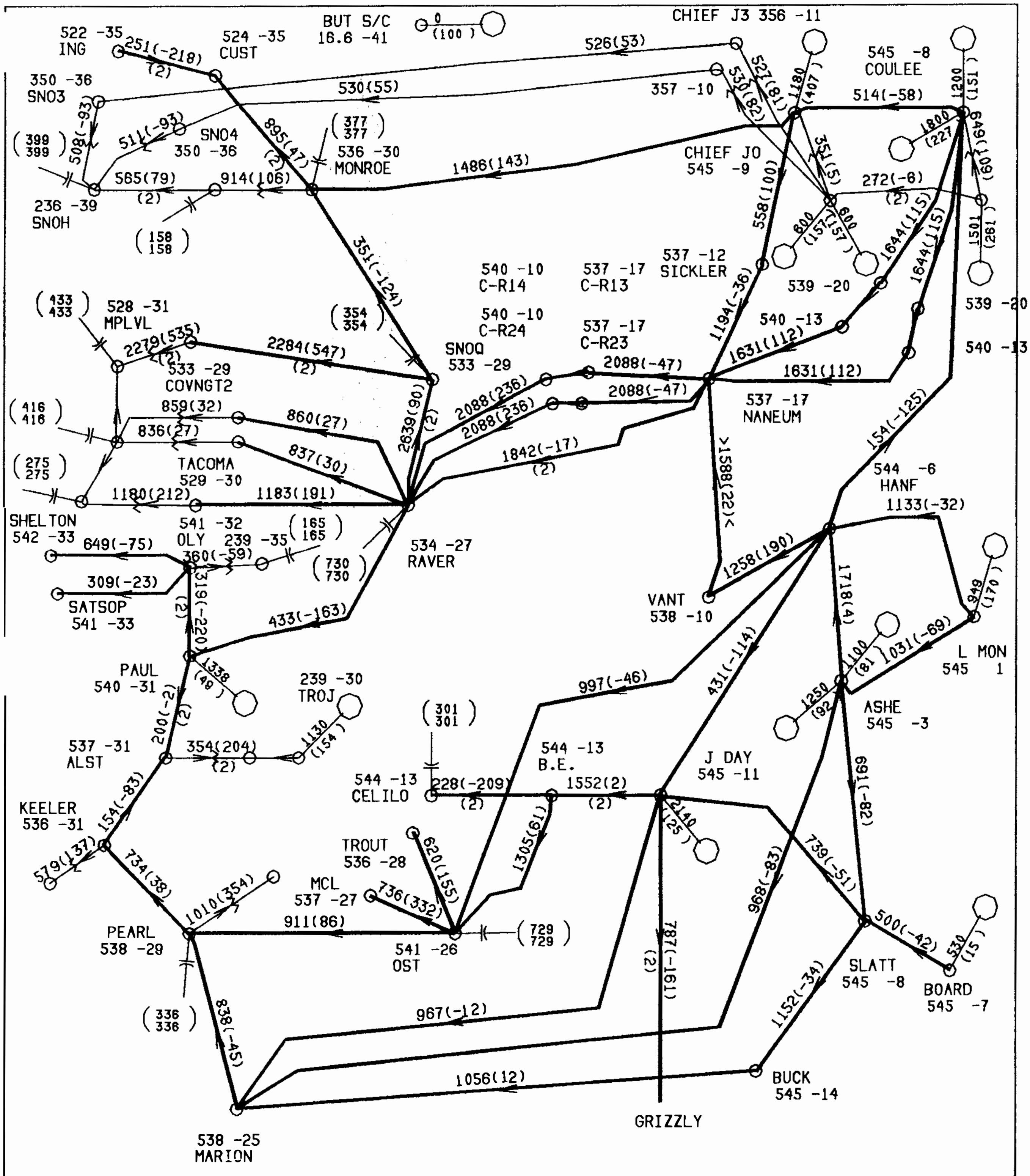
MONT TO PNW
SI= 1250.
AI= 988.

IDAHO TO PNW
SI= 700.
AI= 680.

J04909 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04905
NANEUN - RAVER 1&2 500KV LINES OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:36:23 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

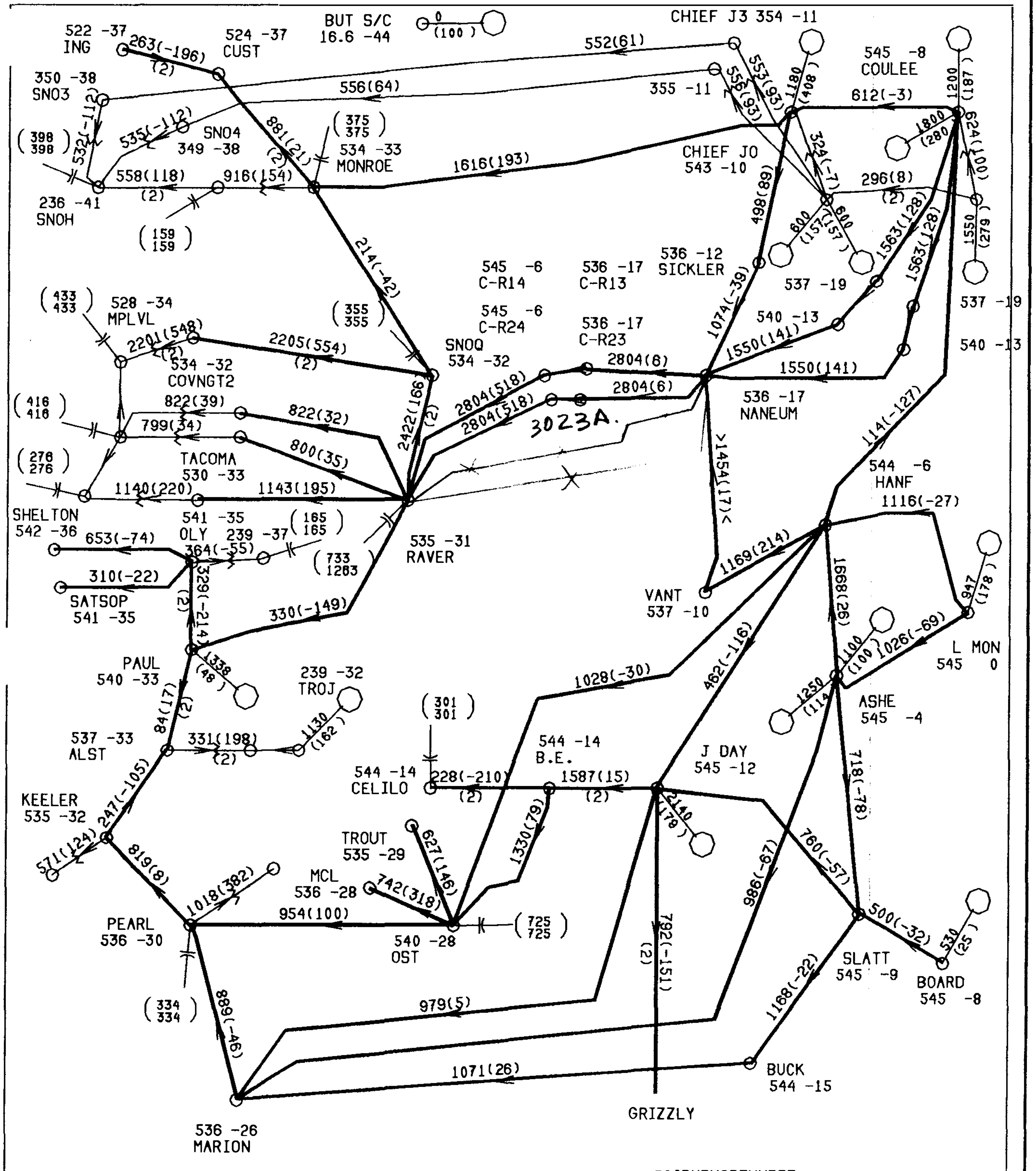
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -279.	BPA= 738.93
DC= 557.	DC= 557.	PNW= 1125.39
		SYSTEM= 3854.95

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 991.	AI= 680.

J04910 10/ 4/91 PF V6012
CY89 ALH-MJL
BASED ON J04632
NANEUM SWYD AND 19 OHMS ADDED

S:PQ R- , PLOTTED 4-OCT-91 AT 13:43:06 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

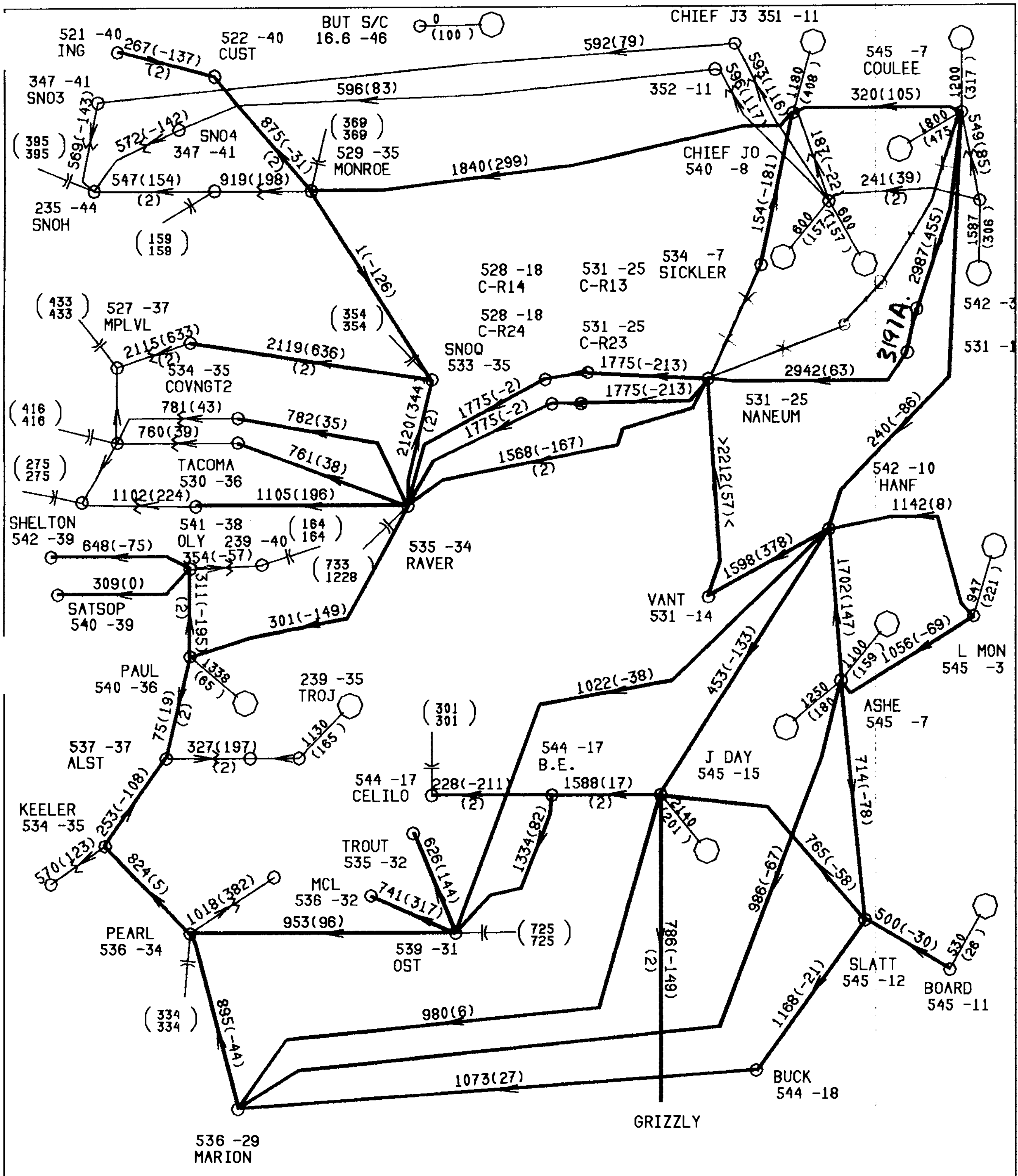
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -282.	BPA= 778.85
DC= 557.	DC= 557.	PNW= 1168.35
		SYSTEM= 3901.32

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 988.	AI= 680.

J04911 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04910
NANEUN - RAVER 1&2 500KV LINES OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:37:16 HOURS

PFPLOT PFP334 : REVISED 10/11/90



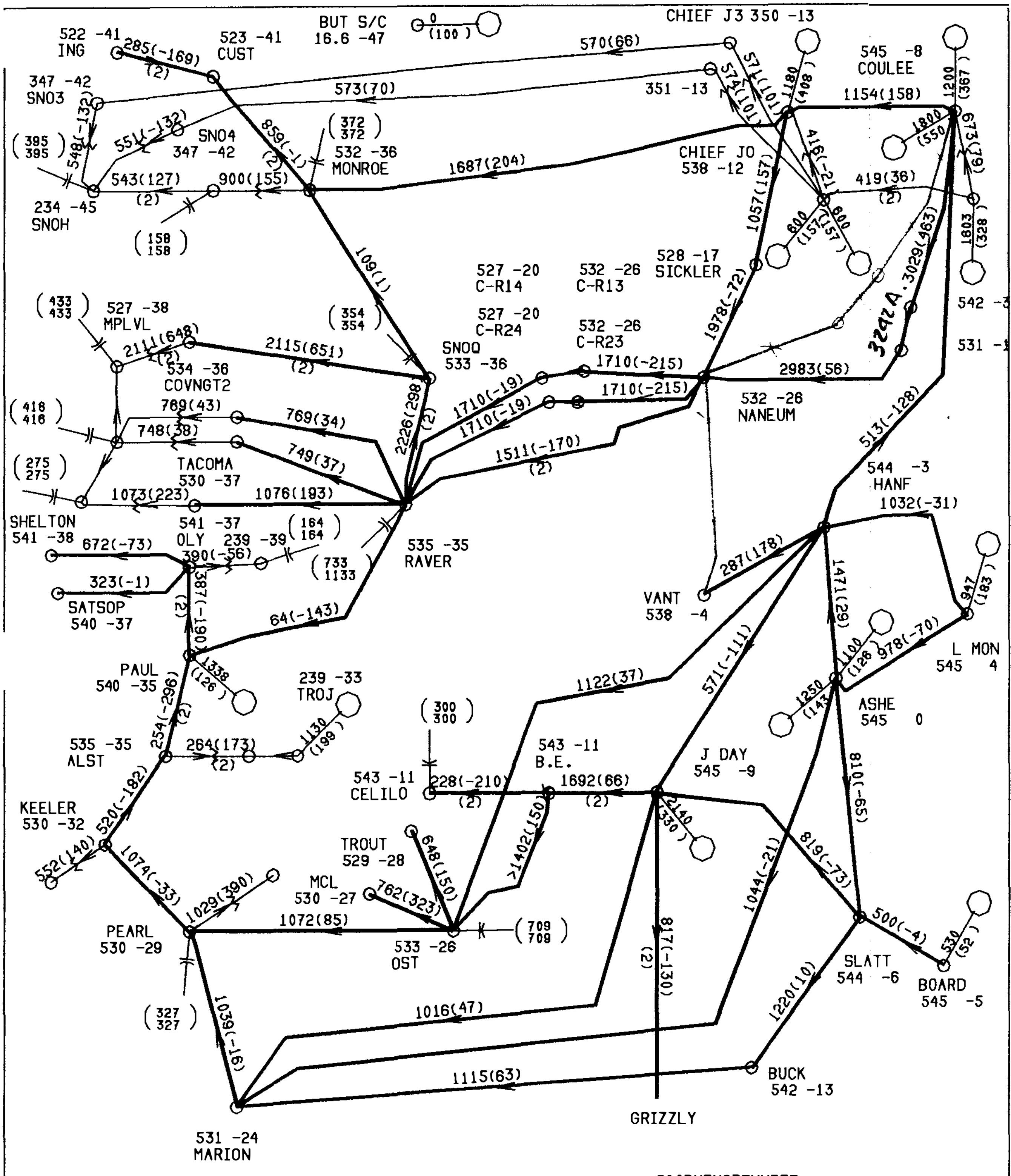
500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -286.	BPA= 803.47
DC= 557.	DC= 557.	PNW= 1205.95
		SYSTEM= 3941.29

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 979.	AI= 685.

J04912 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04910
SICKLER - NANEUM 500KV LINE OUT
COULEE - NANEUM 1 500KV LINE OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:38:23 HOURS PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

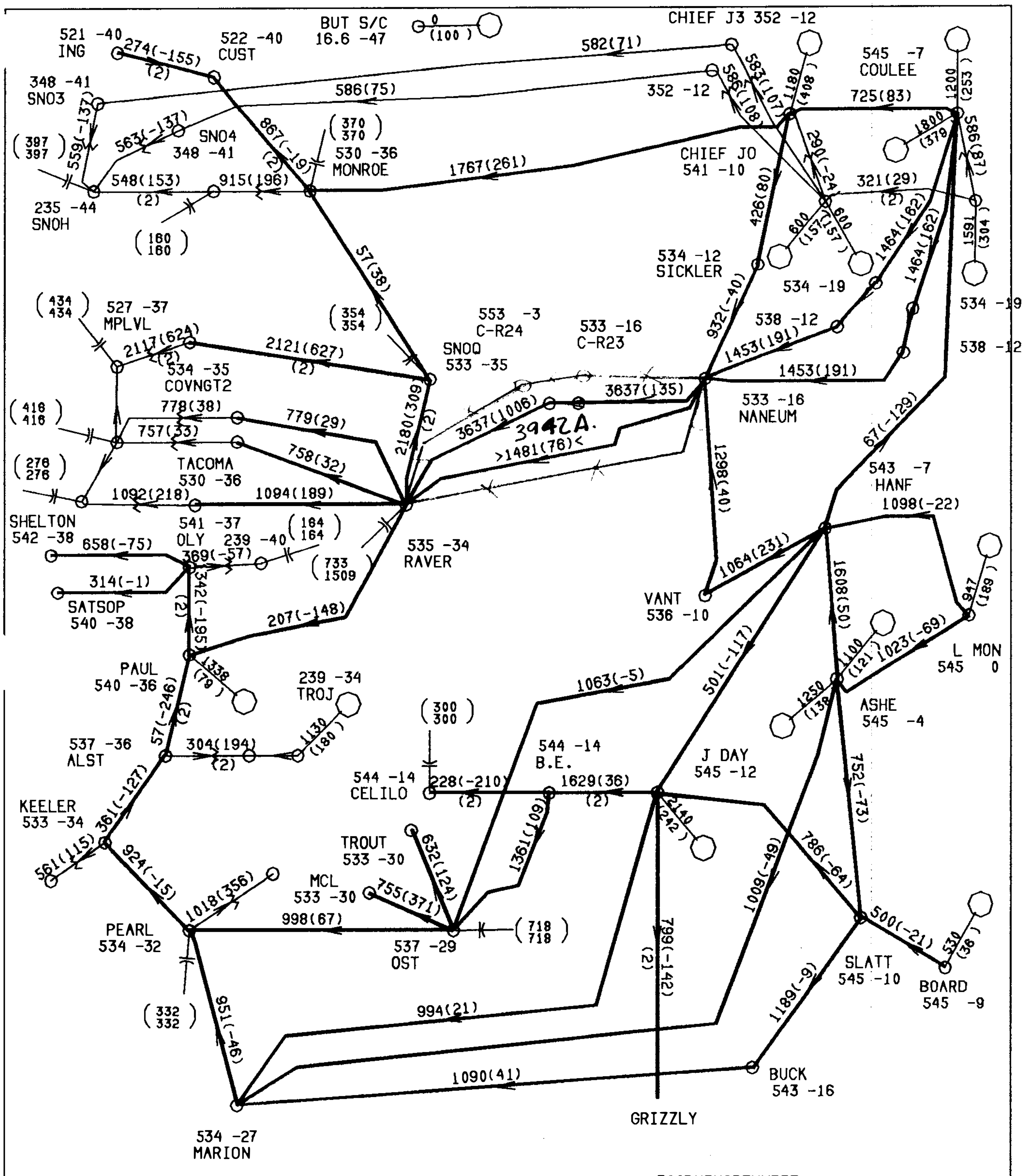
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -282.	BPA= 821.19
DC= 557.	DC= 557.	PNW= 1221.78
		SYSTEM= 3960.36

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 993.	AI= 675.

J04913 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04910
VANTAGE - NANEUM 500KV LINE OUT
COULEE - NANEUM 1 500KV LINE OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:31:19 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= 557.

ACTUAL
AC= -284.
DC= 557.

LOSSES
BPA= 812.84
PNW= 1208.89
SYSTEM= 3945.41

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

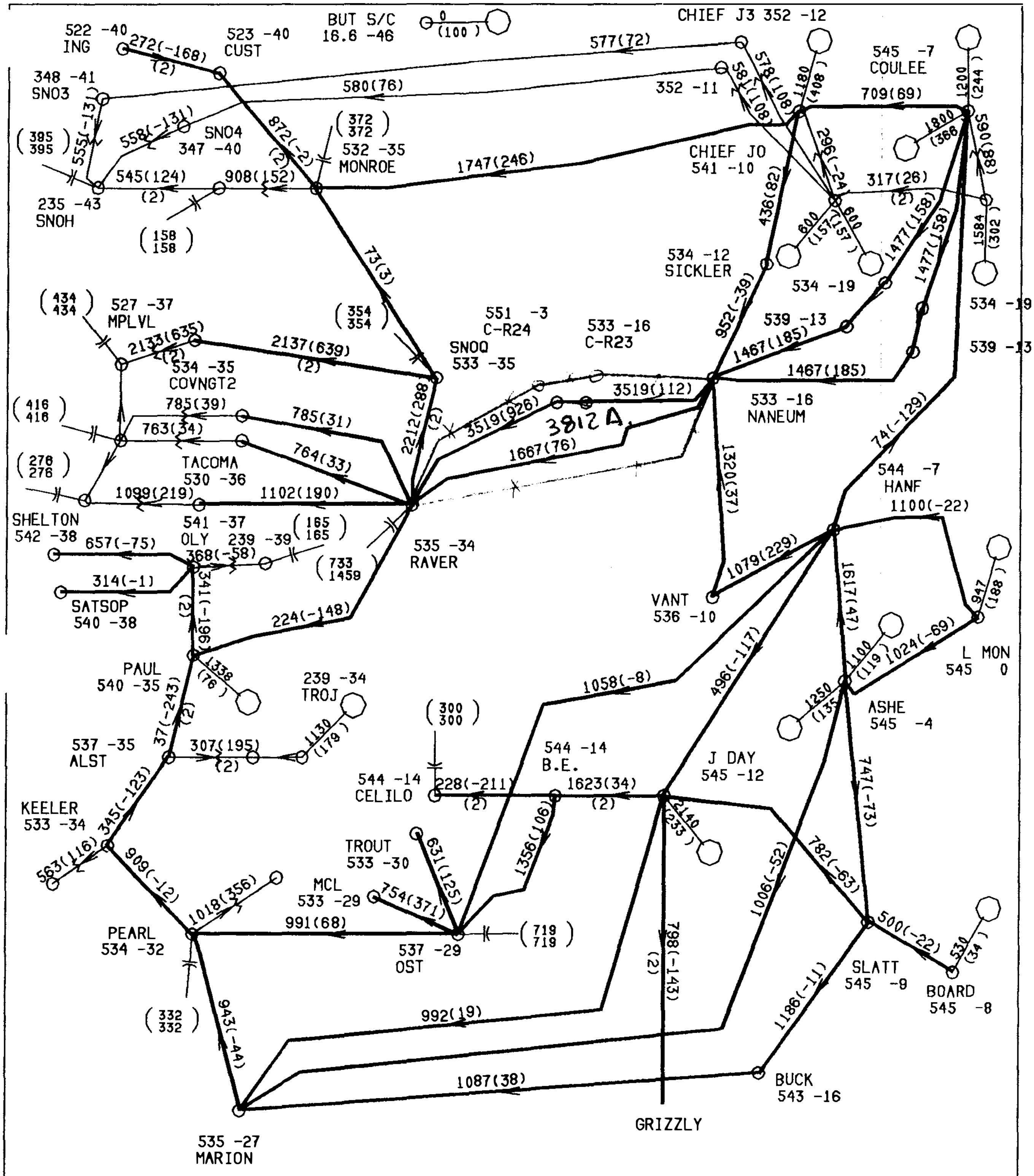
MONT TO PNW
SI= 1250.
AI= 985.

IDAHO TO PNW
SI= 700.
AI= 681.

J04914 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04910
NANEUM - RAVER 1&3 500KV LINES OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:32:42 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

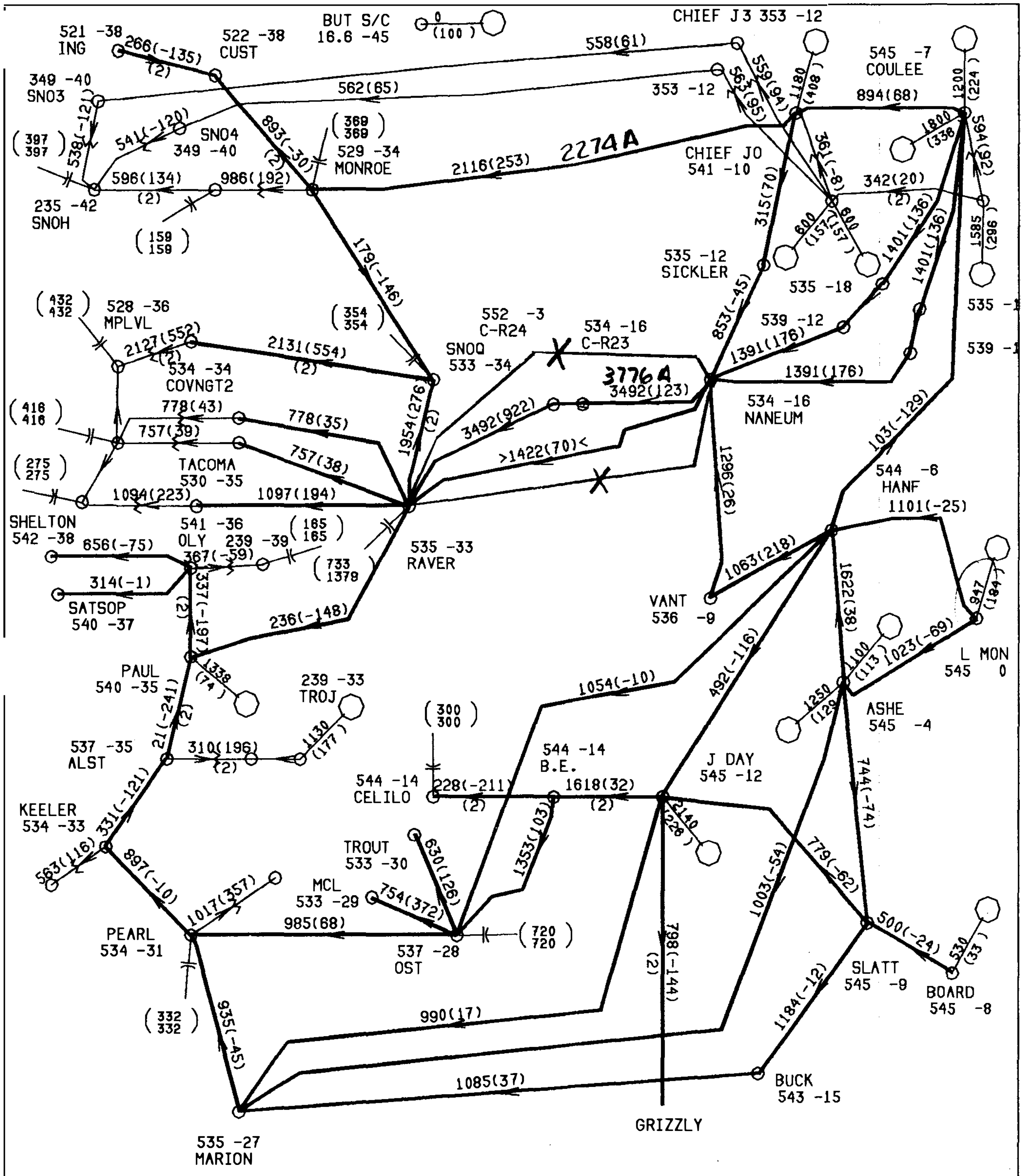
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -284.	BPA= 806.74
DC= 557.	DC= 557.	PNW= 1201.89
		SYSTEM= 3938.61

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 985.	AI= 681.

J04915 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04910
NANEUM - RAVER 2&3 500KV LINES OUT

S:PQ R- , PLOTTED 1-OCT-91 AT 15:39:21 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

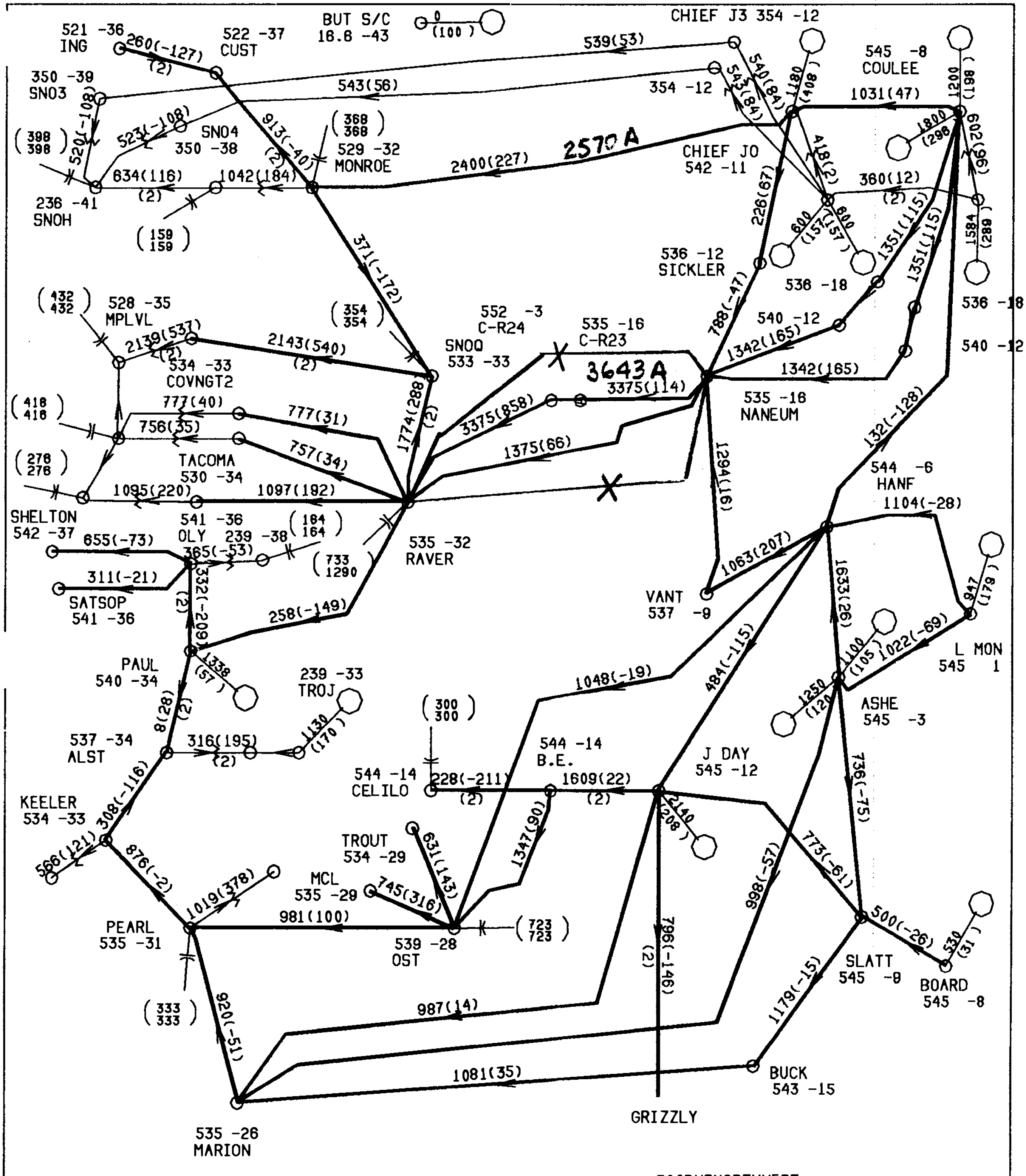
INTERTIE	SCHEDULE	ACTUAL	LOSSES
AC=	0.	AC= -283.	BPA= 811.05
DC=	557.	DC= 557.	PNW= 1203.60
			SYSTEM= 3937.72

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 986.	AI= 680.

J04916 9/30/91 PF V6012
CY89 ALH-MJL
based on J04910
naneum-raver #1 and #3 out
25% comp added to chief joe-monroe

S:PQ R- , PLOTTED 1-OCT-91 AT 07:50:09 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

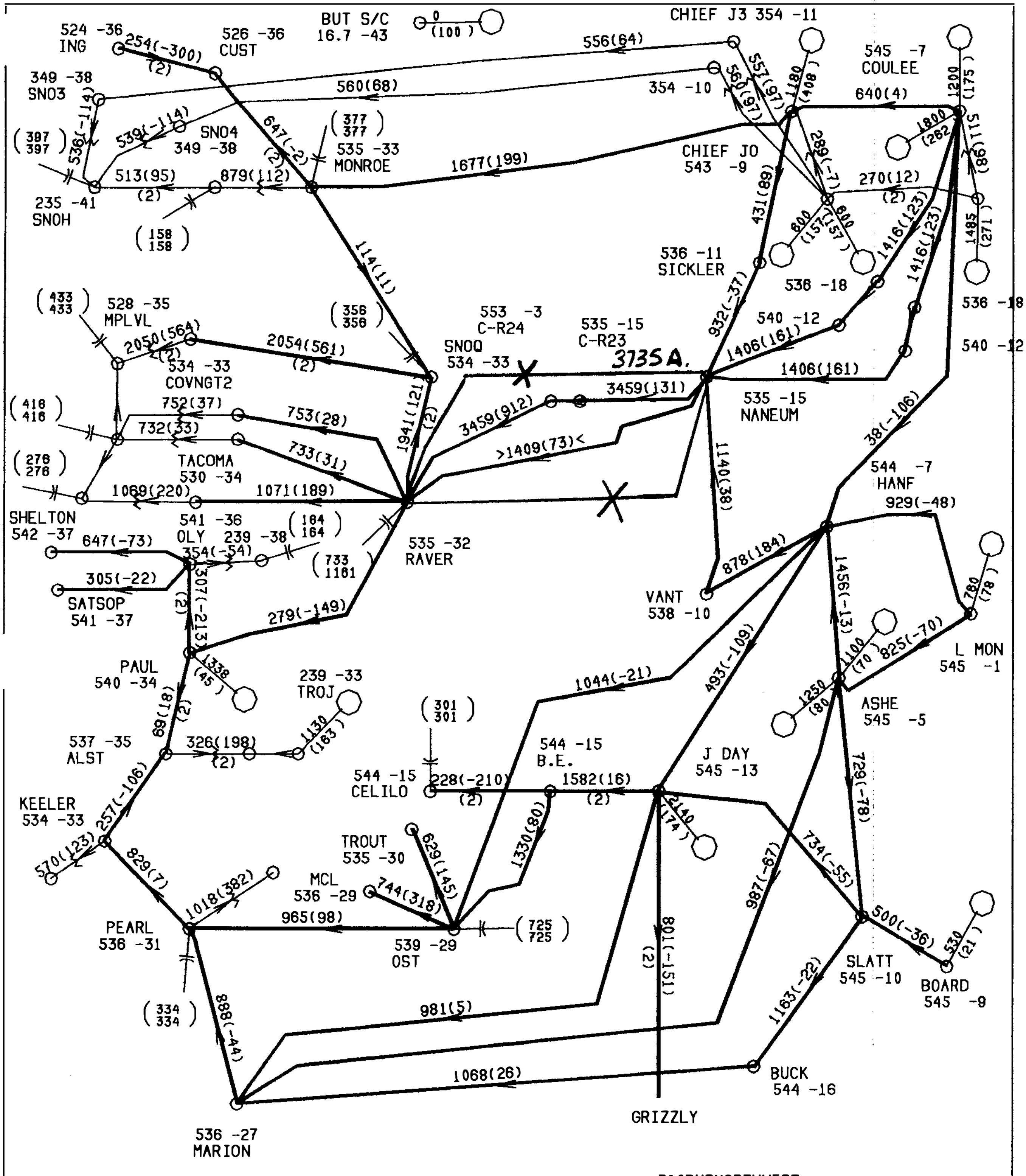
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -283.	BPA= 813.38
DC= 557.	DC= 557.	PNW= 1203.05
		SYSTEM= 3936.11

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 987.	AI= 680.

J04917 9/30/91 PF V6012
CY89 ALH-MJL
based on J04910
naneum-raver #1 and #3 out
35% comp added to chief joe-monroe

S:PQ R- , PLOTTED 1-OCT-91 AT 07:50:58 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE
AC= 0.
DC= 557.

ACTUAL
AC= -279.
DC= 557.

LOSSES
BPA= 758.77
PNW= 1147.07
SYSTEM= 3876.60

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

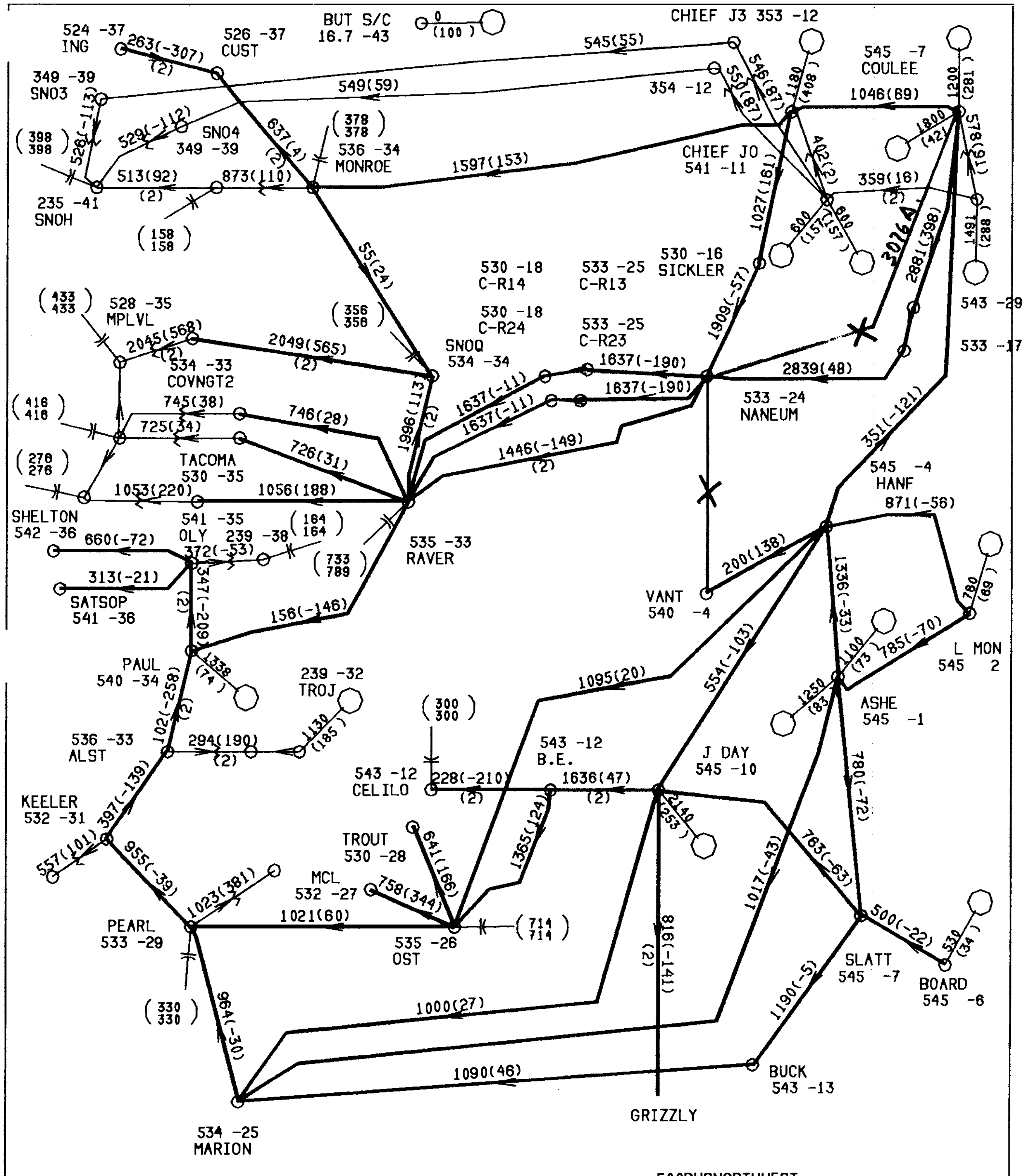
MONT TO PNW
SI= 1250.
AI= 991.

IDAHO TO PNW
SI= 700.
AI= 680.

J04918 10/ 1/91 PF V6012
CY89 ALH-MJL
BASED ON J04910
NANEUM-RAVER #1 AND #3 OUT
604 MW CT'S ADDED IN PUGET SOUND

S:PQ R- , PLOTTED 1-OCT-91 AT 14:48:18 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -278.	BPA= 761.88
DC= 557.	DC= 557.	PNW= 1152.72
		SYSTEM= 3884.34

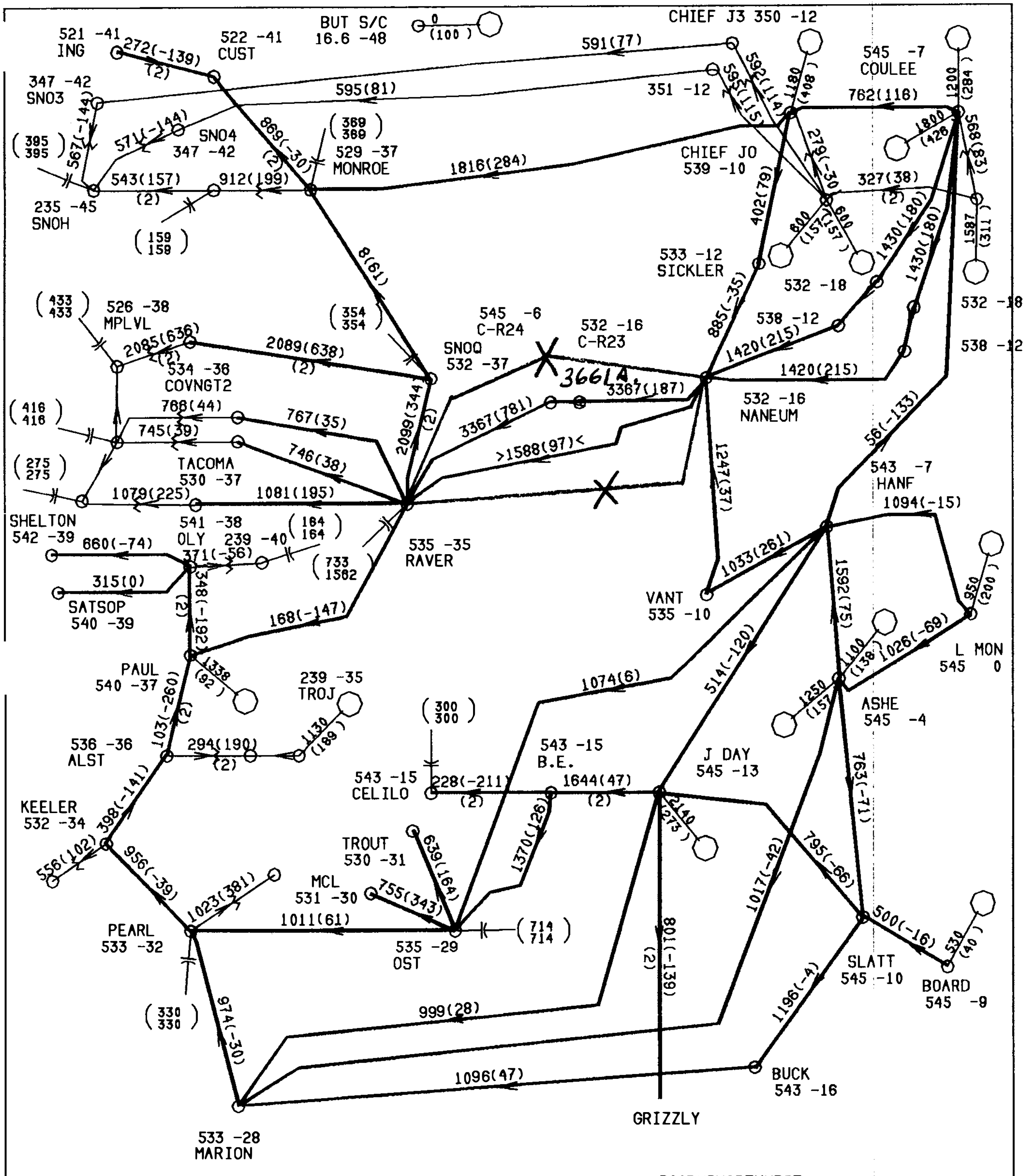
CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 997.	AI= 675.

J04919 10/ 1/91 PF V6012
CY89 ALH-MJL
BASED ON J04910
COULEE-NANEUM #1 AND VANTAGE-NANEUM OUT
604 MW CT'S ADDED IN PUGET SOUND

S:PQ R- , PLOTTED 1-OCT-91 AT 14:14:33 HOURS

PFPLOT PFP334 : REVISED 10/11/90

140
601



500BUSNORTHWEST

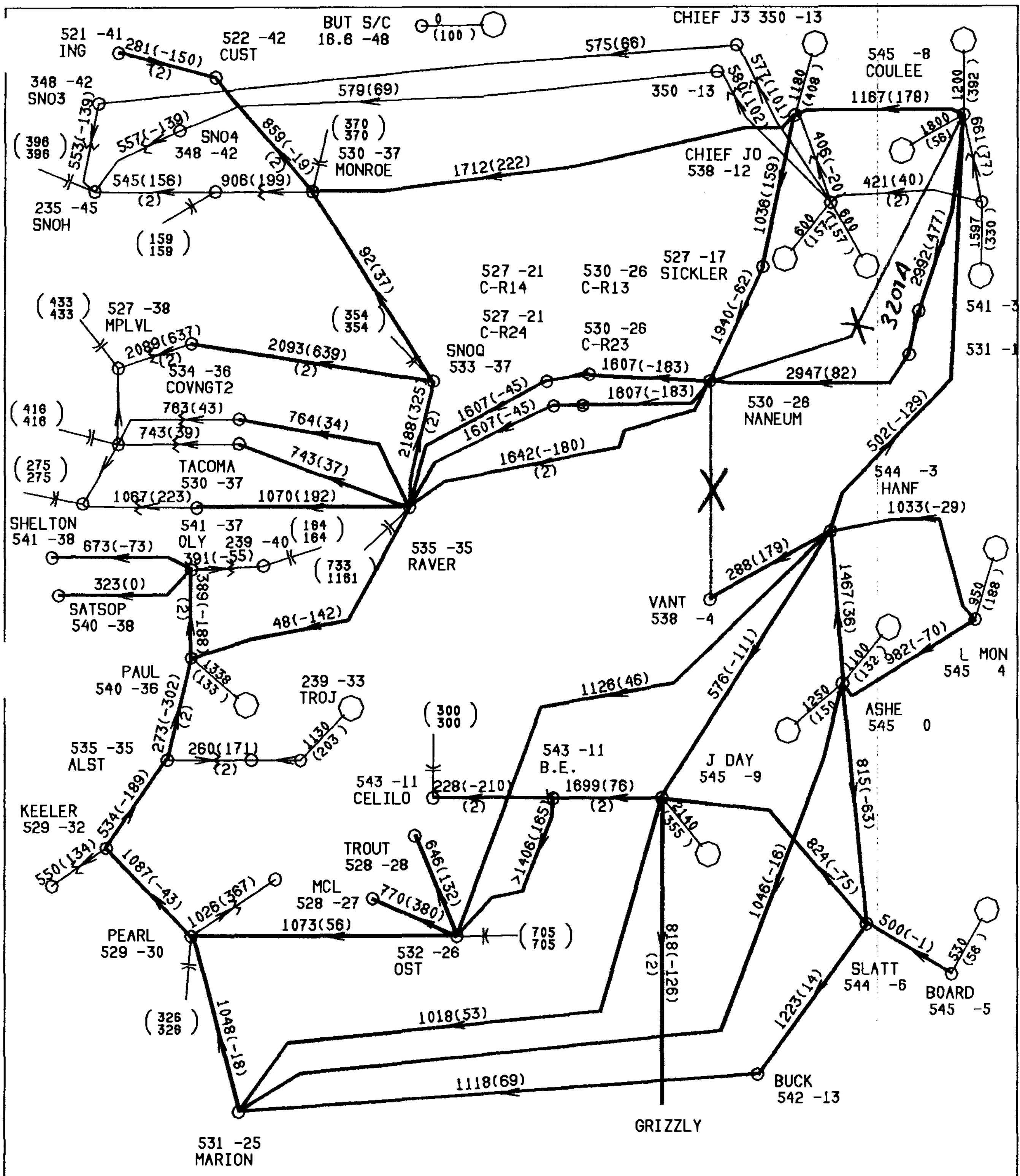
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -285.	BPA= 815.86
DC= 557.	DC= 557.	PNW= 1214.78
		SYSTEM= 3953.06

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 984.	AI= 681.

J04962 10/ 3/91 PF V6012
CY89 ALH-MJL
BASED ON J04960
NANEUM-RAVER #1 AND #3 OUT

S:PQ R- , PLOTTED 3-OCT-91 AT 13:14:48 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

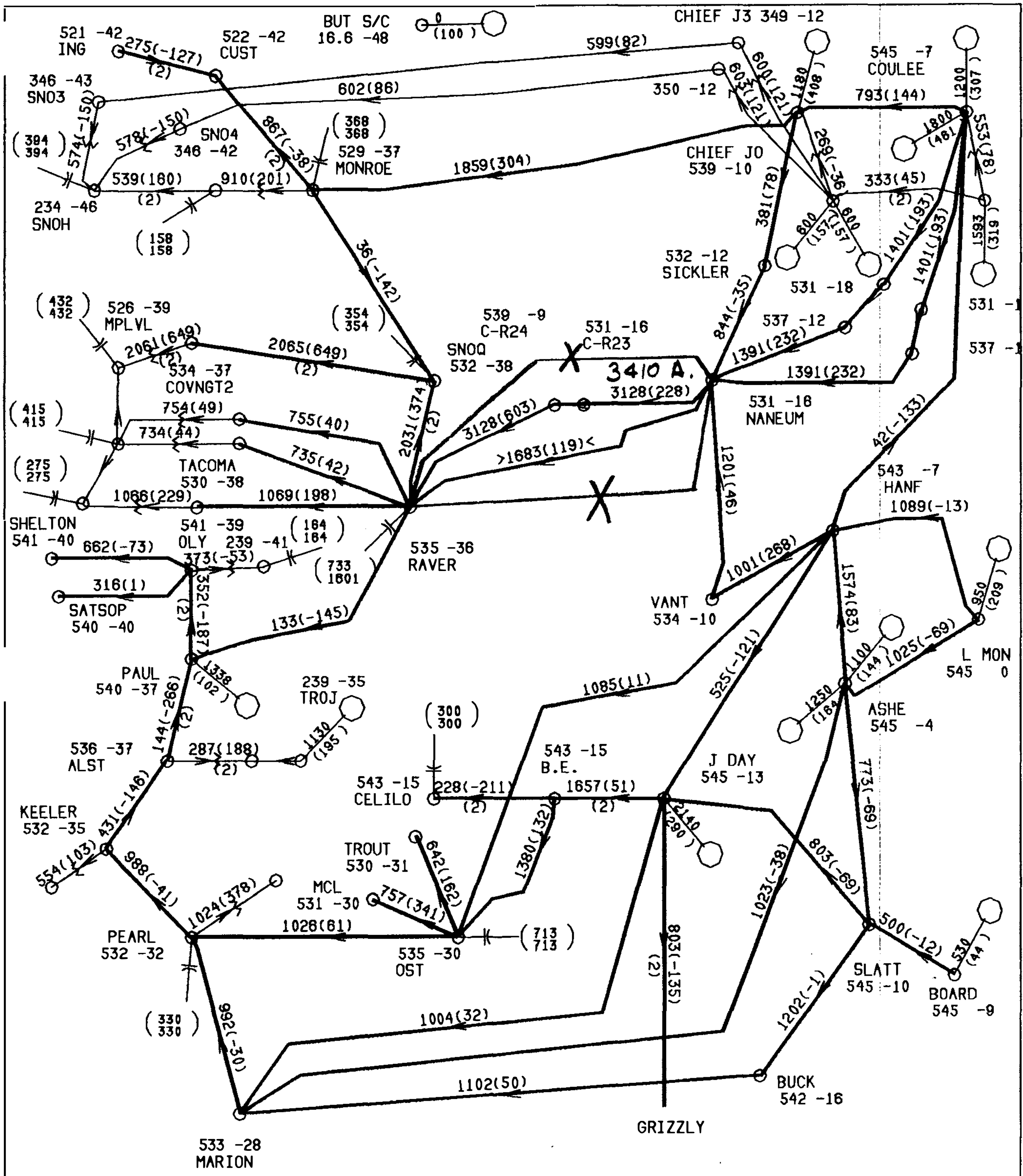
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -283.	BPA= 823.35
DC= 557.	DC= 557.	PNW= 1225.15
		SYSTEM= 3964.50

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 992.	AI= 676.

J04963 10/ 3/91 PF V6012
CY89 ALH-MJL
BASED ON J04960
VANTAGE-NANEUM OUT
COULEE-NANEUM #1 OUT
15Ω N-R #3 + #4

S:PQ R- , PLOTTED 3-OCT-91 AT 13:18:36 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

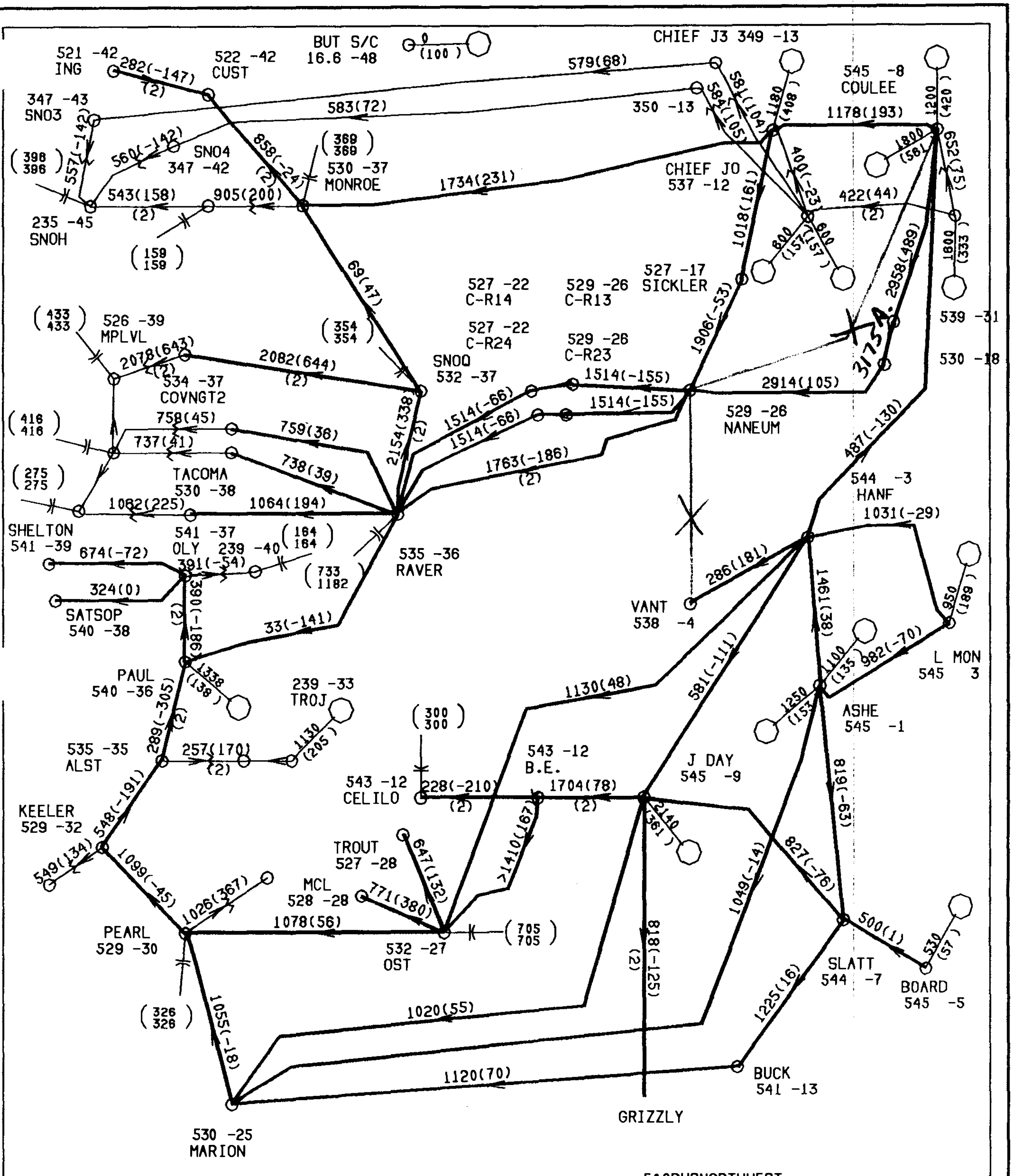
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -286.	BPA= 819.06
DC= 557.	DC= 557.	PNW= 1220.20
		SYSTEM= 3959.69

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 983.	AI= 681.

J04964 10/ 3/91 PF V6012
CY89 ALH-MJL
BASED ON J04960
NANEUM-RAVER #1 AND #3 OUT
11 OHM COMP IN OTHER NAN-RAV LINE

S:PQ R- , PLOTTED 3-OCT-91 AT 14:01:35 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

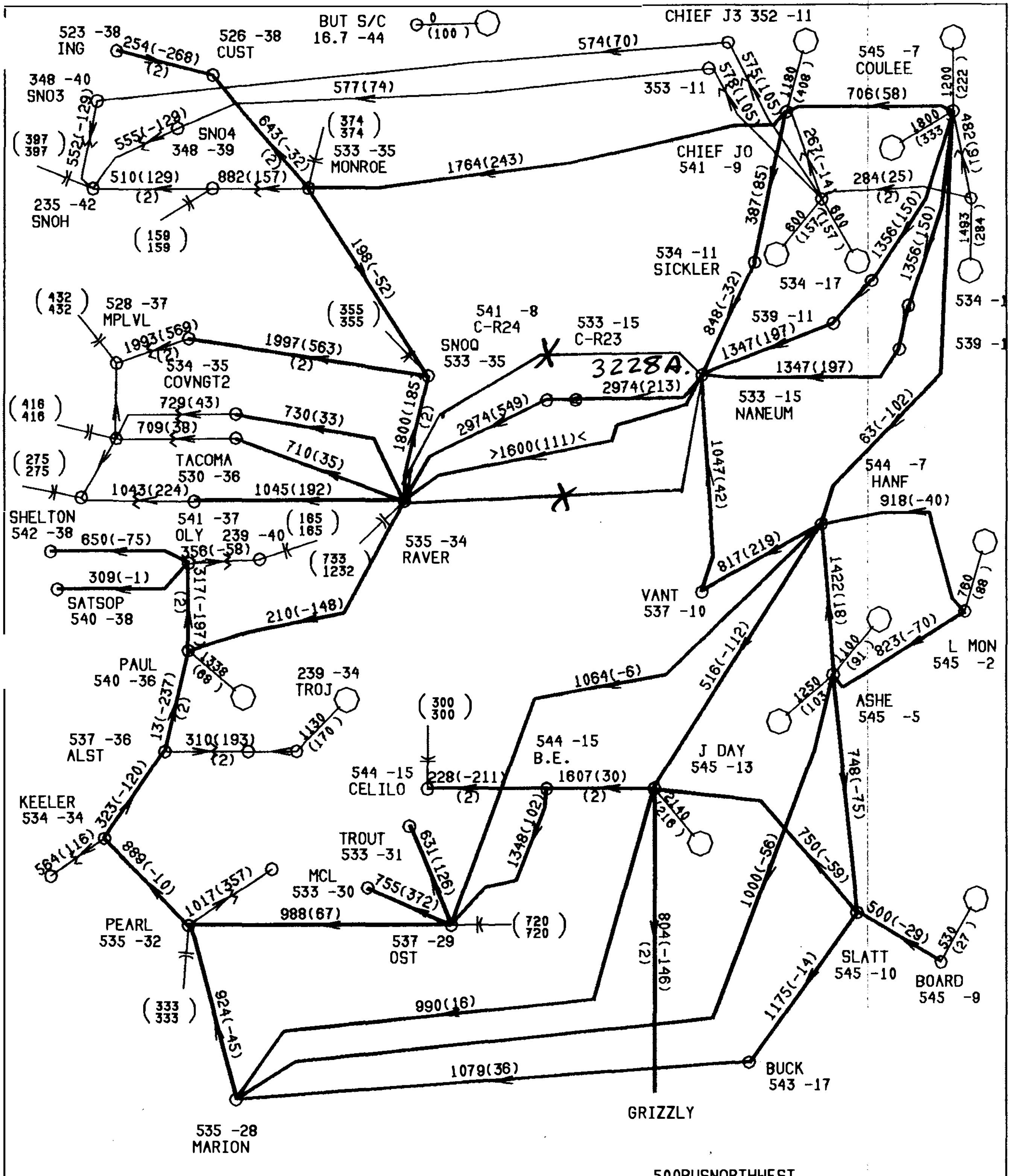
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -283.	BPA= 824.55
DC= 557.	DC= 557.	PNW= 1227.22
		SYSTEM= 3967.26

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 991.	AI= 676.

J04965 10/ 3/91 PF V6012
CY89 ALH-MJL
BASED ON J04960
VANTAGE-NANEUM AND
COULEE-NANEUM #1 OUT
11 OHM COMP IN NANEUM-RAVER LINES

S:PQ R- , PLOTTED 3-OCT-91 AT 14:38:56 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

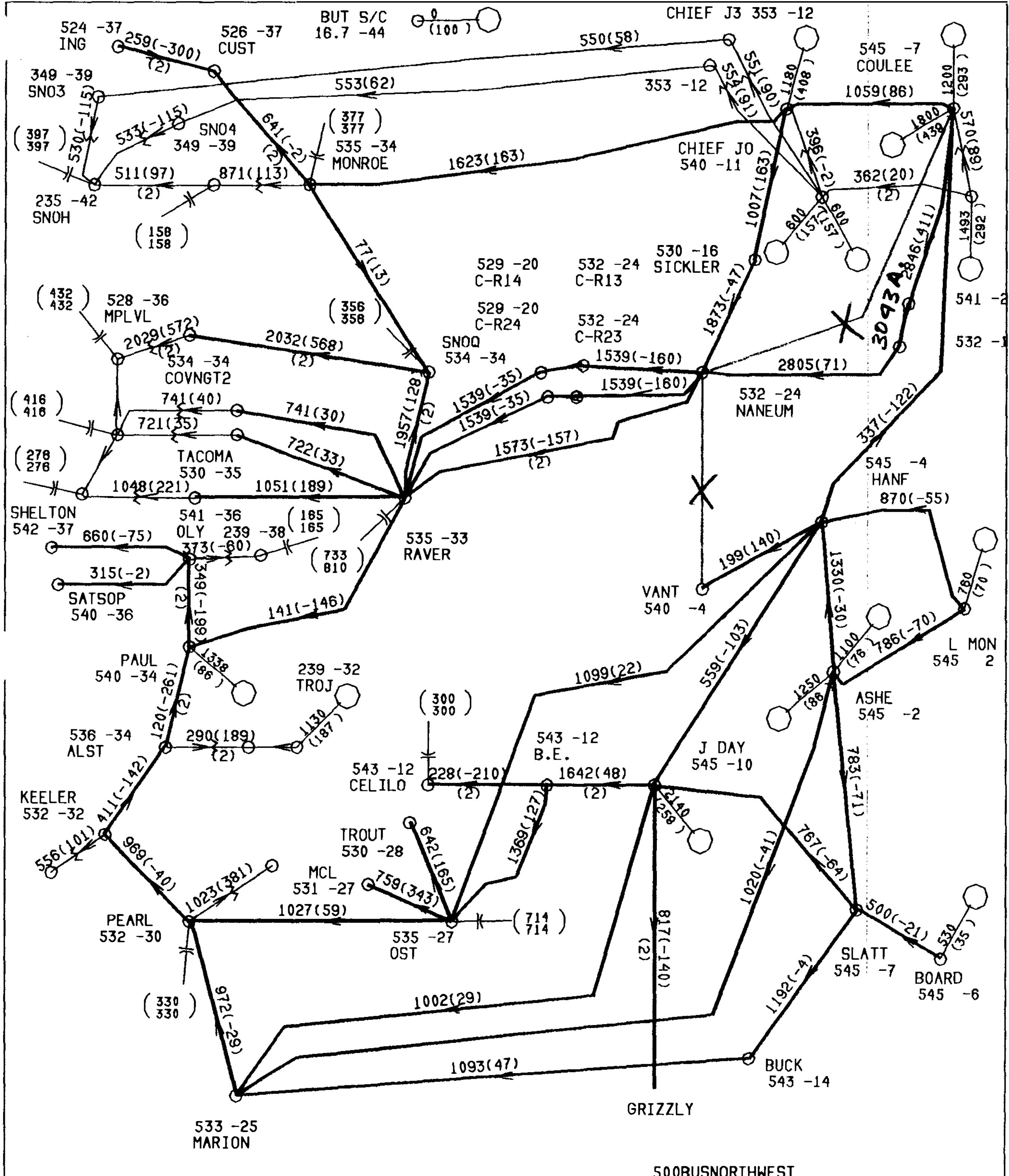
INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -281.	BPA= 763.04
DC= 557.	DC= 557.	PNW= 1154.90
		SYSTEM= 3886.71

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 989.	AI= 680.

J04966 10/ 3/91 PF V6012
CY89 ALH-MJL
BASED ON J04960
NANEUM-RAVER #1 AND #3 OUT
11 OHM COMP IN OTHER NAN-RAV LINE
604 MW CT'S ADDED IN PUGET SOUND

S:PQ R- , PLOTTED 3-OCT-91 AT 14:05:14 HOURS

PFPLOT PFP334 : REVISED 10/11/90



500BUSNORTHWEST

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -278.	BPA= 763.02
DC= 557.	DC= 557.	PNW= 1155.16
		SYSTEM= 3886.35

CANADA TO PNW (BCH & WKOOT)	MONT TO PNW	IDAHO TO PNW
SI= 450.	SI= 1250.	SI= 700.
AI= 450.	AI= 997.	AI= 675.

J04969 10/ 3/91 PF V6012
CY89 ALH-MJL
BASED ON J04960
VANTAGE-NANEUM OUT
COULEE-NANEUM #1
15 OHMS IN NAN-RAV #3 AND #4
604 MW CT'S ADDED IN PUGET SOUND

S:PQ R- , PLOTTED 3-OCT-91 AT 16:15:56 HOURS

PFPLOT PFP334 : REVISED 10/11/90

Attachment 4

ATTACHMENT 4 11-4-91

PLAN 6 DEVELOPMENT - REPLACEMENT OF ROCKY REACH-MAPLE VALLEY 345 LINE

by Marv Landauer - BPA

One of the obvious rebuild options for Cross Mountain lines is the Rocky Reach-Maple Valley 345-kV line. However, as is shown below, Sickler is not a very strong source for a new double-circuit line. Sickler must also be reinforced. There are several option to do this:

Plan 6: Replacement of Rocky Reach-Maple Valley 345-kV with Sickler-Snoqualmie 500-kV double circuit line. The second Maple Valley 500/230-kV transformer was added to replace the 345/230-kV transformer that was remove and provide needed additional transformation in the Puget Sound Basin.

Plan 6A: same as Plan 6 plus Chief Joe-Sickler 500-kV single circuit added.

Plan 6B: same as Plan 6 plus Naneum Switchyard added (NO Coulee-Raver comp). This plan was investigated to see if Naneum development could reinforce the Sickler area enough.

Plan 6C: same as Plan 6 plus double circuit 500-kV tie added to new Columbia switchyard from closest point on the 345-kV right-of-way.

Plan 6D: same as Plan 6C plus 500-kV single circuit tie added from Columbia to Rocky Ford.

Plan 6E: same as Plan 6 plus Chief Joe-Sickler 500-kV double circuit line added creating Chief Joe-Snoqualmie and Chief Joe-Sickler-Snoqualmie 500-kV circuits.

Plan 6F: same as Plan 6 plus Chief Joe-Sickler 500-kV double circuit line added without the tie into Sickler, ie, a new Chief Joe-Snoqualmie double circuit.

Plans 6, 6A and 6B have unacceptably low voltages at Tacoma 500 in the base case with a Centralia unit out of service. Additional shunt capacitors would be needed in this area for these plans.

Local Reinforcement

With the removal of the 345/230-kV transformer at Maple Valley, there will be an increased need for transformation in the Puget Sound area. A second Maple Valley 500/230-kV transformer was added in these cases, however the Snoking transformer may also be needed in this study period.

The transformation in the Sickler-Rocky Reach area needs to be studied since a 345/230-kV transformer is removed at Rocky Reach with these Plans.

Performance Comparison

A comparison of system performance for the critical outages is included in Table 1. A Sickler-Snoqualmie line by itself is not enough to meet the J04 load. The addition of a Chief Joe-Sickler SDC line (Plan 6E and 6F) is still not as strong as Plan 2 (in main report) since this plan involves the removal of the 345-kV circuit which provides some support to the Puget Sound Basin, especially during the abnormally cold weather. With the addition of the loop to Columbia and tie to Rocky Ford (plan 6D), it has similar performance to Plan 2.

Loss Savings Comparison

A comparison of loss saving for the various options is included in Table 1. A Rocky Ford tie added with the Columbia loop-in helps losses two ways by adding additional transmission in parallel with the Coulee-Columbia lines and the Hanford-Vantage-Naneum line. However, some of this loss reduction is due to the assumption of the second unit at Ashe (this increases the Hanford-Vantage-Naneum flow).

If a Chief Joe-Snoqualmie line is built, it appears to be beneficial from loss savings (and outage performance) to tie at least one line into Sickler. A double circuit line between Chief Joe and Sickler does not reduce losses any more than a single circuit line however it does improve post-transient performance.

Staged Development

All of these options start with the replacement of the Rocky Reach-Maple Valley 345-kV line which will work for a while (the study results below are for the year 2004). Any of these plans could be staged as development is needed.

Recommended Plan

Due to system performance and especially loss savings, Plan 6D is favored and included in the favored options.

TABLE 1: COMPARISON OF PLAN 6 OPTIONS FOR PSAERP

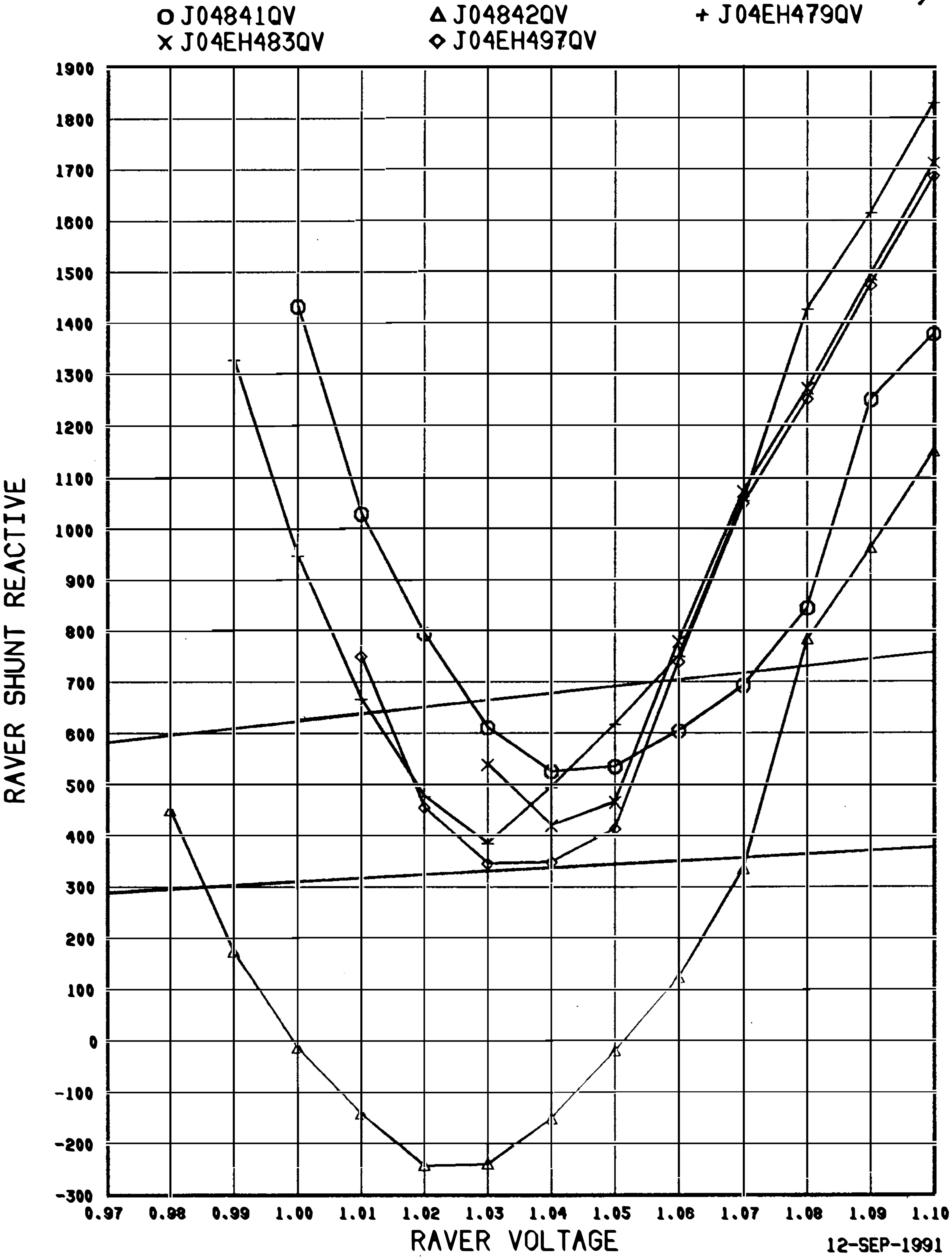
OPTION	DESCRIPTION	PEAK SYSTEM LOSS SAVINGS			REACTIVE MARGIN
		Case #	MW - 2004 BPA	PNW	MVARs - 2004 2-line/1-line/Trojan Margins include unused MSC, QV curves follow
Plan 6	Sick-Snoq SDC	J04840	693	1077	150/300/300
Plan 6A	Sick-Snoq SDC CJ-Sick SSC	J04843	685	1069	400/450/450
Plan 6B	Sick-Snoq SDC Naneum SWYD (no Comp)	J04866	693	1076	900/250/300
Plan 6C	Sick-Snoq SDC SDC loop to Columbia	J04869	691	1075	800/400/500
Plan 6D	Sick-Snoq SDC SDC loop to Columbia SSC tie to Rocky Ford	J04902	677	1058	1100/700/600
Plan 6E	Sick-Snoq SDC CJ-Sick SDC	J04903	685	1070	1200/700/500
Plan 6F	CJ-Snoq SDC no Sickler tie	J04901	693	1082	600/600/450

Sick - Snoq 500 SDC added.

PLAN 6

○J04841:COUL-RAV 1&2(J04840)MSC OLY,SNQ(1),MON(1)
△J04842:SICKL-SNOQ 1&2(J04840)MSC OLY,SNQ(1),MON(1)
+J04EH479:CHIEF J-MON OUT(J04EH471)MSC OLY(1)
J04EH483:TROJAN SCRAM(J04EH475)MSC OLY(1)
◇J04EH497:TROJAN SCRAM(J04EH475)MSC OLY(1),MARION(1

All MSC's used.



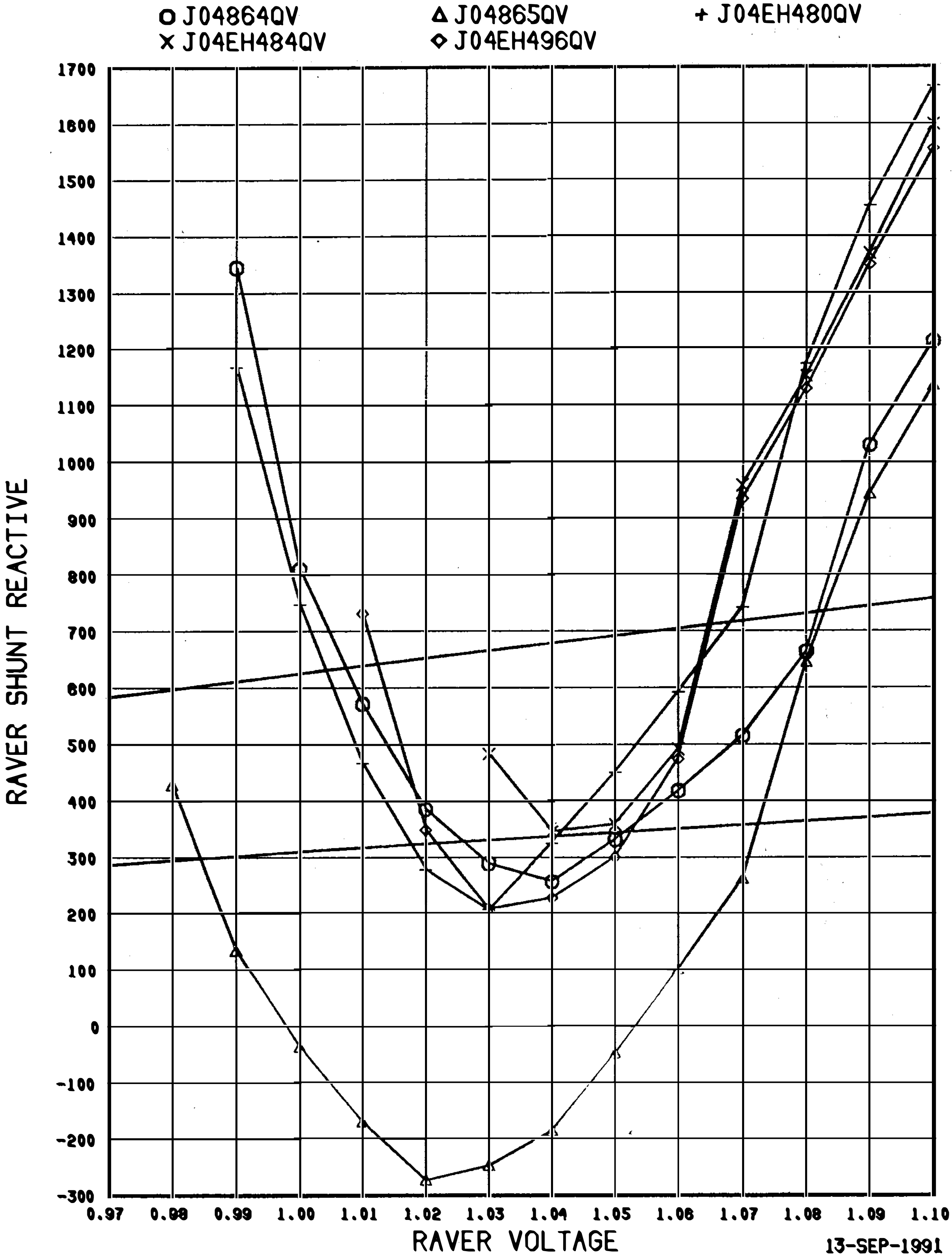
12-SEP-1991
J04841QV.SETUP

Sickler-Snoq SDC and
CJ-Sickler SSC added.

PLAN 6A

○ J04864:COUL-RAV 1&2 (J04843)MSC OLY,SNQ(1),MON(1)
△ J04865:SICKL-SNOQ 1&2(J04843)MSC OLY,SNQ(1),MON(1)
+J04EH480:CHIEF J-MON OUT(J04EH472)MSC OLY(1)
×J04EH484:TROJAN SCRAM(J04EH476)MSC OLY(1)
◇ J04EH496:TROJAN SCRAM(J04EH476)MSC OLY(1),MARION(1

All MSC's used.



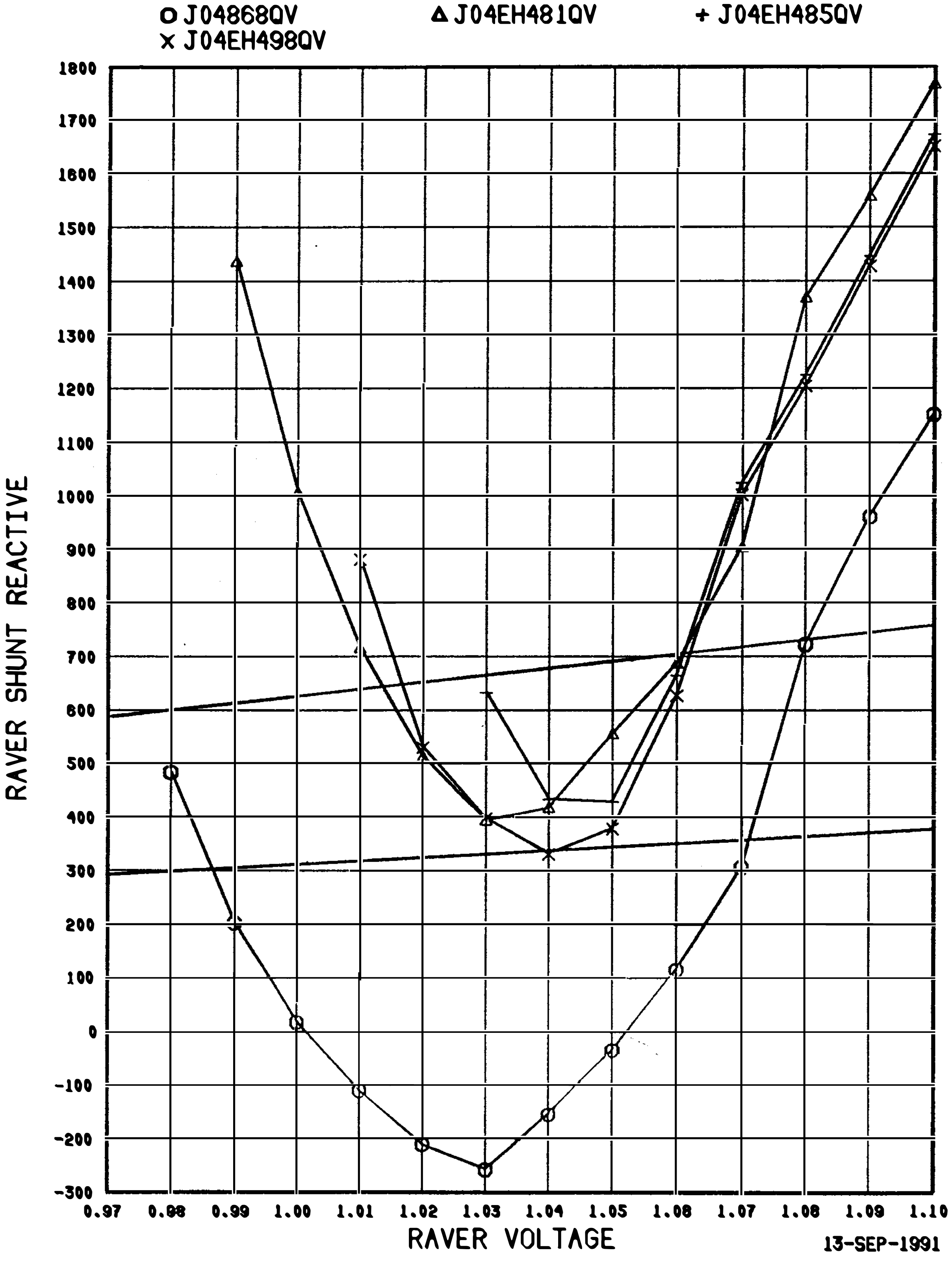
13-SEP-1991
J04864QV.SETUP

Sickler-Snoq SDC added
Naneum SWYD (no comp) added.

PLAN 6B

○ J04868:SICKL-SNQ 1&2(J04866)MSC OLY,SNQ(1),MON(1)
△ J04EH481:CHIEF J-MON OUT(J04EH473)MSC OLY(1)
+J04EH485:TROJAN SCRAM (J04EH477)MSC OLY(1)
×J04EH498:TROJAN SCRAM (J04EH477)
MSC AT OLY(1), MARION(1)

All MSCs USED



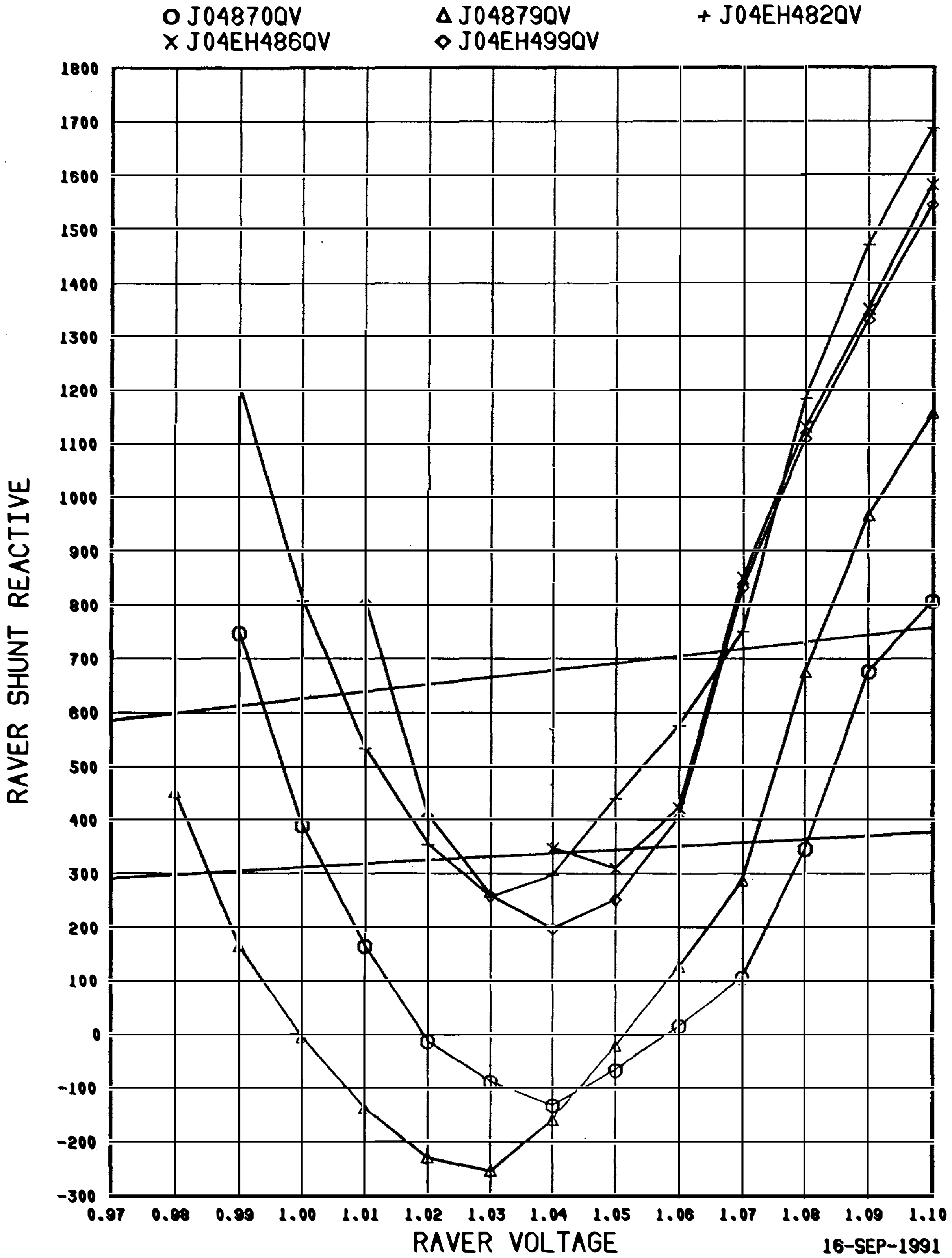
13-SEP-1991
J04868QV.SETUP

Sick-Snoq with DC
loop to Columbia.

PLAN 6C

○ J04870:COUL-COLMBIA 1&2(869)MSC OLY,SNQ(1),MON(1)
△ J04879:COL-SNQ/SICKL-SNQ(879)MSC OLY,SNQ(1),MON(1)
+J04EH482:CHIEF J-MON OUT(J04EH474)MSC OLY(1)
J04EH486:TROJAN SCRAM (J04EH478)MSC OLY(1)
◇ J04EH499:TROJAN SCRAM(J04EH478)MSC OLY(1),MARION(1

All MSC's used.

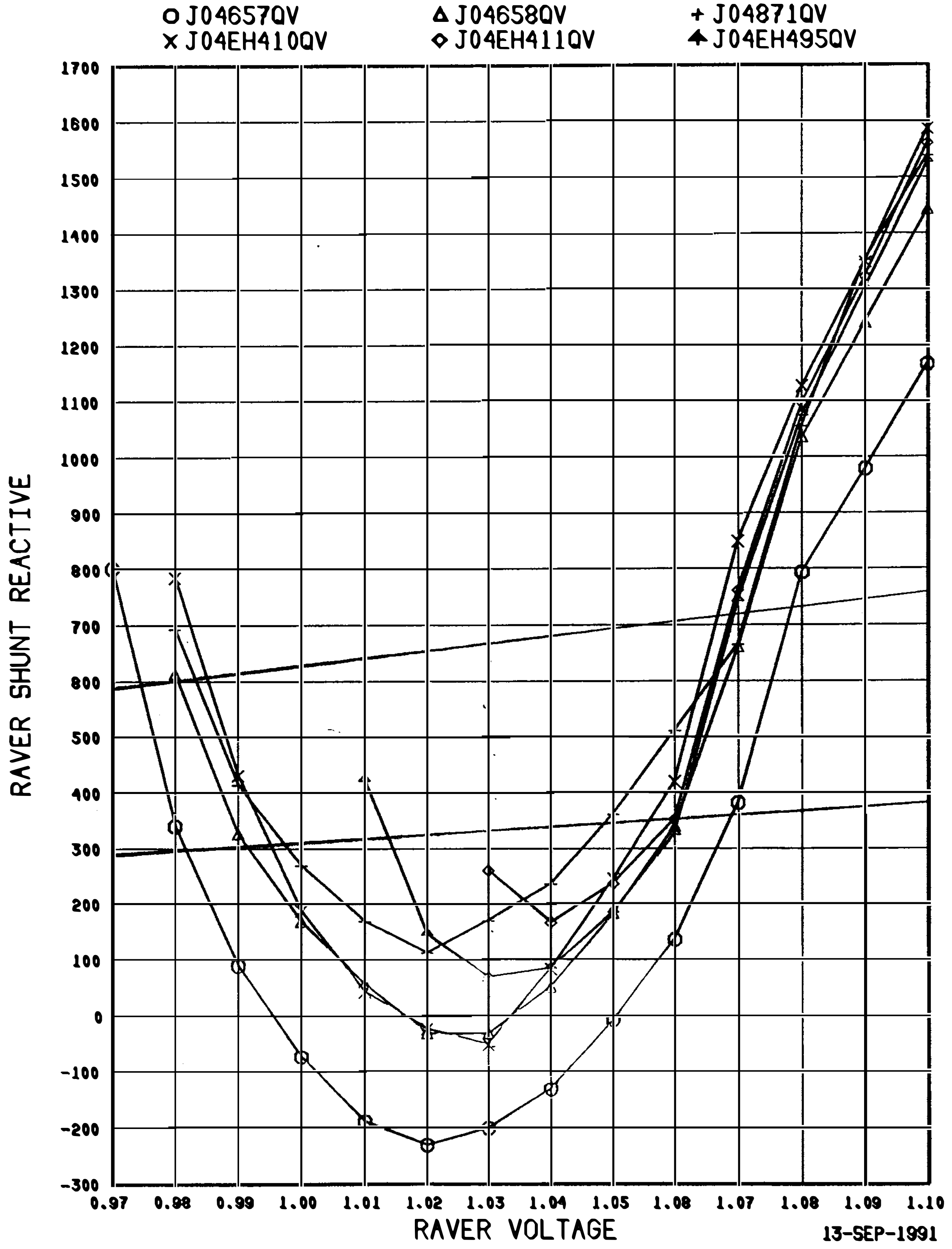


16-SEP-1991
J04870QV.SETUP

Sick-Snoq DC added
with DC loop to Columbia.
Columbia-Rocky Fd SC tie added.

PLAN 6D

○ J04657:COULEE-COLUMBIA 1&2 OUT (J04655)NO MSC — Mon, Snoq, Oly avail.
△ J04658:COL-SNOQ/SICKL-SNOQ(655)MSC SNQ(1),RAV(1) — Mon, Oly avail.
+J04871:RAVER-COLUMBIA 1&2(J04655)NO MSC — Mon, Snoq, Oly avail.
× J04EH410:CHIEF J-MONROE(J04EH404)MSC OLY(1),MON(1) }
⯭ J04EH495/◇411:TROJAN SCRAM(405)MSC OLY1/OLY1,MARN1 } ALL MSC use.

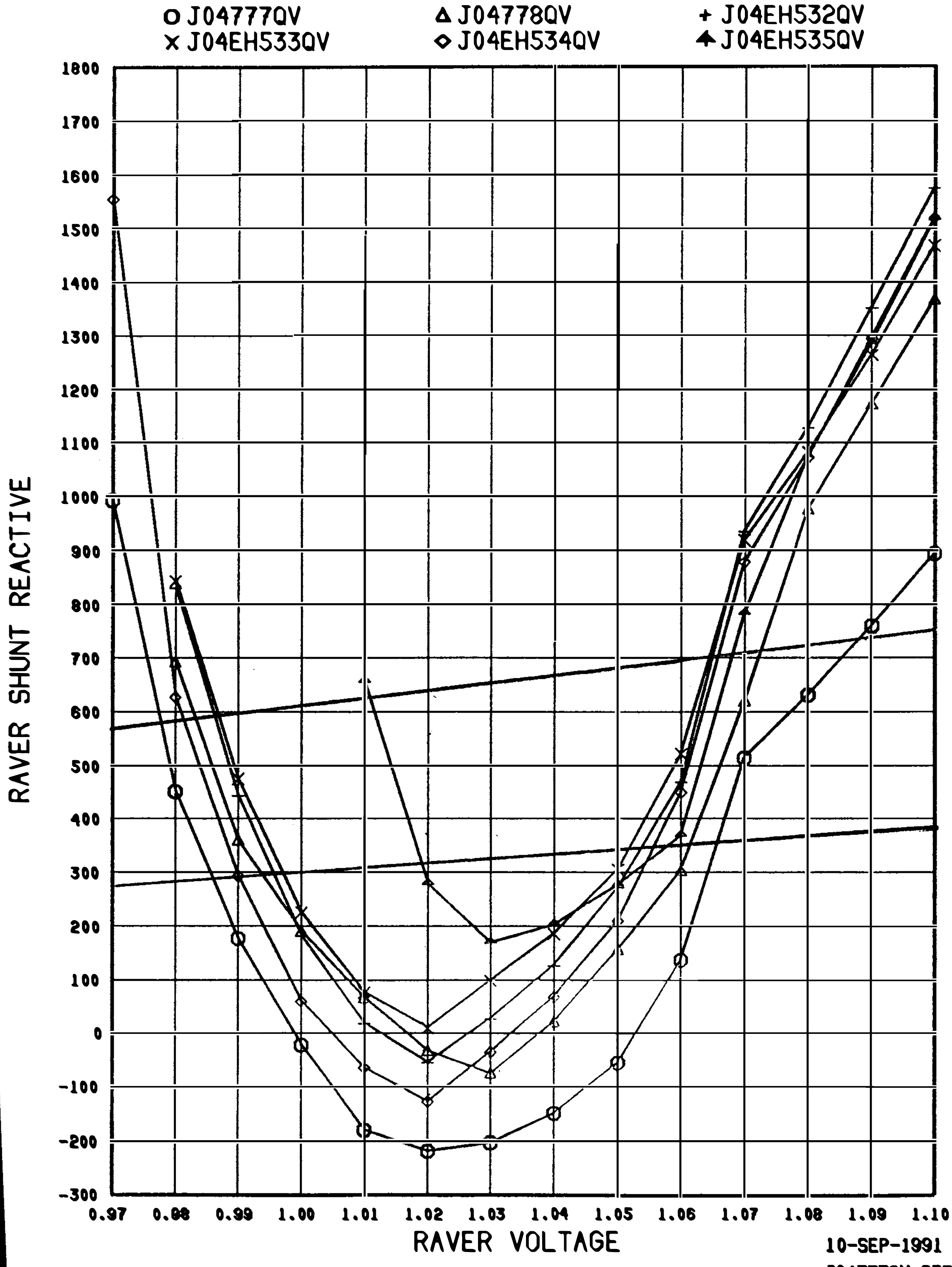


13-SEP-1991
J04657QV.SETUP

Sick-Snoq DC added
CJ-Sickler DC added
one circuit tied to Sickler

PLAN 6E

○J04777:COULE-RAVE 1&2 OUT,MSC @OLY,SNOQ,MON(J04776) Snoq avail
△J04778:CJ-SNQ & SICK-SNQ OUT MSC @OLY,SNQ(J04776) Snoq, Mon avail
+J04EH532:CJ-MON,×EH533:COUL-RVE,◇EH534:CJ-SNOQ,
MSC @OLY, MONROE (J04EH530)
▲J04EH535:TROJAN SCRAM,MSC@OLY,MARION(J04EH531)
} All MSC used.



10-SEP-1991
J04777QV.SETUP

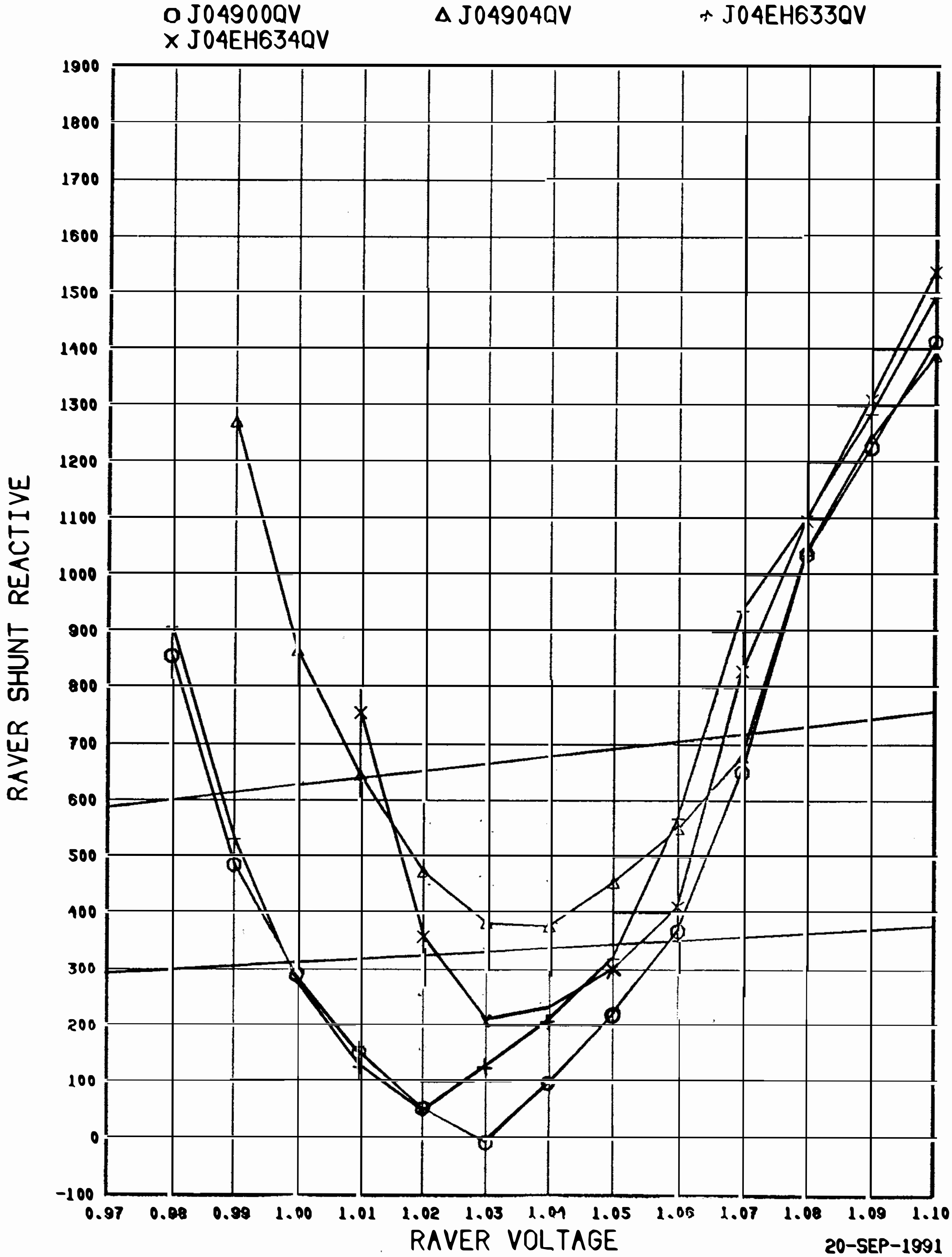
CJ-Snoq SDC added
no tie into Sickler

PLAN 6F

○J04900:CHIEF J-SNOQ 1&2 OUT(J04899)MSC OLY,SNQ(2)
△J04904:COULEE-RAVER 1&2 OUT(J04899)MSC OLY,SNQ(2)
+J04EH633:COUL-RAVER OUT (J04EH631)MSC OLY,MON(1)
×J04EH634:TROJAN SCRAM(J04EH632)MSC OLY,MARION(1)

} MON AVAIL.

} ALL MSC's used



20-SEP-1991
J04900QV.SETUP

Attachment 5

ATTACHMENT 5

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VOLTAGE COLLAPSE STUDIES FOR THE PUGET SOUND AREA

Submitted to the Puget Sound Area Electric Reliability Plan
Transmission Studies Team

By Gordon Comegys
Bonneville Power Administration

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Background

The Puget Sound Area Electric Reliability Plan (PSAERP) Transmission Studies Team directed BPA to investigate the scenario of voltage collapse for their area. The team members are BPA, Snohomish Co. PUD (SPUD), Puget Sound Power and Light (PSPL), Seattle City Light (SCL), and Tacoma City Light (TCL). This report applies the powerflow program to calculate system conditions as snapshots in time.

Steady state powerflow studies assume constant power load models (load demand insensitive to voltage). The winter Puget Sound area powerflow cases need large reactive additions and a high operating voltage near the maximum allowable level to successfully solve. Without these large reactive additions, the powerflow network does not have a mathematical solution. The failed solution indicates that the modeled condition of the existing transmission system and high projected loads cannot exist.

Despite the lack of a mathematical solution for the steady state system, transient stability studies with generator exciters limited show fully satisfactory performance. The key difference is the assumed load model for the transient stability studies. These studies assume voltage sensitive load models and no voltage regulation by distribution voltage regulating transformers. Steady state studies assume load models insensitive to voltage, representing the assumption that the constant energy demand will restore the power demand to pre-outage levels.

The purpose of this study is to explore the general system response during the attempted transition from transient to steady state. The PSAERP "superbase" powerflows are used. The development of the "superbases" is described in Appendix A. The loads are modeled with constant power, constant current, and constant impedance components. Distribution voltage regulating transformers are represented with approximate equivalents. The modeled system is intentionally put into the voltage instability state. The model includes the effects of varying amounts of shunt reactive, transformer tap changing, and added resistive heating load through thermostat action. The powerflow calculations show snapshots in time. At the time of this study, a time domain midterm dynamics program was not available to BPA. Any references to time such as 30 seconds, 2 minutes, or 20 minutes are estimates of regulator time delay, full tap range changing time, or thermostat response time, respectively.

Summary of Key Findings

Studies with voltage sensitive load models confirm that the minimum stable voltage in Puget Sound is the critical voltage calculated with constant power load models. The PSAERP "superbase" studies suggest that uncontrolled, continuously declining voltage and power delivery are the consequences of insufficient reactive. This assumes that a large amount of unconnected thermostatically controlled resistive heating load is available to connect to the system.

Switching shunt capacitors, if available, will successfully bring the voltage from a low unstable level back to the high stable voltage. A voltage level is classified as unstable if voltage and power delivery simultaneously decrease over several minutes (caused by thermostat response or other attempted load pickup). Conversely, a voltage level is classified as stable if power delivery increases as load is added. In actual operation, capacitors will be planned to switch on before the voltage declines to a low, unstable voltage if this can be coordinated. However, switching capactor banks will be difficult to coordinate before distribution voltage regulators change taps. This is due to the small voltage drop (2%-5%) prior to the regulator response, which is about the same as the voltage drop that occurs for a voltage stable system.

Switching the final capacitor bank to restore and maintain a high stable voltage causes a large voltage change. The large change will not occur immediately, but over a period of 1-2 minutes following the switched capacitor bank. A "chain reaction" occurs. The scenario appears to be this: switching the final capacitor bank causes the voltage on one load bus to become slightly high. The voltage regulator changes taps to reduce the voltage. This slightly decreases the system loading, causing the main system voltage to rise. The system voltage rise causes another load bus voltage to become high, causing the voltage regulator taps to change which causes the system loading to decrease and the system voltage rises again. The changing voltage is caused by the rapidly changing power demand as load voltage regulators change load voltages which subsequently changes load. The scenario continues until the voltage regulators are tapped out or equilibrium is reached. This scenario only occurs when voltages are within the voltage control range of the load voltage regulating transformers, about +10% or -10% of the stable main system voltage. If the Puget Sound customers had no load voltage regulating transformers, the voltage changes from capacitor switching would be much slower, perhaps 20 minutes or more.

Voltage control with large switched capacitor banks will be difficult once the minimum amount of shunt reactive is connected. A small increase in load demand will cause a relatively large decrease in voltage. Conversely, a small load decrease could cause a relatively large increase in voltage. These are the consequences of operating near the critical voltage. In the case of Maple Valley, the critical voltage is near the maximum criteria voltage. Exceeding the maximum criteria voltage could occur with voltage control from large shunt capacitor banks.

Key Assumptions

1. The 1993 winter "superbases" with enhanced load models and distribution voltage control modles are accurate. These powerflow bases were approved by PSAERP transmission studies team.

2. Motor and generator dynamics will not be a factor in the post transient state for load voltages above 0.85 per unit.

Conditions Studied

Four system conditions were studied: (1) double Coulee-Raver line outage during 1993 normal winter loads, (2) double Coulee-Raver line outage during 1991 operations Level 1 conditions (about 93% of 1991 normal winter peak), (3) single Chief Jo- Monroe line outage during 1993 abnormal cold, and (4) Trojan outage with one Centralia unit down during 1993 abnormal cold. Condition (1) was found to be most severe. Most of the investigation focused on the most severe condition.

Double Coulee-Raver Line Outage

The constant power V-Q calculation shows that over 1000MVARS of additional shunt reactive is needed for a successful powerflow solution (J93910QV, attachment 1). The constant power critical voltage is 550kV. This severely stressed system is studied further using the newly developed voltage sensitive load models.

Applying voltage sensitive load models show the likely scenario. The system voltage does not initially collapse (powerflow case J93764). Raver voltage drops from the 542kV precontingency voltage to 513kV prior to load voltage regulator response (estimated duration is 30 seconds). The Puget Sound load drops from 11,147MW to 10,448MW.

The effects of load regulator tap changing was modeled (J93765). Raver voltage is down to 475kV at the end of the regulator action, (estimated duration is 2 minutes). This assumes load regulator tap range with 8% remaining boost. The Puget Sound load drops further to 10,159MW. Nearly a 1000MW load reduction occurs. Realistically, some loads will be lost. Some load models will be invalid with voltages below 90% of nominal. For study purposes, the models are assumed to remain valid and all loads are assumed to remain connected.

Much of the 1000MW load reduction occurs from thermostatically controlled resistive heating. A 1% increase in connected resistance load was modeled (J93766). This models the effect of more electric heaters turning on in the next few minutes. The load served drops further. Total thermal output of the heaters is reduced even though more electric heaters have turned on. The system is operating in a voltage instability state.

Changing EHV transformer taps through LTC control further depresses the 500kV voltage. This case does not solve with EHV LTC's active because of voltage collapse on the BC-Hydro system. BCH loads are modeled as constant power. Changing one tap position on the Maple Valley transformer is modeled to check for any benefits in load restoration. The result is negative (J93928). The load drops further.

The constant power V-Q calculation shows EHV LTC's provide benefit (J93927QV, attachment 2). The required amount of shunt capacitors predicted by the constant power load model calculation must be connected before benefits occur with the voltage sensistive loads. Over 200MVARS of reactive benefit occurs with active EHV LTC's at Custer, Monroe, Maple Valley, Tacoma, Olympia, and Satsop (J93929). If the EHV LTC'S operate before the required shunt reactive is switched on, then the LTC's are a detriment to the system (J93928).

The system appears to be in a severe voltage instability state after load regulator and thermostat action. Power delivery decreases as more load is connected. Conversely, power delivery increases as load is disconnected.

The transient stability program is used to model the LOADSYN dynamic load model. The result shows no transient stability problem (swing J93S01).

Switching shunt capacitors was modeled to see how the system could recover from the voltage instability state. Switching shunt capacitors is successful (J93923, J93924). Initially, as shunt reactive is connected, the voltage increase is small. As more shunt capacitors are switched in, the voltage eventually increases enough to cause some load regulators to begin returning to the original tap. Load is slightly reduced from regulator action at these locations. Main system loading slightly decreases and 500kV voltage subsequently increases. More load regulators begin to change taps as voltages increase. After load regulator action the main system voltage begins to dramatically increase for smaller shunt reactive increments. The system voltage is more sensitive to load changes caused by regulator action than shunt reactive changes at any instant in time. Also, the resistive load is decreased to the original state because thermostats restore the diversity of electric heaters as thermal output increases. The system eventually reaches a stable state.

This case shows the amount of shunt capacitors needed to restore full load is the same for voltage sensitive or constant power load models. Switching capacitors does not dramatically change voltage at that instant. However, the voltage significantly changes once the voltage is in the range of load regulator control. This case needed 1000MVARS to restore load. The main system voltage did not significantly change until the last 300MVARS was inserted. The Raver voltage then increased 9% following load regulator action.

Inserting too much shunt reactive causes main system overvoltages after several minutes of load regulator action. Initially, load voltages and system voltages are only slightly high. The voltage sensitive loads increase. The subsequent increase in main system loading damps the initial overvoltage. However, the load regulators begin to change taps to reduce load voltages. The main system loading decreases and the voltage increases. The eventual magnitude of the overvoltage corresponds with constant power load model calculations.

Trojan Outage (One Centralia Unit Off)

This condition is slightly less severe than the double Coulee-Raver outage during normal weather, but more severe than the Chief Jo-Monroe outage. The critical voltage calculated with constant power load models is 535kV (J93EH1058QV, attachment 3). Only a 1% increase in load level raises the critical voltage to nearly 545kV and requires another 300MVARS for a mathematical solution.

Raver voltage drops from the 531kV precontingency voltage to 522kV immediately following the Trojan outage (J93EH1056). Voltage sensitive loads in Western Washington and Oregon drop from 23974MW to 23354MW. Raver voltage drops further to 491KV after load regulator action (J93EH1057). Loads reduce further to 22895MW.

An interesting correlation exists in this case between the constant power critical voltage and positive load restoration by load regulator action (attachment 4). Load appears to partially restore until the main system voltage drops to the constant power critical voltage. The load actually drops as the main system voltage continues to decline below the critical voltage. The double Coulee-Raver outage has a critical voltage too high to see this correlation.

Chief Jo-Monroe Outage

This condition is slightly less severe than either of the above two conditions. The critical Raver voltage using the constant power load model is 540kV following the Chief Jo-Monroe outage (J93EH1045QV, attachment 5). Only a 1% increase in load level raises the critical voltage to 545kV and requires another 250MVARS for a mathematical solution.

The Raver voltage falls from 535kV before the outage to 517kV after the outage (J93EH1038). The voltage sensitive loads drop from 12229MW to 11746MW. Voltage drops further to 496kV following load regulator action (J93EH1039). The load also drops to 11653MW. Increasing constant resistance load to simulate thermostat action decreases load further (J93EH1040). This confirms the system is in the voltage instability state.

The same correlation seems to exist between positive load restoration by load regulator action and the constant power critical voltage (attachment 6).

1991 Level 1 Winter Load Modeling Test (Proposed)

These studies examine voltage stability with a less stressed system. Level 1 for the 1990-91 operating winter is defined by System Operations as the maximum loading level where all load can still be served with no combustion turbine operation following a double Coulee-Raver line outage. The powerflow case under study represents the 1991 system with Puget Sound area load at 89% of the 1993 study. The level 1 condition is analyzed to compare results of a less stressed system with the highly stressed 1993 system above.

Raver voltage is 535kV with all Raver shunt capacitor banks off line and all lines in service. Puget Sound load level is 9956MW. The critical voltage for the post transient double Coulee-Raver outage using constant power load model is 520kV (J9150QV, attachment 7).

Raver voltage drops to 512kV initially after opening the two Coulee-Raver lines (J9145). The voltage sensitive loads drop to 9528MW. Following load regulator tap changes, the Raver voltage drops further to 487kV (J9146). However, a small part of the load partially restores to 9610MW. The system does not appear to be in the voltage instability state because of some load restoration by load regulators. Also, adding a small amount of constant resistance load results in more load served (J9189). Switching the 952MVARS of available Raver shunt capacitors fully restores the load as predicted by the constant power calculation (J9161,J9163).

The previous correlation between load restoration by load regulator action and the constant power critical voltage does not appear with this less stressed system. Also, correlation is not precise between the critical voltage of a P-V curve using voltage sensitive loads and the critical voltage of the constant power V-Q curve (attachment 8).

Conclusions

Constant power studies accurately determine the amount and location of required voltage support to serve full load. This includes benefits from shunt capacitors, EHV LTC adjustment, and line drop compensators at generator terminals. Shunt reactive must be inserted before benefits occur from EHV LTC changes.

The studies show the following:

* the key planning indicator of voltage stability is the critical voltage as calculated from the constant power V-Q curve.

* a system with voltage sensitive loads similar to the Puget Sound area cannot operate below the critical voltage. This conclusion assumes a large amount of resistive heating load can be connected through thermostat response. Shunt reactive additions are no longer an alternative when the critical voltage reaches the maximum system voltage.

* the state of voltage instability is characterized by an actual reduction in load served as more resistive heating load is connected through thermostat response. Sudden voltage collapse does not occur with these PSAERP load models.

* the voltage level that voltage instability occurs from a P-V calculation approximately corresponds with the critical voltage of a constant power V-Q calculation.

* switching capacitors causes large voltage excursions over a several minute period when full load restoration is approached. This assumes the switching of capacitors cannot be coordinated prior to load voltage regulator response (the initial voltage change is small, only 2%-5%).

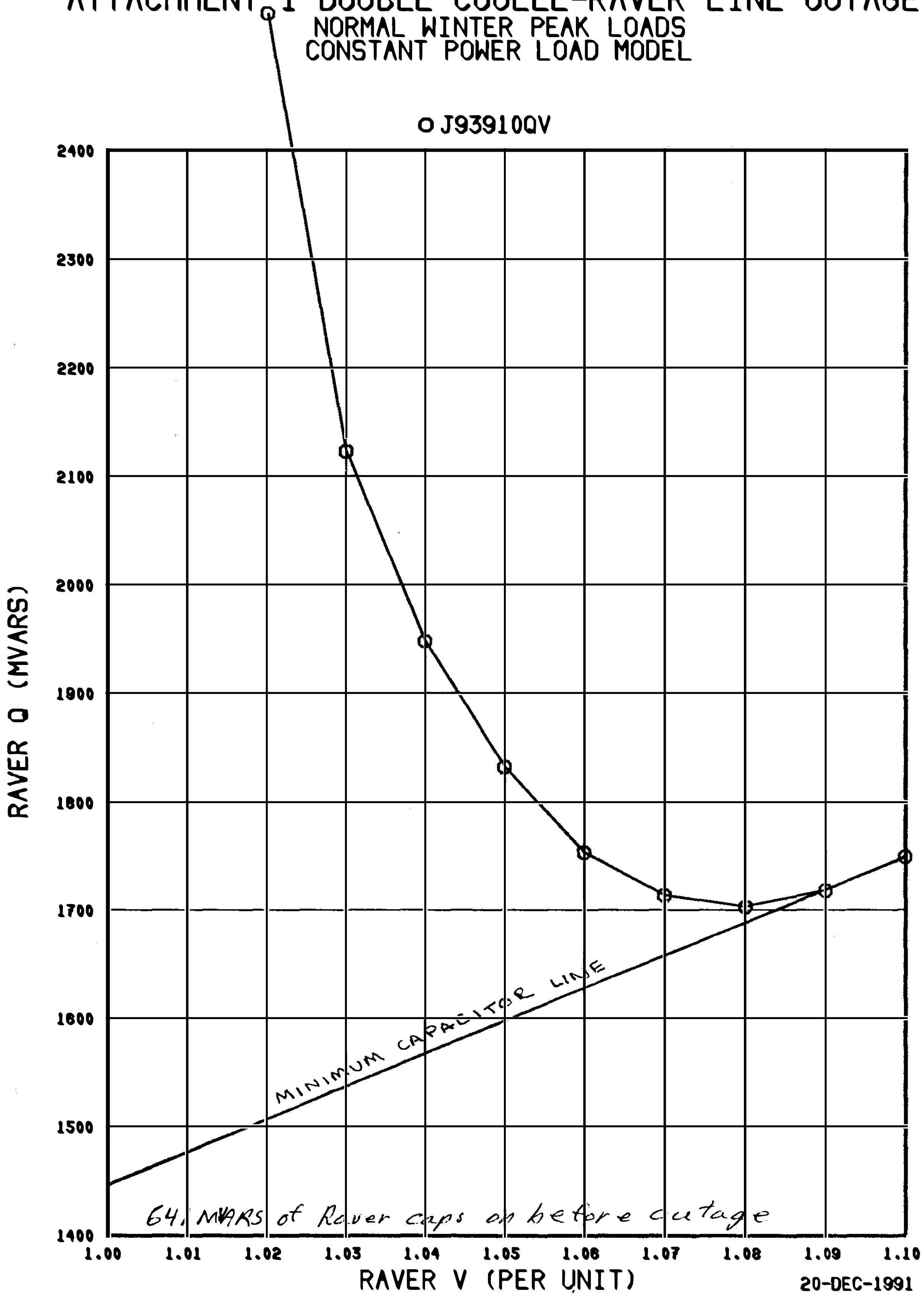
* restoring lines to service after mechanically switched capacitor (MSC) action has occurred does not cause severe overvoltages for 30 seconds. Following load voltage regulator action, the overvoltage is accurately predicted by constant power calculations.

Further Studies

The above information is based on powerflow studies with static load models. This assumes the motor and generator dynamics will not be significant with a load area dominated by constant impedance or resistive heating load. To confirm this assumption, a study using one of the mid-term dynamics programs under development, such as the EPRI ETMSP or the PTI program, is recommended.

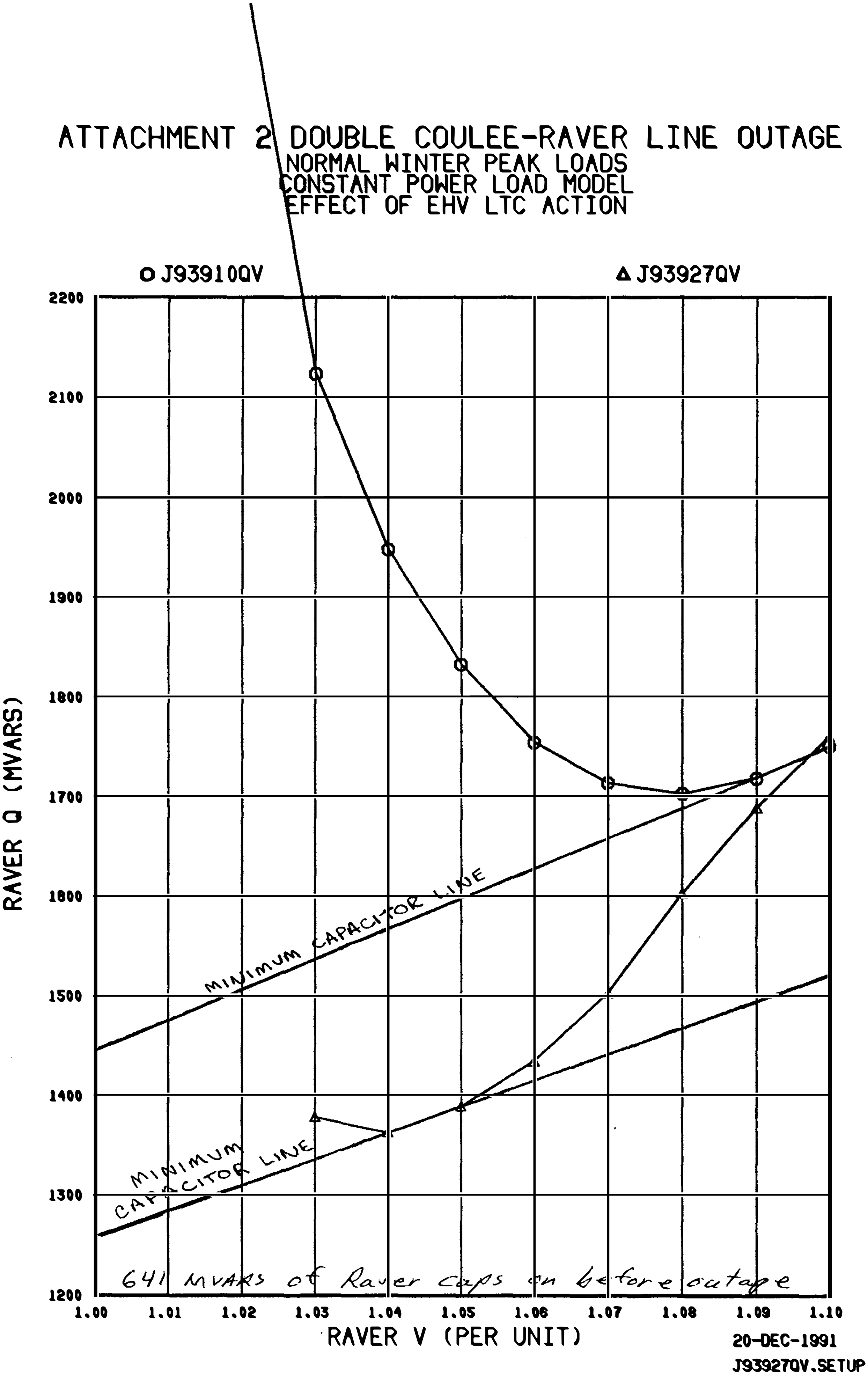
GLC 2/11/91 last revision 2/3/92
bpa65::disk15:[eofcglc]voltagestability.report

ATTACHMENT 1 DOUBLE COULEE-RAVER LINE OUTAGE
NORMAL WINTER PEAK LOADS
CONSTANT POWER LOAD MODEL



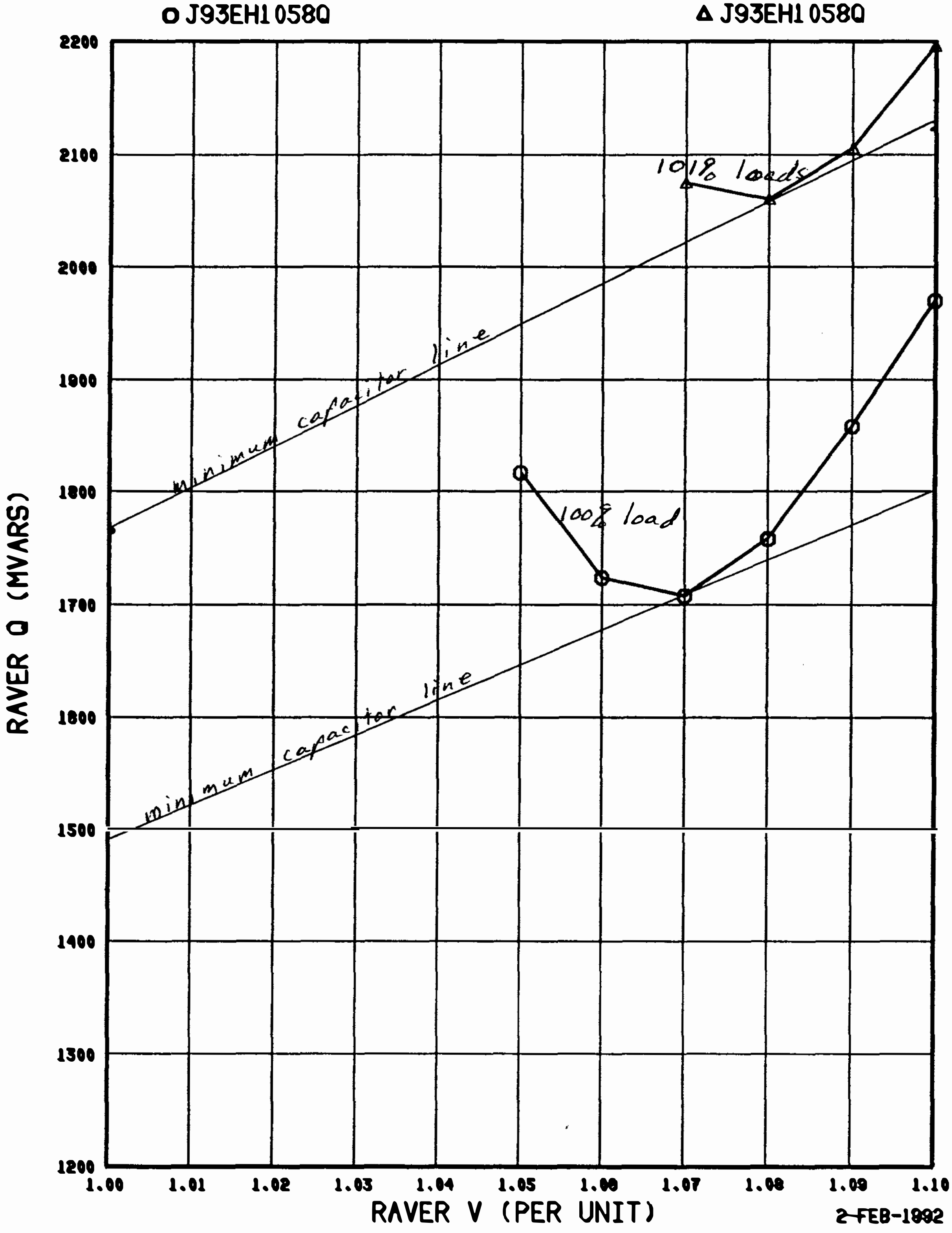
20-DEC-1991
J93910QV.SETUP

ATTACHMENT 2 DOUBLE COULEE-RAVER LINE OUTAGE
NORMAL WINTER PEAK LOADS
CONSTANT POWER LOAD MODEL
EFFECT OF EHV LTC ACTION



20-DEC-1991
J93927QV.SETUP

ATTACH. 3 TROJAN OUT WITH ONE CENTRALIA UNIT OFF
ABNORMAL COLD WINTER PEAK LOADS
CONSTANT POWER LOAD MODEL



2-FEB-1992
J93EH1058QV.SETUP

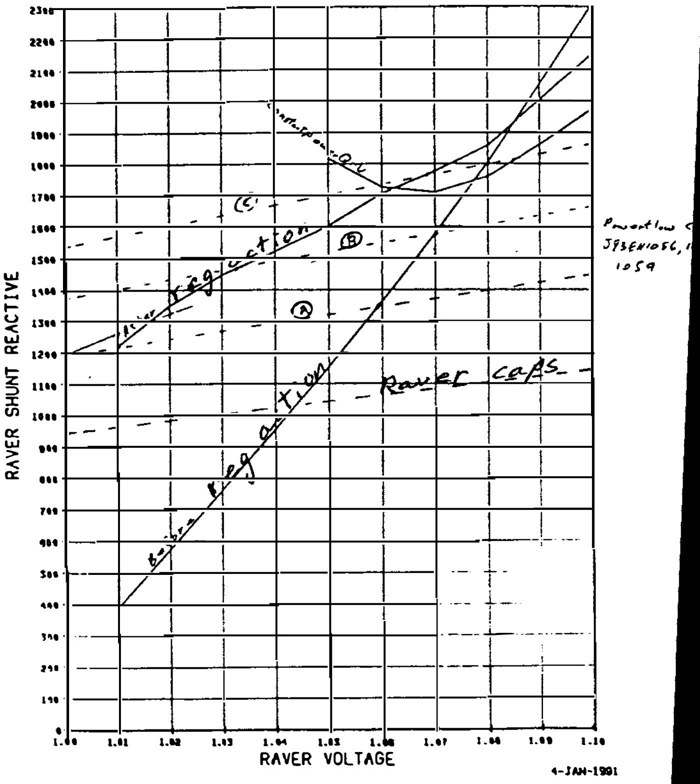
J93 Post Transient Trojan Outage
MSC 300 MVARS AT KEELER

Attachment 4

constant power load
compared to
Voltage sensitive
load models

Ⓐ CAP BANK A
Ⓑ CAP BANK B
Ⓒ CAP BANK C

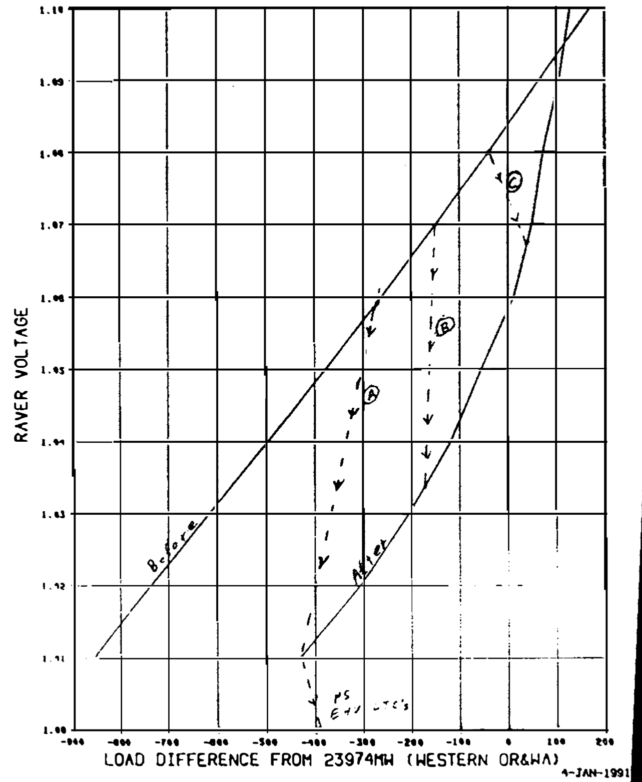
Raver V vs Raver Q



J93 Post Transient Trojan Outage
MSC 300 MVARS AT KEELER

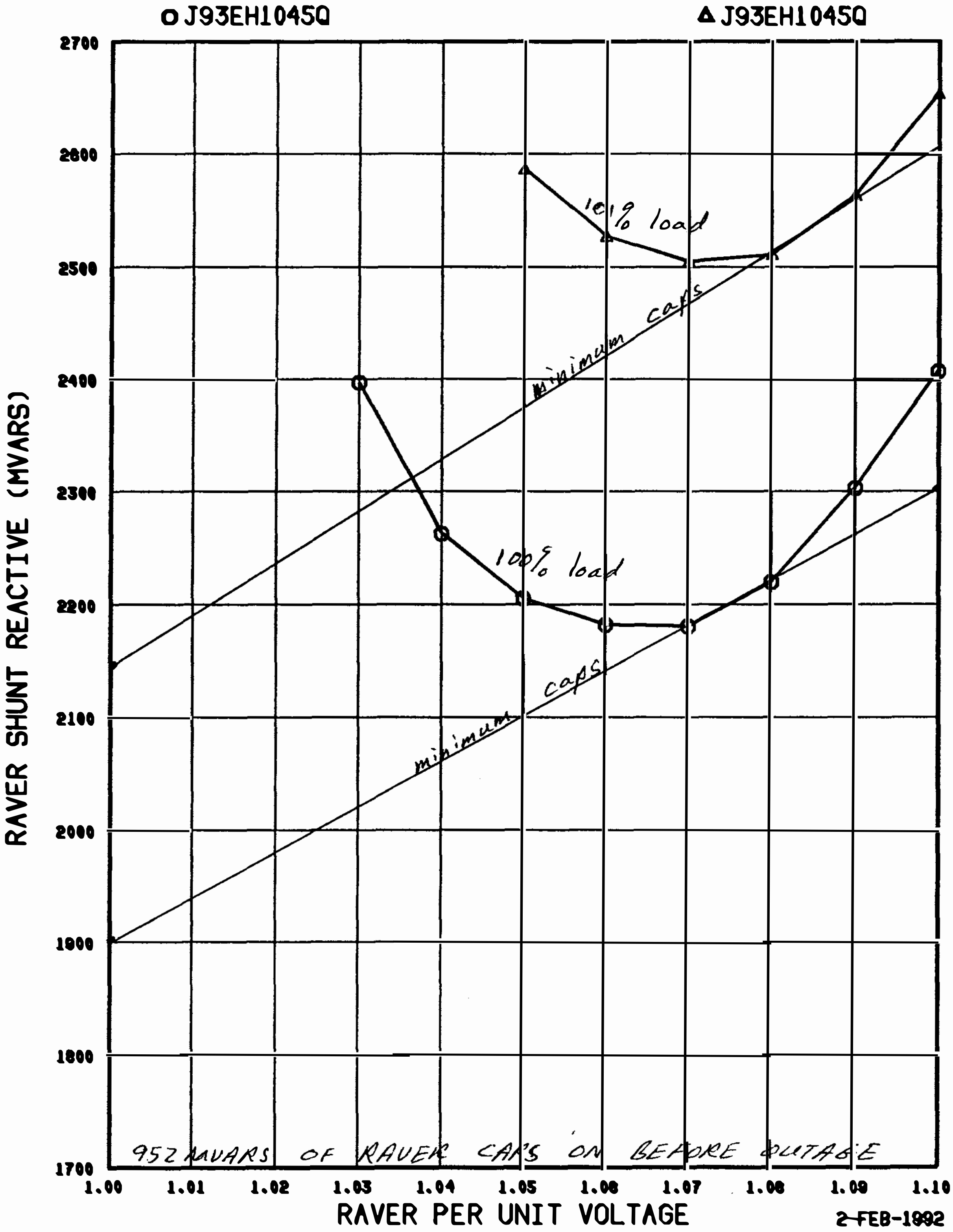
Load unserved vs. Raver Voltage

Ⓐ Ⓑ Ⓒ
refers to
operating points
on VQ curve above



ATTACHMENT 5

CHIEF JO-MONROE 500KV LINE OUTAGE
1992-1993 COLD WINTER LOADS
CONSTANT POWER LOAD MODELS
VOLTAGE VS SHUNT REACTIVE @ RAVER



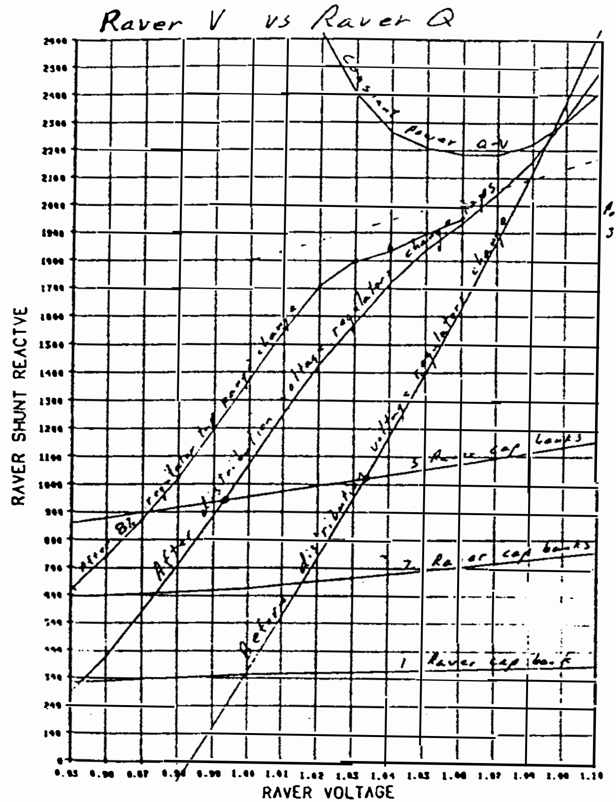
952 MVARS OF RAVER CAPS ON BEFORE OUTAGE

2-FEB-1992
J93EH1045QV.SETUP

J93EH Post Transient CHIEF JO-MONROE OUTAGE
CONSTANT POWER LOAD MODEL COMPARED TO
VOLTAGE SENSITIVE LOAD MODEL
BEFORE AND AFTER DIST VOLTAGE REG CHANGES

Attachment 6

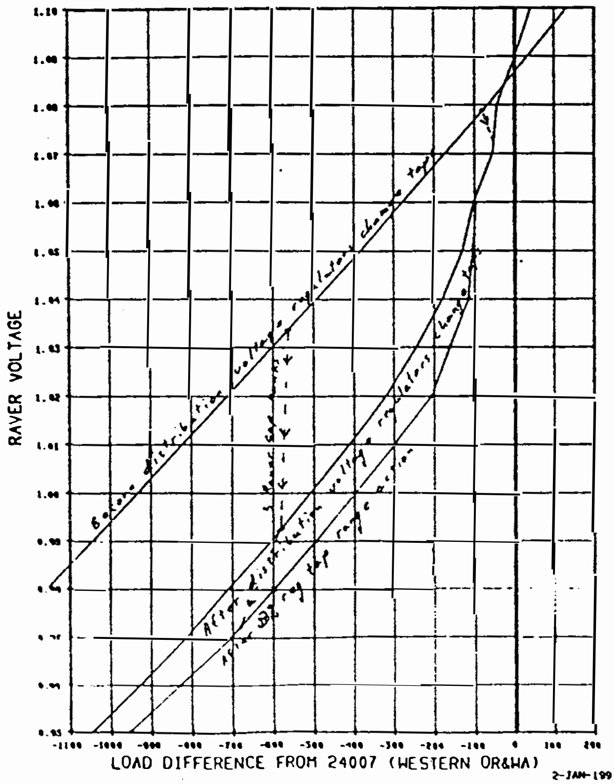
Raver V vs Raver Q



Powerflow cases 393EN1045, 1046, 1047, 1048

gt 2-JAN-1991

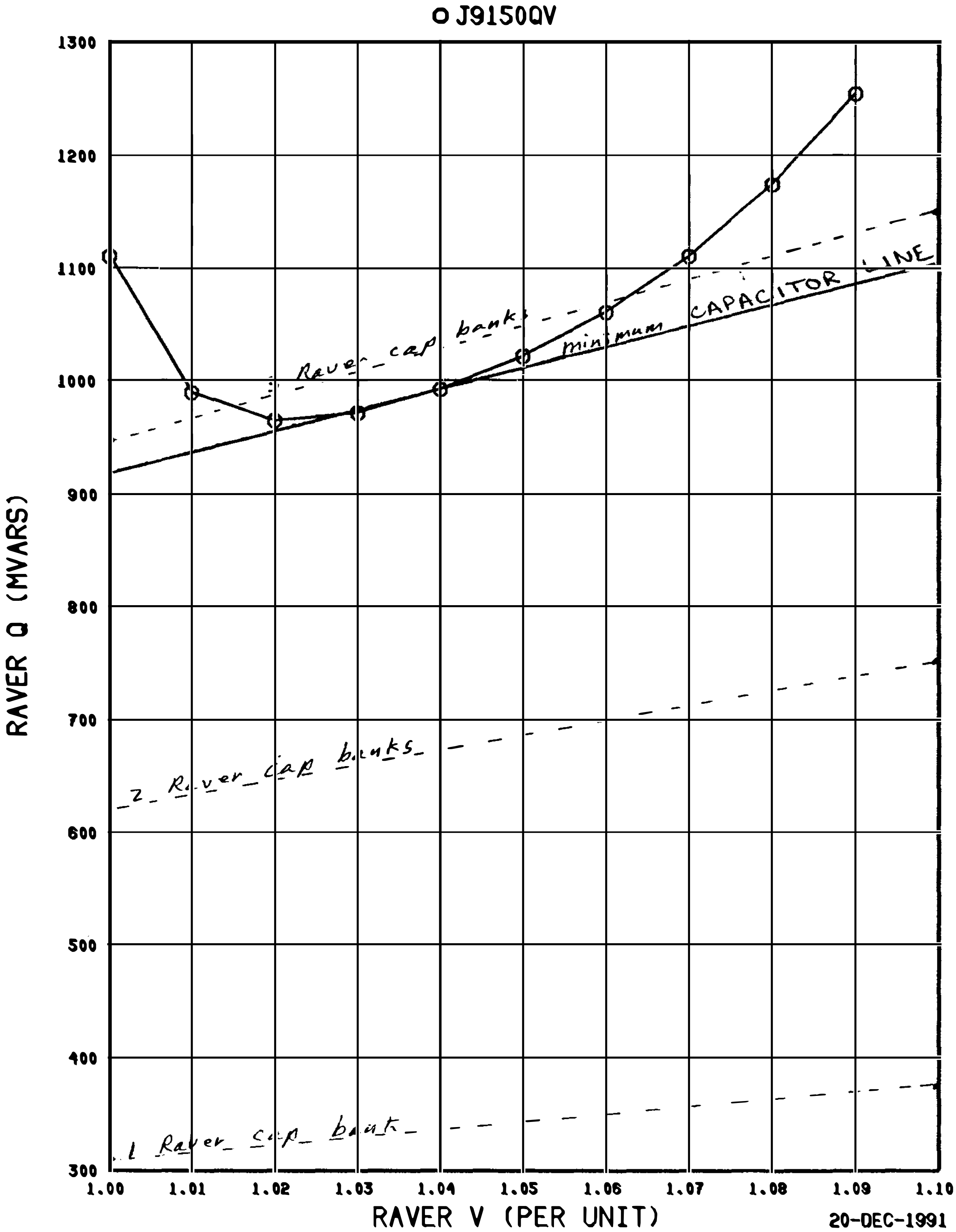
LOAD UNSERVED VS RAVER VOLTAGE



2-JAN-1991

ATTACHMENT 7 1991 LEVEL 1 SYSTEM TEST

DOUBLE COULEE - RAVER OUTAGE



20-DEC-1991

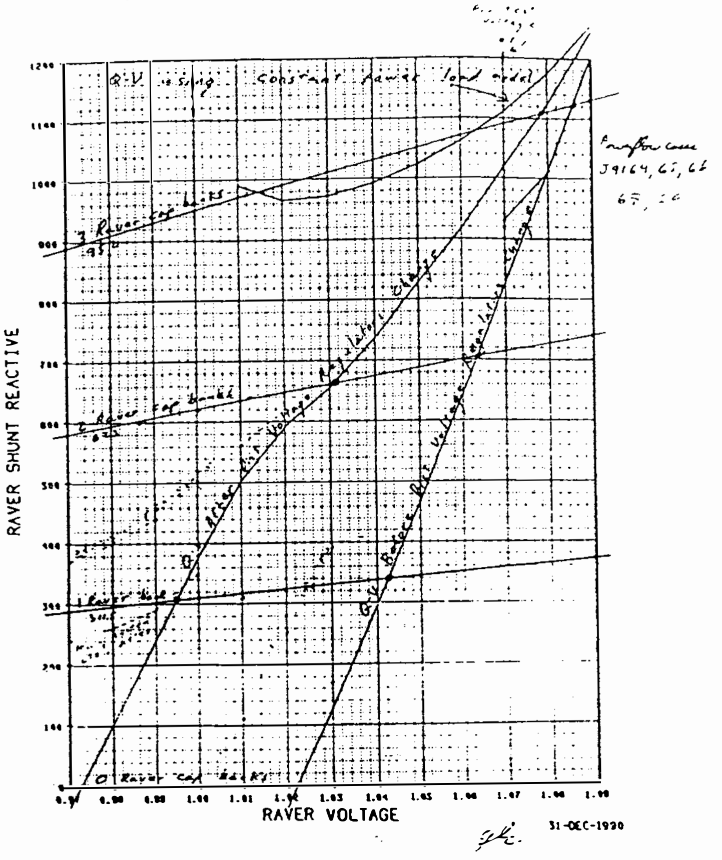
J9150QV.SETUP

J91 Level 1 Load Response Test (proposed)

Raver V vs. Raver Q

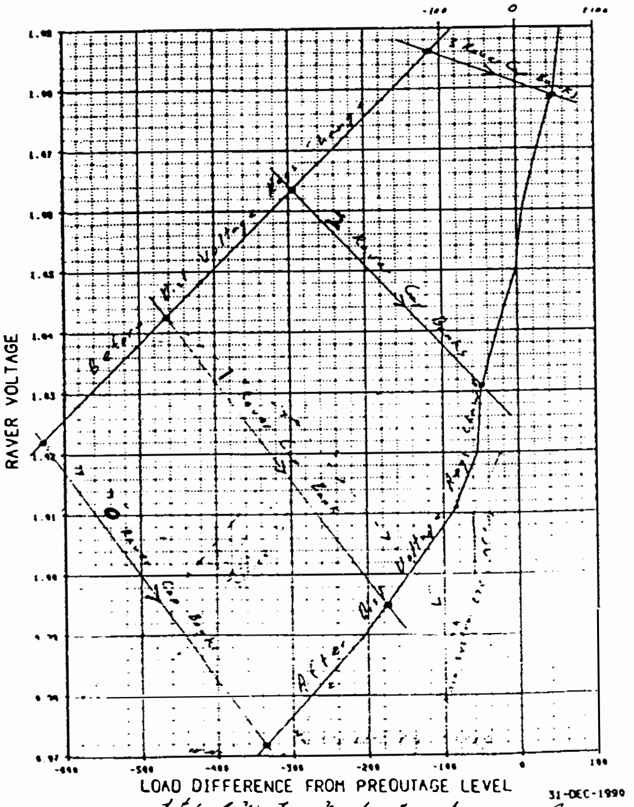
Attachment 8

CONSTANT POWER
LOAD MODEL COMPARED
TO VOLTAGE SENSITIVE
MODEL BEFORE AND
AFTER DIST VOLTAGE
REGS CHANGE TAPS



31-DEC-1990

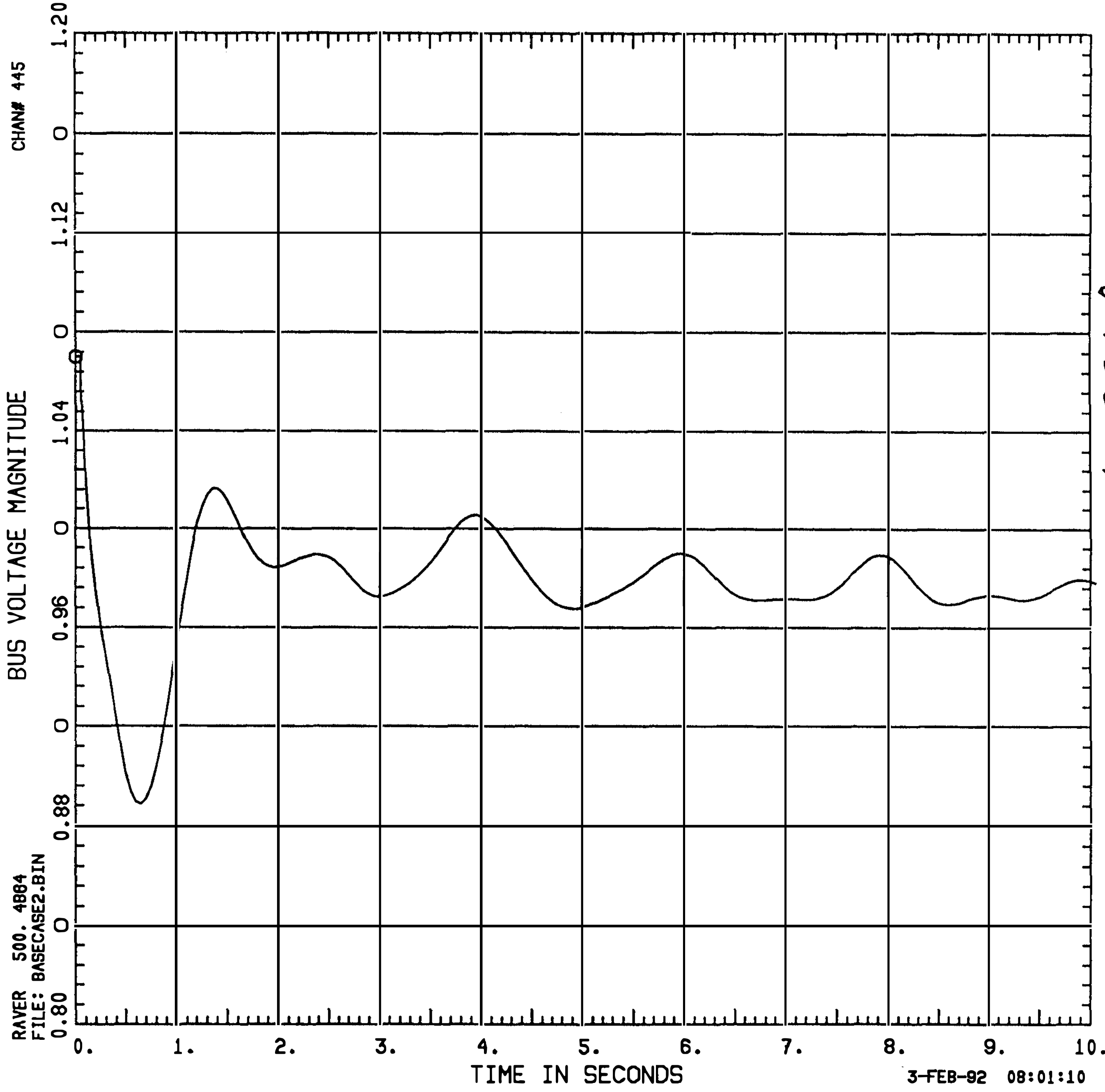
Load unserved vs Raver V



Loss of Western Washington and Western Oregon

31-DEC-1990

COULEE -R : 500KV DOUBLE LINE OUTAGE



J93S01

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J9143 BASE FOR SYSTEM TEST USING VOLTAGE SENSITIVE LOAD MODELS
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
  ....................BUS VOLTAGES (PER UNIT).....................
   STER500  MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500
   059      1.090      1.079      1.070      1.086      1.051
 OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500   OSTRNDER500
 1.087      1.088      1.084      1.083       1.084      1.079
 MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
 1.082      1.038      1.042      1.014      1.013      1.035
 BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
 1.029      1.042      1.026      1.016       1.043      1.041
 TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 1.041      1.032      1.044      1.040      1.052      1.044
 KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
 1.024      1.035      1.035      1.024       0.999      1.004
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 1.009      0.951      0.951      1.034      1.034      0.994
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.994      0.948      0.948      0.984       0.984      0.969
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
 0.969      0.979      0.979      0.973      0.973      0.964
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.964      1.040      1.040      1.040       1.012       1.012
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 1.022      0.968      0.940      0.940      0.998      0.998
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
 0.950      0.950      0.940      0.940       1.000       1.000
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
   176         12          8        182         22        166        -1
 1.045      0.996      0.997      1.026      1.020      1.012      1.002
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD    BONN PH2
  105         -1         10          3          5          88         67
 1.011      1.002      1.050      1.004      1.008      1.014      1.001
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
  105         44       -224       -130        -85        -63
 1.011      1.001      0.959      0.950      0.950      0.978
 ...................SLACK BUS AND AGC BUSES (MW)............................
 RIDGE2    COULEE 2   JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  178         839       2000         600       600        1180      5219
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR)......................
     NA     AA      AB      SC      SP      TC      NB      NC      17
P  1647   3403     501    1706    1284    1417    7081    3307    8419
Q   577   1099     239     437     359     501    1809    1002    3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 9956     Q= 3211              P=20344     Q= 6023
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
     NA     AA      AB      SC      SP      TC      NB      NC      17
P  1913    352       0     298     100     278    3038     700    9466
Q    66     27       0      -5      41      94     385     155     321
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 2941     Q=  223              P= 6679     Q=  540
..................NET MW LOAD (LOAD - GENERATION)................................
PUGET SOUND= 7015      WEST ORE & WA=13665
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
      NA        AA        AB        SC        SP        TC        NB        NC        17    ND+NE+NF+NG+NH
P    206        67         1        19         7        14       159       109       575         314
Q    393       360         0        71        26       186       701      -367     -5625        -856
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  315     Q= 1035              P=  583     Q= 1369
.................BUS SHUNT REACTIVE (MVAR)..................................
RAVER=      0   USED       0        UNSCHEDULED
 ...............ZONE SHUNT REACTIVE (MVAR)..................................
      NA        AA        AB        SC        SP        TC        NB        NC        17   ND+NE+NF+NG+NH
    2668      1007       103       610         0       125      2157       714     -2381         660
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 4513                      QSHUNT= 7384
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J9145 BASED ON J9144, OPEN COULEE-RAVER #2 (BOTH LINES NOW OPEN)
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
  ........................BUS VOLTAGES (PER UNIT).........................
   STER500   MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500
    033      1.047      1.035      1.024      1.066      1.008
  OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500    OSTRNDER500
  1.066      1.067      1.068      1.069       1.070       1.065
  MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
  1.069      1.012      1.014      0.983      0.978      0.997
  BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
  0.994      1.003      0.989      0.978       1.000       0.999
  TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
  0.999      0.991      1.020      1.015      1.025      1.017
  KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
  0.999      1.020      1.025      0.996       0.963       0.969
  AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
  0.970      0.923      0.923      0.979      0.979      0.954
  EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
  0.953      0.920      0.920      0.947       0.947       0.934
  CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
  0.934      0.944      0.944      0.937      0.937      0.925
  HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
  0.925      1.013      1.013      1.013       0.985       0.985
  SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
  0.981      0.930      0.913      0.913      0.955        0.955
  CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
  0.912      0.912      0.914      0.914       0.957       0.957
  ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
  COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
   338        187        134        408        181        240         21
  1.045      0.996      0.997      1.025      1.020      1.012      1.002
  CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD    BONN PH2
   157         21         20          8         19         221          96
  1.000      1.002      1.050      1.004      1.008      1.029      1.001
  CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
   157         66       -187       -111        -72         33
  1.000      1.001      0.959      0.950      0.950      0.978
  ..................SLACK BUS AND AGC BUSES (MW).............................
   RIDGE2     COULEE 2   JOHN DAY     CHIEF J2   CHIEF JO    CHIEF J5 TOTAL PNW
   193         546        1976         561        561        1087       4730
   ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
       NA     AA     AB     SC     SP     TC     NB     NC     17
  P  1591   3230    496   1636   1219   1356   6979   3269   8419
  Q   551   1026    236    410    336    474   1780    988   3340
  SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
      P= 9528     Q= 3033              P=19776     Q= 5801
  ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
       NA     AA     AB     SC     SP     TC     NB     NC     17
  P  1913    352      0    298    100    278   3038    700   9481
  Q   265     59      0     77     50    124    544    193    826
  SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
      P= 2941     Q=  575              P= 6679     Q=  737
 ..................NET MW LOAD (LOAD - GENERATION)................................
  PUGET SOUND= 6587      WEST ORE & WA=13097
  ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
       NA       AA       AB       SC       SP       TC       NB       NC       17     ND+NE+NF+NG+NH
  P   225       74        1       19        7       14      167      111      590          356
  Q  1482      412        1       84       28      175      862     -270    -5276          -21
  SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
      P=  340     Q= 2181              P=  619     Q= 2772
   ...............ZONE SHUNT REACTIVE (MVAR)..................................
       NA       AA       AB       SC       SP       TC       NB       NC       17   ND+NE+NF+NG+NH
     2484      939       97      576        0      115     2111      703    -2634           37
  SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     QSHUNT= 4211                      QSHUNT= 7025
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J9146, BASED ON J9145, SYSTEM AFTER DISTRIBUTION SYSTEM VOLTAGE REGULATOR ADJUST
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 ........................BUS VOLTAGES (PER UNIT).........................
  STER500    MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500
  997        0.998      0.982      0.973      1.037      0.955
 OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500    OSTRNDER500
 1.034      1.034      1.043      1.046       1.048       1.044
 MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
 1.049      0.971      0.965      0.930      0.923      0.943
 BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
 0.942      0.951      0.936      0.922       0.945       0.943
 TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 0.943      0.934      0.980      0.966      0.968      0.958
 KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
 0.945      0.995      1.007      0.942       0.906       0.912
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 0.979      0.851      0.920      0.925      1.000      0.884
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.956      0.847      0.916      0.887       0.959       0.874
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
 0.945      0.885      0.957      0.878      0.949      0.866
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.937      0.953      1.030      1.036       0.920       0.994
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 0.990      0.871      0.929      0.859      0.887        0.959
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
 0.845      0.913      0.859      0.929       0.902       0.975
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
   403        346        249        408        415        371          52
 1.045      0.996      0.997      0.999      1.020      1.012      1.002
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
   157         52         41         15         26        429         143
 0.972      1.002      1.050      0.974      0.969      1.051       1.001
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
   157        102       -137        -85        -55        156
 0.972      1.001      0.959      0.950      0.950      0.978
 ..................SLACK BUS AND.AGC BUSES (MW).............................
 RIDGE2     COULEE 2   JOHN DAY     CHIEF J2   CHIEF JO    CHIEF J5 TOTAL PNW
   14         729       1991          585        585        1145       5035
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA      AA      AB       SC       SP      TC      NB      NC      17
 P  1633    3304     499    1549    1247    1378    7082    3308    8419
 Q   570    1056     238     373     346     483    1808    1002    3340
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 9610      Q= 3067             P=20000     Q= 5878
 ..............ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
     NA      AA      AB       SC       SP      TC      NB      NC      17
 P  1913     352       0     298     100     278    3038     700    9503
 Q   561     102       0     195      50     138     819     267    1544
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 2941      Q= 1047             P= 6679     Q= 1087
.................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 6669       WEST ORE & WA=13321
 ...............ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
     NA        AA        AB        SC        SP        TC        NB        NC        17   ND+NE+NF+NG+N
 P   254       84         2        21         8        16       180       118       611           373
 Q  2135      530         2       139        38       213      1076      -107     -4716           440
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  385      Q= 3058             P=  683     Q= 4027
  ..............ZONE SHUNT REACTIVE (MVAR).................................
     NA        AA        AB        SC        SP        TC        NB        NC        17  ND+NE+NF+NG+NH
   2234       829        87       534         0       102      2027       671     -2586            18
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 3786                       QSHUNT= 6484
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J9161 BASEDON J9145, SWITCH IN 3 RAVER CAP BANKS 20 SECONDS INTO TEST
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 ........................BUS VOLTAGES (PER UNIT).........................
 'STER500   MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500  COULEE500
  050       1.076      1.084      1.087      1.089      1.066      1.080
OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500   OSTRNDER500
1.089      1.090      1.084      1.078       1.076      1.070
MARION500  CUSTER230  BELLNGM230 SEDRO230    MURRAY230  SNOHOMSH230
1.073      1.029      1.032      1.003       1.000      1.021
BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
1.020      1.029      1.018      1.010       1.050      1.043
TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
1.043      1.041      1.043      1.039      1.051      1.044
KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
1.024      1.035      1.034      1.014       0.986      0.996
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
1.010      0.941      0.941      1.009      1.009      0.998
EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
0.998      0.938      0.938      0.972       0.971      0.956
CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
0.956      0.971      0.971      0.960      0.960      0.970
HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
0.970      1.040      1.040      1.040       1.012      1.012
SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
1.028      0.974      0.930      0.930      1.002        1.002
CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
0.953      0.953      0.931      0.931       0.978       0.978
..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
  300        147        105        362        -1         175          6
1.045      0.996      0.997      1.026      1.020      1.012      1.002
CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
  157         6         14          2          2         135          85
1.004      1.002      1.050      1.004      1.008      1.019       1.001
CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
  157        58        -196       -116        -75         11
1.004      1.001      0.959      0.950      0.950      0.978
..................SLACK BUS AND AGC BUSES (MW)..............................
"RIDGE2     COULEE 2    JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  188        850        2001         601       601        1183      5236
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA      AA      AB      SC      SP      TC      NB      NC      17
P  1641    3395     501    1717    1264    1427    7032    3281    8419
Q   574    1096     239     441     352     505    1796     993    3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 9944    Q= 3208               P=20258     Q= 5997
................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
     NA      AA      AB      SC      SP      TC      NB      NC      17
P  1913     352       0     298     100     278    3038     700    9476
Q    42      35       0      19      50      83     440     181     529
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 2941    Q=  229               P= 6679     Q=  621
..................NET MW LOAD (LOAD - GENERATION)................................
PUGET SOUND= 7003      WEST ORE & WA=13579
................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
     NA       AA       AB       SC       SP       TC       NB       NC       17   ND+NE+NF+NG+NH
P   238       76        1       19        7       14      169      112      585             363
Q  1566      417        0       66       27      181      872     -270    -5469             103
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  355    Q= 2258               P=  637     Q= 2860
.................BUS SHUNT REACTIVE (MVAR)..................................
RAVER=  1125  USED         0        UNSCHEDULED
MONROE=   381  USED         0        UNSCHEDULED
 ...............ZONE SHUNT REACTIVE (MVAR)..................................
     NA       AA       AB       SC       SP       TC       NB       NC       17   ND+NE+NF+NG+NH
   3768     1003      101      615        0      127     2136      707    -2652             45
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 5615                      QSHUNT= 8457
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J9163 BASEDON J9161, DIST VOLTAGE REGS ADJUST AFTER 3 RAVER CAP BANKS SWITCHED
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 .........................BUS VOLTAGES (PER UNIT).........................
  STER500    MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500  COULEE500
  045        1.070      1.078      1.081      1.086      1.061      1.078
 OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500    OSTRNDER500
 1.086      1.087      1.080      1.074       1.071       1.066
 MARION500  CUSTER230  BELLNGM230 SEDRO230    MURRAY230  SNOHOMSH230
 1.069      1.023      1.024      0.995       0.992      1.013
 BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
 1.013      1.022      1.010      1.003       1.045       1.037
 TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 1.037      1.035      1.039      1.035       1.046      1.038
 KITSAP230  CHEHALS230 LONGVW230  SEDRO115   SNOHMSH115  SNOKING115
 1.019      1.033      1.032      1.005       0.978       0.988
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 1.009      0.926      0.949      1.003      1.034      0.992
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.992      0.922      0.945      0.962       0.986       0.946
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
 0.970      0.962      0.980      0.951      0.974      0.965
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.965      1.034      1.040      1.040       1.006       1.012
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 1.021      0.970      0.938      0.921      0.996       0.998
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
 0.948      0.948      0.921      0.939       0.970       1.000
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE)......................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
  325        166        119        390         26        196         10
 1.045      0.996      0.997      1.026      1.020      1.012      1.002
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD    BONN PH2
  157         10         17          2          4         161         96
 1.000      1.002      1.050      1.004      1.008      1.022      1.001
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
  157         66       -186       -111        -72         37
 1.000      1.001      0.959      0.950      0.950      0.978
 ..................SLACK BUS AND AGC BUSES (MW)..............................
 BRIDGE2    COULEE 2   JOHN DAY     CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  190        910       2006          609       609        1199      5334
   .............ZONE REAL AND REACTIVE LOADS (MW,MVAR)......................
      NA      AA      AB      SC      SP      TC      NB      NC      17
 P  1643    3400     501    1705    1286    1419    7082    3304    8419
 Q   575    1098     239     437     360     502    1809    1001    3340
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 9955      Q= 3210              P=20340    Q= 6020
 ...............ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
      NA      AA      AB      SC      SP      TC      NB      NC      17
 P  1913     352       0     298     100     278    3038     700    9478
 Q    76      43       0      35      50      91     491     202     623
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 2941      Q=  295              P= 6679    Q= 693
.................NET MW LOAD (LOAD - GENERATION)...............................
 PUGET SOUND= 7014       WEST ORE & WA=13661
 ...............ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
      NA        AA        AB        SC        SP        TC        NB        NC        17    ND+NE+NF+NG+NH
 P   243        77         1        19         8        14       172       114       587           367
 Q  1656       431         0        70        29       181       924      -221     -5402           191
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  362      Q= 2368              P=  648      Q= 3071
 ................BUS SHUNT REACTIVE (MVAR)..................................
 RAVER=  1113   USED         0        UNSCHEDULED
 MONROE=   376  USED         0        UNSCHEDULED
  ..............ZONE SHUNT REACTIVE (MVAR).................................
      NA        AA        AB        SC        SP        TC        NB        NC        17   ND+NE+NF+NG+NH
    3725       990       100       610         0       126      2118       697     -2646            43
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 5550                      QSHUNT= 8365
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J9189 BASEDON J9146, 1% CONSTANT R INCREASE
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 ........................BUS VOLTAGES (PER UNIT)..........................
  STER500   MONROE500   MAPLEVL500  RAVER500    PAUL500     TACOMA500    COULEE500
  994       0.995       0.978       0.970       1.036       0.952        1.064
OLYMPIA500  SATSOP500   ALLSTON500  KEELER500    PEARL500     OSTRNDER500
1.032       1.032       1.041       1.045        1.047        1.043
MARION500   CUSTER230   BELLNGM230  SEDRO230    MURRAY230   SNOHOMSH230
1.048       0.968       0.962       0.927       0.919       0.939
BOTHELL230  MONROE230   SNOKING230  SAMMAMSH230 COVINTN230   TALBOTN230
0.939       0.947       0.932       0.918        0.941       0.939
TALBOTS230  TACOMA230   OLYMPIA230  SHELTON230  FAIRMNT230  PORTANG 230
0.939       0.931       0.977       0.964       0.965       0.955
KITSAP230   CHEHALS230  LONGVW230   SEDRO115     SNOHMSH115   SNOKING115
0.943       0.994       1.006       0.939        0.903        0.909
AMESL R115  BROOK H115  BRK H R115  CLE ELM115  CLE E R115  E PT ORC115
0.975       0.847       0.915       0.921       0.996       0.880
EPTOR R115  LANGLY115   LANGL R115  NBOTHEL115   NBOTH R115   CAMANO115
0.952       0.843       0.911       0.884        0.955        0.870
CAMNO R115  MEADWD115   MEADW R115  NSTAN115    NSTA R115   HYLEBOS115
0.941       0.882       0.953       0.874       0.945       0.863
HYLE R115   PORTAN69    PORTARR69   PAPN1 R69    SAPPHO69     SAPPHO R69
0.933       0.950       1.027       1.033        0.917        0.991
SUR LK12.5 SUR LK115   ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
0.986       0.867       0.925       0.856       0.883        0.955
CLAY C57.5 CLAYCK R57 FIR57.5     FIR R57.5    SKYKOMSH115 SKYKMH R115.
0.841       0.909       0.856       0.925        0.898        0.971
..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
COULEE2     COULEE51    COULEE52    CHIEF J5    CENTRALA20 TROJAN22     ROSS42
 403         358         257         408         429        379           54
1.045       0.996       0.997       0.997       1.020       1.012        1.002
CHIEF J2    ROSS44      UP BAKER    CUSHMN1     CUSHMN2      BURRARD      BONN PH2
 157          54          42          15          26          445          145
0.970       1.002       1.050       0.970       0.966       1.052        1.001
CHIEF JO    BONNVIL2    DALLES 3    DALLES21    DALLES22    JOHN DAY
 157         103         -136         -85         -55        160
0.970       1.001       0.959       0.950       0.950       0.978
...................SLACK BUS AND AGC BUSES (MW)..............................
RIDGE2     COULEE 2    JOHN DAY     CHIEF J2    CHIEF JO    CHIEF J5 TOTAL PNW
 217         738         1992         587         587         1148      5051
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA      AA      AB      SC      SP      TC      NB      NC      17
P  1642    3306     499    1550    1247    1378    7081    3307    8419
Q   570    1049     238     371     344     481    1809    1002    3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 9622      Q= 3052             P=20010      Q= 5863
................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
     NA      AA      AB      SC      SP      TC      NB      NC      17
P  1913     352       0     298     100     278    3038     700    9505
Q   579     104       0     203      50     138     833     268    1606
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 2941      Q= 1074             P= 6679      Q= 1101
..................NET MW LOAD (LOAD - GENERATION)................................
PUGET SOUND= 6681       WEST ORE & WA=13331
................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
     NA        AA        AB        SC        SP        TC        NB        NC        17   ND+NE+NF+NG+NH
P   256        85         2        21         8        16       180       118       614            375
Q  2185       538         2       146        39       215      1084      -102     -4660            465
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  389      Q= 3124             P=  687      Q= 4106
................BUS SHUNT REACTIVE (MVAR)..................................
RAVER=      0   USED         0       UNSCHEDULED
MONROE=   326   USED         0       UNSCHEDULED
 ...............ZONE SHUNT REACTIVE (MVAR).................................
    NA        AA        AB        SC        SP        TC        NB        NC        17  ND+NE+NF+NG+NH
  2219       823        86       530         0       102      2024       670     -2582             17
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 3759                      QSHUNT= 6453
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J93764 OUTAGE BEFORE DIST VOLTAGE REGS CHANGE
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 ........................BUS VOLTAGES (PER UNIT)..........................
  STER500  MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500
  012      1.011      1.012      1.025      1.061      1.019
 LYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500    OSTRNDER500
 1.059     1.060      1.061      1.058       1.058       1.051
 MARION500 CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
 1.065     1.001      0.993      0.953      0.938      0.962
 BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
 0.961     0.980      0.958      0.947       0.988       0.982
 TALBOTS230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 0.982     0.977      1.012      1.007      1.009      1.004
 KITSAP230 CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
 0.990     1.014      1.021      0.987       0.945       0.944
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 0.951     0.922      0.922      0.950      0.950      0.929
 EPTOR R115 LANGLY115 LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.929     0.918      0.918      0.927       0.927       0.905
 CAMNO R115 MEADWD115 MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
 0.905     0.911      0.911      0.910      0.910      0.912
 HYLE R115 PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.912     1.005      1.005      1.005       0.971       0.970
 SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 0.966     0.918      0.901      0.901       0.938       0.938
 CLAY C57.5 CLAYCK R57 FIR57.5   FIR R57.5   SKYKOMSH115 SKYKMH R115.
 0.893     0.893      0.901      0.901       0.930       0.930
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2   COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
  403        312        223        408        218        271        41
 1.045     0.998      0.999      1.006      1.019      1.013      1.007
 CHIEF J2  ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
  157        41         24         10         23         279        104
 0.978     1.007      1.050      1.004      1.008      1.035       1.002
 CHIEF JO  BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY   MSASVC
  157        71        -112        -85        -59        142      ???????
 0.978     1.002      0.969      0.956      0.954      0.983      ???????????
 ..................SLACK BUS AND AGC BUSES (MW).............................
 RIDGE2    COULEE 2   JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  207        1022       2100       537       537        1029     5225
   .............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA      AA      AB      SC      SP      TC      NB      NC      17
 P  1684    3622    528    1721    1451    1441    7194    3276    8419
 Q   577    1142    248     425     400     501    1827     990    3340
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=10448     Q= 3292              P=20918     Q= 6109
 ...............ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
     NA      AA      AB      SC      SP      TC      NB      NC      17
 P  1913     432      0     298     100     278    3038     700    9495
 Q   319      89      0     172      50     130     616     204    1094
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 3021     Q=  760              P= 6759     Q=  820
 .................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 7427       WEST ORE & WA=14159
 ...............ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
     NA       AA       AB       SC       SP       TC       NB       NC       17   ND+NE+NF+NG+NH
 P   280      87        2       22       10       14      178      108      604        381
 Q  2447     493       12      156       42      177     1152     -346    -5007        548
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  415     Q= 3328              P=  701     Q= 4134
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
     NA       AA       AB       SC       SP       TC       NB       NC       17  ND+NE+NF+NG+NH
   3189      915       95      548        0      400     2119      682    -2420        543
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 5146                      QSHUNT= 7947
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J93765 OUTAGE AFTER DIST VOLTAGE REGS ADJUST, LDC'S AT BCH BRIDGE R & MICA
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 .......................BUS VOLTAGES (PER UNIT)..........................
  'STER500  MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500
   958      0.941      0.935      0.950      1.015      0.941
 JLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500    OSTRNDER500
 1.010      1.009      1.020      1.020       1.022       1.017
 MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
 1.031      0.940      0.923      0.877      0.859      0.884
 BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
 0.884      0.904      0.880      0.865       0.907       0.900
 TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 0.900      0.895      0.953      0.940      0.930      0.921
 KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
 0.915      0.975      0.988      0.910       0.862       0.864
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 0.930      0.827      0.895      0.869      0.940      0.833
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.900      0.824      0.890      0.840       0.909       0.818
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
 0.884      0.825      0.892      0.823      0.890      0.829
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.896      0.919      0.994      0.999       0.879       0.951
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 0.945      0.835      0.892      0.824      0.843        0.911
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
 0.800      0.865      0.825      0.892       0.848       0.917
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22    ROSS42
   403        526        377        408        560        400          85
 1.045      0.998      0.999      0.972      1.016      0.998       1.003
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
   157        85         50         15         26         537         178
 0.942      1.003      1.037      0.938      0.933      1.052       1.002
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY   MSASVC
   157        128        -31        -43        -32        332              0
 0.942      1.002      0.969      0.956      0.954      0.983                0
 ..................SLACK BUS AND AGC BUSES (MW).............................
 ¬RIDGE2    COULEE 2   JOHN DAY    CHIEF J2   CHIEF JO   CHIEF J5 TOTAL PNW
  243        1013       2100        535        535        1027      5209
   ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR)......................
     NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1700   3561    527   1536   1422   1414   7326   3324   8419
 Q   584   1115    247    354    390    489   1865   1008   3340
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=10159     Q= 3178              P=20810     Q= 6050
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
     NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1913    432      0    298    100    278   3038    700   9531
 Q   756    132      0    338     50    138    984    278   2179
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 3021     Q= 1413              P= 6759     Q= 1262
..................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 7138       WEST ORE & WA=14051
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
     NA       AA       AB       SC       SP       TC       NB       NC       17   ND+NE+NF+NG+NH
 P   307       97        2       25       11       16      197      117      640            402
 Q  3155      620       16      210       55      218     1484      -90    -4123           1122
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  459     Q= 4274              P=  772     Q= 5668
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
     NA       AA       AB       SC       SP       TC       NB       NC       17  ND+NE+NF+NG+NH
   2725      763       80      463        0      332     1976      634    -2381            -81
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 4364                       QSHUNT= 6973
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J93766 BASEDON 765, 1% INCREASE IN CONSTANT R LOAD
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
  .......................BUS VOLTAGES (PER UNIT)..........................
   'STER500  MONROE500  MAPLEVL500 RAVER500    PAUL500     TACOMA500   COULEE500
   .954      0.936      0.929      0.944       1.010       0.935       1.052
 OLYMPIA500  SATSOP500  ALLSTON500 KEELER500    PEARL500     OSTRNDER500
 1.005       1.004      1.015      1.016        1.018        1.014
 MARION500   CUSTER230  BELLNGM230 SEDRO230    MURRAY230   SNOHOMSH230
 1.027       0.936      0.918      0.871       0.853       0.878
 BOTHELL230  MONROE230  SNOKING230 SAMMAMSH230 COVINTN230   TALBOTN230
 0.879       0.899      0.874      0.859        0.901        0.894
 TALBOTS230  TACOMA230  OLYMPIA230 SHELTON230  FAIRMNT230  PORTANG 230
 0.894       0.889      0.947      0.934       0.923       0.914
 KITSAP230   CHEHALS230 LONGVW230  SEDRO115     SNOHMSH115   SNOKING115
 0.909       0.970      0.983      0.904        0.857        0.858
 AMESL R115  BROOK H115 BRK H R115 CLE ELM115  CLE E R115  E PT ORC115
 0.923       0.821      0.888      0.864       0.934       0.827
 EPTOR R115  LANGLY115  LANGL R115 NBOTHEL115   NBOTH R115   CAMANO115
 0.894       0.818      0.884      0.835        0.903        0.812
 CAMNO R115  MEADWD115  MEADW R115 NSTAN115    NSTA R115   HYLEBOS115
 0.878       0.820      0.886      0.817       0.884       0.823
 HYLE R115   PORTAN69   PORTARR69  PAPN1 R69    SAPPHO69     SAPPHO R69
 0.890       0.912      0.986      0.992        0.872        0.943
 SUR LK12.5  SUR LK115  ANAC R57.5 ANACPUMP57  BOE AUB313.1 B AUB3 R13.1
 0.939       0.829      0.886      0.819        0.836        0.904
 CLAY C57.5  CLAYCK R57 FIR57.5    FIR R57.5    SKYKOMSH115 SKYKMH R115.
 0.794       0.859      0.819      0.886        0.843        0.911
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2     COULEE51   COULEE52   CHIEF J5    CENTRALA20  TROJAN22    ROSS42
   403         541        387        408         560         400          85
 1.045       0.998      0.999      0.970       1.011       0.994       0.999
 CHIEF J2    ROSS44     UP BAKER   CUSHMN1     CUSHMN2      BURRARD     BONN PH2
   157         85         50         15          26           553         186
 0.940       0.999      1.032      0.933       0.927        1.052       1.002
 CHIEF JO    BONNVIL2   DALLES 3   DALLES21    DALLES22    JOHN DAY
   157         134        -25        -40         -30         346
 0.940       1.002      0.969      0.956       0.954       0.983
 ..................SLACK BUS AND AGC BUSES (MW)..............................
 "RIDGE2      COULEE 2   JOHN DAY     CHIEF J2   CHIEF JO    CHIEF J5 TOTAL PNW
   247          997        2098         533        533         1022      5184
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
      NA      AA      AB      SC      SP      TC      NB      NC      17
 P  1697    3547     526    1529    1417    1409    7329    3326    8419
 Q   579    1100     247     348     385     484    1865    1008    3340
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=10124     Q= 3143              P=20779      Q= 6016
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
      NA      AA      AB      SC      SP      TC      NB      NC      17
 P  1913     432       0     298     100     278    3038     700    9535
 Q   760     132       0     344      50     138    1010     280    2262
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 3021     Q= 1424              P= 6759      Q= 1290
..................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 7103       WEST ORE & WA=14020
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR)......................
      NA        AA        AB        SC        SP        TC        NB        NC        17     ND+NE+NF+NG+NH
 P   308        97         2        25        12        16       198       118       644          403
 Q  3191       626        17       216        55       220      1512       -69     -4044         1151
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  460     Q= 4325              P=  777      Q= 5768
.................BUS SHUNT REACTIVE (MVAR)..................................
RAVER=    571   USED          0          UNSCHEDULED
MONROE=    288  USED          0          UNSCHEDULED
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
      NA        AA        AB        SC        SP        TC        NB        NC        17    ND+NE+NF+NG+NH
    2691       753        79       457         0       328      1960       629     -2376             -80
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 4308                      QSHUNT= 6898
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J93837  BASE CASE FOR NORMAL SYSTEM PEAK, ONE RAVER CAP BANK IN RESERVE
...........................BUS VOLTAGES (PER UNIT)...........................
 CUSTER500  MONROE500   MAPLEVL500 RAVER500    PAUL500     TACOMA500   COULEE500
   047      1.069       1.069      1.083       1.086       1.075       1.090
  YMPIA500  SATSOP500   ALLSTON500 KEELER500    PEARL500    OSTRNDER500
 1.087      1.087       1.082      1.077        1.076       1.069
 MARION500  CUSTER230   BELLNGM230 SEDRO230    MURRAY230   SNOHOMSH230
 1.081      1.037       1.033      0.996       0.989       1.018
 BOTHELL230 MONROE230   SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
 1.014      1.037       1.012      1.001       1.044       1.039
 TALBOTS230 TACOMA230   OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 1.039      1.029       1.043      1.039       1.044       1.039
 KITSAP230  CHEHALS230 LONGVW230   SEDRO115     SNOHMSH115  SNOKING115
 1.023      1.034       1.035      1.026        1.000       0.997
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 1.004      0.960       0.960      1.021       1.021       0.982
 EPTOR R115 LANGLY115   LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.982      0.956       0.956      0.981        0.981       0.958
 CAMNO R115 MEADWD115   MEADW R115 NSTAN115    NSTA R115   HYLEBOS115
 0.958      0.965       0.965      0.962       0.962       0.962
 HYLE R115  PORTAN69    PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.962      1.040       1.040      1.040       1.006       1.006
 SUR LK12.5 SUR LK115   ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 1.018      0.967       0.938      0.938       0.996       0.996
 CLAY C57.5 CLAYCK R57 FIR57.5     FIR R57.5    SKYKOMSH115 SKYKMH R115.
 0.943      0.943       0.938      0.938        0.992       0.992
..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
COULEE2     COULEE51    COULEE52    CHIEF J5    CENTRALA20 TROJAN22    ROSS42
  236         36          24          388         13          173          9
1.045       0.998       0.999       1.047       1.019       1.013       1.007
CHIEF J2    ROSS44      UP BAKER    CUSHMN1     CUSHMN2      BURRARD     BONN PH2
  157          9          10           3           5           91          72
1.019       1.007       1.050       1.004       1.008        1.014       1.002
CHIEF JO    BONNVIL2    DALLES 3    DALLES21    DALLES22    JOHN DAY
  157         47         -160        -109         -76          21
1.019       1.002       0.969       0.956       0.954       0.983
...................SLACK BUS AND AGC BUSES (MW).............................
BRIDGE2     COULEE 2    JOHN DAY    CHIEF J2   CHIEF JO    CHIEF J5 TOTAL PNW
  186         1497        2140         600        600        1180       6017
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
       NA      AA      AB      SC      SP      TC      NB      NC      17
P   1764    3888     534    1866    1567    1527    7331    3328    8419
Q    613    1255     253     479     440     539    1866    1009    3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=11147     Q= 3578              P=21805     Q= 6453
................ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
       NA      AA      AB      SC      SP      TC      NB      NC      17
P   1913     432       0     298     100     278    3038     700    9474
Q     64      36       0      48      42      98     417     152     396
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 3021     Q=  288              P= 6759     Q=  569
..................NET MW LOAD (LOAD - GENERATION)...............................
PUGET SOUND= 8126       WEST ORE & WA=15046
................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
       NA        AA        AB        SC        SP        TC        NB        NC        17    ND+NE+NF+NG+NH
P    257        80         2        23        10        14       167       105       583          329
Q   1358       436        10       155        40       188       937      -469     -5506         -417
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  387     Q= 2187              P=  659     Q= 2654
................BUS SHUNT REACTIVE (MVAR)..................................
RAVER=   751  USED          0       UNSCHEDULED
MONROE=   376  USED          0       UNSCHEDULED
 ...............ZONE SHUNT REACTIVE (MVAR)..................................
       NA        AA        AB        SC        SP        TC        NB        NC        17   ND+NE+NF+NG+NH
    3523      1005       102       613         0       443      2179       697     -2176          578
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 5686                      QSHUNT= 8562
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J93923 BASEDON J93765, MSC 590MVARS @ MONROE AND 781MVARS @ RAVER TO GET
       SYSTEM OUT OF VOLTAGE INSTABILITY STATE FOLLOWING DIST REG ACTION
 .:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
   ........................BUS VOLTAGES (PER UNIT)..........................
  STER500   MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500   COULEE500
 1.019      1.021      1.010      1.027      1.046      1.015      1.057
 OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500   OSTRNDER500
 1.042      1.041      1.043      1.033       1.031      1.024
 MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
 1.037      1.000      0.982      0.930      0.911      0.936
 BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
 0.938      0.968      0.936      0.924       0.976      0.967
 TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 0.967      0.962      0.985      0.973      0.965      0.957
 KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
 0.949      0.999      1.006      0.962       0.915       0.919
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 0.998      0.879      0.950      0.911      0.985      0.897
 EPTOR R115 LANGLY115   LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.970      0.875       0.946      0.893       0.965       0.870
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
 0.940      0.877      0.948      0.875      0.946      0.893
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.965      0.956      1.033      1.039       0.915       0.990
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 1.018      0.899      0.945      0.874      0.913        0.986
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
 0.860      0.931      0.874      0.945       0.889       0.961
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
   403        466        334        408        335        392         56
 1.045      0.998      0.999      0.981      1.019      1.013      1.007
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD    BONN PH2
   157         56         33         15         26        205        163
 0.947      1.007      1.050      0.999      0.995      1.027      1.002
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
   157        116        -45        -50        -36        308
 0.947      1.002      0.969      0.956      0.954      0.983
   ..................SLACK BUS AND AGC BUSES (MW).............................
   IDGE2     COULEE 2   JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
   201        1664       2154        622       622        1199      6261
 ................ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
      NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1818   3902    535   1695   1546   1539   7422   3345   8419
 Q   638   1260    254    411    433    544   1894   1015   3340
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=11035      Q= 3540             P=21802      Q= 6449
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
      NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1913    432      0    298    100    278   3038    700   9489
 Q   477    108      0    226     50    138    914    276    985
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 3021      Q=  999             P= 6759      Q= 1189
 .................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 8014       WEST ORE & WA=15043
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
      NA        AA        AB        SC        SP        TC        NB        NC        17    ND+NE+NF+NG+NH
 P   340       102         2        23        12        16       201       119       598          418
 Q  3497       640        14       181        54       222      1522       -77     -5313         1466
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  496      Q= 4609             P=  815      Q= 6054
 .................BUS SHUNT REACTIVE (MVAR).................................
 RAVER=  1500   USED         0        UNSCHEDULED
 MONROE=   959  USED         0        UNSCHEDULED
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
      NA        AA        AB        SC        SP        TC        NB        NC        17  ND+NE+NF+NG+NH
    4543       864        91       532         0       384      2016       639     -2486           -65
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     QSHUNT= 6414                       QSHUNT= 9069
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J93924 BASEDON J93923, DIST VOLTAGE REGULATORS ADJUST AFTER MONROE & RAVER MSC
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 .........................BUS VOLTAGES (PER UNIT).........................
  STER500  MONROE500  MAPLEVL500 RAVER500    PAUL500    TACOMA500   COULEE500
  .070     1.095      1.092      1.108       1.090      1.099       1.075
OLYMPIA500 SATSOP500  ALLSTON500 KEELER500    PEARL500    OSTRNDER500
1.090      1.090      1.081      1.066        1.062       1.053
MARION500  CUSTER230  BELLNGM230 SEDRO230    MURRAY230  SNOHOMSH230
1.065      1.058      1.050      1.005       0.992      1.018
BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
1.018      1.048      1.019      1.010        1.061       1.055
TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
1.055      1.048      1.044      1.040      1.045      1.039
KITSAP230  CHEHALS230 LONGVW230  SEDRO115     SNOHMSH115  SNOKING115
1.024      1.035      1.033      1.035        1.001       1.004
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
1.007      0.971      0.959      0.992      1.023      1.001
EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
0.982      0.967      0.955      0.982       0.982       0.960
CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
0.960      0.966      0.966      0.964      0.964      0.979
HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
0.960      1.041      1.041      1.041       1.006       1.006
SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
1.018      0.984      0.936      0.948      1.014        0.996
CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
0.958      0.941      0.948      0.936       0.973       0.991
..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
  403        234        167        408        -18        198          7
1.045      0.998      0.999      1.019      1.019      1.013      1.007
CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
  157          7          6          0         -2        -53         101
0.987      1.007      1.050      1.004      1.008      0.998      1.002
CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
  157         69       -113        -85        -60        143
0.987      1.002      0.969      0.956      0.954      0.983
...................SLACK BUS AND AGC BUSES (MW).............................
 RIDGE2     COULEE 2   JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  180        1628       2151        617       617        1188      6202
   ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA      AA     AB      SC      SP      TC      NB      NC      17
P  1766    3890    534    1897    1570    1525    7325    3329    8419
Q   614    1255    253     492     441     538    1864    1009    3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=11181     Q= 3592              P=21835     Q= 6465
   ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
     NA      AA     AB      SC      SP      TC      NB      NC      17
P  1913     432      0     298     100     278    3038     700    9468
Q    29      22      0      41      41      67     521     211      31
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 3021     Q= 201               P= 6759     Q= 732
..................NET MW LOAD (LOAD - GENERATION)................................
PUGET SOUND= 8160      WEST ORE & WA=15076
   ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR)......................
     NA      AA      AB      SC      SP      TC      NB      NC      17    ND+NE+NF+NG+NH
P   310      89       2      22      10      14     184     112     577          399
Q  2704     491      10     135      40     174    1228    -283   -5941          899
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  447     Q= 3555              P=  743     Q= 4500
.................BUS SHUNT REACTIVE (MVAR)..................................
RAVER= 1745   USED          0       UNSCHEDULED
MONROE= 1104  USED          0       UNSCHEDULED
  ..............ZONE SHUNT REACTIVE (MVAR)...................................
     NA       AA       AB       SC       SP       TC       NB       NC       17  ND+NE+NF+NG+NH
   5288     1028      106      627        0      458     2135      677    -2526          -36
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 7507                      QSHUNT=10319
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J93928 BASEDON 765, ADJUST MAPLE VL TX BY ONE TAP
                    FROM 534.38 TO 531.25
`::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 ..........................BUS VOLTAGES (PER UNIT)............................
 JSTER500   MONROE500  MAPLEVL500 RAVER500   PAUL500     TACOMA500   COULEE500
 J.958      0.940      0.932      0.949      1.014       0.939      1.052
 OLYMPIA500 SATSOP500  ALLSTON500 KEELER500    PEARL500    OSTRNDER500
 1.009      1.008      1.018      1.019        1.020       1.016
 MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230   SNOHOMSH230
 1.029      0.940      0.923      0.876      0.858       0.883
 BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230   TALBOTN230
 0.884      0.904      0.880      0.865        0.907       0.900
 TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230  PORTANG 230
 0.900      0.894      0.951      0.938      0.928       0.919
 KITSAP230  CHEHALS230 LONGVW230  SEDRO115     SNOHMSH115  SNOKING115
 0.914      0.974      0.986      0.909        0.862       0.864
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115  E PT ORC115
 0.930      0.827      0.894      0.868      0.939       0.833
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115   NBOTH R115  CAMANO115
 0.900      0.823      0.889      0.840        0.908       0.817
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115   HYLEBOS115
 0.884      0.825      0.892      0.822      0.889       0.828
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69    SAPPHO69    SAPPHO R69
 0.896      0.918      0.992      0.998        0.878       0.949
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1  B AUB3 R13.1
 0.945      0.834      0.891      0.824      0.842         0.910
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5    SKYKOMSH115 SKYKMH R115.
 0.800      0.865      0.824      0.891        0.847       0.916
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).........................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22    ROSS42
   403        531        381        408         560        400         85
 1.045      0.998      0.999      0.971      1.015       0.996      1.003
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2      BURRARD     BONN PH2
   157         85         50         15          26        539         181
 0.941      1.003      1.037      0.938      0.932       1.052       1.002
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22    JOHN DAY
   157        130        -29        -42         -31        338
 0.941      1.002      0.969      0.956      0.954       0.983
  ..................SLACK BUS AND AGC BUSES (MW)................................
  IDGE2    COULEE 2   JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  243      1015       2100         536        536       1027       5213
 ................ZONE REAL AND REACTIVE LOADS (MW,MVAR).........................
     NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1697   3558    526   1536   1421   1412   7330   3330   8419
 Q   583   1113    247    354    389    488   1866   1010   3340
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=10151     Q= 3174               P=20811     Q= 6050
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)...................
     NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1913    432      0    298    100    278   3038    700   9531
 Q   757    132      0    338     50    138    994    279   2187
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 3021     Q= 1415               P= 6759     Q= 1273
..................NET MW LOAD (LOAD - GENERATION)..................................
 PUGET SOUND= 7130      WEST ORE & WA=14052
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).......................
      NA      AA      AB      SC      SP      TC      NB      NC      17   ND+NE+NF+NG+NH
 P   308      97       2      25      11      16     198     118     640         403
 Q  3165     621      16     210      55     218    1497     -75   -4123        1134
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  459     Q= 4285               P=  775     Q= 5707
..................BUS SHUNT REACTIVE (MVAR)....................................
RAVER=   576    USED        0       UNSCHEDULED
MONROE=    290  USED        0       UNSCHEDULED
  ...............ZONE SHUNT REACTIVE (MVAR)...................................
      NA      AA      AB      SC      SP      TC      NB      NC      17  ND+NE+NF+NG+NH
   2719     763      80     463       0     331    1969     631   -2380         -78
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 4356                      QSHUNT= 6957
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J93929 BASEDON J93765, EHV LTC'S ACTIVE, MSC 590MVARS @ MONROE AND
                         @ RAVER
`:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 ........................BUS VOLTAGES (PER UNIT)..........................
  STER500  MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500   COULEE500
1.056      1.069      1.061      1.079      1.077      1.069       1.071
OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500   OSTRNDER500
1.076      1.076      1.071      1.059       1.056      1.048
MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
1.060      1.044      1.036      0.993      0.981      1.008
BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
1.007      1.040      1.007      0.997       1.041      1.039
TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
1.039      1.030      1.038      1.034      1.038      1.032
KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
1.017      1.029      1.027      1.023       0.990      0.992
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
1.002      0.955      0.961      0.974      1.022      0.980
EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
0.980      0.952      0.957      0.970       0.982      0.947
CAMNO R115 MEADWD115  MEADW R115 NSTAN115    NSTA R115  HYLEBOS115
0.959      0.954      0.966      0.952       0.964      0.962
HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
0.962      1.033      1.040      1.040       0.999      1.005
SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
1.018      0.967      0.936      0.935      0.994        0.996
CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
0.938      0.944      0.936      0.936       0.959       0.989
..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE)......................
COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
  403        291        208        408         85        240        14
1.045      0.998      0.999      1.009      1.019      1.013      1.007
CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2    BURRARD     BONN PH2
  157        14         11          3          5         12          113
0.978      1.007      1.050      1.004      1.008      1.005      1.002
CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
  157        78        -101        -79        -55        174
0.978      1.002      0.969      0.956      0.954      0.983
 ..................SLACK BUS AND AGC BUSES (MW)...........................
  IDGE2    COULEE 2   JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  184       1603       2149         614       614        1199      6179
................ZONE REAL AND REACTIVE LOADS (MW,MVAR)......................
      NA     AA     AB     SC     SP     TC     NB     NC     17
P  1764   3889    534   1861   1571   1526   7325   3329   8419
Q   613   1254    253    477    441    538   1864   1009   3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=11144     Q= 3577             P=21799    Q= 6451
................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
      NA     AA     AB     SC     SP     TC     NB     NC     17
P  1913    432      0    298    100    278   3038    700   9472
Q   148     41      0     67     50     98    601    230    292
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 3021     Q=  403             P= 6759     Q=  831
.................NET MW LOAD (LOAD - GENERATION)...............................
PUGET SOUND= 8123      WEST ORE & WA=15040
................ZONE REAL AND REACTIVE LOSSES (MW,MVAR)......................
      NA      AA      AB      SC      SP      TC      NB      NC      17   ND+NE+NF+NG+NH
P   314      92       2      22      11      14     186     113     581         401
Q  2860     516      11     141      42     181    1273    -249   -5804         985
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  455     Q= 3750             P=  754     Q= 4774
................BUS SHUNT REACTIVE (MVAR)...................................
RAVER=  1466   USED         0        UNSCHEDULED
MONROE=  1052  USED         0        UNSCHEDULED
 ...............ZONE SHUNT REACTIVE (MVAR)..................................
      NA      AA      AB      SC      SP      TC      NB      NC      17  ND+NE+NF+NG+NH
    4898     998     103     609      0     442    2112     671   -2520         -42
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 7051                     QSHUNT= 9833
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J93EH1021 COLD WEATHER BASE, BOTH CENTRALIA UNITS OPERATING
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 ........................BUS VOLTAGES (PER UNIT)..........................
  STER500   MONROE500   MAPLEVL500 RAVER500    PAUL500     TACOMA500
  .043      1.049       1.051      1.070       1.080       1.049
 OLYMPIA500 SATSOP500   ALLSTON500 KEELER500    PEARL500    OSTRNDER500
 1.081      1.078       1.075      1.065        1.066       1.061
 MARION500  CUSTER230   BELLNGM230 SEDRO230    MURRAY230   SNOHOMSH230
 1.082      1.035       1.033      1.002       0.986       1.019
 BOTHELL230 MONROE230   SNOKING230 SAMMAMSH230 COVINTN230   TALBOTN230
 1.013      1.048       1.009      0.995        1.036       1.031
 TALBOTS230 TACOMA230   OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 1.031      1.029       1.041      1.040       1.041       1.036
 KITSAP230  CHEHALS230 LONGVW230   SEDRO115     SNOHMSH115   SNOKING115
 1.043      1.031       1.034      1.025        0.998        1.005
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 1.001      0.972      0.972      1.006      1.006      0.976
 EPTOR R115 LANGLY115   LANGL R115 NBOTHEL115  NBOTH R115   CAMANO115
 0.976      0.968       0.967      0.976        0.976        0.953
 CAMNO R115 MEADWD115   MEADW R115 NSTAN115    NSTA R115   HYLEBOS115
 0.953      0.958       0.958      0.959       0.959       0.961
 HYLE R115  PORTAN69    PORTARR69  PAPN1 R69    SAPPHO69     SAPPHO R69
 0.961      1.040       1.040      1.040        0.995        0.994
 SUR LK12.5 SUR LK115   ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 1.008      0.964       0.935      0.935      0.997        0.997
 CLAY C57.5 CLAYCK R57 FIR57.5     FIR R57.5    SKYKOMSH115 SKYKMH R115.
 0.957      0.957       0.935      0.935        0.988       0.988
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2     COULEE51    COULEE52    CHIEF J5    CENTRALA20 TROJAN22    ROSS42
   264         190         126         408          91        297         10
 1.045       1.009       1.009       1.044       1.022      1.028       1.007
 CHIEF J2    ROSS44      UP BAKER    CUSHMN1     CUSHMN2     BURRARD     BONN PH2
   157          10          10           6          10          93        106
 1.014       1.007       1.050       1.011       1.012       1.014        1.009
 CHIEF JO    BONNVIL2    DALLES 3    DALLES21    DALLES22    JOHN DAY    MSASVC
   157          69          94          64          44         193       ???????
 1.014       1.008       1.006       1.006       1.006       0.995       ???????????
 ...................SLACK BUS AND AGC BUSES (MW)..............................
 RIDGE2     COULEE 2    JOHN DAY     CHIEF J2   CHIEF JO    CHIEF J5 TOTAL PNW
  224        1503        2140          600        600         1180      6023
   ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
       NA      AA      AB      SC      SP      TC      NB      NC      17
 P   1919    4217     534    2032    1777    1750    8149    3629    8556
 Q    652    1361     253     522     500     615    2037    1096    3380
 SUM PUGET SOUND  (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=12229      Q= 3904               P=24007      Q= 7037
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
       NA      AA      AB      SC      SP      TC      NB      NC      17
 P   1913    1047       0     298     100     278    3038     700    9632
 Q    162     176       0      52      44     113     646     154     521
 SUM PUGET SOUND  (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 3636      Q=  546               P= 7374      Q=  800
..................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 8593       WEST ORE & WA=16633
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
       NA       AA       AB       SC       SP       TC       NB       NC       17   ND+NE+NF+N
 P    285       89        1       27       13       18      214      130      604         340
 Q   1893      544       11      232       53      259     1610      -65    -5240        -373
 SUM PUGET SOUND  (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  433      Q= 2992               P=  776      Q= 4537
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
       NA       AA       AB       SC       SP       TC       NB       NC       17  ND+NE+NF+NG
     3989     1004      103      702        0      441     2543     1206    -1935        -672
 SUM PUGET SOUND  (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 6239                        QSHUNT= 9988
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J93EH1023 - BASE WITH ONE CENTRALIA UNIT DOWN
.........................BUS VOLTAGES (PER UNIT).........................
 CUSTER500 MONROE500 MAPLEVL500 RAVER500  PAUL500   TACOMA500  COULEE500
   040     1.044     1.042      1.062     1.080     1.036      1.090
  YMPIA500 SATSOP500 ALLSTON500 KEELER500  PEARL500   OSTRNDER500
 1.081     1.078     1.073      1.058      1.057      1.051
 MARION500 CUSTER230 BELLNGM230 SEDRO230  MURRAY230 SNOHOMSH230
 1.075     1.044     1.041      1.004     0.986     1.017
 BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
 1.011      1.045     1.008      0.994       1.034      1.032
 TALBOTS230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 1.031      1.033     1.041      1.040      1.041      1.036
 KITSAP230  CHEHALS230 LONGVW230 SEDRO115   SNOHMSH115 SNOKING115
 1.042      1.031      1.033     1.027      0.997      1.003
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 1.001      0.973      0.973      1.002      1.002      0.977
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115 NBOTH R115 CAMANO115
 0.977      0.969      0.969      0.975      0.974      0.952
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
 0.952      0.956      0.956      0.957      0.957      0.963
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69  SAPPHO69   SAPPHO R69
 0.963      1.040      1.040      1.040      0.995      0.994
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 1.012      0.967      0.936      0.936      0.998        0.998
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5  SKYKOMSH115 SKYKMH R115.
 0.958      0.958      0.937      0.937      0.985       0.985
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
   277        288        192        408        112        308        11
 1.045      1.016      1.015      1.042      1.038      1.029      1.008
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
   157        11          9          5          8          93         108
 1.011      1.008      1.050      1.009      1.011      1.014      1.010
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY
   157        70         -5         -3         -2         95
 1.011      1.008      0.998      0.994      0.993      0.988
 ..................SLACK BUS AND AGC BUSES (MW).............................
 BRIDGE2    COULEE 2   JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
   224        1497       2140        600       600        1180      6017
   ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA     AA      AB     SC     SP     TC     NB     NC     17
 P  1890   4217    534   2032   1777   1750   8145   3628   8556
 Q   628   1361    253    522    500    615   2036   1095   3380
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=12200     Q= 3880              P=23974     Q= 7012
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
     NA     AA      AB     SC     SP     TC     NB     NC     17
 P  1244   1047      0    298    100    278   3038    700   9632
 Q   184    166      0     57     46    110    669    156    531
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 2967     Q=  564              P= 6705     Q=  825
..................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 9233       WEST ORE & WA=17269
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR)......................
     NA       AA       AB       SC       SP       TC       NB       NC       17    ND+NE+NF+NG+NH
 P   299      90        1       26       13       18      230      133      604          371
 Q  2051     552       10      232       54      260     1825        9    -5230           48
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  447     Q= 3158              P=  809     Q= 4993
.................BUS SHUNT REACTIVE (MVAR)..................................
RAVER=  1073  USED          0       UNSCHEDULED
MONROE=   358  USED         0       UNSCHEDULED
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
     NA       AA       AB       SC       SP       TC       NB       NC       17   ND+NE+NF+NG+NH
   3971     1005      103      702        0      444     2520     1204    -1889         774
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 6225                      QSHUNT= 9950
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J93EH1038 POST TRANSIENT CJ-MONROE OUTAGE BEFORE DIST VOLTAGE REGS ADJUST
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
  ........................BUS VOLTAGES (PER UNIT).............................
  USTER500  MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500
  .027      1.025      1.015      1.033      1.065      1.012
 OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500    OSTRNDER500
 1.065      1.062      1.064      1.057       1.058       1.054
 MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
 1.077      1.019      1.017      0.983      0.959      0.987
 BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
 0.982      1.018      0.978      0.963       0.999       0.993
 TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 0.993      0.993      1.023      1.022      1.021      1.016
 KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115 SNOKING115
 1.023      1.020      1.027      1.010       0.967       0.973
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 0.965      0.963      0.963      0.971      0.971      0.941
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115 CAMANO115
 0.941      0.959      0.959      0.945       0.945       0.924
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
 0.924      0.927      0.927      0.929      0.929      0.927
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.927      1.019      1.019      1.019       0.974       0.974
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE3 57.5  BOE3 R57.5
 0.973      0.931      0.921      0.921      ??????????????????????
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   PACCAR57.5 PACCAR R57
 0.924      0.924      0.921      0.921       ????????????????????????
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
   347        327        226        408        213        350         28
 1.045      1.009      1.009      1.041      1.022      1.028      1.007
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
   157         28         15         11         22        180        119
 1.002      1.007      1.050      1.011      1.012      1.024       1.009
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY   COWLITZ
   157         79        111         73         50        231          0
 1.002      1.008      1.006      1.006      1.006      0.995      0.941
 ...................SLACK BUS AND AGC BUSES (MW)..............................
 BRIDGE2    COULEE 2   JOHN DAY    CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
   241      1188       2114         558       558       1080     5498
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1873   4040    530   1925   1698   1680   8082   3610   8556
 Q   632   1287    250    483    473    584   2018   1089   3380
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=11746     Q= 3710               P=23438     Q= 6817
  ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
     NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1913   1047      0    298    100    278   3038    700   9650
 Q   314    234      0    123     50    130    742    179    888
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 3636     Q=  851               P= 7374     Q=  921
.................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 8110        WEST ORE & WA=16064
  ..............ZONE REAL AND REACTIVE LOSSES (MW,MVAR)......................
     NA      AA      AB      SC      SP      TC      NB      NC      17   ND+NE+NF+NG+NH
 P   307     101       2      29      13      18     217     130     621          345
 Q  2536     616      12     261      54     258    1676     -28   -4934         -247
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  468     Q= 3737               P=  815     Q= 5385
  ..............ZONE SHUNT REACTIVE (MVAR)...................................
     NA      AA      AB      SC      SP      TC      NB      NC      17  ND+NE+NF+NG+NH
    3763     950      99     654       0     412    2511    1197   -2198         -679
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 5879                       QSHUNT= 9587
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J93EH1039 POST TRANSIENT OUTAGE AFTER DIST VOLTAGE REGS ADJUST
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 .........................BUS VOLTAGES (PER UNIT)........................
 'STER500   MONROE500  MAPLEVL500 RAVER500   PAUL500    TACOMA500
 .001       0.986      0.971      0.993      1.038      0.969
OLYMPIA500 SATSOP500  ALLSTON500 KEELER500   PEARL500    OSTRNDER500
1.036      1.032      1.039      1.033       1.035       1.033
MARION500  CUSTER230  BELLNGM230 SEDRO230   MURRAY230  SNOHOMSH230
1.056      0.990      0.984      0.948      0.916      0.942
BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
0.938      0.975      0.932      0.915       0.952       0.946
TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
0.946      0.945      0.987      0.979      0.968      0.960
KITSAP230  CHEHALS230 LONGVW230  SEDRO115    SNOHMSH115  SNOKING115
0.976      0.995      1.004      0.980       0.919       0.926
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
0.967      0.943      0.955      0.929      0.987      0.884
EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
0.901      0.939      0.939      0.895       0.963       0.872
CAMNO R115 MEADWD115  MEADW R115 NSTAN115   NSTA R115  HYLEBOS115
0.921      0.877      0.916      0.878      0.933      0.877
HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
0.942      0.961      0.961      1.039       0.912       0.957
SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE3 57.5  BOE3 R57.5
0.920      0.880      0.935      0.890      ??????????????????????
CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   PACCAR57.5  PACCAR R57
0.870      0.924      0.891      0.907       ????????????????????????
..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
  403        502        351        408        430        400         55
1.045      1.009      1.009      1.023      1.022      1.013      1.007
CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
  157         55         27         15         26        332         168
0.983      1.007      1.050      0.976      0.971      1.041       1.009
CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY   COWLITZ
  157        116        160         98         67        344          0
0.983      1.008      1.006      1.006      1.006      0.995      0.889
...................SLACK BUS AND AGC BUSES (MW)..............................
'RIDGE2    COULEE 2   JOHN DAY    CHIEF J2   CHIEF JO   CHIEF J5  TOTAL PNW
  258        1220       2116        562        562        1090       5551
   ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA      AA      AB      SC      SP      TC      NB      NC      17
P  1877    4056     530    1789    1713    1689    8147    3632    8556
Q   632    1291     250     434     477     589    2037    1097    3380
SUM PUGET SOUND  (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=11653      Q= 3674              P=23432      Q= 6808
................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
     NA      AA      AB      SC      SP      TC      NB      NC      17
P  1913    1047       0     298     100     278    3038     700    9666
Q   594     298       0     224      50     138     949     258    1428
SUM PUGET SOUND  (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 3636      Q= 1304              P= 7374      Q= 1207
..................NET MW LOAD (LOAD - GENERATION).................................
PUGET SOUND= 8017       WEST ORE & WA=16058
................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
     NA        AA        AB        SC        SP        TC        NB        NC        17    ND+NE+NF+NG+NH
P   328       109         2        29        14        20       229       136       638          353
Q  3071       709        13       278        64       298      1896       131     -4514           40
SUM PUGET SOUND  (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  501      Q= 4433              P=  867      Q= 6460
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
     NA        AA        AB        SC        SP        TC        NB        NC        17   ND+NE+NF+NG+NH
   3451       862        92       594         0       369      2403      1145     -2176          -683
SUM PUGET SOUND  (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
   QSHUNT= 5368                       QSHUNT= 8917
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J93EH1040 OUTAGE AFTER 5% CONSTANT R INCREASE, SIMULATING THERMOSTATS
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
..........................BUS VOLTAGES (PER UNIT).........................
  STER500   MONROE500   MAPLEVL500 RAVER500    PAUL500     TACOMA500
  .987      0.968       0.950      0.973       1.025       0.948
 OLYMPIA500 SATSOP500   ALLSTON500 KEELER500    PEARL500     OSTRNDER500
 1.021      1.017       1.026      1.021        1.023        1.021
 MARION500  CUSTER230   BELLNGM230 SEDRO230    MURRAY230   SNOHOMSH230
 1.044      0.976       0.967      0.929       0.896       0.921
 BOTHELL230 MONROE230   SNOKING230 SAMMAMSH230 COVINTN230   TALBOTN230
 0.917      0.954       0.911      0.894        0.930        0.923
 TALBOTS230 TACOMA230   OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 0.923      0.923       0.970      0.960       0.947       0.938
 KITSAP230  CHEHALS230 LONGVW230   SEDRO115     SNOHMSH115   SNOKING115
 0.955      0.983       0.992      0.962        0.897        0.904
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 0.942      0.925       0.936      0.907       0.964       0.861
 EPTOR R115 LANGLY115   LANGL R115 NBOTHEL115   NBOTH R115   CAMANO115
 0.877      0.921       0.921      0.873        0.939        0.850
 CAMNO R115 MEADWD115   MEADW R115 NSTAN115    NSTA R115   HYLEBOS115
 0.898      0.856       0.893      0.856       0.909       0.855
 HYLE R115  PORTAN69    PORTARR69  PAPN1 R69    SAPPHO69     SAPPHO R69
 0.919      0.938       0.938      1.020        0.888        0.932
 SUR LK12.5 SUR LK115   ANAC R57.5 ANACPUMP57 BOE3 57.5   BOE3 R57.5
 0.896      0.859       0.927      0.872       ??????????????????????
 CLAY C57.5 CLAYCK R57 FIR57.5     FIR R57.5    PACCAR57.5   PACCAR R57
 0.847      0.900       0.873      0.889        ????????????????????????
..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2     COULEE51    COULEE52    CHIEF J5    CENTRALA20 TROJAN22    ROSS42
   403         561         427         408         536         400         68
 1.045       1.006       1.009       1.013       1.022       1.001       1.007
 CHIEF J2    ROSS44      UP BAKER    CUSHMN1     CUSHMN2       BURRARD      BONN PH2
   157          68          33          15          26         416          193
 0.972       1.007       1.050       0.954       0.949       1.049        1.009
 CHIEF JO    BONNVIL2    DALLES 3    DALLES21    DALLES22    JOHN DAY    COWLITZ
   157         136         186         112          76         404           0
 0.972       1.008       1.006       1.006       1.006       0.995       0.868
...................SLACK BUS AND AGC BUSES (MW)..............................
 BRIDGE2     COULEE 2    JOHN DAY    CHIEF J2   CHIEF JO    CHIEF J5 TOTAL PNW
   268         1221        2117        562         562         1091       5554
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
        NA      AA      AB      SC      SP      TC      NB      NC      17
 P    1887    4056     528    1771    1704    1678    8152    3626    8556
 Q     615    1242     249     411     458     567    2038    1094    3380
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=11625      Q= 3541             P=23402      Q= 6674
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
        NA      AA      AB      SC      SP      TC      NB      NC      17
 P    1913    1047       0     298     100     278    3038     700    9676
 Q     730     313       0     272      50     138    1030     271    1717
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 3636      Q= 1503             P= 7374      Q= 1301
..................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 7989         WEST ORE & WA=16028
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
        NA        AA        AB        SC        SP        TC        NB        NC        17    ND+NE+NF+NG+NH
 P     339       113         2        31        15        20       236       139       648        358
 Q    3360       752        14       310        68       311      2005       203     -4271        207
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  520      Q= 4816             P=  894      Q= 7024
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
        NA        AA        AB        SC        SP        TC        NB        NC        17   ND+NE+NF+NG+NH
      3309       824        88       564         0       351      2346      1117     -2163       -687
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 5137                      QSHUNT= 8600
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J93EH1056 TROJAN OUTAGE, POST TRANSIENT BEFORE DIST VOLTAGE REGS CHANGE
:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
  .........................BUS VOLTAGES (PER UNIT)..........................
  STER500  MONROE500   MAPLEVL500 RAVER500    PAUL500     TACOMA500
  .034     1.032       1.027      1.044       1.055       1.018
 OLYMPIA500 SATSOP500  ALLSTON500 KEELER500    PEARL500    OSTRNDER500
 1.056     1.053       1.042      1.029        1.031       1.027
 MARION500  CUSTER230  BELLNGM230 SEDRO230    MURRAY230   SNOHOMSH230
 1.055     1.038       1.035      0.997       0.976       1.006
 BOTHELL230 MONROE230  SNOKING230 SAMMAMSH230 COVINTN230  TALBOTN230
 1.000     1.033       0.996      0.981        1.017       1.016
 TALBOTS230 TACOMA230  OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 1.016     1.015       1.016      1.015       1.014       1.009
 KITSAP230  CHEHALS230 LONGVW230  SEDRO115     SNOHMSH115  SNOKING115
 1.016     1.009       0.996      1.021        0.986       0.991
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 0.986     0.970       0.970      0.986       0.986       0.962
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.961     0.965       0.965      0.964        0.964       0.942
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115    NSTA R115   HYLEBOS115
 0.941     0.946       0.946      0.947       0.947       0.947
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69    SAPPHO69    SAPPHO R69
 0.947     1.012       1.012      1.012        0.967       0.967
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 0.994     0.951       0.931      0.931       0.980       0.980
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5    SKYKOMSH115 SKYKMH R115.
 0.943     0.943       0.931      0.931        0.973       0.973
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE)......................
 COULEE2    COULEE51   COULEE52   CHIEF J5    CENTRALA20 TROJAN22   ROSS42
   360        383        260        408         216           0         18
 1.045      1.016      1.015      1.033       1.038                 01.008
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1     CUSHMN2      BURRARD     BONN PH2
   157        18         12          7          14          127          167
 1.003      1.008      1.050      1.009       1.011       1.018        1.010
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21    DALLES22    JOHN DAY    MSASVC
   157        115        48         25          16          213              0
 1.003      1.008      0.998      0.994       0.993       0.988                 0
 ..................SLACK BUS AND AGC BUSES (MW).............................
 RIDGE2     COULEE 2   JOHN DAY     CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  227        1479       2162         605       605        1190      6042
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1846   4122    531   1988   1749   1715   7848   3554   8556
 Q   612   1322    251    506    490    600   1950   1068   3380
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=11952     Q= 3781              P=23354     Q= 6799
 ...............ZONE REAL AND REACTIVE GENERATION (MW,MVAR).................
     NA     AA     AB     SC     SP     TC     NB     NC     17
 P  1255   1055      0    303    100    278   1922    706   9695
 Q   347    198      0     84     50    119    564    228    703
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P= 2991     Q=  797              P= 5619     Q=  792
.................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 8961      WEST ORE & WA=17735
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....................
     NA       AA       AB       SC       SP       TC       NB       NC       17    ND+NE+NF+NG+NH
 P   308       90       1       26       13       18      253      136      613          383
 Q  2324      562      10      230       54      258     2111      143    -5101          341
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    P=  456     Q= 3439              P=  845     Q= 5692
  ...............ZONE SHUNT REACTIVE (MVAR)..................................
     NA       AA       AB       SC       SP       TC       NB       NC       17   ND+NE+NF+NG+NH
   3846      976      102      682       0      429     2389     1170    -2161          167
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 6035                      QSHUNT= 9593
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J93EH1057 TROJAN OUTAGE AFTER DIST VOLTAGE REGS CHANGE TAPS
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
 .........................BUS VOLTAGES (PER UNIT).........................
  3TER500   MONROE500   MAPLEVL500 RAVER500    PAUL500     TACOMA500
  003       0.983       0.967      0.983       0.984       0.954
 JLYMPIA500 SATSOP500   ALLSTON500 KEELER500    PEARL500     OSTRNDER500
 0.983      0.978       0.973      0.965        0.971        0.972
 MARION500  CUSTER230   BELLNGM230 SEDRO230    MURRAY230   SNOHOMSH230
 1.003      1.005       0.998      0.957       0.925       0.950
 BOTHELL230 MONROE230   SNOKING230 SAMMAMSH230 COVINTN230   TALBOTN230
 0.944      0.978       0.939      0.920        0.950        0.950
 TALBOTS230 TACOMA230   OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
 0.950      0.945       0.939      0.929      0.915      0.907
 KITSAP230  CHEHALS230 LONGVW230   SEDRO115     SNOHMSH115   SNOKING115
 0.925      0.944      0.926       0.988        0.928        0.932
 AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
 0.971      0.949      0.960      0.927      0.985      0.886
 EPTOR R115 LANGLY115  LANGL R115 NBOTHEL115  NBOTH R115  CAMANO115
 0.902      0.945      0.945      0.904       0.972       0.881
 CAMNO R115 MEADWD115  MEADW R115 NSTAN115    NSTA R115   HYLEBOS115
 0.930      0.886      0.925      0.887       0.942       0.877
 HYLE R115  PORTAN69   PORTARR69  PAPN1 R69   SAPPHO69    SAPPHO R69
 0.943      0.907      0.963      0.986       0.858       0.901
 SUR LK12.5 SUR LK115  ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
 0.973      0.880      0.938      0.898      0.901        0.957
 CLAY C57.5 CLAYCK R57 FIR57.5    FIR R57.5   SKYKOMSH115 SKYKMH R115.
 0.867      0.921      0.898      0.915       0.916       0.956
 ..........GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).......................
 COULEE2    COULEE51   COULEE52   CHIEF J5   CENTRALA20 TROJAN22   ROSS42
   403        561        483        408        280            0       51
 1.045      1.007      1.015      1.002      0.986                  01.008
 CHIEF J2   ROSS44     UP BAKER   CUSHMN1    CUSHMN2     BURRARD     BONN PH2
   157         51         24         15         26        296         242
 0.973      1.008      1.050      0.975      0.971      1.037       0.986
 CHIEF JO   BONNVIL2   DALLES 3   DALLES21   DALLES22   JOHN DAY   MSASVC
   157        191        167         86         57        465            0
 0.973      0.989      0.998      0.994      0.993      0.988                  0
 ...................SLACK BUS AND AGC BUSES (MW)..............................
 RIDGE2     COULEE 2   JOHN DAY     CHIEF J2  CHIEF JO   CHIEF J5 TOTAL PNW
  186        1417       2162          605       605        1190      5979
  ..............ZONE REAL AND REACTIVE LOADS (MW,MVAR).......................
     NA      AA      AB      SC      SP      TC      NB      NC      17
 P  1787    4016     527    1803    1735    1681    7814    3531    8556
 Q   589    1276     248     439     485     586    1938    1059    3380
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=11550     Q= 3624               P=22895     Q= 6621
 ................ZONE REAL AND REACTIVE GENERATION (MW,MVAR)..................
     NA      AA      AB      SC      SP      TC      NB      NC      17
 P  1255    1055       0     303     100     278    1922     706    9654
 Q   490     287       0     210      50     138     812     292    1285
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P= 2991     Q= 1175               P= 5619     Q= 1104
..................NET MW LOAD (LOAD - GENERATION)................................
 PUGET SOUND= 8559       WEST ORE & WA=17276
 ................ZONE REAL AND REACTIVE LOSSES (MW,MVAR).......................
     NA        AA        AB        SC        SP        TC        NB        NC        17   ND+NE+NF+NG+NH
 P   326        97         1        27        14        20       277       145       625            389
 Q  2956       653        12       246        64       296      2553       432     -4698            752
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
     P=  484     Q= 4227               P=  906     Q= 7212
  ...............ZONE SHUNT REACTIVE (MVAR)...................................
     NA        AA        AB        SC        SP        TC        NB        NC        17  ND+NE+NF+NG+NH
   3383       852        92       600         0       368      2099      1046     -2141            136
 SUM PUGET SOUND (NA+AA+AB+SC+SP+TC)  WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
    QSHUNT= 5296                       QSHUNT= 8441
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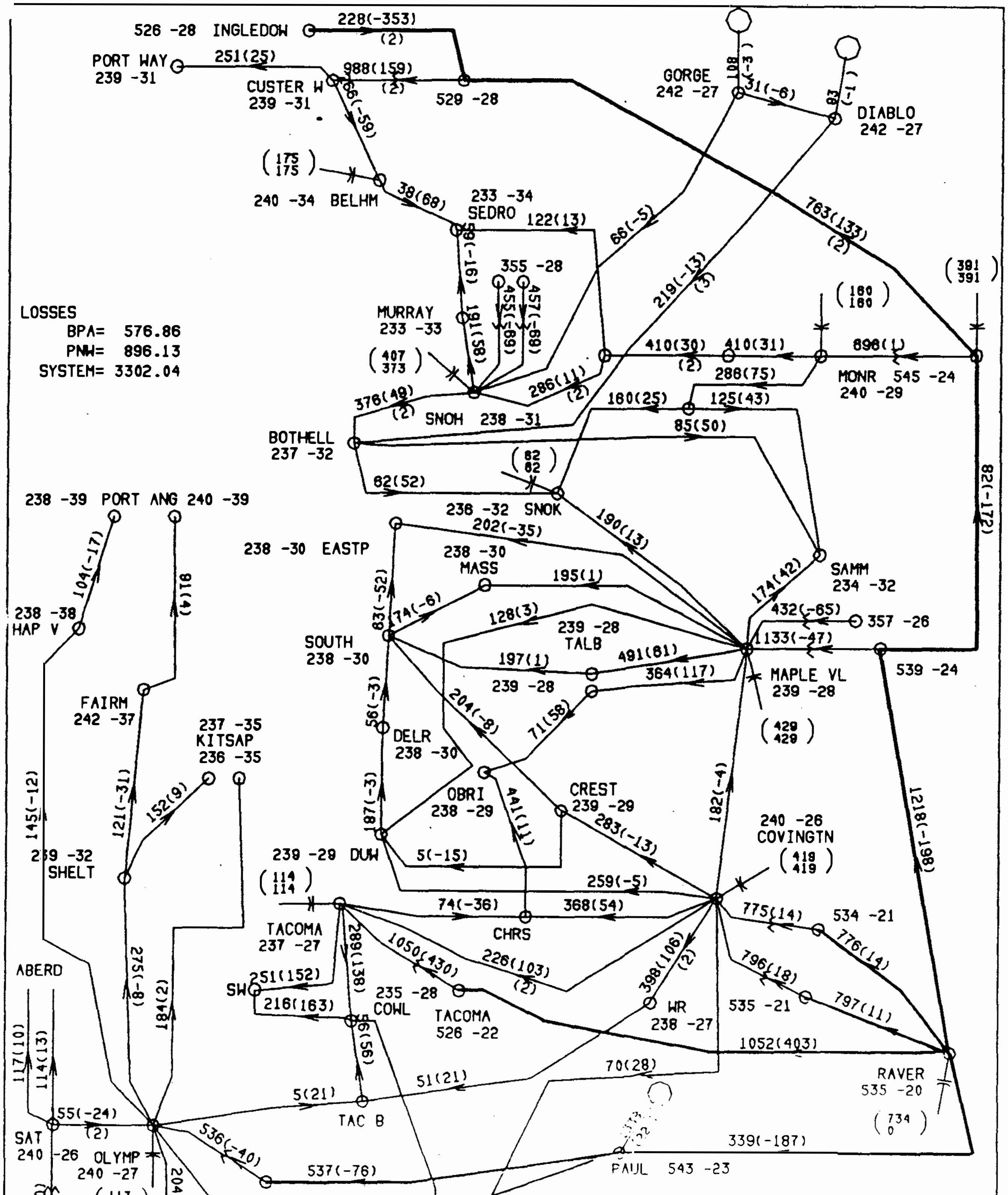
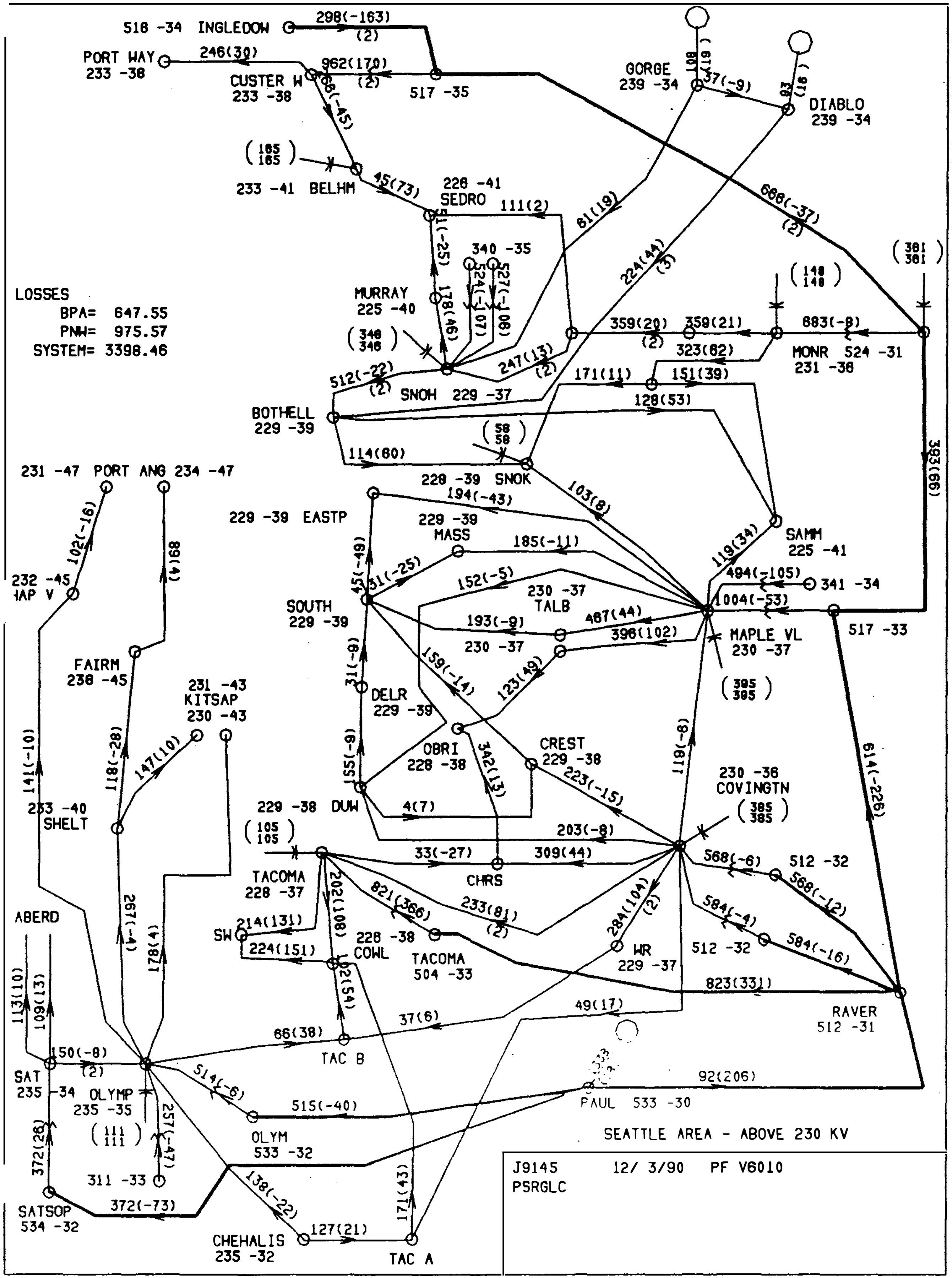


SEATTLE AREA - ABOVE 230 KV

J9143 12/ 3/90 PF V6010
CY89 PAL-MSB

S:PQ R- , PLOTTED 12-FEB-91 AT 08:56:57 HOURS

PFPLOT PFP335 : REVISED 11/14/90

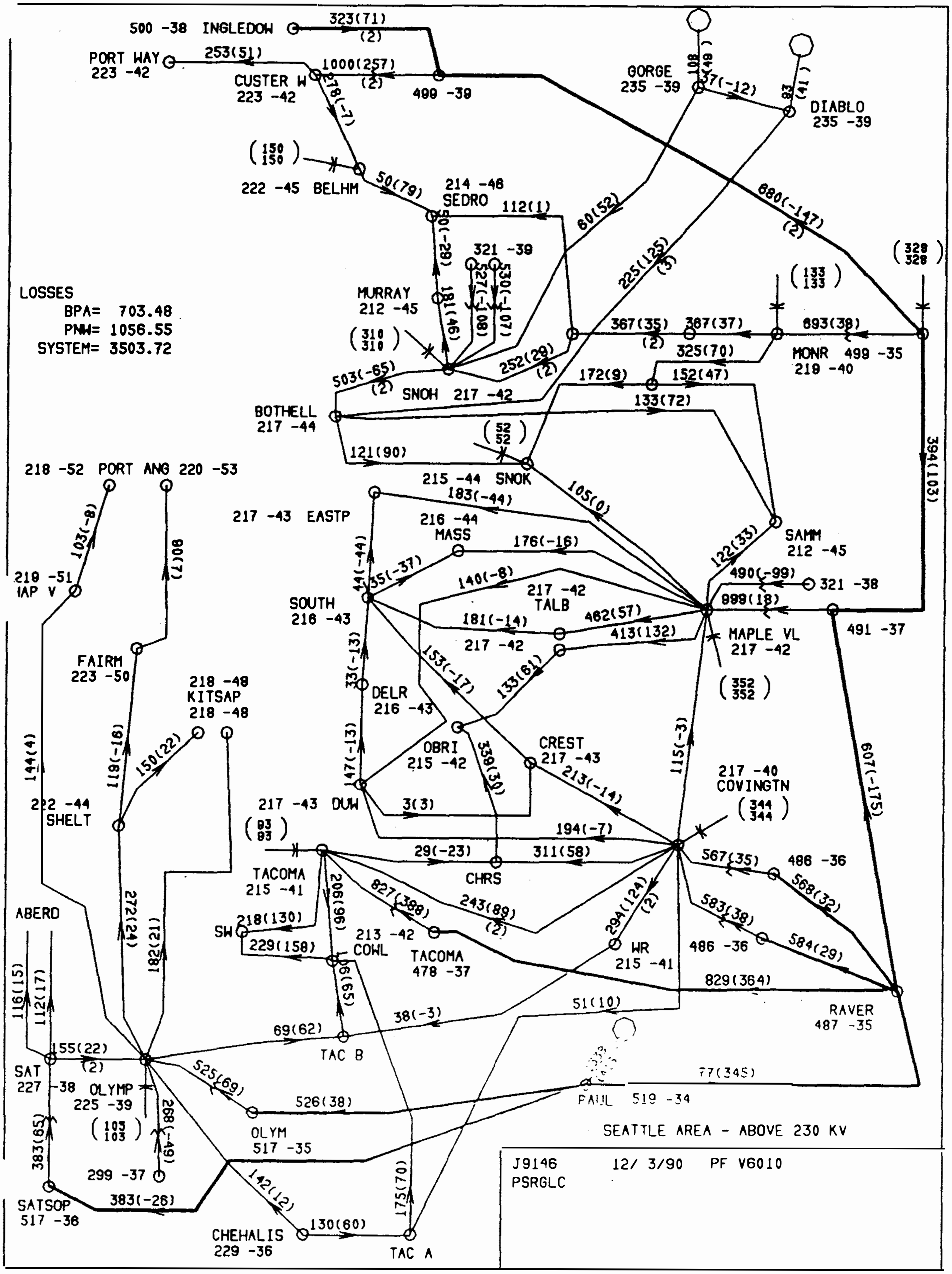


SEATTLE AREA - ABOVE 230 KV

J9145 12/ 3/90 PF V6010
PSRGLC

S:PQ R- . PLOTTED 11-FEB-91 AT 11:35:45 HOURS

PFPLOT PFP335 : REVISED 11/14/90

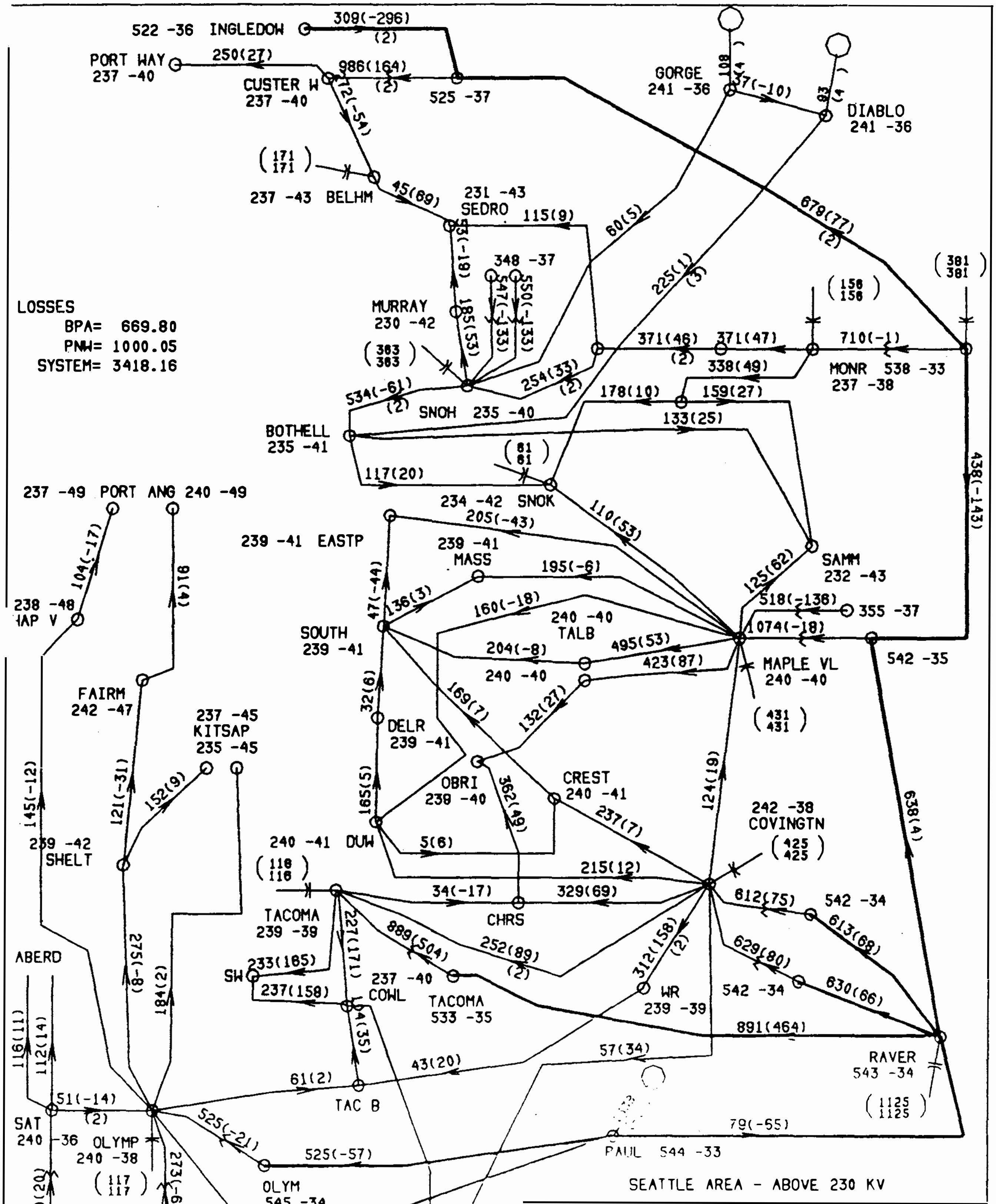


SEATTLE AREA - ABOVE 230 KV

J9146 12/ 3/90 PF V6010
PSRGLC

S:PQ R- , PLOTTED 11-FEB-91 AT 11:38:34 HOURS

PFPLOT PFP335 : REVISED 11/14/90



LOSSES
BPA= 669.80
PNW= 1000.05
SYSTEM= 3418.16

SEATTLE AREA - ABOVE 230 KV

J9162 12/27/90 PF V6011
PSRGLC

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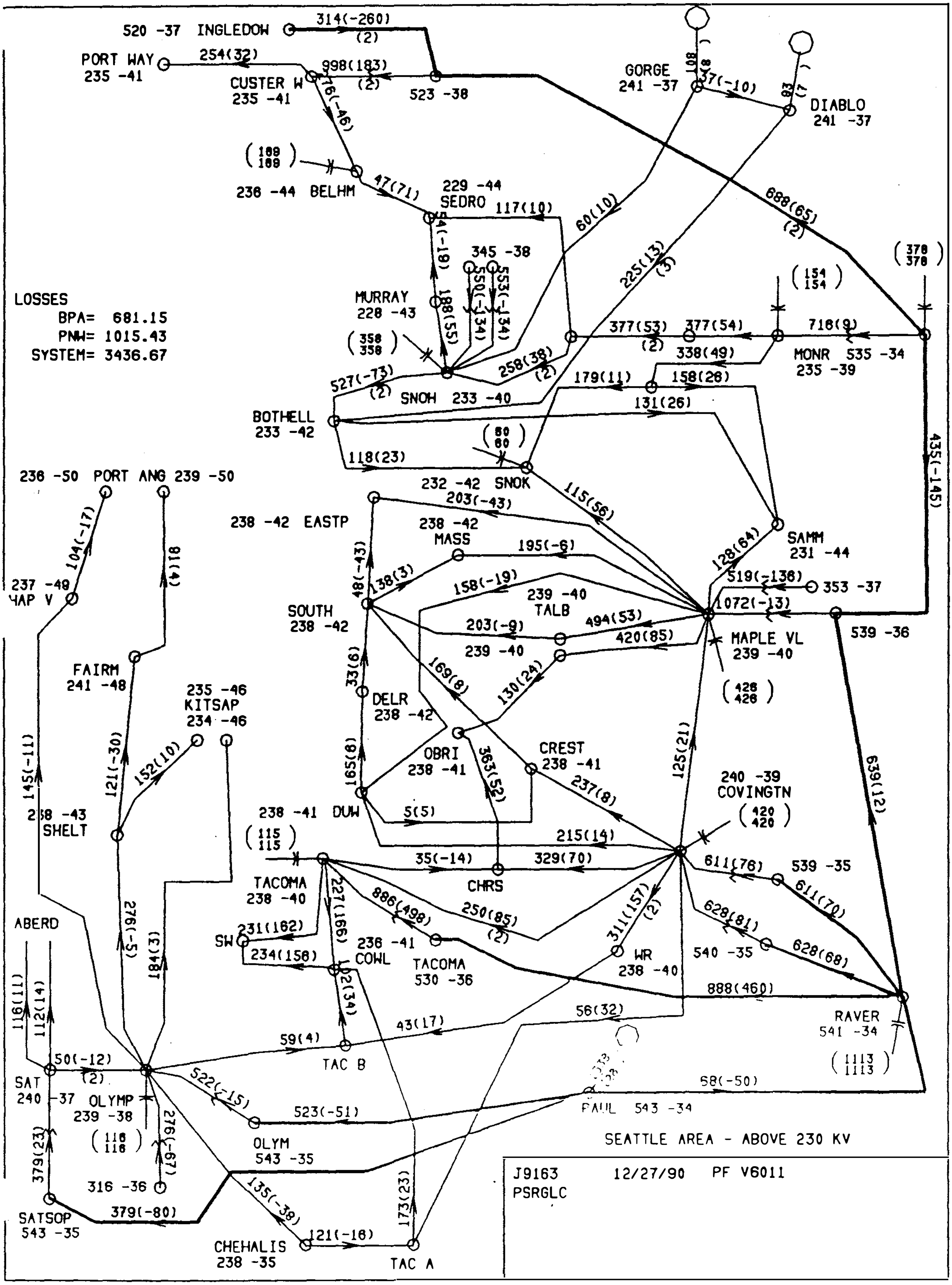

SEATTLE AREA - ABOVE 230 KV

J9163 12/27/90 PF V6011
PSRGLC

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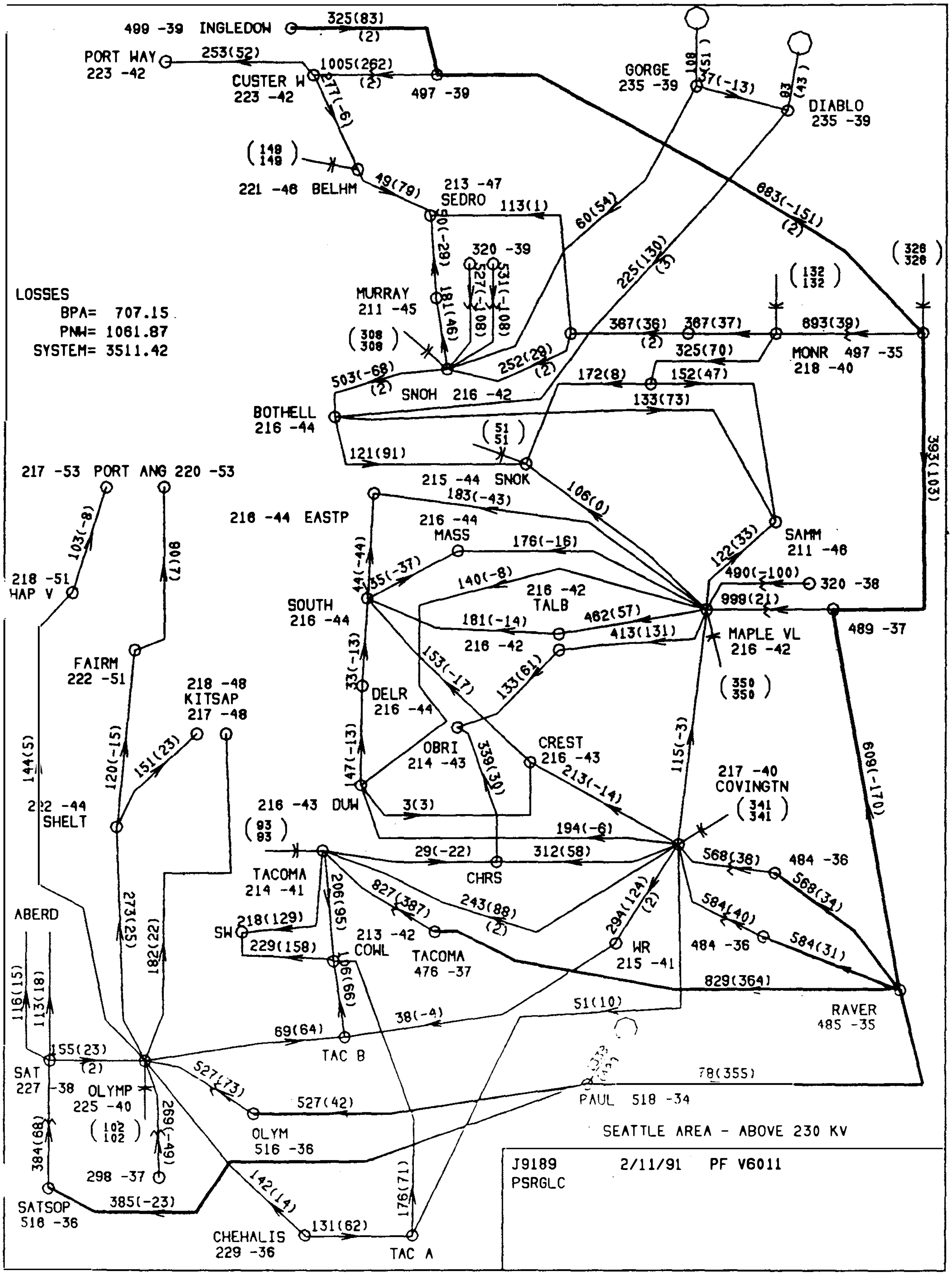
PFPLOT PFP335 : REVISED 11/14/90



LOSSES
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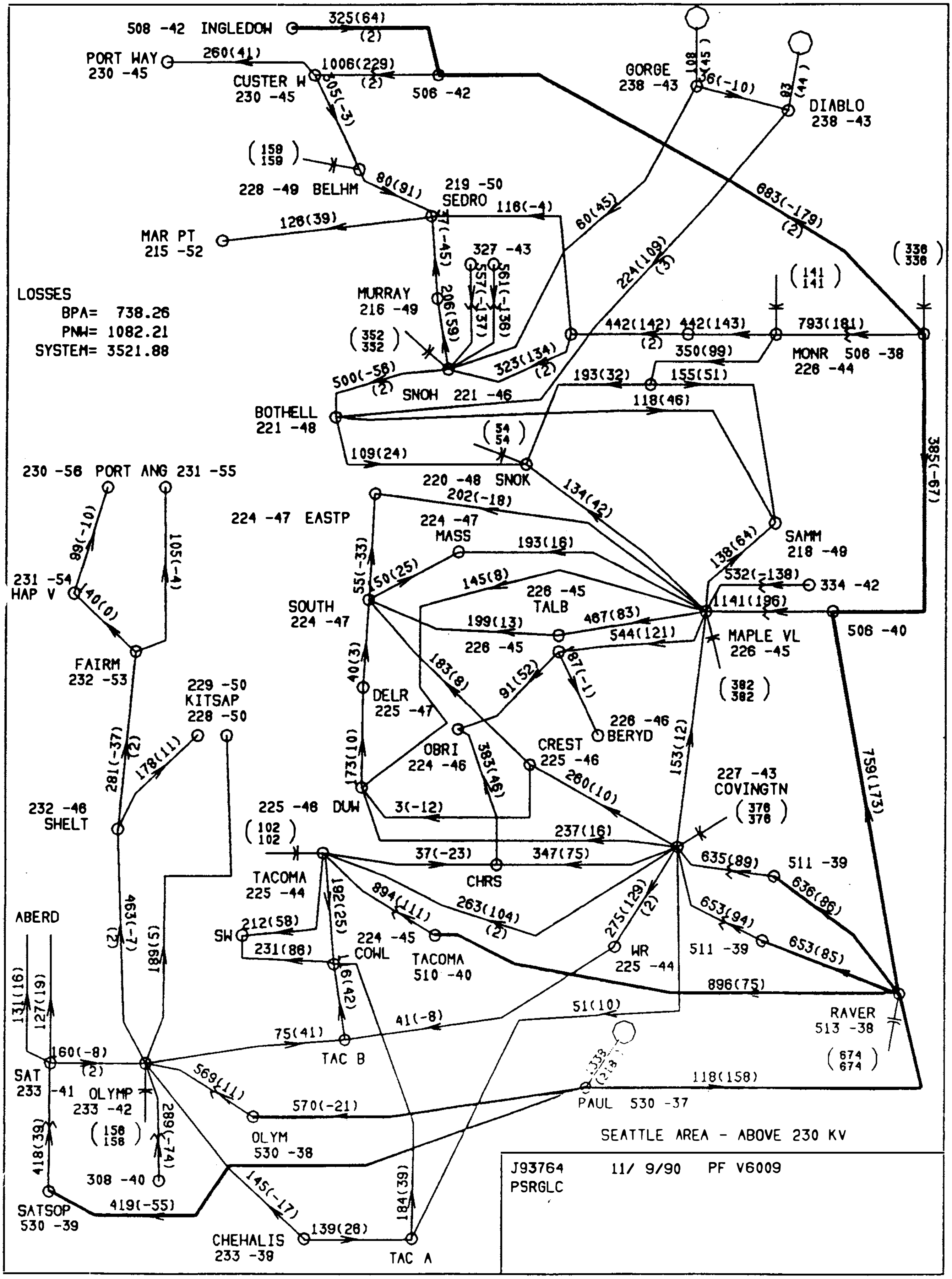
PNW= 1061.87
SYSTEM= 3511.42

SEATTLE AREA - ABOVE 230 KV

J9189 2/11/91 PF V6011
PSRGLC

S:PQ R- , PLOTTED 12-FEB-91 AT 10:00:08 HOURS

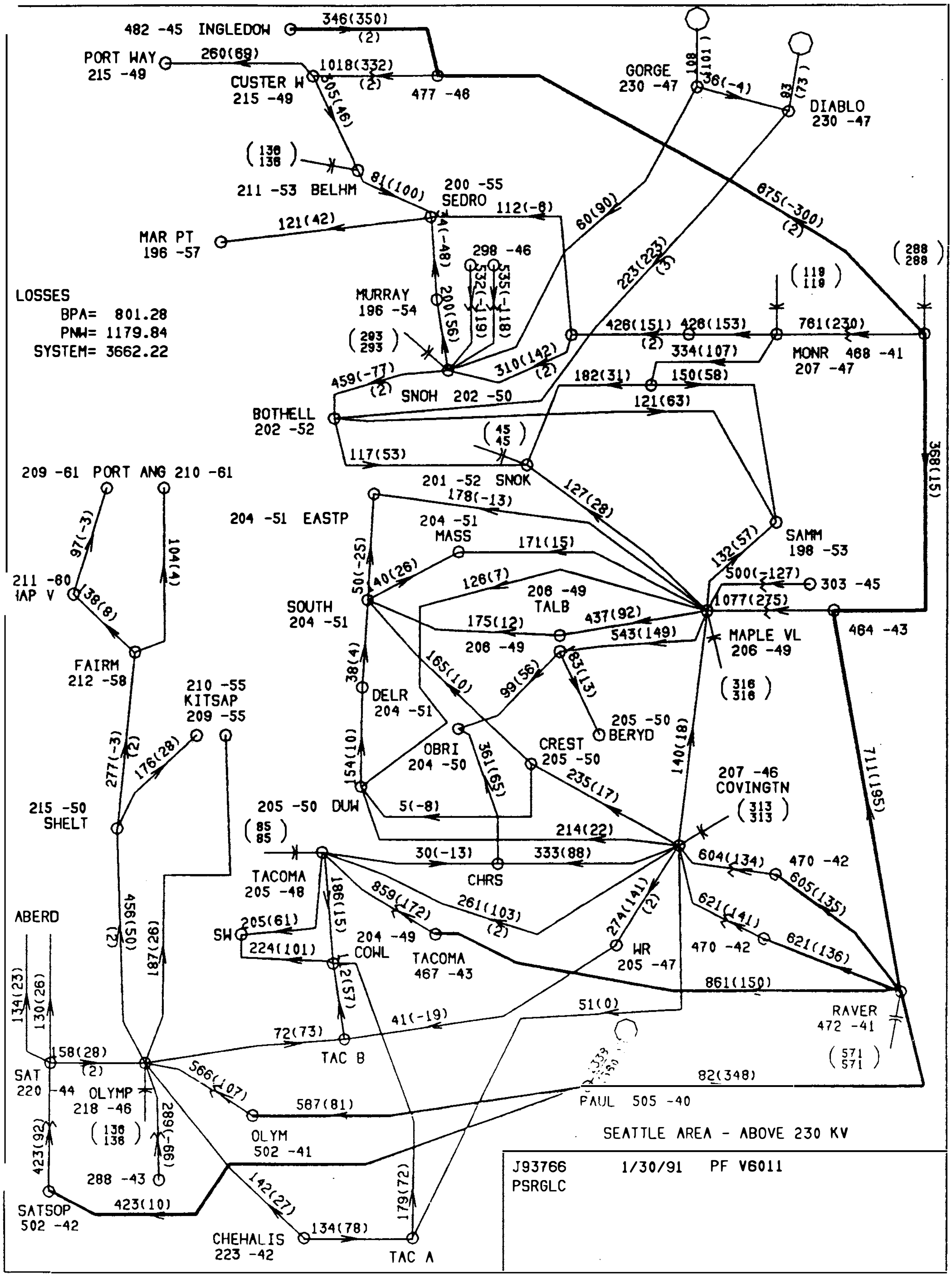
PFPLOT PFP335 : REVISED 11/14/90



J93764 11/ 9/90 PF V6009
PSRGLC

S:PQ R- , PLOTTED 11-FEB-91 AT 11:15:47 HOURS

PFPLOT PFP335 : REVISED 11/14/90



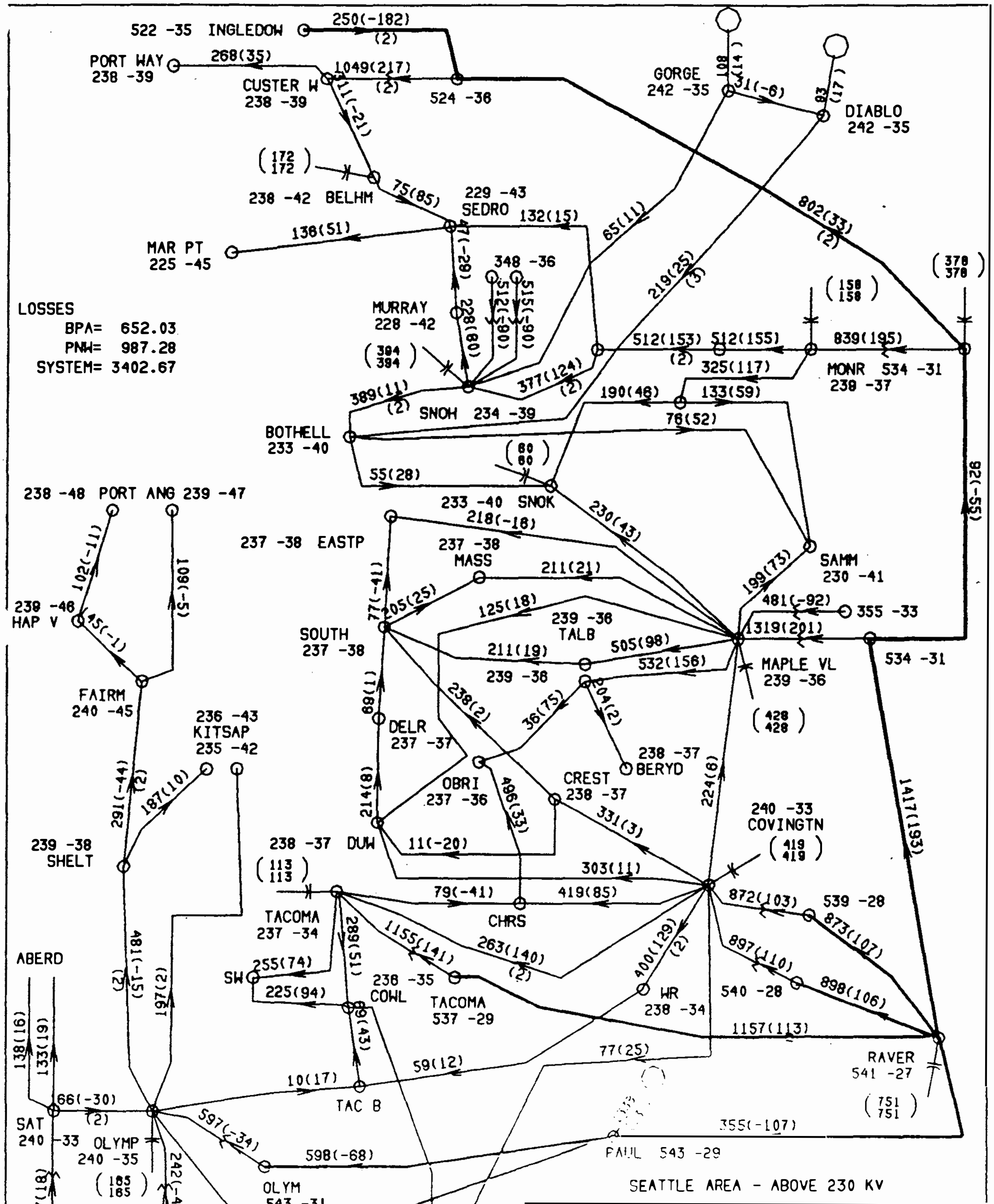
LOSSES
BPA= 801.28
PNW= 1179.84
SYSTEM= 3662.22

SEATTLE AREA - ABOVE 230 KV

J93766 1/30/91 PF V6011
PSRGLC

S:PQ R- , PLOTTED 11-FEB-91 AT 17:35:52 HOURS

PFPLOT PFP335 : REVISED 11/14/90

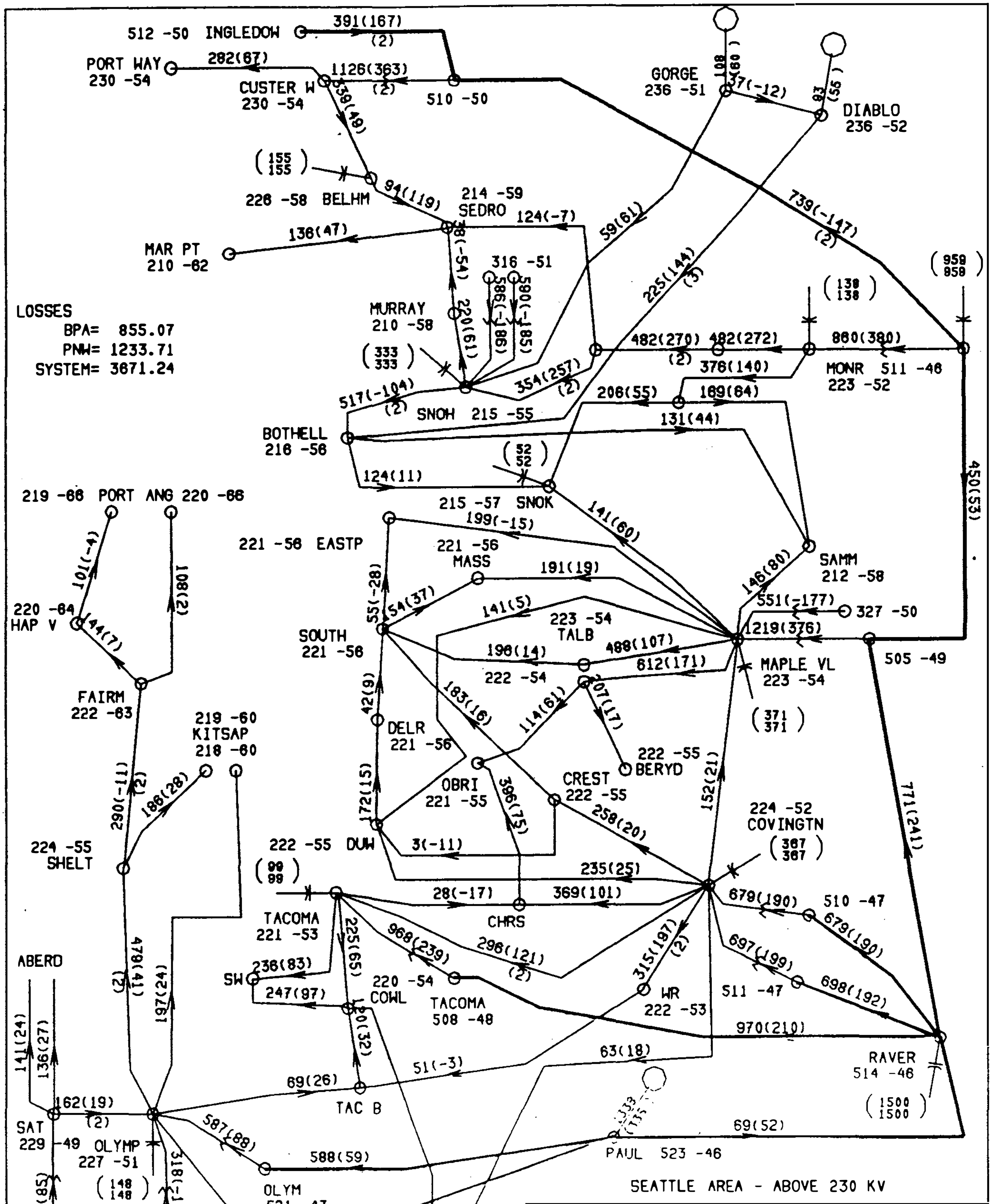


SEATTLE AREA - ABOVE 230 KV

J93837 11/ 8/90 PF V6009
CY89 PAL-MSB

S:PQ R- , PLOTTED 12-FEB-91 AT 08:01:59 HOURS

PFPLOT PFP335 : REVISED 11/14/90



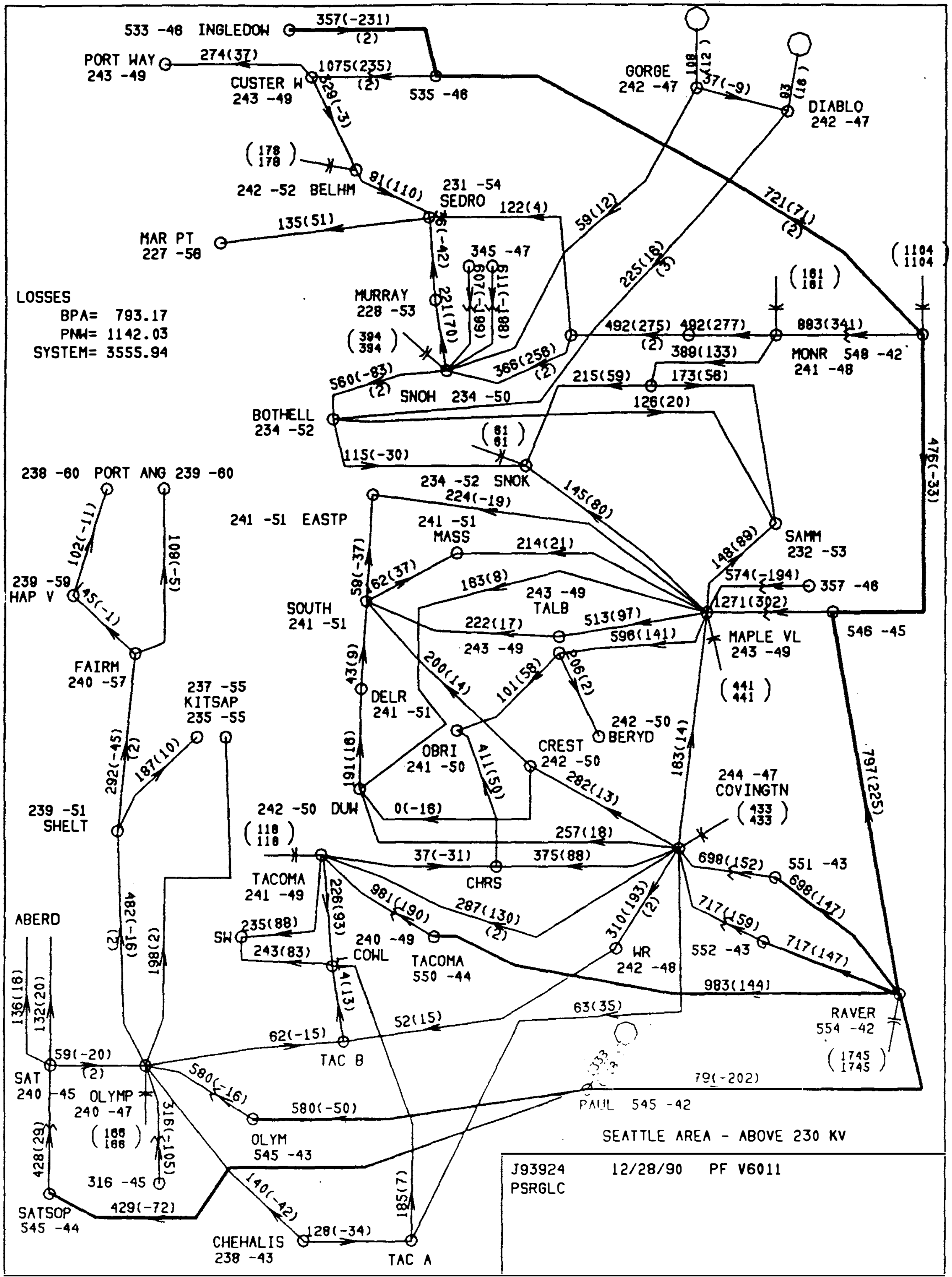
LOSSES
BPA= 855.07
PNW= 1233.71
SYSTEM= 3671.24

SEATTLE AREA - ABOVE 230 KV

J93923 12/28/90 PF V6011
PSRGLC

S:PQ R- , PLOTTED 11-FEB-91 AT 11:22:57 HOURS

PFPLOT PFP335 : REVISED 11/14/90



LOSSES
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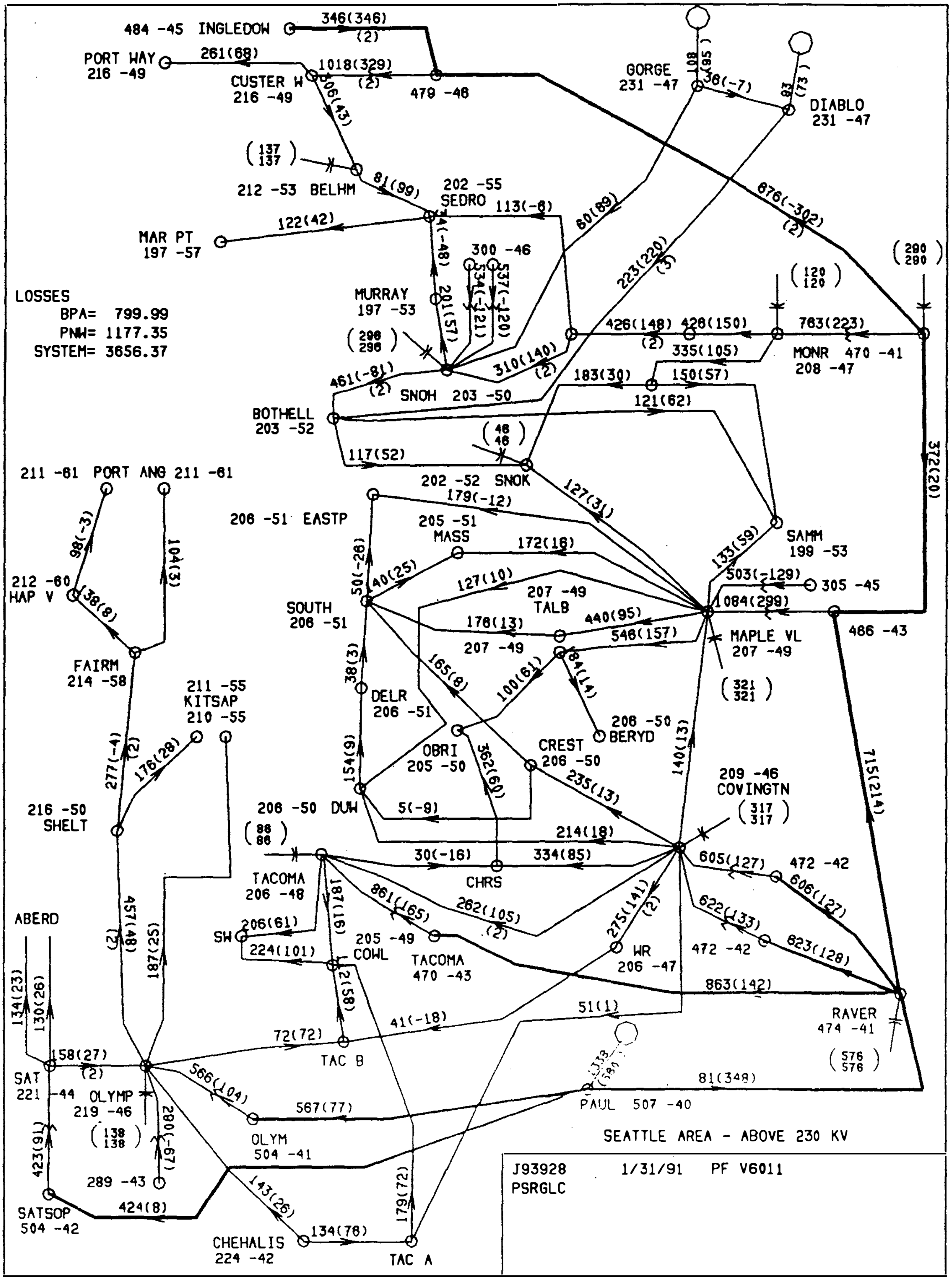
PNW= 1142.03
SYSTEM= 3555.94

SEATTLE AREA - ABOVE 230 KV

J93924 12/28/90 PF V6011
PSRGLC

S:PQ R- , PLOTTED 11-FEB-91 AT 11:25:37 HOURS PFPLOT PFP335 : REVISED 11/14/90



LOSSES
BPA= 799.99
PNW= 1177.35
SYSTEM= 3656.37

SEATTLE AREA - ABOVE 230 KV

J93928 1/31/91 PF V6011
PSRGLC

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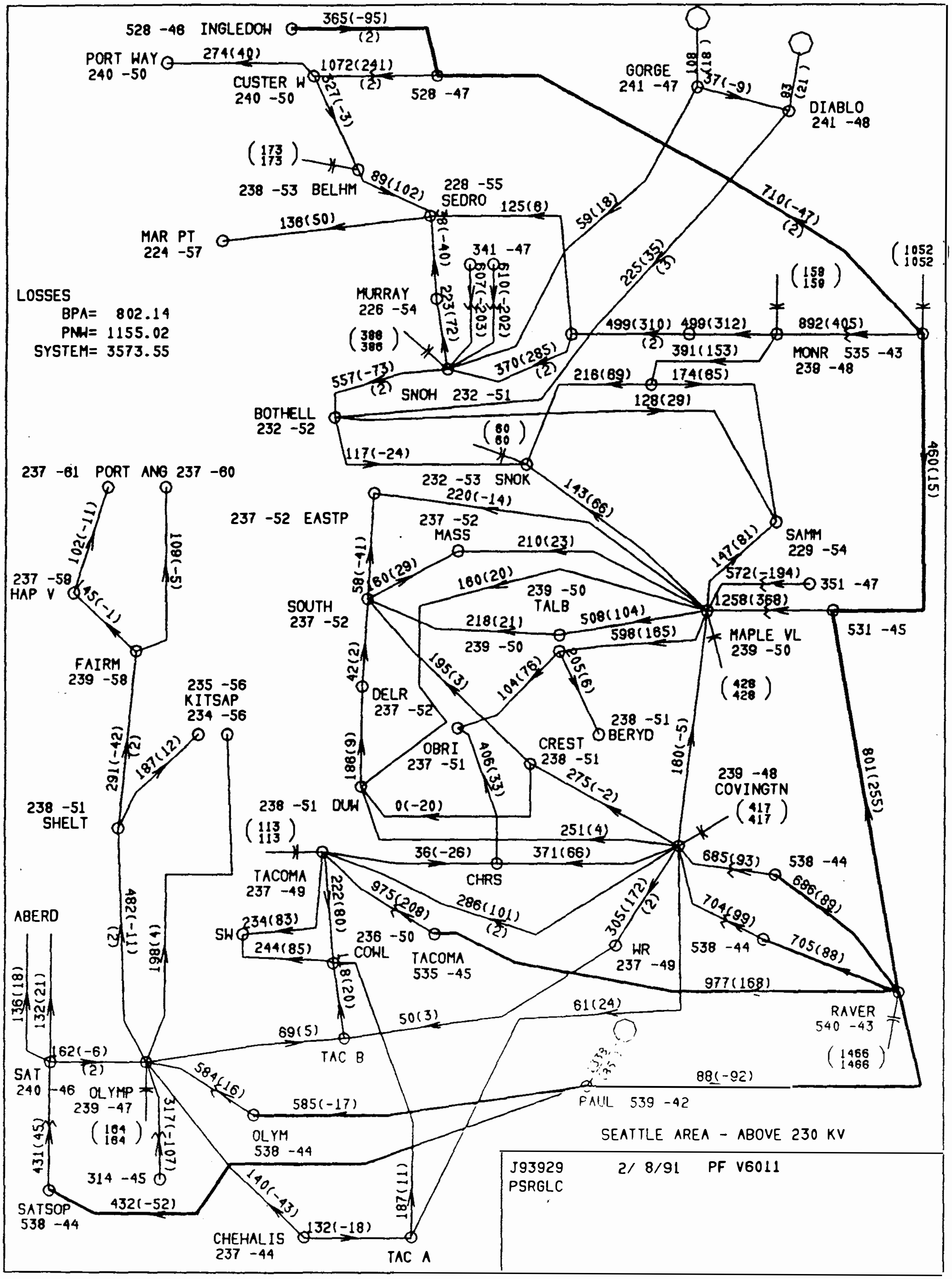


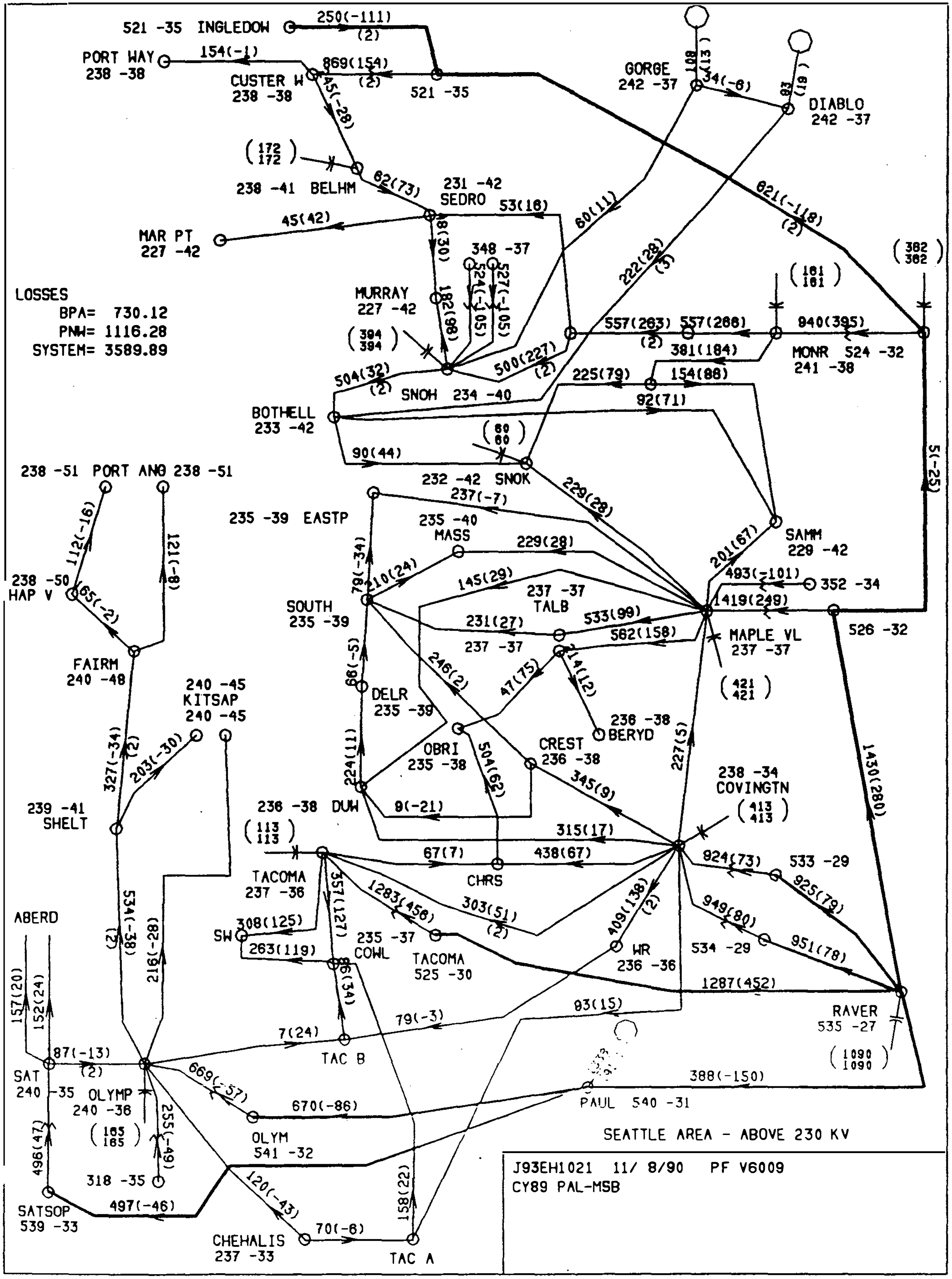
LOSSES
BPA= 802.14
PNW= 1155.02
SYSTEM= 3573.55

SEATTLE AREA - ABOVE 230 KV

J93929 2/ 8/91 PF V6011
PSRGLC

S:PQ R- , PLOTTED 11-FEB-91 AT 11:22:08 HOURS

PFPLOT PFP335 : REVISED 11/14/90



SEATTLE AREA - ABOVE 230 KV

J93EH1021 11/ 8/90 PF V6009
CY89 PAL-MSB

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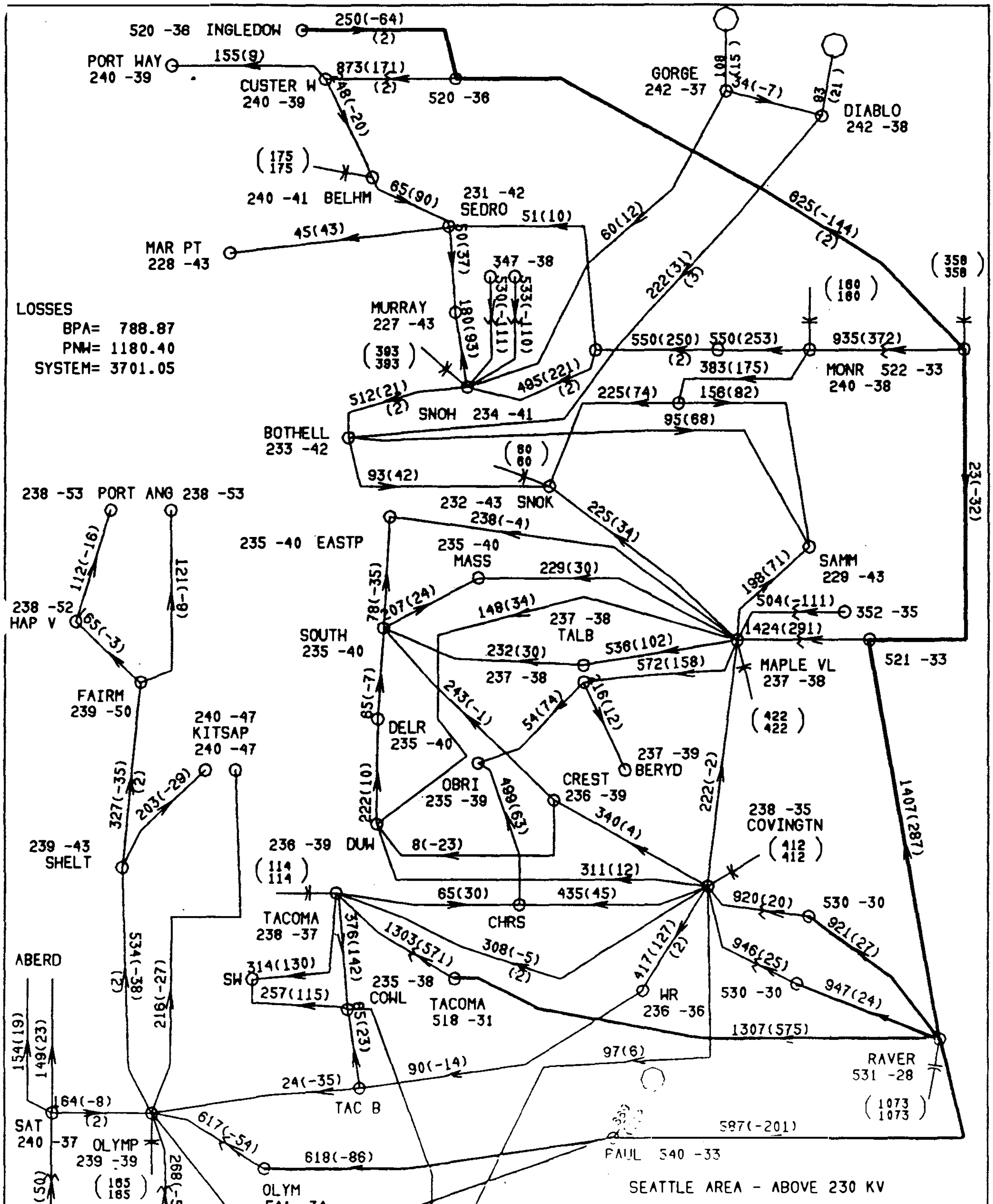
PFPLOT PFP335 : REVISED 11/14/90



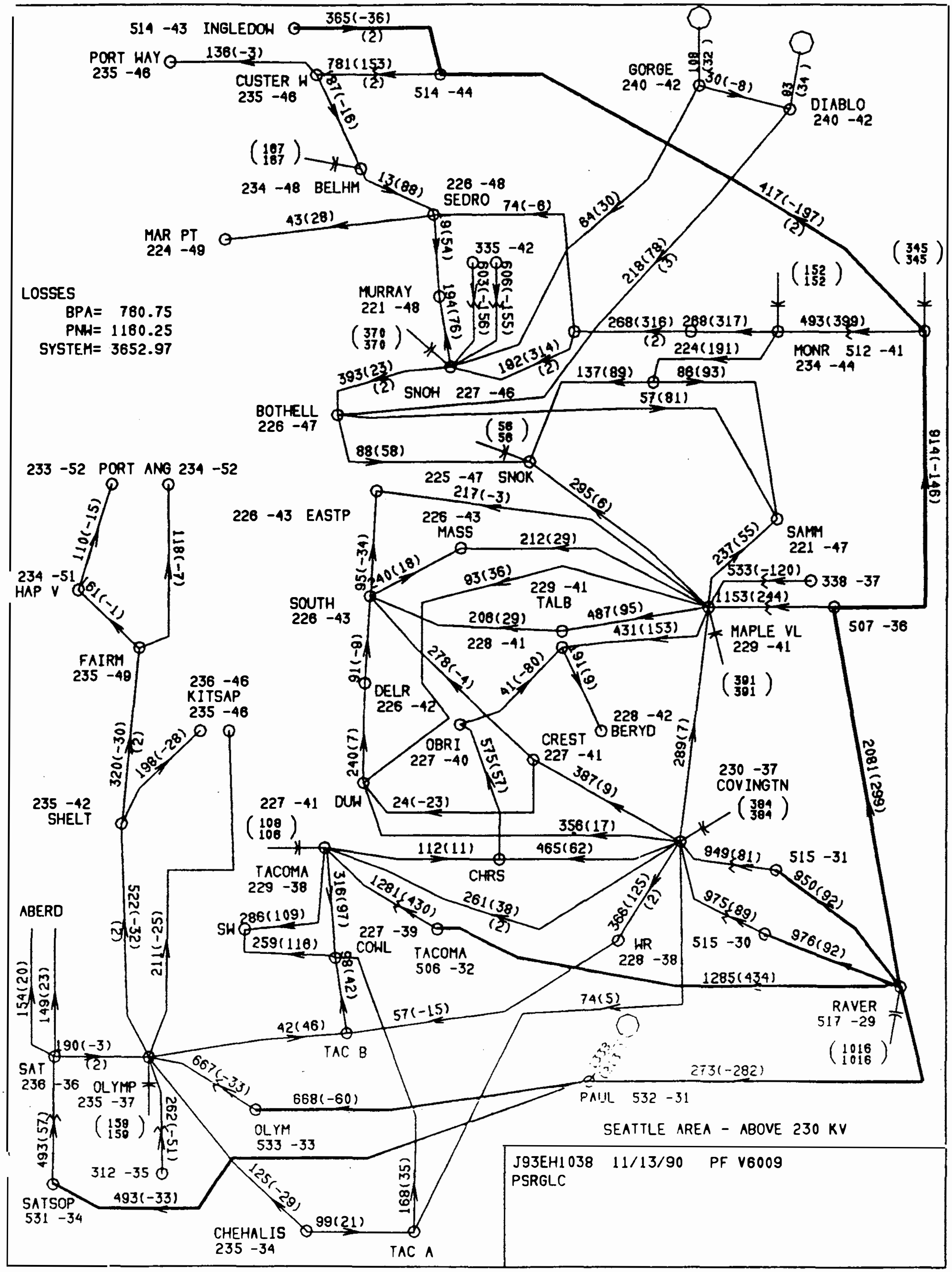
LOSSES
BPA= 788.87
PNW= 1180.40
SYSTEM= 3701.05

SEATTLE AREA - ABOVE 230 KV

J93EH1023 11/ 9/90 PF V6009
CY89 PAL-MSB

:PQ R- , PLOTTED 12-FEB-91 AT 09:00:59 HOURS

PFPLOT PFP335 : REVISED 11/14/90



SEATTLE AREA - ABOVE 230 KV

J93EH1038 11/13/90 PF V6009
PSRGLC

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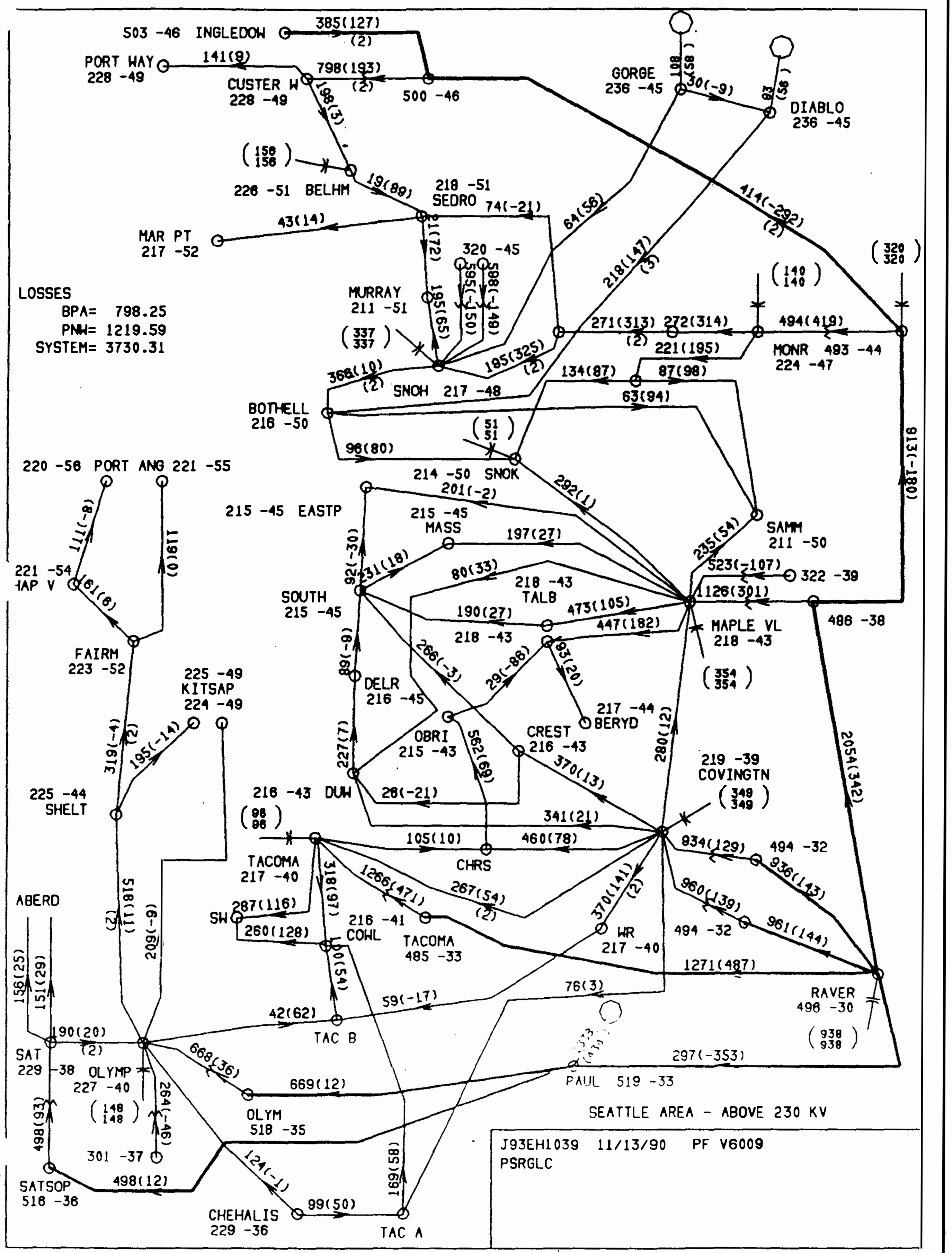
PFPLOT PFP335 : REVISED 11/14/90

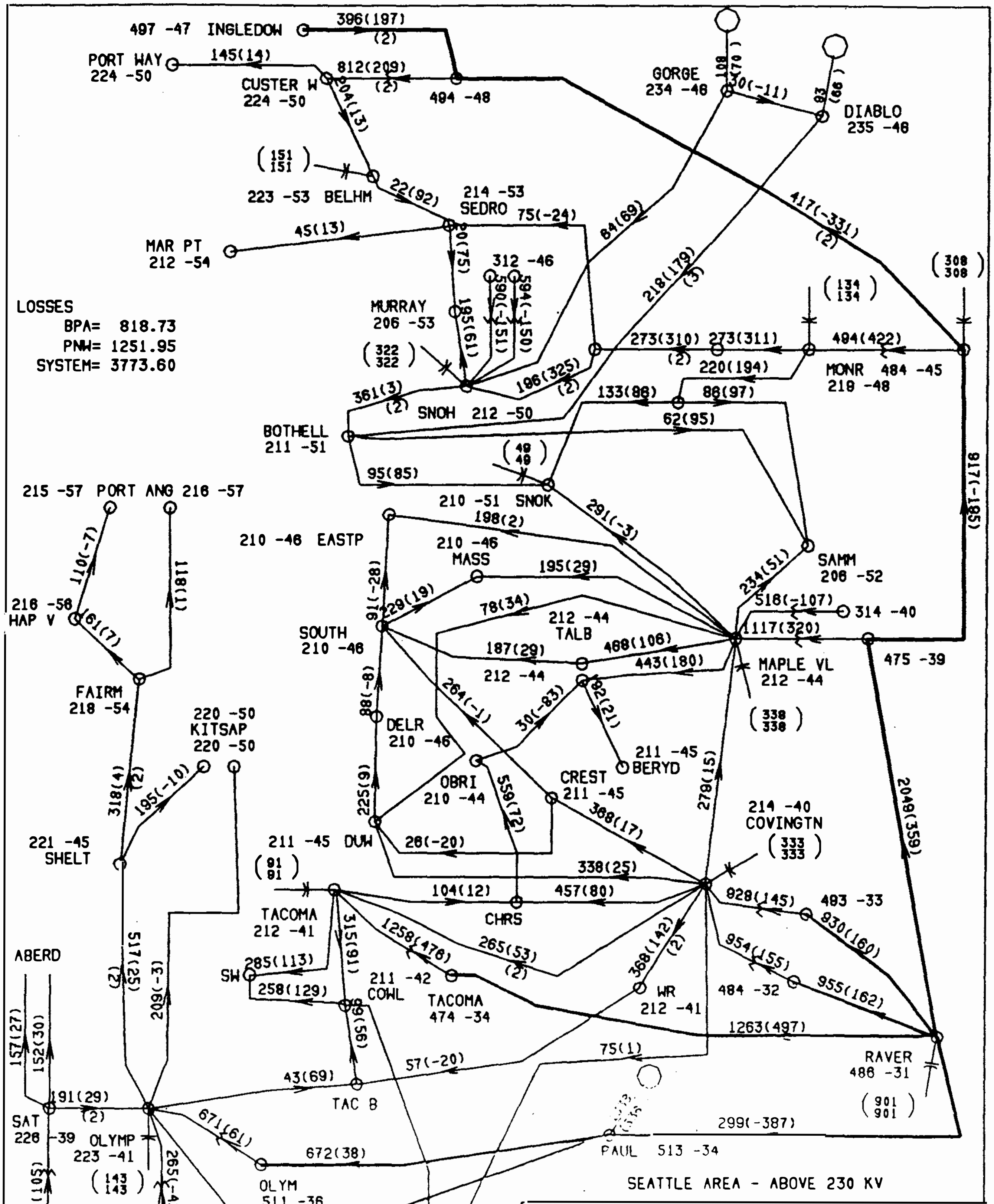


SEATTLE AREA - ABOVE 230 KV

J93EH1039 11/13/90 PF V6009
PSRGLC

S:PQ R- , PLOTTED 11-FEB-91 AT 11:32:35 HOURS

PFPLOT PFP335 : REVISED 11/14/90



SEATTLE AREA - ABOVE 230 KV

J93EH1040 11/13/90 PF V6009
PSRGLC

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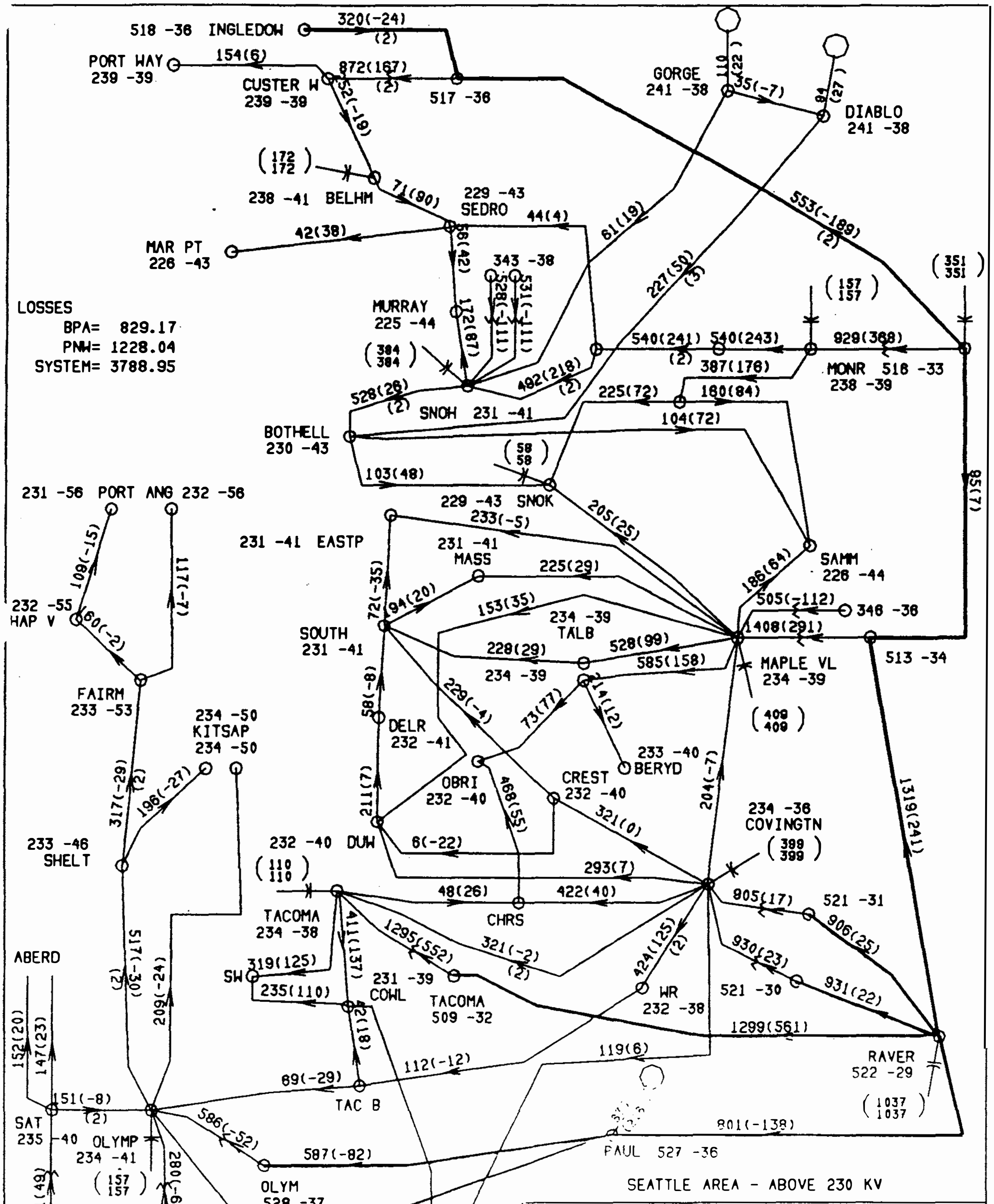
PFPLOT PFP335 : REVISED 11/14/90



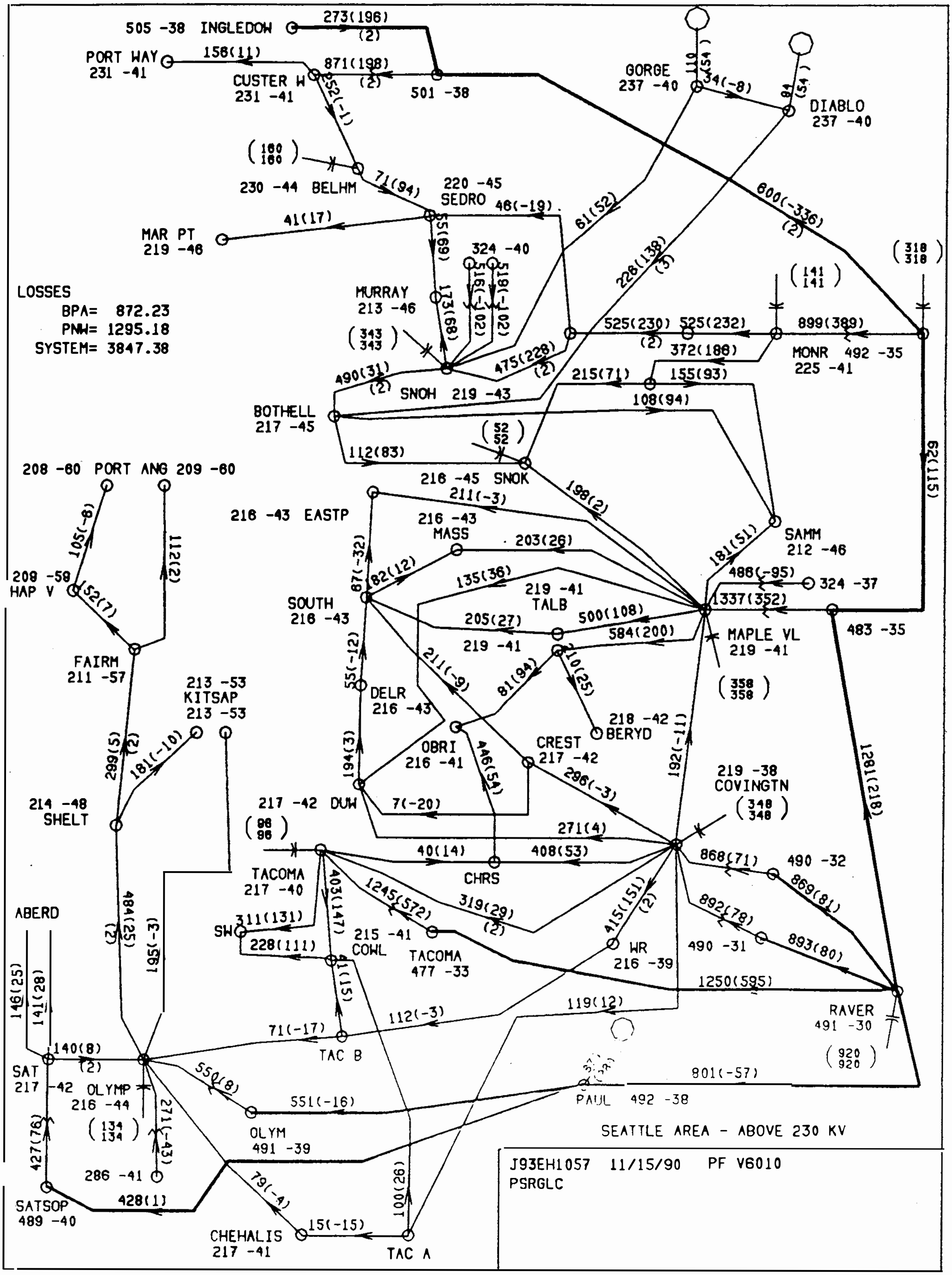
SEATTLE AREA - ABOVE 230 KV

J93EH1056 11/15/90 PF V6010

PSRGLC

S:PQ R- . PLOTTED 11-FEB-91 AT 11:26:30 HOURS

PFPLOT PFP335 : REVISED 11/14/90



SEATTLE AREA - ABOVE 230 KV

J93EH1057 11/15/90 PF V6010
PSRGLC

S:PQ R- . PLOTTED 11-FEB-91 AT 11:29:15 HOURS

PFPLOT PFP335 : REVISED 11/14/90

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APPENDIX 1

Development of the PSAERP "Superbases" with enhanced load and voltage regulating models

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The decision to develop the "superbases" was made in the Fall of 1989. Two key reasons were involved:

(1) Uncertainty from PSAERP Technical Studies Team members that a Puget Sound area voltage stability problem really existed. Some members believed that detailed modeling could potentially show a much less severe problem existed. The near term winter operating plans required uneconomical generation dispatch from combustion turbines. If no problem actually existed, the uneconomcial CT operation would not be needed.

(2) recognition that a detailed model could potentially provide insight into the problem, improve the accuracy in reactive additions, learn more about the systems of other utilities, and establish credibility. We recognized that the detailed case might provide nothing new. Less detailed cases clearly showed that the problem was due to the cross mountain main grid lines and, to a lesser extent, the local 230kV system. However, we would never know unless we devoted the resources and went through the exercise.

The utilities committed resources to research and share their system data. BPA created a comprehensive questionaire. The utilities responded with detailed information on load composition, distribution voltage regulating transformers, miscellaneous voltage controls, and generator data. The Puget Sound Area helped Transmission Planning in obtain similar information from other BPA customers. The BPA Power Forecasting Branch devoted very important resources to research load component information from conservation research (End-Use Load and Consumer Assessment Program or ELCAP). The total load magnitudes for each utility were developed by the PSAERP Load Forecasting Team.

The EPRI LOADSYN program was applied to obtain load models. The program used load composition and component data to model loads for powerflow and transient stability application (constant impedance, constant current, and constant power). Distribution voltage regulating transformer tap setting and tap range were modeled from survey results. Load and voltage regulation models were expected to provide important study results.

bpa65::disk15:[eofcglc]porter.memo

Percent of Utility Load

Data for 1993

CLASS MIX	PUGET		SEATTLE		SNOHOMISH		TACOMA		NGN	
	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal
Residential	57.9	57.7	51.1	51.1	63.4	63.2	43.3	43.3	68.4	68.4
Commercial	29.8	28.6	37.9	36.5	26.2	25.2	27.3	27.3	13.6	13.6
Heavy Ind.	12.3	13.7	6.9	7.8	10.4	11.6	29.4	29.4	17.9	17.9
Steel Mill	0.0	0.0	4.2	4.7	0.0	0.0	0.0	0.0	0.0	0.0
Power Plant Aux.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ag. Pumping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Primary Alum.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RESIDENTIAL COMPOSITION		PUGET		SEATTLE		SNOHOMISH		PIERCE, NGN	
		Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal
Resistance Heat	REHT	58.4	48.4	54.5	44.3	61.4	52.0	58.6	48.9
Heat Pump	RSPM	4.2	4.2	5.1	5.1	5.2	5.2	4.9	4.9
Furnace Fan	FFAN	1.0	0.8	0.7	0.6	0.9	0.8	0.9	0.8
Air Conditioning	3 AC's	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL HEAT		63.6	53.4	60.3	50.0	67.5	58.1	64.4	54.6
Water Heat	ELWH	15.8	23.1	17.1	24.6	11.9	17.9	14.2	20.9
Range	ELRA	4.7	5.4	1.1	1.2	2.9	3.3	2.9	3.4
Referigeration	REFR	8.2	9.4	7.5	8.5	7.5	8.8	7.9	9.0
Dishwasher	DWSH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Clothes Washer	CWSH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dryer	DRYR	1.2	1.3	1.1	1.2	1.1	1.3	1.1	1.3
Incandescent Lights	ILIT	5.9	6.7	11.9	13.3	8.3	9.7	8.7	9.9
Flourescent Lights	FLIT	0.6	0.7	1.1	1.2	0.8	0.9	0.8	0.9
Television	TVSN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL MISCELLANEOUS		20.6	23.5	22.6	25.4	20.6	24.0	21.4	24.5

COMMERCIAL COMPOSITION		PUGET		SEATTLE		OTHER	
		Extreme	Normal	Extreme	Normal	Extreme	Normal
Resistance Heat	REHT	44.7	42.7	39.8	37.7	42.1	40.1
Heat Pump	CSPM	7.7	7.3	7.5	7.1	7.6	7.2
Fan/Ventilation	FFAN	12.8	12.2	11.8	11.2	12.3	11.7
Air Conditioning	3 AC's	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL HVAC		65.1	62.2	59.1	56.0	62.0	59.0
Incandescent Lights	ILIT	4.0	4.2	4.8	5.0	4.4	4.6
Flourescent Lights	FLIT	20.1	21.0	22.8	23.6	21.6	22.4
TOTAL Lights		24.1	25.2	27.7	28.6	26.0	27.0
Referigeration	REFR	2.7	3.6	3.3	4.4	3.0	4.0
Water Heat	ELWH	6.7	7.5	4.5	5.0	5.8	6.4
Range	ELRA	1.3	1.5	0.9	1.0	1.2	1.3
Other	METC	0.0	0.0	4.5	5.0	2.0	2.3
TOTAL Miscellaneous		8.1	9.0	9.9	11.0	9.0	10.0

19 July 1990

Attachment 6

ATTACHMENT 6

POWER TECHNOLOGIES, INC.

A REVIEW OF
BONNEVILLE POWER ADMINSTRATION
VOLTAGE STABILITY ANALYSIS
AND SYSTEM UPGRADE PLANS
WITH COMMENTS AND RECOMMENDATIONS

January 29, 1992

PTI Report # R7-92

Harrison K. Clark
Power Technologies, Inc.
Roseville, CA

A REVIEW OF

BONNEVILLE POWER ADMINISTRATION

VOLTAGE STABILITY ANALYSIS

AND SYSTEM UPGRADE PLANS

WITH COMMENTS AND RECOMMENDATIONS

Introduction

Planning and operating studies conducted in 1989 and 1990 at the Bonneville Power Administration have demonstrated that under winter peak load conditions, certain system disturbances can leave the Pacific Northwest system in a condition of voltage instability. The studies also show that the voltage stability problem will grow worse through time as the system load peak grows and is served largely from existing hydro generation to the east.

In 1990 BPA engineers examined potential solutions and developed an economical plan to reduce the risk of voltage instability. This report presents the results of my review of that plan.

Information on BPA studies and plans came from discussions with BPA engineers Marvin Landauer and Gordon Comegys and a review of three documents:

- Load and LTC data survey
- Voltage Collapse Report - Final Draft 11/18/91
- Attachment 3: The Reactive Plan

Reactive Plan Summary

The reactive plan is very well conceived. It consists of a new intermediate substation at Naneum, the addition of series compensation, and a combination of switched shunt capacitors and static var systems. Breaking the long lines down into shorter sections reduces the impact of line outages. Series compensation is very effective at improving voltage stability because it effectively shortens the lines. Shunt compensation is also very effective so long as it is not used to excess. The combination of series and shunt compensation is economical and avoids excessive use of shunt compensation.

Reactive Plans - Observations

The chief problem with heavy use of shunt compensation is that as the use increases, the reactive reserve that must be provided grows rapidly, and an increasing share of the total must be in the form of an SVS. The level of shunt compensation planned for the Puget Sound area is high, but is manageable.

The V-Q curve is being used extensively in BPA's analysis of the voltage problems in the 1993-2004 period. This is an appropriate and effective tool. There are, however, some concepts associated with its use that are not discussed in the reports. To ensure that final studies, and future studies (and there will be future studies -- voltage stability problems are a constant battle once they appear) are as effective as possible, I will cover those I feel are particularly important to the problems BPA is facing.

Critical Voltage

The critical voltage is often considered to be the 'bottom' of the V-Q curve. The critical point is at the lowest Q value only when the V-Q curve is tangent to the zero Mvar line at its lowest point as shown in Figure 1. When the V-Q curve is above the zero Mvar line, the critical voltage is the point at which a capacitor characteristic is just tangent to the V-Q curve, and occurs to the right of the lowest point as shown in Figure 1. These are, in fact, the same point, and differ only in whether or not the critical amount of shunt compensation is included in the system model under test.

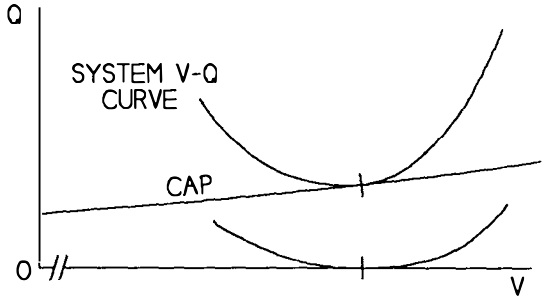

Figure 1

V-Q Curve Shape

The V-Q curve shape is heavily system dependent, and may vary from one operating condition to another in the same system. Post-contingency V-Q curve shape may also be different for different disturbances. A sharp V-Q curve like (a) in Figure 2 presents the problem keeping voltages in a narrow range to ensure stability. If voltage is allowed to drop, the reactive demand grows dramatically, making it difficult to restore voltages without load shedding. If the V-Q curve is quite flat in the desired operating

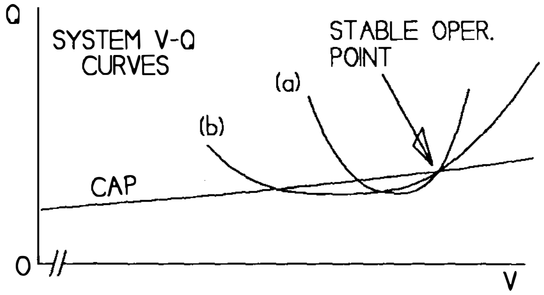

Figure 2

region as shown in (b) of Figure 2, that is, it is more-or-less parallel to the capacitor characteristic, normal load variations will require frequent trimming of the amount of shunt compensation that is on-line to keep voltages in the desired operating range. A flat V-Q curve will also require some banks to be constructed in relatively small sizes, about 100 Mvar for the planned Northwest 500 kV system. There must be sufficient shunt compensation to always provide a stable intersection of the capacitor and system characteristics or an intersection with the 0 Mvar line if the on-line capacitors are all included in the V-Q curve development.

The 'Critical' Voltage Can Be Above The Operating Voltage

The reactive planning and operating strategy outlined in the previous section is not sufficient when the lowest voltage at which a stable intersection can occur is above an acceptable system operating voltage as shown in Figure 3. When this is the case, the system can be operated at the desired voltage by operating to the left of the critical voltage on the V-Q curve. Operation to the left of the critical voltage is feasible and practical and has been a planned operating condition in some systems. There is just one requirement for operation in this region, and that is that at least one generator, condenser, or SVS be actively regulating voltage. This means it must be operating below its maximum reactive limit.

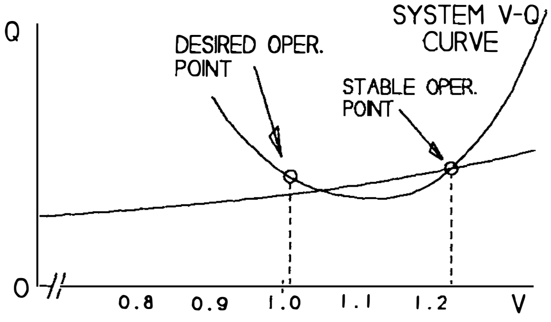

Figure 3

Comparing the characteristics of generator and SVS regulators with the system steady state V-Q curve would seem to indicate that operation on the left side of the V-Q curve will not be stable. After all, conventional wisdom would seem to indicate that these devices are supposed to provide increased reactive power when voltage falls, while the V-Q curve seems to show that increasing reactive Fpower would drive voltage lower. However, neither is true.

The left side of the steady state V-Q curve is no different from the combination of an induction motor and a shunt capacitor. Dropping the voltage on either will increase the reactive power needed to hold voltage. Generators and SVS can handle this kind of load. A review of the steady state relationships in a voltage regulator on either will show why this is the case. For instance, reducing the voltage setpoint on a generator will reduce field voltage and the terminal voltage, but the terminal voltage fed back to the regulator will tell it that only a small change in field voltage is needed to cause a large change in voltage. Because flux in the generator is changed a small amount while the terminal voltage drops a large amount, the reactive power delivered is increased.

The stability of voltage controls on generators and SVS also seems questionable when they are faced with the left side of a V-Q curve. The answer here is that the V-Q curve we normally plot is a *steady state* curve, and generator and SVS regulators are dynamic controls that make corrective adjustments, effectively, dozens, or hundreds of times each second. They thus only interact with the system in a dynamic state. In the dynamic state the system V-Q curve is a positive slope as shown in Figure 4.

From the point of view of any one generator or SVS, the dynamic characteristic is a combination of the system short-circuit impedance and the load transient characteristics (i.e., resistance heat load is a resistance, and motors are a voltage behind a transient reactance). All systems have a positive slope transient characteristic as shown in Figure 4.

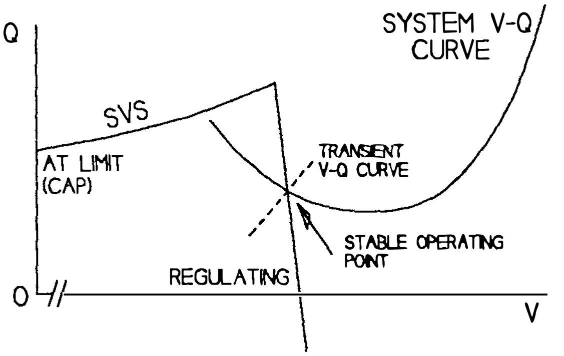

Figure 4

That operation with voltage regulation from an SVS is stable is most readily explained by recognizing that the SVS rapidly and continuously adjusts admittance in small steps. Assume that the system is operating at the stable operating point shown in Figure 4. The SVS admittance and the system transient characteristic are shown for that initial operating point in Figure 5. If system load increases, the transient curve will move to the left and voltage will fall toward the intersection of the SVS admittance and the new system transient V-Q curve. This voltage is below the setpoint of the SVS regulator, and will cause the SVS to increase its admittance. The intersection of the new system transient V-Q curve and the new SVS admittance will be at a higher voltage back on the SVS regulating characteristic. After this, the system,

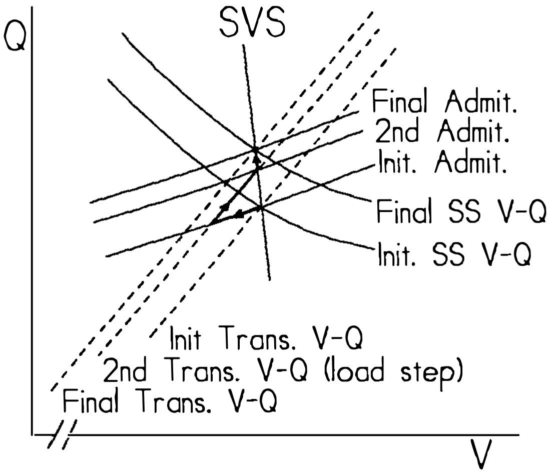

Figure 5

through the slow dynamics of LTCs and loads, will adjust to the slightly lower voltage, causing voltages to drift even lower as the system approaches a new steady state operating point on a new steady state V-Q curve. Before, during, and following this process, the SVS continues to reset its admittance in response to the transient characteristic so that the voltage remains at some point on the SVS regulator droop curve. The SVS, in effect, never sees the steady state V-Q curve, but only the transient characteristic to which it responds in a stable manner. Though the SVS (or generator) may not recognize the steady state V-Q curve, when the system settles at a new operating point on the steady state V-Q curve, the SVS or generator average output will be on that curve, and, as noted earlier, it's steady state equations will be satisfied.

Though it was stated above that automatic voltage control is required for stable operation to the left of the critical voltage, this is, strictly speaking, not true. It is, theoretically at least, possible for operators to regulate voltage on the left side of the V-Q curve with switched shunt capacitors. This is the case because, as noted above for generators and SVSs, the V-Q curve that we work with in power flow studies is the *steady state* system characteristic, and does not reflect how the system responds to changes in shunt compensation from second to second (see the transient characteristic in Figure 4). This is especially the case in the northwest when much of the load is resistance heating. As long as the effective "time constant" of operator response is shorter than the system time constant, operators can control voltage. The system time constant is dictated primarily by LTC response time at voltages above 92% and thermostats when voltages are below 92%. However, capacitor banks would have to be added or removed as frequently as once every few minutes, in steps as small as 50 Mvar (on the planned Northwest system). When the compensation is above the steady state V-Q curve, that is, the capacitor and system transient V-Q curves intersect above the steady state V-Q curve, voltage will drift up until the operator removes a bank. If removing a bank places the system under the steady state V-Q curve, voltages will drift down until the operator switches a bank on. If removing a bank leaves the system above the steady state V-Q curve, voltages will continue drifting up and another bank will need to be switched off. This phenomena is shown in Figure 6. Figure 6a shows how voltage will behave for a system operating right on the V-Q

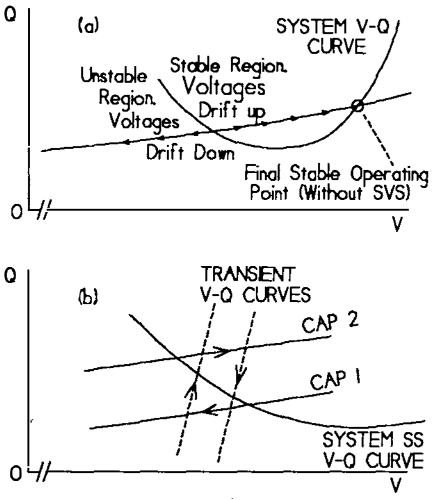

Figure 6

curve. Because this is not a stable operating point, voltage will drift away from this point and may drift up or down. A slight increase in load will put the operating point below the V-Q curve, and voltages will drift down and the system may collapse. A slight decrease in load will put the operating point above the V-Q curve, and voltages will drift up and ultimately reach a stable point on the right side of the V-Q curve.

Operators can control voltage if they continuously cycle banks on and off as shown in Figure 6b. When voltage is drifting down the Capacitor 1 curve and a bank is switched on, the voltage will jump up the transient V-Q curve to its intersection with the Capacitor 2 curve, then slowly rise further until the bank is switched off. When the bank is switched off, the voltage will jump down the new transient curve and then drift lower until it is switched back on to repeat the cycle. This burden on operators, and the capacitor switch duty are unacceptable for obvious reasons, and thus make *automatic* voltage control essential for operation below the critical voltage on the V-Q curve.

SVS Need

The SVSs planned for the Northwest will provide this automatic regulation if and when it is needed. Like the control suggested above for operators, the SVS could be designed to provide only step changes in shunt compensation. The step size would be limited primarily by the step change in voltage that customers can tolerate on a relatively frequent basis, probably on the order of 1 percent. A step size on the order of 50 Mvar in the 500 kV stations would probably be sufficiently close to the 'noise' to be acceptable. Thyristor switched capacitors, if used, would probably consist of, for instance, 50, 100, and 200 Mvar banks to provide 0 to 350 Mvar in 50 Mvar steps.

Unless there is a significant cost advantage, including losses, of thyristor switched capacitors, the smooth control of thyristor controlled reactors is preferable. Thyristor controlled reactors are more effective at providing system damping, and avoid any question of customer tolerance for step changes in voltage.

Providing for stable operation to the left of the V-Q curve critical voltage is essential in the Northwest. With the system that is planned, the 'critical voltage' point on the V-Q curve will be very close to the nominal operating voltage during contingencies. Hence a fairly minor second contingency, a higher than expected load level, an unexplored dispatch, an operator error, or any number of other events could place the system on the left side of the V-Q curve.

SVS Size

The size and type of SVS capacity required in the Northwest is largely a judgement call. That is, there are no specific voltage stability studies that can be run to pin down explicitly or precisely the necessary SVS capacity. For a problem such as first-swing stability, one can establish criteria such as fault type and location and transfer level, and then increase series compensation or SVS size in, say, 5% steps, until the system is first-swing stable. For the voltage stability problem no analogous set of cases can be defined (though some very useful guidance may be available from extended-term simulations as discussed later in this letter).

It is my opinion that the two SVSs that are planned for the Northwest (+/- 300 Mvar), combined with adequate controls for the mechanically switched capacitors, will provide adequate voltage control for the contingencies that have been identified as a threat to voltage stability, and for these contingencies combined with modest second contingencies or less than ideal system conditions. The adequacy of the planned SVSs cannot be proven by power flow cases, but I believe the SVSs are adequate and prudent because:

- The dynamic range from the normal operating point to ceiling, 300 Mvar for each unit, will quickly provide about one third of the reactive power required to stabilize voltage following one of the limiting disturbances.[1] This leaves it necessary for relays, controls, or operators to apply several 300 Mvar switched banks, or the equivalent, within about one minute to prevent continuing voltage decay. The planned SVS capacity, though it does not relieve the operators or undervoltage relays of the need to promptly switch on additional capacitor banks, does reduce the urgency somewhat, and will cover an error such as applying more banks than are needed. Also, operators will find the SVS reactive loading a more sensitive measure of system reactive need than system voltages. That is, they will find it easier to switch banks to keep the SVS in its regulating range than to switch banks to bring voltage into line.

- The 300 Mvar SVS capacitive range matches the largest mechanically switched banks, so that the combination of one SVS and mechanically switched banks at 300 Mvar and below provides, effectively, dynamic

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[1] The total 600 Mvar of SVS capacitive range would provide more than one third of the total requirements, however, because one SVS is at Keeler, near Portland, and the other is at Maple Valley, near Seattle, most disturbances will only drive one SVS or the other to ceiling. For instance, the Keeler SVS will contribute only 100 to 150 Mvar when line outages occur in the Seattle area.

control over a much larger range (potentially 1200 to 1800 Mvar). The inductive range will also be used because operators will want to switch on mechanical banks before the SVS hits ceiling, and switching on 300 Mvar banks will thus push the SVS underexcited by 50 to 100 Mvar in practice.

In this respect, the size of the SVS is somewhat arbitrary. In the time frame of the slow dynamics of voltage instability, mechanically switched capacitors can be used as part of the dynamic var control without undue duty on the mechanical switches. The switched banks can be switched on to keep the SVS in its regulating range as the system responds to a line outage in the minutes following the line outage. If the largest mechanically switched banks were 200 Mvar, a 200 Mvar SVS (+200/-200) could be used, but mechanical switching would be more frequent. Economics, burden on operators, control complexity, system step voltages upon bank connection and disconnection, site availability, and communications requirements thus play a role in selecting the size of SVS and switched banks. 300 Mvar appears to be a reasonable trade-off among these requirements.

- The underexcited capability of the SVS is an even more difficult judgement call. As discussed elsewhere in this letter, the SVS will be critical to the limiting of equipment damage during system break-up. The two SVS can cover up to two capacitor banks, and this seems reasonable to me. As an aside, overvoltage withstand of the SVS is an important part of the SVS specification to ensure that it will remain on-line through system break-up overvoltages, or can bring potentially damaging overvoltages under control even when break-up does not occur.

- Though some equipment protection would be lost if the SVS were operated underexcited during peak load conditions to provide a larger capacitive response range, this option is available. For instance, if winter peak loads exceed expectations and it is found that the 0 to 300 Mvar range is not adequate, the SVS can be operated underexcited to provide a larger range.

- Another requirement that dictates SVS size is the shape of the V-Q curve in the vicinity of normal voltage under heavy system loading, and the normal area load variations. If normal system load variations would require excessively frequent switching of modest size banks (under 100 Mvar) to keep the SVS close to zero Mvar, then some SVS capacity must be allotted to cover normal minute to minute load variations. I expect that BPA will find it necessary to allow the SVS to 'wander' between about -50 to +50 Mvar, or maybe even -100 to +100 Mvar to limit the operations of mechanically switched banks. This means that only 200 to 250 Mvar of the SVS capacity can be relied upon to be available when a contingency occurs. This argument also suggests that the SVS controls need to have access to banks on the order of 100 to 200 Mvar in order to keep the SVS within the desired operating range (+/-50 Mvar and +/-100 Mvar respectively).

- Finally, the system Mvar per MW characteristic during the worst-case line outage contingencies should have some impact on the size of the SVS. For instance, if the load tends to vary 50 MW within periods of 5 to 10 minutes, and changes reactive demand by 3 Mvar per MW, then the two +/-300 Mvar SVS should be capable of regulating voltage under such conditions without hitting ceiling or going underexcited. The switched capacitors would be selected to keep the SVS between 100 and 200 Mvar so that it can handle load variations with little attention from operators (operators will have plenty of other tasks to occupy their time during contingencies). If a control system will allow the SVS to switch mechanically switched banks on and off, and some of those banks are in the vicinity of 100 Mvar, then the 0 to 300 Mvar SVS size should be adequate to limit the frequency of mechanical switching to an acceptable level during severe contingencies.

In addition to the above, I believe that the limited experience with operation of voltage stability limited systems, and the significant change in the character of the system in the Northwest over the next 10 years calls for highly conservative planning in the early years (early to mid 90's). Though I expect the system could be reliable with SVS smaller than those planned, the risks of inadequate voltage control are too high to base plans on 'expectations.' A conservative approach is needed. The two planned SVS provide this conservative approach in my opinion. If experience shows that the two SVS provide more dynamic range than is essential, then later in the 90's additional SVS capacity will not be needed or can be deferred. On the other hand, experience or more in-depth studies in the early 90's may show that more SVS capacity is needed. Experience is unlikely to be very helpful because the kinds of contingencies that are being guarded against and which would provide a meaningful test may not occur. Further studies, including simulations, should be undertaken, and should provide reliable guidance for the late 90's.

SVS Operation and Overvoltages

The two 300 Mvar SVS can be operated 'underexcited' when load is heavy so that they will each be able to provide 400 or 500 Mvar quickly when a disturbance occurs. This will increase the security relative to voltage instability. However, in heavily compensated (shunt) systems, there is another risk. This risk is possible system breakup, for any reason, that would leave long lines lightly loaded and with large amounts of mechanically switched capacitors at or near their terminals. This kind of breakup can cause severe overvoltages, and equipment damage that would delay full restoration, perhaps for days. The levels of shunt compensation planned for the Northwest system make consideration of such events, no matter how unlikely, very important.

One possible scenario is voltage instability that triggers steady state angular instability. Angular instability is likely to cause line tripping in both the 500 kV and 230 kV systems. This kind of separation will leave many, if not all, of the 500 kV lines connected to the system and with capacitors at their receiving ends, possibly including some capacitors on nearby 230 kV buses. It simply is not possible to get mechanically switched shunt capacitors off the system quickly enough to prevent large Ferranti-effect overvoltages and even self-excitation of remote hydro plants. And, once the overvoltages occur, circuit breakers are likely to fail if opened. The overvoltages will cause arrester failures or flashovers which depress voltages, but then when circuit breakers open to clear the faults, voltages will rise again, repeatedly, causing additional equipment to fail. Cable potheads and transformer bushings are particularly susceptible to overvoltage failure, and can delay restoration even more than failed arresters and insulators.

It is essential that BPA, in planning and operating the Northeast system, take the possibility of the overvoltages described above into account. After looking at the potential for system breakup overvoltages, BPA will likely deem it unacceptable to operate the SVSs 'underexcited' when the system is heavily stressed. Not operating underexcited also implies fewer capacitor banks on-line as well as more SVS reactive range to control overvoltages. Fewer capacitor banks on-line also implies more reliance on operators or automatic controls to bring them on when necessary. It is possible to have the SVS controls extend to some of the capacitor banks, and this should be considered. The planned alarm system should be retained so operators can bring the banks on in the best sequence if automatic controls fail or they are able to perform the switching more quickly or in a pattern that is best for the present system condition (unless the SVS control over mechanical banks is quite sophisticated, it will not necessarily switch on banks where the voltage is lowest).

Load Characteristics - Summary of BPA Report

Load characteristics are extremely important in designing a system to avoid voltage instability. Load characteristics are needed to determine how much time operators have to deal within a disturbance, how much automation is needed, and whether or not load characteristics will help protect a system from collapse.

BPA load investigations have shown that LTCs in distribution substations have enough tap range to keep most customers at normal voltage with the bulk system as low as about 92%. They have also shown that it will take only about two minutes for LTCs to restore distribution voltage and drive bulk system voltages down to this level.

The investigations have also shown that much of the area load, especially the resistance heating load, will return to its pre-disturbance power levels within about 20 minutes after it experiences a drop in voltage. Hence in a disturbance in which LTCs reach limits and allow utility customer voltages to drop, there will be only a temporary drop in load. Some utility customers, such as many of those in the Seattle area are not on LTCs, and will not be even partially restored by LTCs in the first minutes after a disturbance, but will self-restore over 20 minutes. Self-restoration occurs through manual adjustment and thermostat action. Some loads will be restored in 5 minutes or less (e.g., aluminum reduction loads).

The conclusion from the above is that operators will have only a minute or two before substantial load restoration occurs, and drags voltage down substantially, possibly down close to 90% where area reactive demand will be very high. Also, if LTCs reach limits and leave some customer voltages below nominal, the remaining restoration will occur over the next 10 to 20 minutes dragging voltage down further.

In summary, without remedial action, bulk system voltages will drop several percent when the disturbance occurs, then drop to about 92% over several minutes as LTCs respond, then drop more slowly over the next 10 to 15 minutes as thermostats restore resistance heating load. The voltages are likely to reach levels that will cause angular instability or motor stalling and complete collapse within 10 to 15 minutes depending on the extent of the reactive shortage.

These changes can be visualized in terms of the V-Q curve. Figure 7 shows the V-Q curve at several points in time after a disturbance that leaves the system with insufficient reactive power to provide a stable operating point. In the first

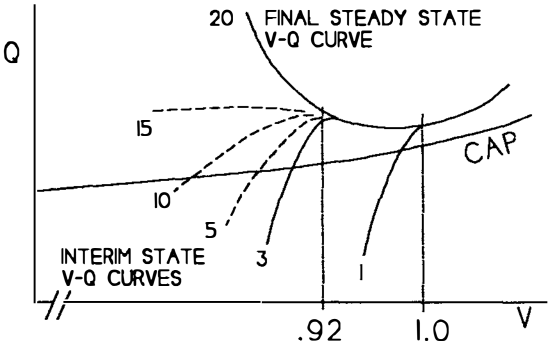

Figure 7

minute or so the LTCs will remain at their initial settings, and the thermostats will restore only about 5% of the drop in resistance heating load power (curve 1). After two or three minutes, the LTCs will have run to limits, and pushed bulk system voltages down (curve 3). Then thermostats will continue to restore the resistance heating load to its initial power level over the next 17 minutes or so (curves 5, 10, 15 and 20). The system will reach curve 20 only if there is no load that remains voltage sensitive at the end of 20 minutes. Because, today, at least, most lighting load varies with voltage, the final V-Q characteristic of the Northwest system is probably somewhere between curves 10 and 15. Whether or not this load varies enough with voltage to provide an 'S' shaped V-Q curve with a stable operating point at a reasonable voltage (above 85%, preferably close to 90%) with the planned reactive compensation has not been determined. However, field tests conducted by BPA are not encouraging, and BPA plans to proceed on the basis that the system will collapse if a stable operating point above 90% isn't provided by compensation. Without convincing proof that load characteristics will provide a stable operating point, or some permanent load relief, this is a wise choice. Further, if a stable operating point were known to exist for a given load level and compensation level, depending on this operating point, even as backup to other solutions, may not be wise. This stable operating point, at best, would be very fragile so that even a modest additional contingency, or a slightly higher than expected load level could put the stable operating voltage so low that collapse through angular instability or motor stalling would occur. Any such operating point might become even more fragile or even cease to exist in the future as load characteristics move ever closer to constant power.

Load Characteristics - Observations

The first important conclusion from this knowledge is that operators have very little time to react to a disturbance that leaves the system short of reactive power. The second important conclusion is that the winter loads in the Northwest may not provide the system with a stable operating point down around 90% voltage as is typical today in some other portions of the country. The PJM system, for instance, has long had enough steady-state load relief as customer voltages drop (after LTCs have reached limits) to stabilize voltages at about 90%. In August 1988, the midwest experienced voltage instability on 6 days when loads reached new peaks, and in each case 345 and 138 kV voltages stabilized between 88 and 92%. From the load information collected by BPA, it appears that this may not be the case in the Northwest.

The modeling done to date by BPA engineers takes into account that the Seattle City light system has few LTCs between the subtransmission system and customers. However, I understand the City is studying several options to improve voltage regulation, one of which is to add regulators to the system or replace transformers with LTC units. This would strengthen further the arguments used to justify use of constant kVA loads in BPA studies.

Another aspect of load characteristics justifies the use of the constant kVA characteristics. Load characteristics are changing and more and more load devices are exhibiting a constant kVA characteristic. Computers are an increasing share of the load and are a constant power load. New electronic ballasts and high efficiency fluorescent lamps are being used in new construction and being retrofit to existing buildings, and impose nearly a constant kVA load on the system. New solid state switching of resistance heat is reducing thermostat cycle times from the traditional 20 minutes to 6 seconds, thus leaving only the room thermal time constant (on the order of a minute or two) to control the time required for resistance heat load to return to constant power after a change in voltage. This trend to constant power loads, or rapid self-restoring loads appears likely to continue at a steady pace, thus making a conservative approach to voltage control essential.

Several utilities have observed this change in load characteristics. Consolidated Edison and utilities in the Northeast have long used voltage reduction to curtail demand when generation shortages occur, or transmission bottlenecks arise. In recent years they have had increasing difficulty confirming that there is a drop in demand when voltage is reduced 5% or 8%.

There are differences between the load on the systems in the Pacific Northwest and the load on other systems. The load in the Northwest, during winter peak conditions when the system is at highest risk of voltage problems, contains a large amount of resistance heating load. This contrasts with systems in other regions, such as the Northeast where the motor content of the load is large due to heavy industry, heat pumps, conventional air conditioners, and other factors. However, though the loads are very different, the nature of the loads in terms of their sensitivity to voltage is not so different. Motors and resistance heat both exhibit nearly a constant power characteristic in the steady state. The chief difference is that resistance heat returns to its initial power in about 20 minutes, while motors return to their initial power in several seconds. This difference gives operators in the Northwest some time to deal with the voltage problem that may be useful, for instance, to manually reduce load through tripping of distribution circuits.

The share of the load that is voltage-sensitive is important if consideration is being given to using load characteristics to provide a stable operating point when there is a reactive shortage. Loads in Pennsylvania, New Jersey, and the Midwest have demonstrated that there is enough voltage-sensitive load in these systems to provide a stable operating point below the voltage at which LTCs reach their limits (about 90% of nominal). However, how secure this operating point is and the relationship between amount of compensation and voltage (the slope of the V-Q curve at the stable operating point (curve 3 or 5 in Figure 7) have not been determined. As noted in the previous section, BPA studies and field tests raise doubts as to whether there is enough voltage-sensitive load to provide a sufficiently stable operating point to be useful. Though other systems have demonstrated that a stable operating point exists, and have unwittingly used it to prevent collapse on many occasions, to my knowledge, only Ontario Hydro has planned portions of its system to take advantage of it. Ontario Hydro uses LTC blocking in substations feeding voltage-sensitive loads to provide a stable operating point at a voltage of about 95% of nominal. I understand Ontario Hydro also provides undervoltage load shedding as backup to LTC blocking.

BPA plans to proceed on the assumption that load characteristics do not offer a solution to the voltage stability problem are prudent. However, further knowledge of load characteristics would be helpful. If there are some distribution substation in the system that serve largely voltage-sensitive load, LTC blocking (see next section) in those substations could offer significant benefits including, possibly, the deferral of some of the planned shunt capacitor banks.

LTC Blocking

At this time BPA does not plan to use LTC blocking to provide temporary load relief when voltages fall. LTC blocking, or advanced LTCs that reduce distribution voltage when the upstream voltage drops below some threshold, have the following potential advantages:

- Avoid the rapid drop in voltage that occurs in the first several minutes after a disturbance (after which voltages decay more slowly), instead providing a gradual voltage decay over 20 minutes, and

- Allows whatever voltage-sensitive non-restoring load there is to be taken greater advantage of (that load sees essentially the transmission voltage instead of a voltage 8 to 10% higher).

The largest benefit is the additional time operators would have to deal with the disturbance. However, the low voltage on utility customer devices would provide some permanent load relief, and could, in a marginal situation, provide stability where it would not otherwise occur. The permanent load relief could, alternatively, save some investment in shunt capacitor banks.

Modifying or retrofitting many existing distribution substation LTCs to provide blocking would be a major task. However, it would seem prudent to estimate the cost and benefit of this option. If it can be done for several thousand dollars per transformer, it might be worth doing. The cost may be not much over one million dollars (400 distribution substation transformers at $3000 each).

LTC blocking should only be used in distribution substations serving load that is known to have sufficient voltage-sensitive component to provide a benefit. If the industrial content is high, the high concentration of shunt compensation and induction motor load may yield a load characteristic in which the drop in power factor more than offsets any drop in active load when voltage is allowed to drop. Tests at each substation are necessary to determine the best course of action for each substation.

There are several approaches to blocking LTCs. The simplest may be to adjust the tap mechanism boost limit switch so that it operates at one or two tap steps below the highest boost tap that is normally used. If this can be done on most transformers, the total cost could be just several hundred dollars per transformer.

Voltage Control of Capacitor Banks

It would be highly desirable to automatically bring off-line capacitor banks on-line quickly and automatically when a disturbance poses a voltage stability threat. BPA engineers have studied the benefits of getting the off-line banks on quickly when a disturbance threatens voltage stability, but also has found that voltages only drop one or two percent in the first minute or two after a disturbance, and that a secure and reliable scheme to apply the banks during this period will be difficult to design. A scheme that would switch on capacitor banks following such small changes might switch them on inadvertently often enough to create a nuisance or overvoltage hazard. A disturbance that causes capacitor banks to be switched on but also causes system break-up could aggravate break-up overvoltages.

Capacitor banks near SVSs could be controlled by SVS controllers. In fact, capacitor banks some distance away might also be controlled by the SVS controllers. This approach would be less likely to cause nuisance switching of the banks, and should switch them off within minutes or seconds if they are switched on when not needed. If unnecessary bank switching occurs only a few times per year, it would be acceptable (that is, operators could deal with the events, and mechanical switch life and reliability would not be unduly reduced).

Operators will, of course, also have control of the banks. If operators have enough information, such as SVS reactive loadings, coastal area generator reactive loadings, cogenerator reactive loadings, and key area voltages, they should be able to make prompt decisions about capacitor switching when disturbances occur. Because voltage instability occurs over a period of minutes, operators will be able to take actions to halt voltage decay that they cannot take for problems such as steady state monotonic instability (which occurs over a few seconds).[2]

Also as recognized in BPA studies, inverse time undervoltage relays set somewhat above undervoltage load shedding relays can be used as backup to the operators and any extended SVS controls to ensure all capacitor banks are on-line before voltages reach the point where undervoltage load shedding begins. *As long as there are enough banks available to meet system steady state reactive requirements with some margin at the voltage setting of the capacitor bank undervoltage relays, the system voltage decay will be halted by these relays.*

Capacitor Bank Undervoltage Relay Settings

The undervoltage relay settings are somewhat arbitrary. The relays should be set in the vicinity of 95% voltage and have enough time delay to ride through faults, including reclosing on downstream distribution circuits. Banks in the same station should have different time delays to ensure they will not be switched on simultaneously. All banks can have similar voltage settings

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[2] Steady state monotonic instability is the current IEEE term for what previously was called steady state instability. It is the problem of angles between voltage control points reaching 90 degrees, at which time a drop in voltage or any further attempt to increase transfer results in a drop in transfer, acceleration of the sending end machines, deceleration of the receiving end machines, and the "slipping of poles" or operation of distance relays to split the system. The corresponding term for what used to be called dynamic instability is now steady state oscillatory instability.

because there will be enough voltage difference from one substation to the next to ensure that the bank in the substation with the lowest voltage will be switched on first. When that bank comes on the voltage will rise and additional banks will not be switched on until voltage again drifts down to the relay setting. The dynamics of voltage instability is slow enough, even while LTCs are moving, that banks will switch on one by one, even with time delays of just a few seconds. These considerations are discussed further in the following paragraphs.

The capacitor bank undervoltage relays should be set somewhat below the point at which the SVSs hit ceiling. Hence the system will be operating without automatic regulation as the voltages fall toward the bank relay settings, and *may* be on the left side of the V-Q curve. However, this is not a problem *so long as the total capacity of the banks exceeds the steady state reactive requirements of the system at the voltage at which the capacitor bank undervoltage relays are set.* Once enough banks have switched on to provide some reactive margin above the steady state V-Q curve, voltages will stop decaying and will drift up as shown earlier in Figure 6a.

Figure 8 shows how voltage will behave if the system is voltage-unstable and relays on capacitor banks begin switching them on at 95% voltage. The voltage will rise and fall as the banks are switched on. If the last bank does not provide enough capacity to take the system above the steady state V-Q curve, voltage will continue to fall until collapse occurs. Also shown in Figure 8 is the voltage trajectory that will occur if one of the banks moves the system above the steady state V-Q curve. When this occurs, voltages will drift up. It can be seen in Figure 8 that the level of compensation required to initiate upward movement of the voltage may be considerably larger than the reactive power needed to sustain nominal voltage. Also, an unacceptably high final voltage may occur unless one or more of the banks are switched off manually, or an SVS takes control as the voltage closes in on the nominal voltage. Figure 9 shows how an SVS will take control of the voltage when voltage rises to the point that the SVS will come off ceiling.

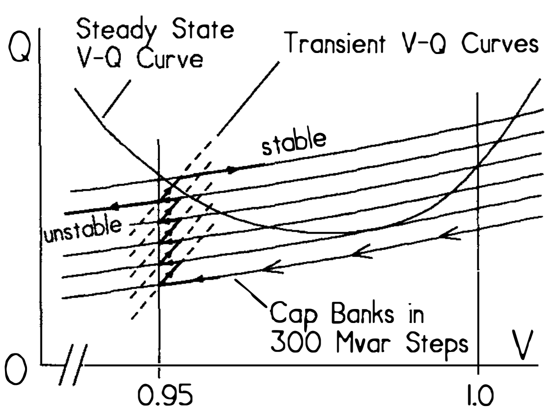

Figure 8

The following points may help clarify the system dynamics that can occur if a disturbance lands the system in the vicinity of the left side of the steady state V-Q curve.

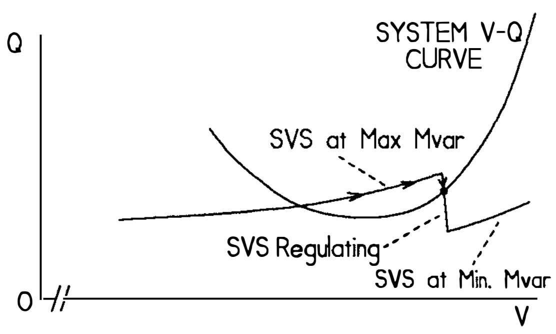

Figure 9

- Thermostats and similar loads and LTCs will cause the downward drift in voltage after each capacitor bank switching because of the dynamics shown in Figure 7.

- If the voltages change as little as shown in Figure 8 when each bank is switched on, LTCs may not move significantly during this period because of the deadband that is included in their control to prevent unnecessary operation. If this is the case, thermostats will dominate the system response, and the process shown in Figure 8 will occur over 10 or 15 minutes.

- Once the system is above the steady state V-Q characteristic, voltage will drift upward with no further operator action or bank switching. Because thermostats are slow to respond, the voltage may move very slowly at first.

- Once thermostats have responded sufficiently to allow the voltage to rise about 2%, through the LTC deadband, or into the LTC range if the voltage is in the vicinity of 92%, LTCs will respond and allow voltage to rise further. LTCs are likely to start and stop, as the voltage moves into and out of their deadband. This may slow the voltage rise because of the one minute initial delay on each LTC.

- Figure 8 assumes the capacitor banks will be switched on at 95% voltage. It also assumes a V-Q curve shape and position. Neither are necessarily correct for the Northwest, but do indicate the behavior that can be expected.

Because it is always desirable to keep voltages in the vicinity of nominal, an extension of the SVS controls to apply available banks when the SVS hits, or approaches ceiling, will be very attractive. Such a system could continue applying mechanically switched banks at intervals until the voltage is within the SVS dynamic range, even when a disturbance has put the SVS on ceiling.

This would have to be done at a pace that is fast compared to LTC response. For instance, if LTCs begin moving about one minute after a drop in voltage, the controller should be applying banks at intervals of 5 to 15 seconds so that several banks can be switched on during the one to two minute period of LTC activity that follows the trip of a line.

The extension of SVS controls to control nearby capacitor banks can be made more secure by supervising signals to switch on banks with undervoltage relays at the bank locations. This would be a relay set 2 or 3% above the voltage at which the SVS controls are expected to start bringing on banks. For instance, if the SVS has a 3% droop and will start bringing banks on at about 98% of its voltage reference setting, the undervoltage relays at the banks would be set at about 100% of nominal voltage. Because the primary purpose of these relays is to avoid banks being inadvertently applied when voltages are above normal, a setting at the nominal voltage is appropriate.

The bank inverse time undervoltage relays would not need to operate quickly. Because the LTCs move over a period of minutes (typically they will correct voltage and reset several times as voltages drop, thus extending the time it will take to reach limits), the delay on the undervoltage relays can be 15 to 30 seconds or more which will allow them to ride through most normal voltage excursions. Also, voltage differences between substations will prevent more than one bank from coming on at a time. Instantaneous reset should not be used because it could delay the switching of the banks (when one is switched on the others would reset and then could not come on for another 30 seconds). An integral reset, or slow reset, would allow the banks to come on as quickly as necessary.

I suggest that undervoltage relays, extensions to the SVS controls, *and* operators all have the ability to apply the large capacitor banks when voltages are low. The 1978 New York City blackout occurred in part because of a communications problem (people and equipment) that caused operators to think they had reclosed a line when they hadn't. The system might have been saved if the operators had known about the open line. Having undervoltage relays on the capacitor banks would help guard against problems in the control center and failure, or too slow operation of the SVS control.

Undervoltage Load Shedding

BPA plans undervoltage load shedding for the Pacific Northwest. Undervoltage load shedding is absolutely essential, and should virtually eliminate the risk of voltage collapse and blackout from voltage instability. It will also virtually eliminate the risk of angular instability *if* the system is stable at the settings of the undervoltage load shedding relays.

Few utilities have experience with large scale undervoltage load shedding, so BPA will be largely breaking new ground in this area. The extended term simulations discussed later in this report will be very important to understanding the intricacies of undervoltage load shedding, and the selection and setting of undervoltage load shedding relays.

Load should be shed in modest steps in order to minimize the load that must be shed. If load shedding is done at the distribution substation level (like underfrequency load shedding), load will inherently be shed in modest steps, regardless of relay voltage or time settings. The slow dynamic nature of the voltage changes will ensure this. Because voltages will be moving relatively slowly compared with relay timer settings, each relay will have ample time to operate before others once voltage reaches its setpoint. Because voltages vary slightly from one bus to another, even similar voltage settings will not cause several relays to operate in close time proximity. As each relay operates, the load it drops will raise voltage and delay the operation of nearby relays, even if they are set the same.

With load shed in modest steps, the load shedding will, effectively, regulate the system voltage at the relay settings. As resistance heating load 'self-restores' over a period of 20 minutes or so, load will increase gradually, voltages will fall slowly, and load will be shed periodically. Each segment of load that is dropped will cause voltage to rise slightly. As resistance load increases further and pulls voltage back down, another segment of load will drop. Voltage will remain at the undervoltage relay settings and load will continue to grow and be shed until the steady state V-Q curve intersects the capacitor characteristic, or the 0 Mvar axis, at a point below the undervoltage relay settings. Once the steady state V-Q curve is below the capacitor characteristic at the undervoltage relay settings, voltage will begin rising and no further load shedding will occur. The voltage will slowly rise to a stable operating point on the right side of the V-Q curve.

This process is demonstrated in Figure 10. Figure 10 is simplified in that the dynamics of self-restoration of resistance heating load is not shown, and load shedding is assumed to occur in three steps. Visualize the voltage below 92% so LTCs are on limits, and sliding down the capacitor curve as the resistance load is in the process of self-restoration (as shown in Figure 7). When a step of load shedding occurs, the operating point will jump to the intersection of the capacitor and transient V-Q curve of the remaining load. As remaining load continues to increase, this process repeats. When the steady state V-Q curve drops below the capacitor characteristic, voltages will begin rising and no further load shedding will occur. The whole process of load shedding to a point where voltages will rise will take about 20 minutes — the time it takes self-restoring load to completely return to its initial power level.

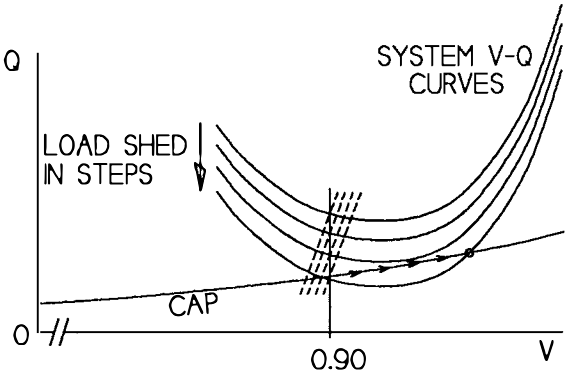

Figure 10

Figure 10 assumes that the undervoltage relay settings are to the left of the critical voltage of the V-Q curve. This may not be the case. Figure 11 shows a situation similar to that shown in Figure 10, except the system is to the right of the critical voltage at the undervoltage relay voltage settings. The process is similar.

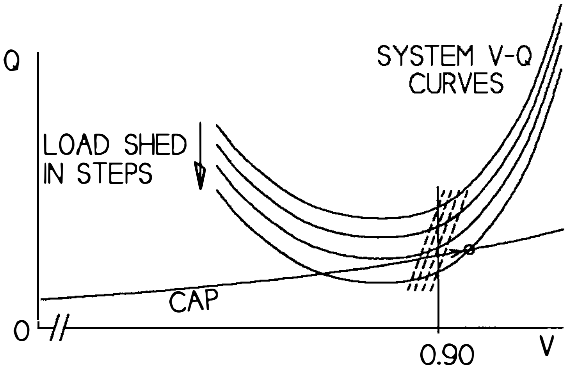

Figure 11

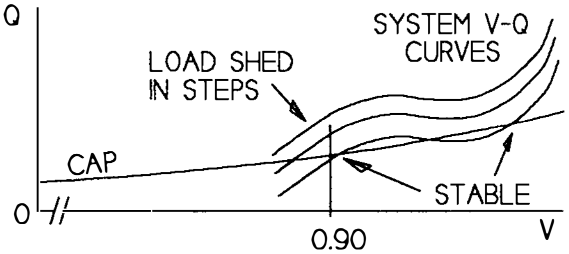

Figure 12

In the above discussions, it has been assumed that there is little or no load that is not self-restoring. That is, the V-Q curve is roughly a parabola. If there is more non self-restoring load than we anticipate, the system may stabilize at a voltage slightly above the load shedding relay setpoints rather than drifting up to a higher value. This is shown in Figure 12. The V-Q curve in Figure 12 has the 'S' shape (perhaps somewhat exaggerated) that has provided a stable operating point in some systems. There is enough shape to the S curves in Figure 12 to provide two stable operating points for a small range of system load, though the actual S curve may be too flat for this to be the case. In any event, operators could drop additional load until the system moves up to a higher voltage.

The order in which various feeders in a given substation are to be tripped to provide undervoltage load shedding can be controlled by selecting three voltage levels such as 92, 91 and 90% and the same time settings. It can also be done by selecting time delay settings such as the 3.5, 5, and 8 second settings presently being considered by BPA, and the same voltage settings. A combination of staggered time and voltage settings could also be used.

Neither time delay or voltage settings will provide good selectivity among loads in different substations. There are two reasons for this:

- There will be normal differences in voltage from one substation to the next across the system, and these voltages will not be known well enough to take them into account in selecting the relay voltage settings. The voltage relays would have to have settings differing by 2% or more to provide even modest selectivity from one substation to the next. Also, attempting significant coordination of load shedding across large areas is not desirable if load dropped in the area where voltages are the lowest will be most effective (see further discussion of this below).

- Because reasonable timer settings will be very short compared to the 'slow dynamics' of unstable voltages (see Figure 7), they will have little impact on the order in which relays in different substations will operate. Once LTCs are on limits, voltages will decay so slowly that timer settings of several minutes would be needed to overcome voltage differences from one substation to the next.

Voltage or timer settings will provide selectivity within a substation. Voltage settings will provide some selectivity from one substation to the next in an area. Attempts to provide selectivity from one area to another are unlikely to be successful and may be undesirable.

Allowing undervoltage load shedding to occur where voltage is lowest is not a safe approach in some systems, but appears reasonable in the Northwest. The concern is that load shedding may increase loading on the weakened portion of the system. For instance, if load shedding along the coast could occur because of transmission outages to the south, and could also increase flows on those lines because power from the north (Canada) is not reduced, then the undervoltage load shedding could accelerate the decline in voltage. If load shedding along the coast will result in reduced loading on the weakened 500 kV lines across the Cascades, then it will improve voltages. That AGC systems will reduce loading on the stressed portion of the system following load shedding should be confirmed.

Timer setting need to ride through faults, including the last re-close that may be prolonged to force lateral fuses to blow. As noted, undervoltage load shedding timer settings are somewhat arbitrary, but delays in the 5 to 15 second range seem reasonable. Extended term simulations may provide additional insights.

Reactive Power Margin

The 500 Mvar reactive power margin planned for the system appears reasonable. For instance, there will still be a 200 Mvar margin if one of the 300 Mvar banks, or an SVS, initially floating, does not respond to a disturbance or fails during a disturbance.

However, I suggest that this margin be checked in terms of the additional load it will support, and the risk that loads may exceed that level. The errors in annual load forecasts that have occurred over the last 10 years or so should be reviewed. A credible margin for error in the MW prediction should be established, then the reactive plan should be set to cover this load, plus provide a modest reactive margin. For instance, the reactive power could cover the largest anticipated error in load forecast, plus provide 200 Mvar of margin to ensure continuous automatic control if that load level does occur. As a point of reference, if the reactive losses are about 3 Mvar per MW of load in the mid nineties, a peak load 167 MW above the expected peak would exhaust the presently planned reactive margin (500 Mvar). An additional 200 Mvar, or a total of 700 Mvar would be indicated in this case. However, some other action such as manual load shedding by operators or undervoltage load shedding could be considered as a means to deal with such load forecast errors.

Extended Term Simulations

Though I feel confident that my knowledge of voltage stability is adequate to confirm that BPA analysis of load and LTC characteristics and power flow studies have resulted in good decisions regarding system adequacy to avoid voltage instability, I also urge that present BPA work on extended term simulation models continue and ultimately be used to confirm and refine present plans.

Extended term simulations will be very useful for a variety of reasons:

- Simulations will provide a full understanding and confirmation of the impact of load and LTC dynamics on reactive requirements.

- The selection, location, and setting of inverse time undervoltage load shedding relays will be much more reliable if tested in simulations.

- The selection and setting of primary and backup systems, including operator actions, to switch capacitor banks on following disturbances will be greatly eased by simulations.

- Simulations would confirm to the satisfaction of all that operation on the left side of the V-Q curve is feasible and can be achieved by the planned compensation,

- Extended term simulations will very effectively show the adequacy of the shunt capacitor banks and the SVSs. For instance, successive cases might be run with capacitor bank and SVS sizes changed to see the impact on voltages and show the reactive margins available through time after a disturbance.

- Cases showing the effect of normal load variations on reactive loading of the SVS during contingencies could help confirm SVS adequacy and indicate the best operating point for SVSs during the contingency.

- Cases with different initial SVS settings (voltage and Mvar) may help define the best defensive settings for the SVSs under winter peak and other conditions.

The extended term simulations will require large amounts of engineering time and will take many months to complete. However, they provide the only means to set SVS controls, to set undervoltage relays on capacitor banks, and to set undervoltage load shedding relays with confidence. The confidence in final settings will be much higher than it could be with the conventional approach using power flows and stability type simulations.

Closing

The material presented in this report covers a wide range of voltage stability concepts and comments and recommendations. The presentation of this material is not intended in any way to imply any short-comings in the work done by BPA engineers. The voltage stability problem is a new one for the industry, and few engineers have experience with it. BPA engineers have done well in defining the problem and identifying solutions, and I hope this material will help them continue on a sound basis, understand all aspects of the problem and choose the best solutions.

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Attachment 7

ATTACHMENT 7

GE Industrial
& Power Systems

Final Report

Voltage Stability of the Puget Sound System Under Abnormally Cold Weather Conditions

Puget Sound Power & Light Company
Bellevue, Washington

Puget Power Contract ZZ-02287-W-LS

Principal Contributors:
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October 31, 1991

EXECUTIVE SUMMARY

The potential for voltage collapse in the Puget Sound area during conditions of abnormally cold weather has been revealed through recent engineering studies by PSP&L, BPA and others in WSCC. Concerns about this condition led to the "Puget Sound Reinforcement Project". The project is to evaluate measures for coping with these extreme conditions.

The interested parties were particularly concerned about the level of understanding of the voltage collapse phenomena and the suitability of tools for analyzing such behavior. On behalf of the project participants, PSP&L contracted this study to GE because of recent GE activity in the development of new power system software for the analysis of voltage stability and related phenomena.

The objective of this study was to address the following questions:

1. Is there a problem?
2. How will the system behave, if there is a problem?
3. Which measures will be most effective in correcting the problem, if there is one?

In order to answer these questions, a relatively detailed model of the Puget Sound area system was developed from a large data set provided by PSP&L. The behavior of the system in response to severe loading and critical disturbances, under a range of conditions and proposed remedial measures was examined. The answers to these questions, based on the results of this study are as follows:

Yes, there is a problem.

The system behavior is typical of highly stressed, winter peaking networks. The total import of power to the Puget Sound area in the base case is very close to the steady-state maximum. Loss of critical system components, most notably both of the Coulee-Raver 500 kV lines, stresses the system beyond its ability to serve the load. Once such an outage occurs, the voltage regulating action of the LTC's at the distribution voltage levels throughout the system drives the system into voltage collapse, over a period of about five minutes.

Subsequent to the action of the load LTC's, thermostatic effects on the loads will tend to drive the system into progressively more distressed conditions. Unless corrective actions are taken, such as start-up of local generation, the system will eventually (20 minutes for our modeling assumptions) breakup. The normal action of the system dispatchers to adjust the taps on the EHV transformers substantially aggravates this voltage collapse.

The total Puget Sound area import capability, for the base system as modeled, is reduced to around 7800 MW, more that 500 MW less than the base case import, following trip of the Coulee-Raver double circuit.

The candidate measures for correcting the problem fall into two categories:

1. Stiffen the system, so that the voltage is supported and the load is served under the condition of increased stress.
2. Relieve the stress on the system by reducing the amount of load to be served.

Remedial measures of the first type include shunt and series compensation options, while remedial measures of the second type include undervoltage load shedding (UVLS) and locking of LTC taps.

A summary ranking of the effectiveness of the proposed measures is presented below in Tables 1 and 2. Details of the various schemes are included in Sections 2 and 3. The ranking presented in Table 1 is based on the steady-state "System Normal" capacity of the system. No lines or plants are tripped, and normal manual regulation of the EHV transformer taps is assumed. The results summarized in Table 2 are based on the system response following loss of the Coulee-Raver double circuit line. The ranking here is based on the voltage of the Maple Valley 500 kV bus 20 minutes after the disturbance. These results include the assumption that system dispatchers will *not* move the EHV taps, and that thermostatic effects will slowly change the system loads. Comparison of the two classes of remedial action must be done with care, since the latter category necessarily involves some adverse impacts on the utility customers (i.e., tripped loads or depressed voltages).

Table 1

Effect of Candidate Remedial Measure
on Maximum Power Transfer into the Puget Sound Area
(in increasing order of effectiveness)

Condition	Maximum Power Import (MW)
Base w/Taps Locked	8600
Base	8700
Base w/UVLS (1)	8700
Kittitas Reinforcement	8950
Base w/Shunt Caps only	9100
Base w/Shunt Compensation	9250
Kittitas w/Shunt Compensation	9650

(1) UVLS does not affect the maximum transfer

Table 2

Effect of Candidate Remedial Measures
on 500 kV System Voltage for Double Circuit
Outage of the Coulee-Raver Lines
(in increasing order of effectiveness)

	Maple Valley 500 kV Voltage			Power flow (@ 20 mins)	
Condition	Initial	5 min	20 min	Cross Mtn	Total Import
Base	1.07	.94	.84	6620	6850
Base w/Shunt Caps only	1.07	.99	.94	7500	7750
Kittitas	1.08	1.0	.95	7620	7820
Base w/UVLS	1.07	.97	.97	7380	7650
Base w/Shunt Comp	1.07	1.02	.98	7800	8120
Base w/UVLS Modified	1.07	1.00	1.01	7500	7750
Kittitas w/Shunt Comp	1.08	1.04	1.06	8220	8400

The first 25 minutes of system time response for the trip of the 500 kV lines east from Raver over the mountains is shown in Figure E-1. The solid curves are for the base system and the dotted curves are for the system with all of the planned shunt and series compensation installed. These curves dramatically illustrate the collapse of the base system and the satisfactory recovery of the future system.

This study supports the overall plans for reinforcement of the Puget Sound area bulk power system, including addition of mechanically switched capacitors, SVC's, series capacitors and new switching stations. The location and size of these devices appears to be well chosen. Substantial potential benefits from undervoltage load shedding and centralized or more sophisticated LTC control were identified. With further design effort, these could be exploited in a fashion which is complementary to the reinforcement plans.

The net result of implementation of the planned system reinforcements and undervoltage load shedding will be a system which is substantially better prepared to handle conditions of abnormal cold in the Puget Sound area than is the base system.

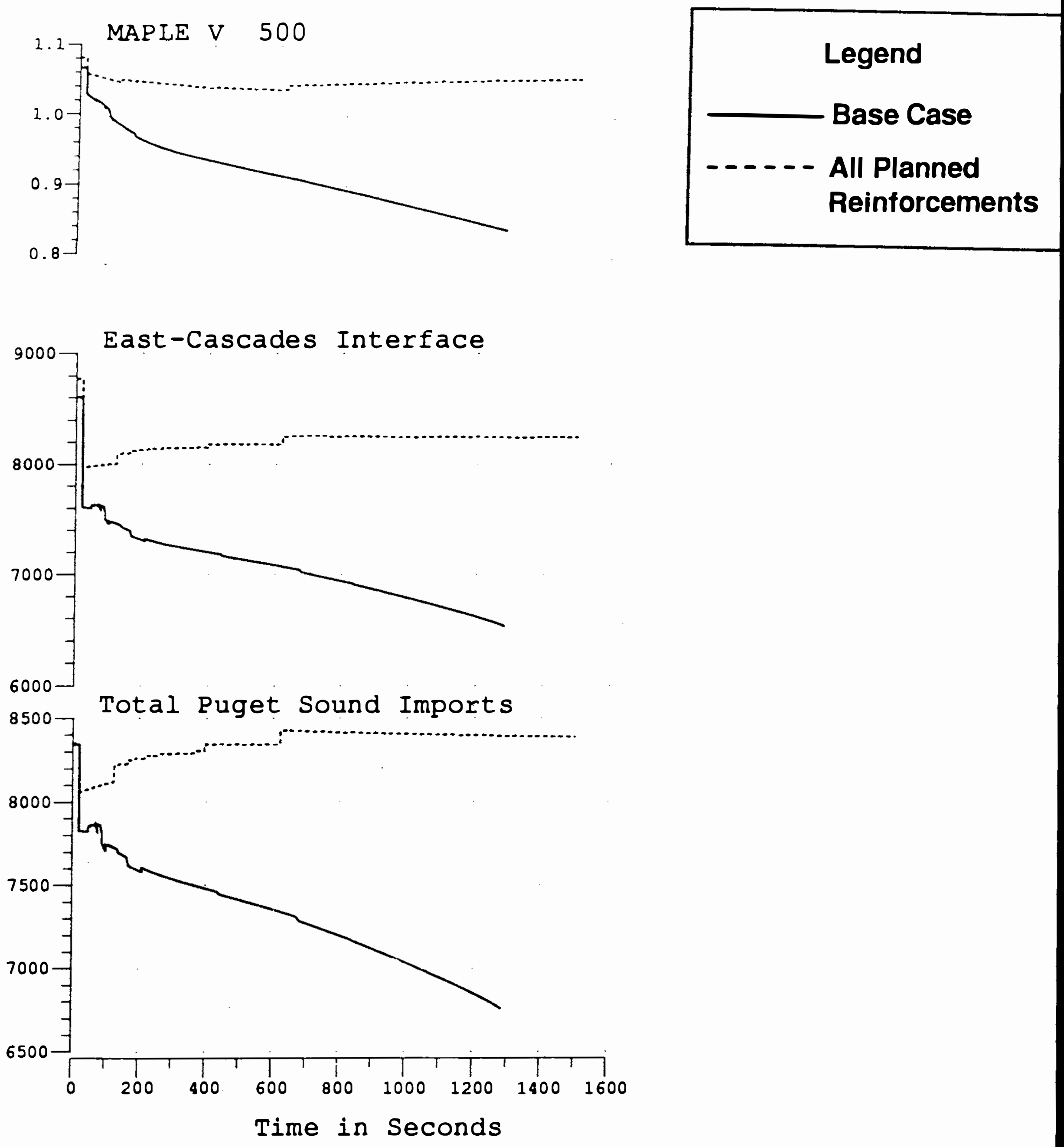

Figure E-1. Response of System to Trip of Raver → East 500 kV Double Circuit.

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Puget Sound Area Electric Reliability Plan

Transmission Reinforcement Analysis - Appendix E