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May 27, 1986
ANPP-36692-EEVB/LAS/DRL-92.11

U. S. Nuclear Regulatory Commission
Region V
1450 Maria Lane - Suite 210
Walnut Creek, California 94596-5368

Attention: Mr. D. F. Kirsch, Acting Director
Division of Reactor Safety and Projects
Palo Verde Nuclear Generating Station (PVNGS)
Units 1, 2, 3
Docket Nos. 50/528, 529, 530

Subject: Final Report - DER 86-14
A 50.55(e) and 10CFR21 Reportable Condition Relating to Weld Failure on Pipe Support Structure
File: 86-006-216; D.4.33.2

Reference: (A) Telephone Conversation between A. Toth and D. R. Larkin on March 20, 1986. (Initial Reportability - DER 86-14)

(B) ANPP-36021, dated April 9, 1986 (Report on Pipe Support Failure, Rev. 1)

(C) ANPP-36154, dated April 16, 1986 (Report on Pipe Support Failure, Rev. 2)

(D) ANPP-36289, dated April 18, 1986 (Report on Pipe Support Failure, Rev. 3)

Dear Sir:

Attached, is our final written report on the Reportable Deficiency under 10CFR50.55(e) referenced above. The 10CFR21 evaluation is also included.

Very truly yours,

E. E. Van Brunt

E. E. Van Brunt, Jr.
Executive Vice President
Project Director

EEVB/DRL:kp

Attachments

cc: See Page 2

IE-27

cc: J. M. Taylor
Office of Inspection and Enforcement
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FINAL REPORT - DER 86-14
DEFICIENCY EVALUATION 50.55(e)
ARIZONA NUCLEAR POWER PROJECT (ANPP)
PVNGS UNITS 1, 2, 3

I. Description of Deficiency

A surveillance inspection of Unit 1 on March 13, 1986, identified a failed pipe support (Support No. 1-SG-005-H008). The failed support was located inside the Containment Building and was a strut type support for the 24 inch main feedwater line to Steam Generator No. 2. The failure occurred in the weld between the flange connection of the upper and lower support beams. The lower portion of the support separated completely from the upper support beam (see Attachment A). The axes of the two beams were oriented 90°, and it was discovered that the two 4 inch long, 1/4 inch leg fillet welds between member A (upper beam) and E (lower beam) fractured. Attachment A shows the location of the failure. A distortion of the beam flanges at the weld location occurred.

The time of failure of the support is not known. A visual inspection of the hanger was performed by ANPP in March 1985, prior to Post-Core Hot Functional Testing, at which time the support was intact.

Evaluation

A. Metallurgical Aspects at Weld Failure Location on Unit 1

The failed support was visually inspected. The upper beam's bottom flange edge showed substantial bending. Similarly, the lower beam's upper flange showed some bending. Part of the fractured weld remained on the upper beam with the remainder on the lower beam.

The weld surfaces on the lower beam were also examined under a Stereo Microscope. Part of the fracture was in the base metal near the fusion zone and part was in weld metal. The weld quality was satisfactory. The fractured surface of the beam had a woody appearance, but the fractured surface in the weld metal appeared smooth.

The fractured surfaces were additionally examined under a Scanning Electron Microscope (SEM). The examination showed elongated dimple structures typical of a ductile overload under shear stresses. The base metal had some equiaxed dimples and elongated fibers indicating ductile overload fracture. No evidence of any striation was seen under the SEM, proving that fatigue was not a factor in this fracture.

Chemical analysis of the base material and weld material showed that the materials conform with ASTM A-36 and AWS SFA 5.1 Type E7018 requirements. Hardness tests showed the base material had an approximate tensile strength of 72,000 psi. The filler material tensile strength was approximately 90,000 psi. Typically, this material has elongation, at fracture, of approximately 30%.

Based on the above observations, it was concluded that the weld fractured due to overloading. Deformation of the flanges indicate that the weld transferred the loads until it could no longer accommodate strains imposed by deformation of the flange, causing the weld to fracture.

B. Unit 1 Pipe Support Design and Loading

Attachments B-1 and B-2 summarize the results of loading combinations and design capability of the failed Unit 1 support (1-SG-005-H008). The originally installed pipe support had an allowable maximum permitted load of 7.5 Kips under vertical loading (See Attachment B-1). The actual load (dead weight plus thermal) applied to the support was 17.7 Kips. The vertical component of the load which acts at 5.9 degrees off vertical is 11.7 Kips with a maximum permitted load of 9.9 Kips, not considering flange bending (see Attachment B-2), thereby resulting in overloading of the support. The support has been modified to provide additional capacity as shown in Attachments B-1 and B-2.

The pipe support design loads were reviewed and determined to be proper and appropriate loads except for not applying the load eccentrically. Therefore, the design loads used for evaluating the pre-modified and modified design are the same for the three PVNGS Units.

C. Unit 2 Pipe Support Design and Loading

Investigation of the same support in Unit 2 (Support 2-SG-005-H008), which had experienced hydrotest and precore Hot Functional Testing (HFT) thermal loads as well as dead weight loads, determined no flange deformation or weld damage existed. Further examination revealed that the lower beam on that support was not a W6 x 12 but a W6 x 15.5 member. Since the flange is 2 inches wider than the member used in Unit 1, it provides four additional inches of weld (two inches on each side of the beam). The larger beam size substitution was permitted per installation Specification 13-PM-204, since it was an upgrade in beam size.

Results of the calculation of the Unit 2 support are also shown in Attachments B-1 and B-2. The unmodified support has an allowable maximum permitted load of 10.35 Kips under vertical loading. The applied normal load (thermal and dead weight) is 17.7 Kips (see Attachment B-1). The vertical component of the applied load which acts at 5.3 degrees off vertical is 11.7 Kips with a maximum permitted load of 19.5 Kips, not considering flange bending (see Attachment B-2). This support has been modified to provide additional post modified capacity as shown by Attachment B-1 and B-2.

D. Root Cause

The root cause of the failure of Unit 1 support 1-SG-005-H008 was not adjusting the direction of the applied loads to accommodate the normal thermal motion of the pipe and not considering the effect of localized flange bending.

The combination of a relatively large thermal motion and short sway strut length resulted in a large angle which generated a horizontal force not accounted for in the original design. The effect of this horizontal force on the failed weld was amplified by its acting not only through the pin to back plate height of the rear bracket but also through the six-inch height of the W6 x 12 lower beam.

Additionally, the failed weld joined two open section members connected flange to flange at right angles (see Attahcment A). It is believed that the welds parallel to the web of the upper member are subject to a prying action resulting from the bending of the lower flanges of that upper beam (localized flange bending). Finite element analysis of the failed structure has indicated that this action does reduce weld capability.

Prior to plant heat up, the Unit 1 pipe support (1-SG-005-H008) was subjected to loads above the yield point due to dead load only. During subsequent and repeated hot functional tests, the loading on the support increased even higher above the yield point. This resulted in local flange bending and deformations and, as a result, imposed stresses in the welds attached to the support flange. This significantly reduced the weld capacity to carry additional loads. Thermal movements resulting from hot conditions during power operations applied eccentric loads to these welds. These two effects created excessive stresses in welds that led to the failure. Failure of the welds may have occurred prior to or during the power operation phase.

The design loads were reviewed and were determined to be proper and appropriate, and no new loads were identified that could have caused the failure.

Two conditions that potentially contributed to the failure, a slight tilt along the axis of the pipe and a vertical displacement of pipe due to thermal movement perpendicular to the pipe, were evaluated and determined to have an insignificant effect on the failure.

E. <u>Review of Other Supports</u>

The failure mechanism of the damaged support is identified as not properly considering the horizontal component of the applied loads (swing angle) and not considering localized flange bending in the original design. It is also noted that minor contributions were made by (1) the lateral thermal motion requiring that the sway strut pull the pipe upward, and (2) axial tilting action of the pipe could generate an additional and unbalanced load on the sway struts.

To address these areas, the following reviews were executed:

1) All large bore Q-Class supports that are designed to accomodate a swing angle, including struts, rods, snubbers, and springs were evaluated. A total of 852 supports were reviewed and, in addition to support 1-SG-005-H008, it was determined that five supports in Units 1 and 2 and seven in Unit 3 require modification to accommodate the off-vertical loading condition. In view of the small number of modifications required, it is concluded that the horizontal load component was adequately addressed in the overall design of large bore Q-Class supports.

2) A review was conducted on 100% of the large bore Q-Class pipe supports for flange bending. This involved 3,678 design drawings and "as-built" documentation. In addition to support 1-SG-005-H008, it was determined that five other supports required modification to preclude flange bending.

3) The supports requiring modification based on the above reviews are tabulated below:

Swing Angle Review	Flange Bending Review
13-SG-005-H008	13-SG-005-H008
13-SG-002-H004	13-SG-036-H011
13-SG-005-H009	13-SG-042-H011
13-SG-011-H003	13-SG-042-H017
13-SG-033-H018	13-SI-220-H020
13-SI-202-H004	13-SI-220-H024
13-AF-013-H012 (Unit 3 only)	
13-SG-008-H003 (Unit 3 only)	

Note that only pipe support 13-SG-005-H008 is susceptible to swing angle and flange bending effects.

4) A review of design documents was expanded beyond the specific areas of the support failure to include:

a. An investigation which sampled small bore Q-Class and seismic Category IX pipe supports. The results of this selective investigation indicated the supports had adequate designs.

b. An investigation of the design of other equipment (structural steel, raceway supports, HVAC, instrumentation, fire protection, major Q-Class equipment supports) utilizing configurations that could be subject to localized flange bending failures. The results of this selective investigation indicated all had adequate designs.

F. Safety Significance Assessment

The supports identified as requiring modification are in eight lines in systems SG and SI. An additional two supports on two separate lines in systems CH and SI attach to one of the identifed supports and are also included in this assessment. Also, two other supports on two lines in systems AF and SG were identified as requiring modification in Unit 3 only. To assess the safety significance of these conditions, criteria was established and the separate lines were evaluated as follows:

1. Assessment Criteria

To determine the safety significance of the conditions reported herein, the following methods of analysis were utilized:

a. For all lines except the Main Feedwater Line on which the damaged support was found:

i. All pipe stress analysis was rerun and reviewed utilizing the following:

- The Interim Summary Report, dated December, 1983, by the Pressure Vessel Research Committee (PVRC) Task Group on Damping Values (Code Case No. 411).

- Stress check used ASME Section III, 1981 Edition Code equations in Section NC-3650 with 2Sy limit for Level D.

- Piping stresses and support loads from earthquake and waterhammer, due to check valve slam from pipe break, are decoupled since the probability of these events occurring simultaneously is very small.

- Maximum loads and deflections from SSE inertia response, SSE structural displacements, and LOCA induced motion with jet impingement were combined using square root of the sum of the squares (SRSS) based on methodology of Regulatory Guide 1.92.

ii. If piping stresses met the 1981 code limits, taking credit for actual material properties, and all supports were shown to carry the new loads, then the line was considered capable of maintaining structural integrity, and the condition was deemed not safety significant.

iii. If piping stresses met the 1981 code limits, taking credit for actual material properties, but some pipe supports could not be shown to carry their new loads, then a new piping model was generated which had those "failed" supports removed, and the remaining system was checked for integrity.

iv. If the piping stresses exceeded the 1981 code limit when taking credit for actual material properties, the line was not considered capable of maintaining structural integrity, and the condition was deemed safety significant.

b. For the Feedwater Line SG-005, the same methods as above were utilized, except the analyses started with the failed pipe support (13-SG-005-H008) removed from the model.

2. Results

The results of the safety significance evaluation, using the assessment criteria on the various lines associated with the pipe supports requiring modification, are given in the following table:

Pipe Support	Line/Function	Piping Stresses Meet Assessment Criteria? Yes	No	* Notes
13-AF-013-H012	AFWP Turbine Exh.	X		1, 3
13-CH-120-H00J	RCP Cont. Bleed	X		4
13-SG-002-H004	Main Feedwater	X		1
13-SG-005-H008	Main Feedwater		X	1, 2, 5
13-SG-005-H009	" " "	X		1
13-SG-008-H003	Downcomer Feed	X		1, 3
13-SG-011-H003	Downcomer Feed	X		1
13-SG-033-H018	Main Steam	X		1
13-SG-036-H011	Main Steam	X		2
13-SG-042-H011	Main Steam	X		2
13-SG-042-H017	" "	X		2
13-SI-202-H004	SI to Loop 1A	X		1
13-SI-220-H015	SI to Loop 1B	X		4
13-SI-220-H020	" " " "	X		2
13-SI-220-H024	" " " "	X		2
13-SI-249-H00A	SI Tank Fill	X		4

* - In Notes Column:

1 = Potential pipe support overstress due to eccentric load
2 = Potential pipe support overstress due to flange bending
3 = Unit 3 only
4 = Support is attached to a potentially overstressed support
5 = Support failed in Unit 1

From the above tabulation, it can be seen that all lines, except for the Main Feedwater Line SG-005, meet the assessment criteria and the potential failure of the subject pipe supports is not safety significant. However, the locations of potential overstress in line SG-005 are located at the terminal ends and their potential structural failure are enveloped by the existing pipe break analysis performed as a part of the original design basis and documented in the FSAR.

G. Transportability

The evaluation for these two conditions included both an evaluation of the specific failure of support 1-SG-005-H008 as well as an evaluation of the potential for similar failures of other large bore Q pipe supports. The flange bending concern extended the review to small bore Q-Class and Seismic Category IX pipe supports and the additional support designs for raceways, HVAC, instrumentation, fire protection lines and major Q-Class equipment.

DER 85-29 entitled "Stress in Pipe Support Steel" (Beam Attachment Brackets) specifically restricted its scope of investigation to the orientation of welds between rear end brackets and structural members and did not adequately evaluate the transportability of flange bending structural members welded to similar structural members.

Based on the extensive evaluations conducted to resolve this DER condition, it is concluded that transportability has been adequately addressed.

H. Conclusion

Review of the failure concluded that the support was designed for the load being applied vertically, but due to thermal displacement of the pipe, the load was actually applied at about 6 degrees off vertical. This angle generated a lateral load, the effect of which on the failed weld was amplified by the depth of the lower beam (W6 x 12) which significantly reduced the load capacity of the failed weld. Flange bending flexibility was identified as another factor which further reduced the capacity of the weld.

Based on the evaluation conducted and the limited number of problems identified, it is concluded that there was a loss of design control during the original design of the support for flange bending and eccentric loading, but the loss was an isolated case resulting from an oversight on the part of the designer and checker, and not a generic breakdown of the design process.

II. Analysis of Safety Implications

Based on the above evaluation, this condition is determined to be reportable under 10CFR50.55(e) and 10CFR21 since, if left uncorrected, it could represent a significant safety condition.

III. Corrective Action

A. The following work documents have been issued to strengthen pipe supports to accommodate eccentric loading and/or preclude flange bending:

	Document to Implement Repair	
Support	Units 1 and 2	Unit 3
13-SG-005-H008	EER 86-SG-056	SFR 3SG-008
13-SG-005-H009	EER 86-SG-076	SFR 3SG-022
13-SG-011-H003	EER 86-SG-076	SFR 3SG-028
13-SG-002-H004	EER 86-SG-080	SFR 3SG-024
13-SG-033-H018	EER 86-SG-082	SFR 3SG-023
13-SG-036-H011	EER 85-SG-094 (Unit 1) EER 86-SG-056 (Unit 2)	SFR 3SG-008
13-SG-042-H011	EER 86-SG-056	SFR 3SG-008
13-SG-042-H017	EER 86-SG-056	SFR 3SG-008
13-SI-202-H004	EER 86-RC-080	SFR 3RC-095
13-SI-220-H020	EER 86-SG-056	FCR 70937-P
13-SI-220-H024	EER 86-SG-056	SFR 3RC-089
13-AF-013-H012	No Repair Required	SFR 3AF-021
13-SG-008-H003	No Repair Required	SFR 3SG-029

The work has been completed in Units 1 and 2, and will be completed in Unit 3 prior to pre-core hot functional testing.

B. Procedural Modifications

Orientation sessions for Bechtel Home Office project personnel have been held to assure that the need for proper consideration of lateral loads generated by thermal motion and for proper flange stiffening have been held. Further written instructions documenting these requirements have been issued to all project pipe support personnel. Design Criteria Revision Request No. 958 to the PVNGS Design Criteria Manual has been generated to include this information.

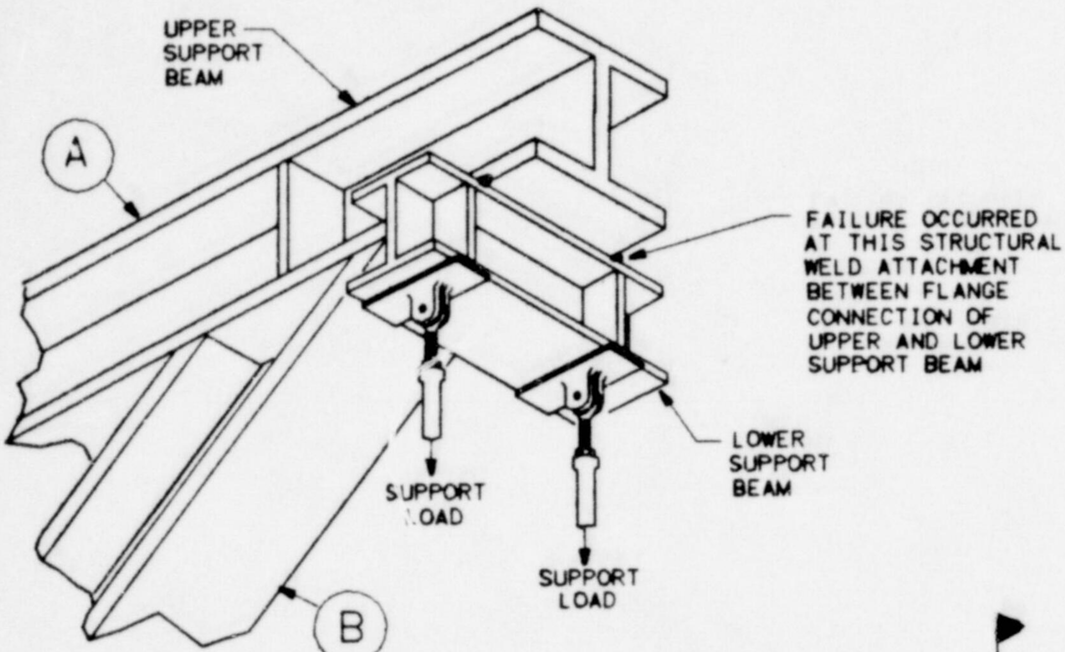
Attachments

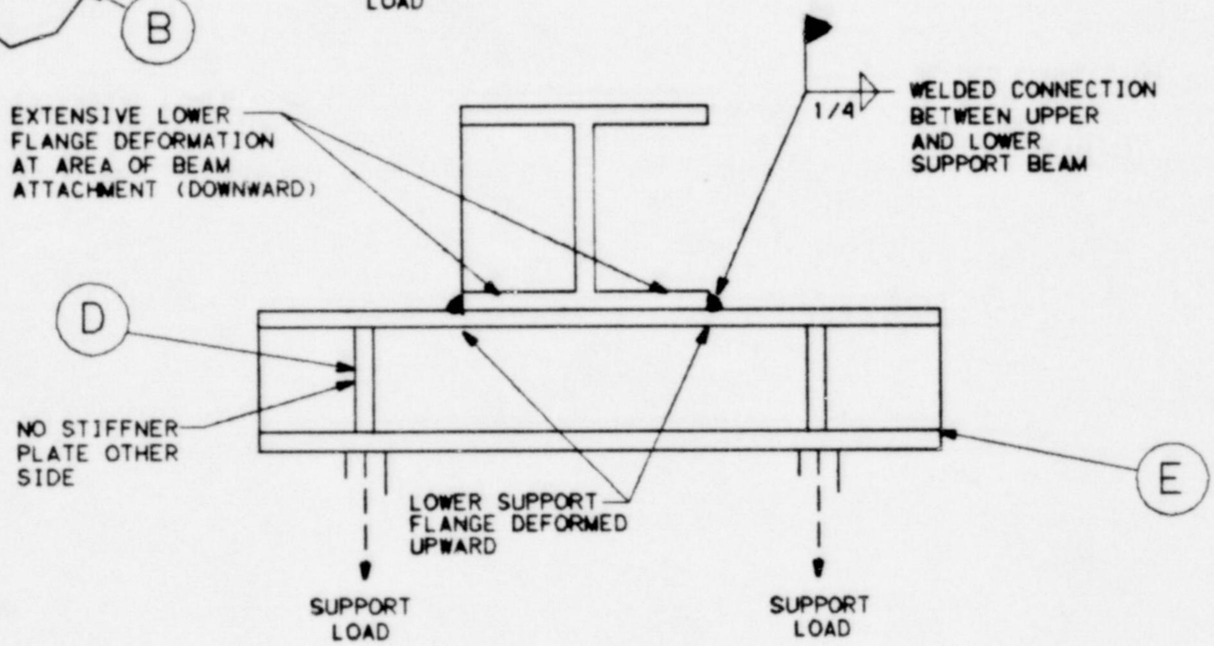
1) Attachment "A"
2) Attachment "B-1"
3) Attachment "B-2"

DER 86-14

PIPE SUPPORT 1-SG-005-H008

FAILURE LOCATION





END VIEW

ITEM NO.	NO. REQ'D	DESCRIPTION
A	1	W6 X 25 X 3'-8"
B	1	W6 X 25 X 3'-6"
D	3	STIFF PL. 1/4 X 2 7/8 X 0'-5 1/2"
E	1	W6 X 12 X 1'-4"

ATTACHMENT "A"

PIPE SUPPORT SG-005-H-008

LOAD SUMMARY	
TYPE	LOAD (KIP)
WEIGHT	-16.6
THRM	+4.9/-1.1
SSE	±11.8
EQ SSE (SAM)	±2.7
LOCA + J.I.	±16.3
W.H.*	+35.0/-6.4

*W.H. INCLUDES DW + THRM

NORMAL LOAD = DW+THRM = 0/-17.7K

FAULTED LOAD = DW + TH + SSE + SAM + WH = +49.5K/-21.0K

OR

FAULTED LOAD = DW + TH + $[(SSE+SAM)^2 + (LOCA+JI)^2]^{1/2}$ = +26.7K/-39.5K

DESIGN LOAD = +49.5^K/-39.5^K

VERTICAL LOADING RESULTS TABLE

UNIT #	PRE-MODIFIED				MODIFIED			
	NORMAL		FAULTED		NORMAL		FAULTED	
	MAX PERMITTED LOAD (KIP)	ACT LOAD (KIP)	MAX PERMITTED LOAD (KIP)	ACT LOAD (KIP)	MAX PERMITTED LOAD (KIP)	ACT LOAD (KIP)	MAX PERMITTED LOAD (KIP)	ACT LOAD (KIP)
1	-7.5	-17.7	+53.4 -15	+49.5 -39.5	-41.4	-17.7	+53.4 -36.6	+49.5 -39.5
2	-10.35	-17.7	+53.4 -20.69	+49.5 -39.5	-41.4	-17.7	+53.4 -37.5	+49.5 -39.5

ATTACHMENT "B-1"

PIPE SUPPORT SG-005-H-008

LOAD SUMMARY	
TYPE	LOAD (KIP)
WEIGHT	-16.6
THRM	+4.9/-1.1
SSE	±11.8
EQ SSE (SAM)	±2.7
LOCA + J.I.	±16.3
W.H.*	+35.0/-6.4

*W.H. INCLUDES DW + THRM

NORMAL LOAD = DW+THRM = 0/-17.7K

FAULTED LOAD = DW + TH + SSE + SAM + WH = +49.5K/-21.0K

OR

FAULTED LOAD = DW + TH + $[(SSE+SAM)^2 + (LOCA+JI)^2]^{1/2}$ = +26.7K/-39.5K

DESIGN LOAD = $+49.5^K/-39.5^K$

ECCENTRIC LOADING RESULTS TABLE

UNIT #	PRE-MODIFIED				MODIFIED			
	NORMAL		FAULTED		NORMAL		FAULTED	
	MAX PERMITTED LOAD (KIP)	ACT LOAD (KIP)	MAX PERMITTED LOAD (KIP)	ACT LOAD (KIP)	MAX PERMITTED LOAD (KIP)	ACT LOAD (KIP)	MAX PERMITTED LOAD (KIP)	ACT LOAD (KIP)
1	-9.9	-11.7	+53.4 -18.8	+49.5 -39.5	-19.3	-11.7	+53.4 -36.6	+49.5 -39.5
2	-19.5	-11.7	+53.4 -37.0	+49.5 -39.5	-19.7	-11.7	+53.4 -37.5	+49.5 -39.5

ATTACHMENT "B-2"