EVALUATION OF SURVEILLANCE FREQUENCY OF ENGINEERED SAFETY FEATURES ACTUATION SYSTEM (ESFAS) SUBGROUP RELAYS

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QL-1 X   Not Safety Related ____

QL-2 ____   QA Requested ____

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NO EPP INTERFACES........ ____

Discipline	Yes	No	Lead	Non-Lead Initials/Date
Mechanical/Nuclear		X		RDW 1/20
Electrical		X		[illegible] 1/23/84
Instrumentation & Control	X			[illegible] 1/20/84
Civil		X		[illegible] 1/20/84
Technical Licensing			X	

EXTERNAL INTERFACES (   )

No External Interfaces	X	Quality Assurance	
General Engineering		Nuclear Analysis	
Nuclear Energy		Security	
Nuclear Plant		Nuclear Mutual Limited (NML)	
Others:		Construction	

ABSTRACT

The St. Lucie Plant Unit No. 2 is provided with an Engineered Safety Features Actuation System (ESFAS) designed to automatically actuate plant protective systems in the event of Loss of Coolant, Steam Generator Tube Rupture and Steam or Feedwater Line Break Accidents. The current Technical Specifications require a semi-annual test of the ESFAS subgroup relays.

This analysis compares the change in availability of the system resulting from an extension of the subgroup relay test from once per six months to once per refueling outage (18 months). The analysis models a typical actuation channel (Safety Injection Actuation Signal (SIAS)) utilizing standard reliability techniques and published component failure rates. The results indicate that the availability of an SIAS channel is insensitive to the change in test interval. The 12 month change in test interval results in a 0.03% change in availability.

The ESFAS system, with the exception of the Auxiliary Feedwater Actuation System (AFAS), was designed under contract to Florida Power & Light and built by Consolidated Controls Corporation. The AFAS was provided by the NSSS vendor, Combustion Engineering. This analyses does not address the AFAS.

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I. PURPOSE

The analysis contained herein demonstrates quantitatively the effect of ESFAS subgroup relay testing frequency on the ESFAS availability. This analysis intentionally overestimates ESFAS availability by not evaluating all possible failure modes for portions of the system other than the subgroup relays and by not including common cause failure. This is conservative in that the relative importance of the subgroup relays to the calculated system availability is maximized.

II. METHODOLOGY

This evaluation was performed using standard reliability/availability modeling and estimation techniques. A typical subsystem of the ESFAS, the Safety Injection Actuation Signal (SIAS) was chosen as the protection system to be analyzed. From plant drawings and the St. Lucie Unit 2 Final Safety Analysis Report (FSAR) block diagrams of the measurement channel instrument loops and actuation logic were developed. The FSAR provided information on component failures which could affect system operation. Additional Failure Modes and Effects Analysis was performed as necessary.

A reliability block diagram was created to show the interrelation of the components. The Boolean expression representing the reliability diagram was written as well as the resulting probability expression for system unavailability. The component unavailabilities were calculated and combined in the system unavailability expression. The unavailability calculation was repeated for the current (semi-annual) interval and the proposed (refueling outage) surveillance interval for the subgroup relays.

Specific assumptions are identified in Section IV, DETAILED ANALYSIS.

General assumptions made are listed below:

A. Faults in wires or cables connecting SIAS components were not considered. Their contribution to system failure is assumed to be negligible. Note that this is a conservative for the reason stated in Section I.

B. Contributions to SIAS unavailability due to test or maintenance were not considered. This, again, is a conservative assumption.

C. Only the automatic actuation circuitry was considered. Manual actuation was not modeled.

D. For components whose Failure rates are listed per hour of operation a "mission time" of 10 hours is assumed. That is, the component must be operable at the start of the transient and for the first 10 hours of the transient. This assumption does not influence the unavailability calculations greatly, since it is applied mainly to the measurement channel components. These components are not large contributors to system unavailability.

E. SIAS is initiated by either low Pressurizer pressure or high Containment pressure. Both of these conditions are assumed present for purposes of the model.

III. SUMMARY OF RESULTS

The Safety Injection Actuation Signal (SIAS) was modeled as typical ESFAS subsystem. Faults contributing to the failure of one of the two actuation channels were identified. The availability of the actuation channel with semi-annual testing of the subgroup relays is estimated to be 0.9987. For testing on a refueling outage basis, the estimated channel availability is 0.9984. The extension of the surveillance interval has the effect of decreasing actuation channel availability by 0.03%. This represents a statistically insignificant change in the ability of the system to perform its function.

IV. DETAILED ANALYSIS

A. System Description

A complete description of St. Lucie Unit 2 ESFAS appears in Section 7.3 of the St. Lucie Unit 2 Final Safety Analysis Report. A brief description of the SIAS subsystem is presented here. The SIAS is initiated by either 2 low Pressurizer pressure signals or 2 high Containment pressure signals. Figures 1 and 2 show the measurement instrument loops for these parameters. There are four independent measurement channels. One channel may be bypassed for test or maintenance. Bistable modules condition these signals and, through isolation modules, provide inputs to the actuation modules. Upon a valid trip signal, the actuation modules' relay drivers de-energize the SIAS subgroup relays which actuate safeguards equipment. The ESFAS is provided with an automatic test circuit as well as manual test capability. Figure 3 shows the actuation logic for the SIAS subsystem.

B. SIAS Model Description

A reliability block diagram (Figure 4) was constructed for SIAS. The system boundaries were chosen in accordance with Regulatory Guide 1.22 definitions of Protection System and Actuation Device. Included in the model are the measurement channels, bistable, isolation and actuation modules, associated power supplies, subgroup relay, control circuit and circuit breaker for the Low Pressure Safety Injection (LPSI) Pump 2A, a typical safeguard equipment. The pump and its motor driver are not included in the model since the system boundary occurs at the motor circuit breaker, a part of the actuation device. The component identifiers shown on Figure 4 may be matched to their associated components on Figures 1, 2, and 3.

C. SIAS Boolean and Probability Expressions

The SIAS reliability block diagram may be translated directly into a Boolean expression. The event described by the block diagram is

"Failure to automatically close LPSI Pump 2A circuit breaker, given the occurrence of low pressurizer pressure and high containment pressure conditions." The Boolean expression for this event is:

Fail to close LPSI 2A Circ Bkr. = 52- +
LPSI 2A Cont. Cir. + K 501 B + Auct. Circuit +
(PS-L-I-A x PS-L-2-A) + AM 501 +
(Failure of 3 of 4 Pressurizer Press. Channels x
Failure of 3 of 4 Containment Press. Channels)

Failure of a Pressurizer Pressure Channel (FPMA) is expressed as:

FPMA = IM 106 A + PS-4-MA + BA-106 + R-5A + PS
+ PY-1102 A-2 + PY-1102 A + PT-1102 A

Failure of a Containment Pressure Channel (FCMA) is expressed as:
FCMA = IM 101 A + PS-1-MA + BA-101 + R-8A +
PS + PY-07-2A-2 + PY-07-2A +
PT-07-2A

Since all measurement channels are identical and no common mode failures are postulated, the failure of 3 of 4 measurement channels can be written as:

Przr. Press. $\binom{4}{3}$(FPMA x FPMA x FPMA) = $\frac{4!}{3!1!}$ (FPMA x FPMA x FPMA)

= 4 (FPMA x FPMA x FPMA)

Cont. Press. $\binom{4}{3}$(FCMA x FCMA x FCMA) = 4 (FCMA x FCMA x FCMA)

Note that this is a conservative assumption for this analysis. The ESFAS may be operated for extended periods with one measurement channel in bypass, in which case only two of three channels must fail to cause the event being modeled.

This assumption will tend to increase the importance of the subgroup relay by minimizing the contributions of other SIAS system components.

The system unavailability (Q sys) expression is written directly from the Boolean expression:

$$Q_{sys} = Q_{52-} + Q_{\substack{\text{LPSI 2A} \\ \text{Cont. Cir.}}} +$$

$$Q_{K501B} + Q_{\substack{\text{Auct.} \\ \text{Circuit}}} +$$

$(Q_{PS\text{-}L\text{-}1\text{-}A} \times Q_{PS\text{-}L\text{-}2\text{-}A}) + Q_{AM\ 501} +$
$(4\ Q^3_{FPMA} \quad \times \quad 4\ Q^3_{FCMA})$

Q xxx = Unavailability of Component xxx

Note that the rare event approximation is made for the measurement channel unavailabilities.

D. Availability Calculations

Appendix A to this attachment contains the individual component unavailability calculations. The individual components of the Containment pressure measurement channels are essentially the same as those of the Pressurizer pressure channel. The unavailability value calculated below for the Pressurizer pressure channel is thus valid for Containment pressure.

$Q_{FPMA} = Q_{PT\ 1102\ A} + Q_{PY\ 1102\ A} + Q_{PY\text{-}1102\ A\text{-}2}$
$+ Q_{PS} + Q_{R\text{-}5A} + Q_{BA\text{-}106}$
$+ Q_{PS\text{-}4\text{-}MA} + Q_{IM\text{-}106A}$

$= \quad 3.4 \times 10^{-4} + 1 \times 10^{-5} + 1 \times 10^{-5}$

$+ \quad 2.5 \times 10^{-4} + 1 \times 10^{-5} + 8 \times 10^{-4}$

$+ \quad 2.5 \times 10^{-5} + 9 \times 10^{-6}$
$= \quad 1.4 \times 10^{-3}$ / Channel

The SIAS system unavailability is calculated:

$Q_{sys} = \quad 1 \times 10^{-3*} + 6 \times 10^{-8} \times T$

$+ \quad 2.5 \times 10^{-5} + (2.5 \times 10^{-4})^2$
$+ \quad 2 \times 10^{-4} + 4\,(1.4 \times 10^{-3})^3$

$\times \quad 4(1.4 \times 10^{-3})^3.$

$Q_{sys} = \quad 1.2 \times 10^{-3} + 6 \times 10^{-8} \times T$

*Includes $Q_{LPSI\ 2A} + Q_{52\text{-}Cont\ Cir}$

The variable T is the fault exposure time (FET) for the subgroup relay K 501 B. The FET depends on the interval between testing of the relay. The FET is calculated by:

$$T = \frac{\text{TEST INTERVAL}}{2}$$

The table shown below calculates SIAS actuation channel availability for the semi-annual (4380 HR) and refueling outage (13140 HR) surveillance intervals.

SURVEILLANCE INTERVAL	Q_{K501B}	Q_{sys}	A_{sys} $(1-Q_{sys})$
4380 HR	1.3×10^{-4}	1.3×10^{-3}	.9987
13140 HR	3.9×10^{-4}	1.6×10^{-3}	.9984

This represents a decrease in SIAS actuation channel availability of 0.03%.

E. Conclusion

The proposed increase in surveillance interval for the subgroup relays has a negligible effect on system availability. In addition, the increased interval should result in a decrease in the risk of inadvertent plant trips due to ESFAS testing.

V. REFERENCES

A. PRA Procedures Guide, NUREG/CR-2300, Final Report, January 1983.

B. Reliability Analysis of Engineered Safeguard Panels for St. Lucie Nuclear Power Station, Unit #2, Engineering Report No. 1213, Consolidated Controls Corp., April 26, 1978.

C. St. Lucie Unit #2 Final Safety Analysis Report, Section 7.3.

D. Component Failure Rates for Nuclear Plant Safety System Reliability Analysis, Nuclear Regulatory Commission (Draft Report issued 9/23/80 for Interim Reliability Evaluation Program use).

E. Reactor Safety Study, WASH-1400, Rasmussen et al, October, 1975.

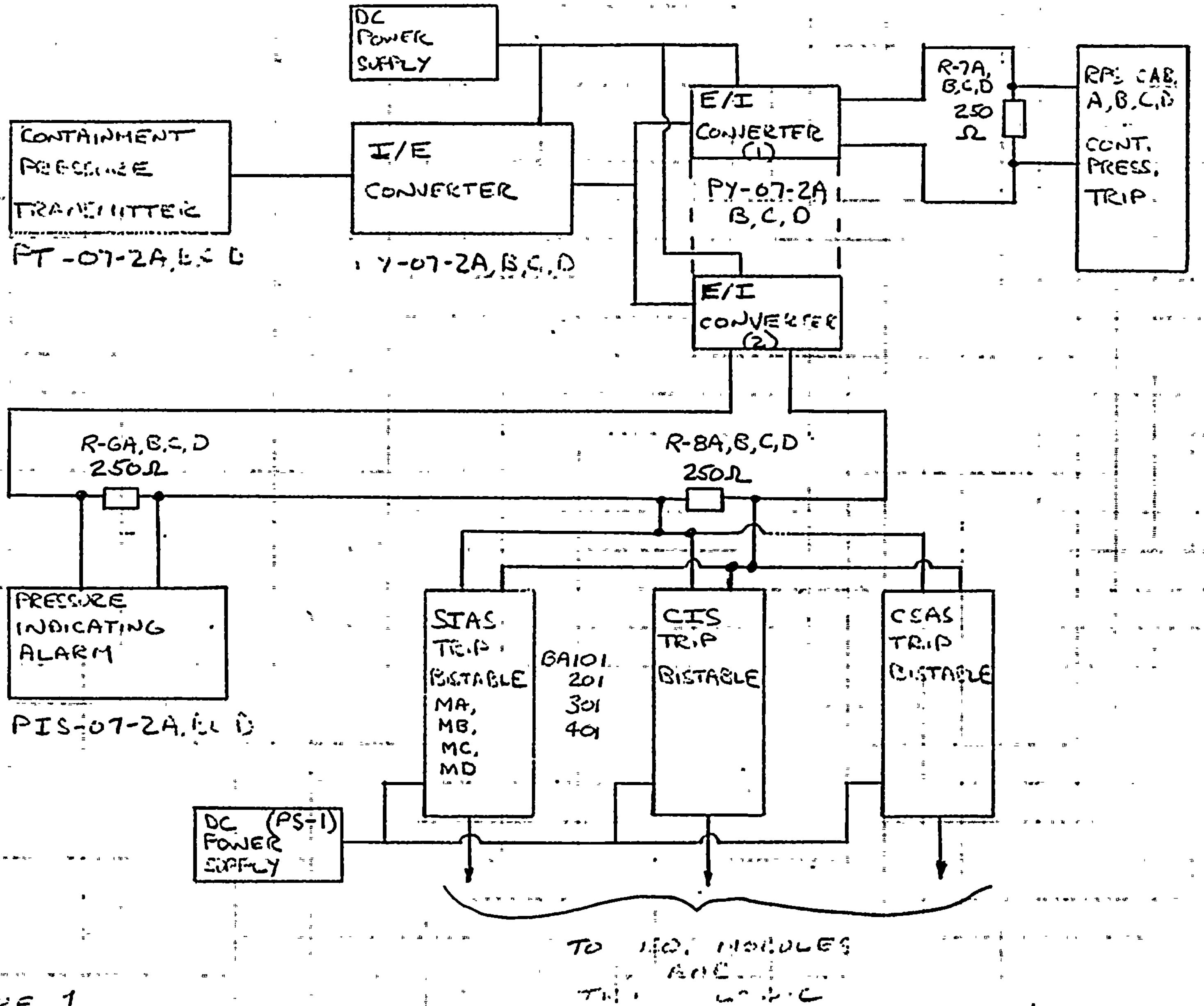


FIGURE 1.
CONTAINMENT PRESSURE MEASUREMENT LOOP
BLOCK DIAGRAM

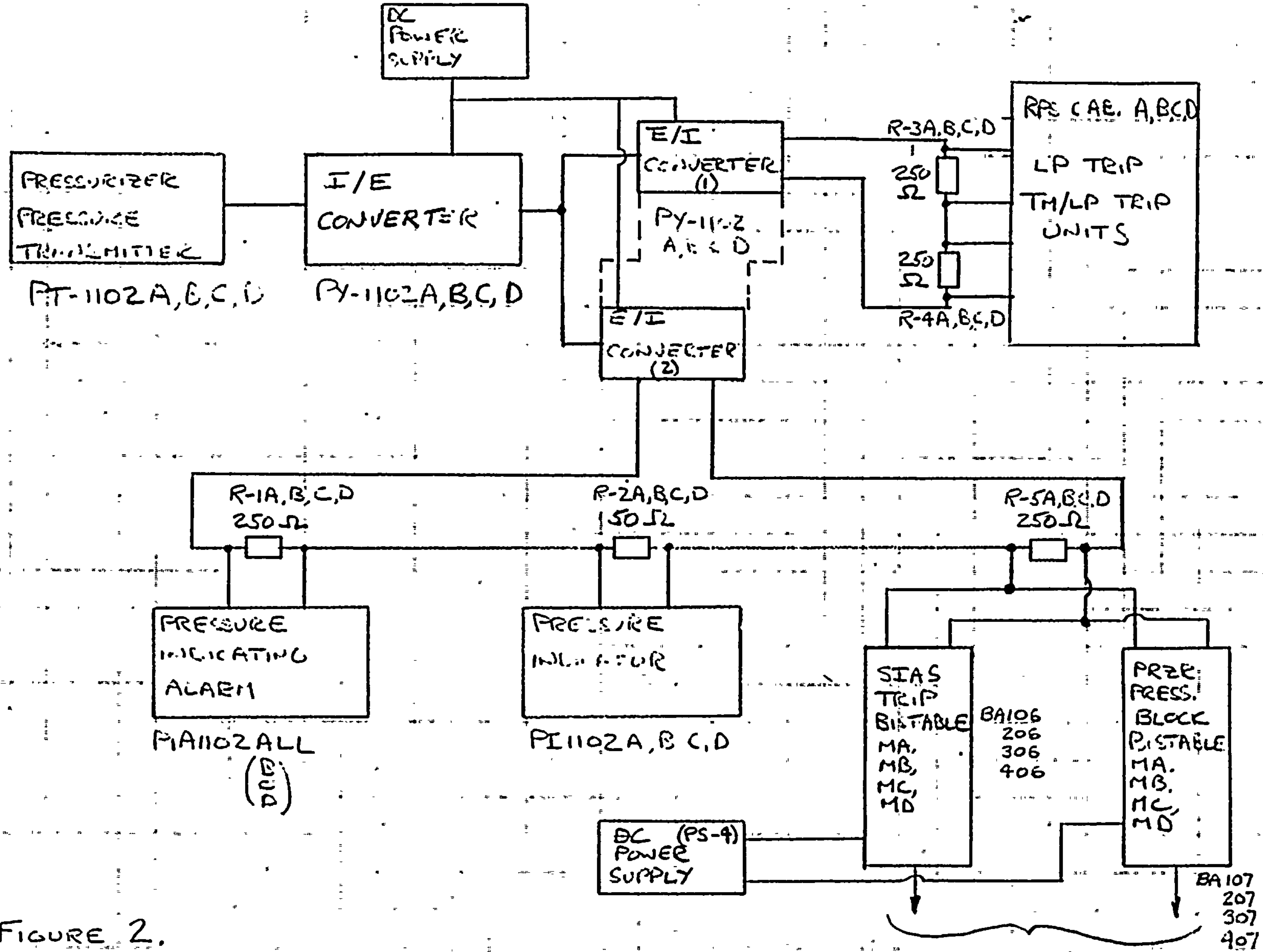


FIGURE 2.
PRESSURIZER PRESSURE MEASUREMENT LOOP
BLOCK DIAGRAM

ACTUATION LOGIC

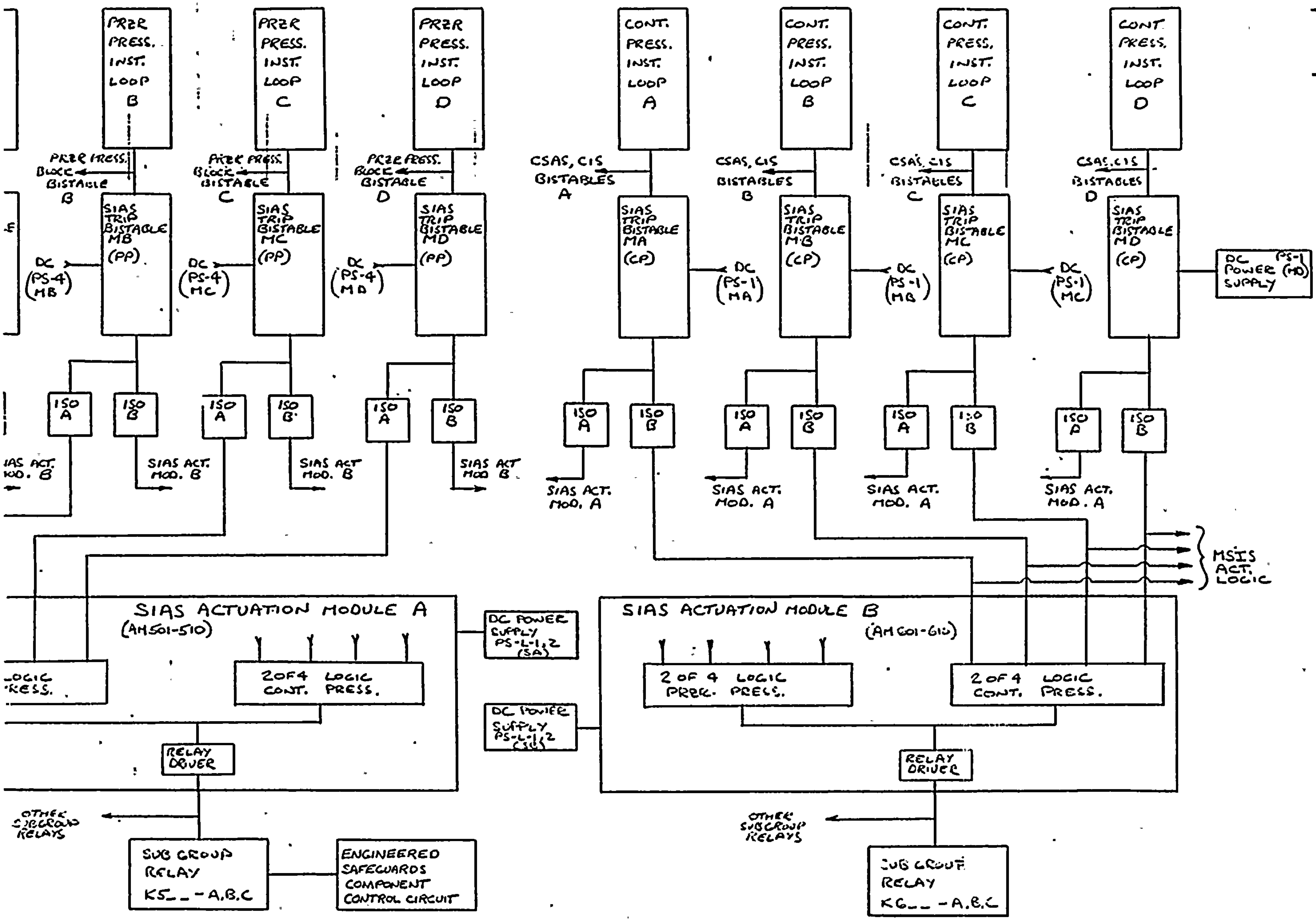
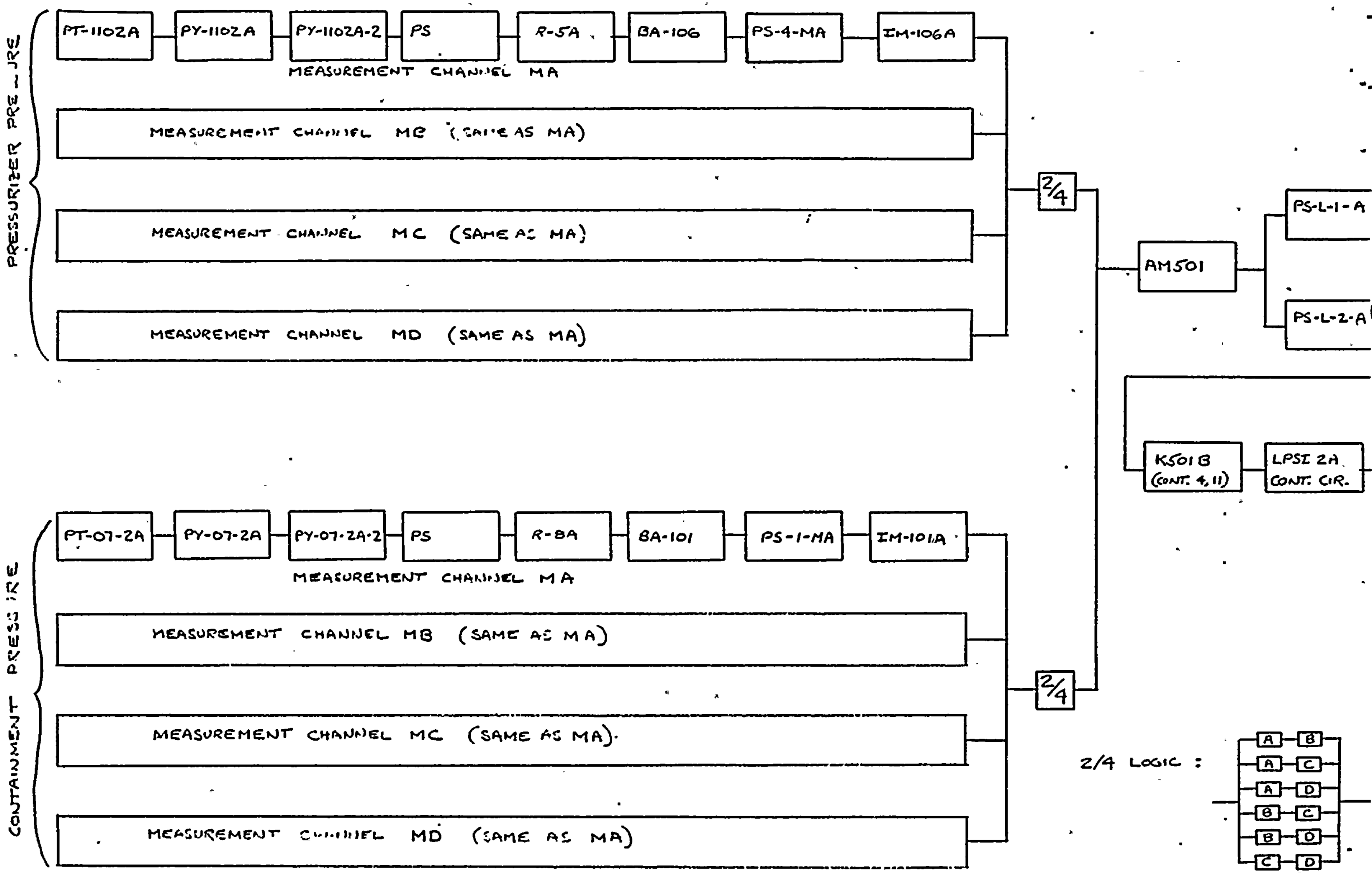


Figure 4. SIAS RELIABILITY BLOCK DIAGRAM - LPSI PUMP 2A ACTUATION



APPENDIX A

SIAS COMPONENT DATA

AND

UNAVAILABILITY CALCULATIONS

COMPONENT:	LPSI 2A Cont. Cir.
DESCRIPTION:	LPSI PUMP 2A Control Circuit
FAILURE MODE(S):	a) Opens, shorts, various component failures
DETECTION:	a) monthly pump test
EFFECT:	a) Failure to auto actuate LPSI 2A pump
FAILURE RATE:	1×10^{-3} /demand (Wash-1400, APP. II S. 5)
FAULT EXPOSURE TIME:	a) 1 month
UNAVAILABILITY:	1×10^{-3}

NOTE: This value includes failure of the circuit breaker. See WASH-1400, Figure II 5-17 for fault tree evaluation of control circuit faults

COMPONENT:	52-
DESCRIPTION:	LPSI 2A Circuit Breaker
FAILURE MODE(S):	a) Fails to close b) Fails to remain closed
DETECTION:	a) monthly pump test b) " " "
EFFECT:	a) No power to LPSI 2A Pump b) Loss of power to LPSI 2A Pump
FAILURE RATE:	See note below
FAULT EXPOSURE TIME:	a) 1 month b) 1 month
UNAVAILABILITY:	See note below

NOTE: The failure probability of the Circuit Breaker is included in the Control Circuit value.

COMPONENT: K501B (cont. 4,11)

DESCRIPTION: Subgroup actuation relay (contact 4, 11)

FAILURE MODE(S):
a) coil fails to de-energize
b) contacts fail to close

DETECTION:
a) Channel functional test
b) Channel functional test

EFFECT:
a) Failure of component (LPSI PP 2A) to actuate
b) Failure of component (LPSI PP 2A) to actuate

FAILURE RATE: 6E-8/hr (See Note 1)

FAULT EXPOSURE TIME:
a) variable-T (see Note 2)
b) variable - T (see Note 2)

UNAVAILABILITY: 6E-8/hr x T

NOTE:

1. Unless otherwise noted the failure rates listed are obtained from Consolidated Controls Corporation Engineering Report No. 1213 (April 26, 1978). The values therein are obtained from MIL-Handbook 217 B, June 1977.

2. The fault exposure time depends on the test interval. Two cases are evaluated:

a) $T_1 = \frac{4380 \text{ HR}}{2}$ (Semi-Annual Interval)

b) $T_2 = \frac{13140 \text{ HR}}{2}$ (Refueling Outage Interval)

COMPONENT:	Auct. Circuit
DESCRIPTION:	Power supply auctioneering circuit
FAILURE MODE(S):	a) High
DETECTION:	a) Alarms
EFFECT:	a) causes Act. module failure to trip
FAILURE RATE:	2.5×10^{-6}/Hr.
FAULT EXPOSURE TIME:	a) immediate
UNAVAILABILITY:	2.5×10^{-6}/hr x 10 hr (see Note 1)
	$= 2.5 \times 10^{-5}$

NOTE: 1. The only unavailability contribution is that due to failure of the circuit during the transient. Failure during standby conditions is alarmed.

COMPONENT:	PS-L-1,2-SA
DESCRIPTION:	Actuation module power supply - 1,2
FAILURE MODE(S):	a) High
DETECTION:	a) Alarms
EFFECT:	a) causes Act. module failure to trip
FAILURE RATE:	2.5×10^{-5}/Hr/Power Supply
FAULT EXPOSURE TIME:	a) immediate
UNAVAILABILITY:	2.5×10^{-5}/hr x 10 hr (see Note 1)
	= 2.5×10^{-4}/Power Supply

NOTE:

1. Failure during standby condition is alarmed. Only unavailability contribution is due to failure during transient.
2. Failure rate obtained from Consolidated Controls Corp. Engineering Report No. 1213 (CCC-ER1213).

COMPONENT:	AM 501
DESCRIPTION:	SIAS Actuation module
FAILURE MODE(S):	a) Non-trip condition
DETECTION:	a) immediate - auto test alarm
EFFECT:	a) Failure to actuate ESFAS components
FAILURE RATE:	2×10^{-5}/Hr
FAULT EXPOSURE TIME:	a) immediate
UNAVAILABILITY:	2×10^{-5}/hr x 10 hr
	$= 2 \times 10^{-4}$

NOTE: 1. Failure rate obtained from CCC-ER 1213.

COMPONENT:	PT-1102 A, B, C, D
DESCRIPTION:	Pressure transmitter
FAILURE MODE(S):	a) ASIS, DRIFT b) HIGH
DETECTION:	a) comparison with remaining channels b) RPS pretrip, trip alarms
EFFECT:	a) Actuation logic becomes 2 of 3 or 2 of 2 (with 1 channel bypassed) b) Same as above
FAILURE RATE:	3.4×10^{-5}/Hr (see Note 1)
FAULT EXPOSURE TIME:	a) $^{8HR}/_{2}$ - Shift channel check b) immediate
UNAVAILABILITY:	3.4×10^{-5}/hr x 10 hr $= 3.4 \times 10^{-4}$

Notes: 1. Value obtained from Interim Reliability Evaluation Program (IREP) Data Base.

COMPONENT:	PY-1102 A, B, C, D
DESCRIPTION:	Current/voltage converter
FAILURE MODE(S):	a) HIGH b) As is, Drift
DETECTION:	a) immediate b) comparison with other channels
EFFECT:	a) RPS Hi-Przr. trip (1 channel), Alarms b) Failure of 1 channel to trip; logic = 2 of 3 or 2 of 2 (if one channel bypassed)
FAILURE RATE:	1×10^{-6}/Hr (see Note 1)
FAULT EXPOSURE TIME:	a) immediate b) 8/hr/2 - shift Ch. Chk.
UNAVAILABILITY:	1×10^{-6}/hr x 10 hr $= 1 \times 10^{-5}$

Notes: 1. Value obtained from IREP Data Base.

COMPONENT: PY-1102 A-2 (1102 B, C, D also)

DESCRIPTION: Voltage to current converter

FAILURE MODE(S): a) HIGH
b) As is, Drift

DETECTION: a) immediate
b) comparison with other channels

EFFECT: a) Alarms (P1A1102 All, B, C, D; PI 1102 A, B, C, D)
b) Failure of 1 channel to trip; logic = 2 of 3 or 2 of 2 (if one channel bypassed)

FAILURE RATE: 1×10^{-6}/Hr (see Note 1)

FAULT EXPOSURE TIME: a) immediate
b) $^{8/hr}/2$ - shift Ch. Chk.

UNAVAILABILITY: 1×10^{-6}/hr x 10 hr

$= 1 \times 10^{-5}$

Notes: 1. Value obtained from IREP Data Base.

COMPONENT: PS

DESCRIPTION: DC Power Supply to Converters

FAILURE MODE(S): a) HIGH

DETECTION: a) immediate

EFFECT: a) SIAS channel fails to trip

FAILURE RATE: 2.5×10^{-5}/Hr

FAULT EXPOSURE TIME: a) immediate

UNAVAILABILITY: 2.5×10^{-5}/hr x 10 hr

$= 2.5 \times 10^{-4}$

NOTE: 1. Failure rate obtained from CCC-ER1213.

COMPONENT:	R-5A
DESCRIPTION:	Precision Resistor (250Ω)
FAILURE MODE(S):	a) Open
DETECTION:	a) Manual Test, alarms, possible immediate detection
EFFECT:	a) Bistable "HI", Channel fails to trip
FAILURE RATE:	1×10^{-6}/Hr (see Note 1)
FAULT EXPOSURE TIME:	a) immediate
UNAVAILABILITY:	1×10^{-6}/hr x 10 hr
	$= 1 \times 10^{-5}$

NOTE: 1. Failure rate obtained from CCC-ER 1213

COMPONENT:	BA-106
DESCRIPTION:	Lo Przr Pr. Bistable
FAILURE MODE(S):	a) Non-trip condition
DETECTION:	a) Manual and Auto test
EFFECT:	a) 1 Ch. fails to trip, logic = 2of3 or 2of2 (if one channel bypassed)
FAILURE RATE:	8×10^{-5}/Hr
FAULT EXPOSURE TIME:	a) immediate (Auto Test)
UNAVAILABILITY:	8×10^{-5}/hr x 10 hr
	$= 8 \times 10^{-4}$

NOTE: 1. Failure rate obtained from CCC-ER 1213.

COMPONENT: PS-4-MA

DESCRIPTION: Przr Press. Bistable Power Supply

FAILURE MODE(S): a) High

DETECTION: a) Alarms

EFFECT: a) Causes high bistable output, fails bistable circ., logic = 2of3 or 2of2

FAILURE RATE: 2.5×10^{-6}/Hr

FAULT EXPOSURE TIME: a) immediate

UNAVAILABILITY: 2.5×10^{-6}/hr x 10 hr

$= 2.5 \times 10^{-5}$

NOTE: 1. Failure rate obtained from CCC-ER 1213.

COMPONENT: IM-106A

DESCRIPTION: "A": Channel Isolation Module

FAILURE MODE(S): a) Non-trip condition

DETECTION: a) Automatic and manual test, auto test light and alarm

EFFECT: a) Failure of 1 ch. to trip; logic = 2 of 3 or 2 of 2 (if one channel bypassed

FAILURE RATE: 9×10^{-7}/Hr

FAULT EXPOSURE TIME: a) immediate

UNAVAILABILITY: 9×10^{-7}/hr x 10hr

$= 9 \times 10^{-6}$

NOTE:

1. Failure rate obtained from CCC-ER 1213.
2. Failure of isolation module is assumed to be detected by automatic test circuitry.