JUL -3 '85 0284752

June 30 1985

10855 - HOPE CREEK GENERATING STATION

REPORT OF

RESOLUTION OF EMI EFFECTS

ON BAILEY INPUT LOGIC MODULES

D.A. van Staveren

CONTENTS

REPORT OF

RESOLUTION OF EMI EFFECTS ON BAILEY INPUT LOGIC MODULES

1.0 PREFACE

This report pertains to the effects of EMI encountered with the Bailey Logic Modules at HCGS during start-up testing in September 1984. The report covers the history, description and the steps taken to nullify these effects. It does not cover matters relating to RFI which will be the subject of a separate report.

1.1 DESCRIPTION OF EMI EFFECTS

During pre-operational testing, incorrect actuation of digital input modules was noted in the form of erroneously activated indicating lights on the main control panel and incorrect logic module operation.

1.2 HISTORY

Malfunction of the Bailey Model 862 input modules was identified by the Public Service Start-up Group and Bechtel, and was verbally reported to Region I, Office of Inspection and Enforcement on September 14, 1984. The following observations were made:

1. While testing Motor Operated Valves in the Condensate System, indicating lights on the control panels were erroneously illuminated. Furthermore, the condensate pump failed to start when the BCCo logic system was incorrectly set due to a false signal indicating that the pump discharge valve was 30% open.

2. During the pre-operational testing of the 4.16 Kv and 7.2 Kv switchgear, a BCCo flip flop was set in spite of its input being deactivated.

An initial review of the BCCo logic system, the field wiring and the power supply indicated no evidence of a design deficiency or incorrect installation. Testing of the BCCo logic modules found no faulty or damaged components.

1.3 EXTENT

2,248 BCCo Model 862 input modules, each with a maximum capacity of 8 inputs are affected. These modules are designed to function as input isolation between field actuation devices, such as relay contacts or position switches and the solid state control logic system. They are used in both Class 1E and non-1E systems.

Incorrect actuation in 1E circuits could result in the inability to bring the plant to a safe shutdown condition.

After the pre-operational testing had identified the incorrect actuation of the logic system, PSE&G performed a series of exploratory tests to determine the cause of the effects. These included tests on a number of valves to insure that it was not an isolated case. All tests showed the same phenomenon.

Two types of induced voltages were identified:

1. An induced steady state voltage from 30 to 90 volts AC RMS.

2. Voltage spikes as a result of de-energizing coils in circuit breakers.

The testing revealed that the principal cause of falsing was high voltage transients occurring when inductive loads, such as a circuit breaker coil, are deactivated. That voltage is coupled from a load (culprit) wire to an input (victim) wire via wire-to-wire capacitance. Worst case, the victim wire is bundled in the same cable as the culprit wire and the victim wire is open at the field end; the induced voltage is large enough to cause the system to "think" that it has a valid input.

An investigation of the input circuit on the BCCo 862 logic modules confirmed the inability to discriminate between actual signals and induced voltages and showed little capability of noise suppression. Any voltage above 10 volts was processed as a valid signal.

1.4 RESOLUTION

Bailey Controls Company were notified of the malfunction and sent engineering and test personnel to the jobsite. Further testing was done with Bailey present. The testing was structured to qualify and quantify the worst case field condition for both steady state and induced voltages. This exploratory testing at the jobsite indicated that a redesign of the input circuit was the most effective means to correct the EMI susceptibility of the Bailey 862 logic system.

A consulting firm, specializing in EMI/RFI effects, was then retained by Bechtel for independent analysis of the cause, extent, evaluation and recommended solution. Their services to include the following:

1. Assist in the analysis of actual wiring layout and practices to identify the "worst case" physical arrangements for noise induction. Evaluate field "worst case" test mock-up. Validate analysis with computer simulation and/or laboratory tests.

2. Provide analysis of the existing and proposed input buffer designs to determine noise rejection capabilities, rejection of crosstalk among control cable conductors, effects due to component tolerances, and a critique of the design in general. Provide circuit designs, component values and limited test data.

3. Submit a report on evaluation of recommended solution and laboratory test and/or computer simulation results.

4. Assist in the development of a final report.

The consultant visited the Hope Creek jobsite to carry out preliminary testing and survey the overall problem.

Following the jobsite visit, the consultant reported his findings to Bechtel on October 12 1984. A further meeting at the consultant's offices on October 23 1984 established the following plan:

1. Perform exploratory testing at the jobsite to determine the worst case field conditions.

2. In conjunction with 1, conduct a survey at Bechtel's San Francisco office to accomplish the following:

    a) Review all documentation pertaining to equipment, control panels, valves and MCC's to identify all inductive loads connected to Bailey system cabinets.

1.4 RESOLUTION (Cont.)

b) Analyze cable configuration to identify the number of conductors within a cable carrying inductive loads.

c) Analyze operation of subject equipment to evaluate probability and frequency of repeated bursts.

d) Analyze the highest probability of simultaneous de-energization of the maximum number of inductive loads.

e) Determine the maximum allowable delay for switching circuits and the minimum time allowed between start and restart attempts.

f) Determine the numbers of AC wires in each cable carrying logic inputs.

g) Identify the lengths of the cables carrying inductive load currents.

h) Investigate the configuration of neutral returns.

i) Locate cases where 24v DC logic inputs are cabled with wires driving 120v AC or 125v DC inductive loads.

j) Determine the L x I (Inductance x Current) product of loads to establish the worst case threat.

k) Determine the frequency of transient repetition.

l) Identify input voltages and tolerances to the Bailey system.

3. Conduct an analytical survey at the consultant's laboratory, using the data from 1 and 2 above, as the means of determination of the correct design.

4. Construct and test a laboratory prototype of recommended design

5. Compare theoretical and practical results and discuss with Bailey.

6. Bailey to produce production prototypes for testing and verification of design.

1.4 RESOLUTION (Cont.)

7. Release Bailey for production.

8. Prepare final report.

9. Review all other systems at Hope Creek to determine potential susceptibility to same effects.

1.5 CONCLUSION

Final resolution took place by November 17 1984 when Bailey, working with Bechtel and the consultant, developed a version of the revised input buffer circuit that was shown to withstand the transient environment known to exist at the plant. The performance of the revised circuit was evaluated by the consultant and correlated with the threat data that had been compiled through prior experiments and theoretical studies.

The consultant's report to Bechtel concludes that the new circuit will eliminate the types of EMI effects that were encountered at Hope Creek with the Bailey 862 Logic Module.

PSE & G is committed to monitoring the functionality of all these modules during their pre op testing.

2.0 REVIEW

2.1 SYSTEM TO FIELD CONNECTIONS

Figure 2.1 (Page 16) illustrates the basic Bailey Logic System-to-Plant connectivity. Figures 2.2 and 2.3 (Pages 17 & 18) show typical field input and output circuits. The cables and field wiring considered in this report are restricted to the inputs to the Bailey 862 logic and termination cabinets.

The Bailey Logic System, controls most Balance-of-Plant items of equipment, both safety and non-safety related, and interfaces with the GE NSSS for information display purposes.

There are 2248 printed-circuit input buffer cards, each with eight inputs, totaling 17,984 inputs, for sensing the status of various plant items including switchgear and motor control centers, valve actuators and other equipment that has a change of state due to process control functions. The inputs are processed by the System and outputs to equipment, annunciators and operator displays.

Field wiring is typically # 12 & # 14 AWG insulated wires, spiraled within the the outer jacket to provide physical flexibility of the resulting multiconductor cable and surrounded by an overall outer insulating jacket.

2.2 Confirmation of Plant Input Configurations.

A. SYSTEM CATEGORIES

All loads connected to the Bailey 862 interposing logic system were reviewed to determine those circuits which will present the worst case voltage induction problem. The loads were categorized as follows:

Category I. Starters
Category II. Solenoids
Category III. Breakers
Category IV. Low or non-inductive loads
Category V. Multiplexed loads
Category VI. Relays

Each category was reviewed to identify cases that contained factors indicating worst case conditions.

B. 120v AC INPUT

Since the revised design of the input circuit on the Bailey logic modules has been shown to reject all 120v AC induced noise, the steady state voltage induction problem is not considered in this review.

2.2 Confirmation of Plant Input Configurations. (Cont.)

C. 24v DC INPUT

Although the revised input buffer provides enhanced immunity to transients for all three input configurations - 125v DC, 120v AC and 24v DC - the 24v DC input configuration is excluded from consideration here. There are no 24v cables connected to inductive loads that would cause a problem.

D. 125v DC INPUT

Circuits have been identified in this review that contain factors or combinations of factors indicating that, within the scope of this review, the circuit will encounter or produce transient voltage induction problems of a large magnitude. Figures 2.4 through 2.8 show the configuration of the cabling for each individual circuit.

CATEGORY I - STARTERS

Only the size 1 starters (for use with motors <10 h.p.) are energized directly from Bailey through a dry contact in the logic system. The remainder of the starters (sizes 2,3 and 4 for motors with ratings of less than 25, 50 and 100 h.p., respectively) are energized via pilot relays and therefore are considered under category VI.

All the MCC starters (sizes 1 thru 4) are fitted with surge suppression devices across their coils. This device limits the amplitude of the transient to approximately 220v p.p. The magnitude of the induced transient is therefore similarly limited. For the reasons stated above, none of the starter circuits will contain worst case conditions and therefore are not considered further in this review.

CATEGORY II - SOLENOIDS

Two cases have been identified:

CASE 1: FEED WATER HEATER VENT VALVES. (Fig 2.4, page 19)

Load: Six ASCO solenoid valves Model no. HT8316165. Each 2.5H, 130mA, 0.33AH, controlled from one hand switch. 120v AC.

Tag No's: SV-1510A, 1519A, 1528A, 1543A, 1545A, 1568A.

2.2 Confirmation of Plant Input Configurations. (Cont.)

CATEGORY II - CASE 1 (Cont.)

Location: Facility A; engineering area 11; elevation 102'.

Solenoids are valve mounted on feedwater htr. S/U and operating vent valves tagged HV-with the same numbers as the solenoids.

Cable:

BECHTEL: 6 cables (1 per solenoid), NP1F0125-B thru G; SV's to term. box 1NTB1236, length from 106' to 156'.

Each cable: 3 culprit; 1 victim; 1 neutral.

2 parallel cables, NP1F0125-H & J; length 360' Termination Cabinet to term. box 1NTB1236.

Cable H: 19 conductor; 11 culprit; 5 victim; 1 neutral; 2 spare.

Cable J: 3 conductor; 2 culprit ; 1 victim .

BAILEY: 2 cables, 1Z2241A, 1Z2242A; length, each 29' - Logic Cabinet to Termination Cabinet.

Cable 1Z2241A: 12 culprit; 6 victim.

Cable 1Z2242A: 6 culprit; 6 neutral.

Transient Repetition Frequency

During normal plant operation, air is vented from the feedwater heaters through an orifice in the operating vent. Vent valves are used only during startup. No conceivable circumstances could result in cycling the valve more than once per second.

CASE 2: CONTROL AND INDICATION FOR ADS PILOT SOLENOID VALVES (Figure 2.4,page 20)

Load: Four parallel connected solenoid valve/relay pairs.

Solenoid: Target Rock P/N 1/2 SMS-A-01, 125v DC, 300mA 20.2H, 6.06AH.

Tag No's: SV-3652A,-3653A,-3654A,-3655A

2.2 Confirmation of Plant Input Configurations. (Cont.)

CATEGORY II - CASE 2 (Cont.)

Location: Facility C; engineering area 17; elevation 121'.

Solenoids are valve mounted on ADS valves 1-SN-PSV-F013A, B, C, D.

Relay: Agastat type GP 125v DC: 100mA, 45H, 4.5AH.

GE Relay Tag No's: K40B, K41B, K42B, K43B.

Location: GE panel H11-P628 (10C628); Fac. E; elev 102'.

Cable:

BECHTEL: Control only, no indication.

BAILEY: 1 cable, 1Z5740; length 38', GE 10C628 to LC: 8 culprit (w/ DC inductive load), 4 victim, 4 indicating lights common.

Transient Repetition Frequency

2 possibilities of solenoid actuation - no possibility of more than one solenoid de-energizations occurring in quick (less than 1 sec) succession.

1. Actuation from control room. Operator should not attempt to de-energize solenoid more than once per second.

2. Actuation by GE level and pressure instruments (relays K6B and K6F). These relays require manual reset.

CATEGORY III - BREAKERS.

Two cases have been identified:

CASE 1: 7.2 kV SWITCHGEAR 10A12002 TRIP COIL(Fig. 2.5 page21)

Load: Primary load: 7.2 kV swgr. trip coil: 140mH, 5.1A, 0.71AH (measured), 125v DC.

Location: Swgr. stack 10A120002; Facility A; engineering area 08; elevation 120'.

2.2 Confirmation of Plant Input Configurations. (Cont.)

CATEGORY III - CASE 1 (Cont.)

Cable:

BECHTEL: 2 parallel cables, NP1Q0201-D & R; length 1521' Termination Cabinet to switchgear 10A1102.

Cable D: 7 conductor, 12 AWG; 2 culprit (w/ DC inductive load), 5 victim.

Cable R: 1 culprit (w/ DC inductive load), 3 victim, 1 negative.

BAILEY: Cable 1Z2271A, Length 29', Termination Cabinet to Logic Cabinet. 3 culprit (w/ DC inductive load), 8 victim, 1 negative.

Transient Repetition Frequency

Less than once per second.

CASE 2: 13.8kV BREAKER TRIP COIL

Load: 13.8kV breaker trip coil.

Location: Switchyard; breaker no. BS1-2.

Cable:

PSE&G: 1 cable, NP1A0111B; (PSE&G #BS1202AP); length 402', TB1042 to breaker 10RBS12.

9 conductor; 2 culprit (trip & close), 2 victim, 1 overall shield, 1 positive and 1 negative (125VDC).

BECHTEL: 2 parallel cables, 9AWG, NP1A0111-C & D; length 446', Termination Cabinet to term. box 1NTB1042.

Cable C: 2 conductor; 1 culprit (close), 1 positive.

Cable D: 4 conductor; 1 culprit (trip), 2 victim, 1 negative.

BAILEY: Cable 1Z2373A; length 29', Termination Cabinet to Logic Cabinet. 2 culprit (AC energized), 2 victim, pos. and neg.

2.2 Confirmation of Plant Input Configurations. (Cont.)

CATEGORY III - CASE 2 (Cont.)

Transient Repetition Frequency

Less than once per second.

The internal circuitry and arrangement of contacts within this breaker are such that it does not pose a potential threat.

CATEGORY IV

This category encompasses all the low inductance loads (i.e. indicating lights). Insufficient energy is stored in these loads to generate significant transients.

CATEGORY V

Multiplexed Loads. These signals are multiplexed onto a single coaxial cable. There is no possibility of cable to cable voltage induction in this case.

CATEGORY VI - RELAYS.

Five cases have been identified:

CASE 1: BAILEY/GE INTERFACE RELAYS (Fig. 2.6, page 22)

Load: Agastat type GP relays. 125v DC, 100mA, 45H, 4.5AH.

Tag No's: K38A, K39A, K40A, K41A, K24A, K27A, K33A, K34A.

Location: GE panel H11-P617 (10C617); Fac. E; elev 102'.

Cable:

BAILEY: Cable 1Z5674; length 42', GE 10C617 to LC 1AC652 7 culprit (w/ DC inductive load), 6 victim, 7 positive, 2 negative, 2 spares.

Transient Repetition Frequency

Less than once per second

2.2 Confirmation of Plant Input Configurations. (Cont.)

CATEGORY VI - CASE 1 (Cont.)

Comments

Worst-case conditions for relay de-energization would occur following reset of the isolation logic shown on 791E418AC sht. 60. At this time it would be possible to de-energize eight relays simultaneously._

CASE 2: CHILLER COMPRESSOR 1AK111, CONTROL & INDICATION (Fig. 2.7, page 23)

Loads: 480v GE AKR Breaker trip coil: 120v AC, 1.83A, 651.0mH; 1.19AH, (measured).

7 relays - Potter & Brumfield P/N KUP-14A15; 120v AC, 1.4H, 113mA, 0.158AH._

1 timer Agastat #7022AAT

Location: Vendor panel 1AC186; Facility A; Engineering area 10; elevation 171'._

Cable:

BECHTEL: 2 parallel cables, NP1V0120-C & G; length 560', TC to vendor panel 1AC186._

Cable C: 5 culprit, 6 Victim, 1 neutral

Cable G: 3 culprit (w/ DC inductive load), 2 victim. 1 positive, 1 negative._

2 parallel cables, NP1V0120-D & E; length 480' & 470', respectively, vendor panel 1AC186 to 10A11006.

Cable D: 1 culprit, 6 victim

Cable E: 2 culprit (w/ DC inductive load),1 victim, 1 negative._

BAILEY: Cable 1Z2282A, length 29', TC to LC, 8 culprit, 8 victim 1 neutral, 1 positive, 1 negative._

2.2 Confirmation of Plant Input Configurations.(Cont.)

CATEGORY VI - CASE 2 (Cont.)

Transient Repetition Frequency

No probability of repetitious de-energization. Compressor safety circuit locks up inputs for 15 min after start attempt.

The internal circuitry and arrangement of contacts within this breaker are such that it does not pose a potential threat.

CASE 3: TEST BYPASS FOR CONDENSATE STORAGE TANK VALVE, 1HV F008.

Loads: 2 pairs, parallel connected, 125v DC relays. GE 1C28001607AF3: 120mA, 3H; 0.357 AH.

Location: MCC cubicle D251103; Facility R; engineering area 24; elevation 54'. Relays for valve 1HV-F008.

Cable:

BECHTEL: AP1Q0715C; length 500'; valve to MCC. 0 culprit, 6 victim, 2 - 125v DC positive.

AP1Q0715D;length 410'; MCC to GE 10C620. 4 culprit (w/ DC inductive load), 5 victim, 1 neg.

BAILEY: Cable 1Z5688A; Length 39', LC to GE10C620. 4 culprit, 5 victim, 1 negative.

Transient Repetition Frequency

High probability of transient repetition. Frequency dependent on operator.

CASE 4: SIZE 2 THROTTLING MOV (HV-F024B)

Load: Cutler-Hammer type M pilot relay 120v AC, 9W, 1.9H (calc), 75mA (calc), 1.425AH

Location: MCC 10B222; Facility R; engineering area 13; elevation 102'. Relays for valve HV-F024B.

2.2 Confirmation of Plant Input Configurations. (Cont.)

CATEGORY VI - CASE 4 (Cont.)

Cable:

BECHTEL: Cable BP1Q0852C; length 299', MCC 10B222063 to RSP C399. 6 culprit, 7 victim, 6 spares, 1 neutral.

Cable BP1Q0852D; length 516', RSP C399 to 10C618 4 culprit, 7 victim, 1 neutral.

BAILEY: Cable BP1Z5723A; length 44', 10C618 to 1BC652. 4 culprit, 7 victim, 1 neutral.

Transient Repetition Frequency

Throttling MOV. High frequency of transients probable. Actual frequency of transients dependent on operator.

CASE 5: RSP INTERFACE

Load: GE MDR relay.(Potter & Brumfield P/N MDR 131-1) 125v DC. 15.6W, 5.1H, 125mA, 0.64 AH. (all values measured.)

Location: MCC cubicle 10B553041; Intake structure; (relays for valve HV-2198A)

Cable:

BECHTEL: 4 series cables, BP1C0223 B, E, C, & D; total length 1874': Mixture of 120v AC and 125v DC in these cables.

Cable B: 78', HV-2198B to 10B563041: 19 conductor; 5 culprit, 6 victim, 2 pos., 1 neg (125VDC) 5 spare.

Cable E: 1106', 10B563041 to 1BTB4114: 19 conductor; 2 culprit, 7 victim, 3 pos, 1 neg, 6 spare

Cable C: 360', 1BTB4114 to RSP C399: Same as cable E.

Cable D: 330', RSP C399 to TC: 12 conductor; 2 culprit 7 victim, 1 pos., 1 neg., 1 spare.

2.2 Confirmation of Plant Input Configurations. (Cont.)

CATEGORY VI - CASE 5 (Cont.)

BAILEY: Cable 1Z2020A; length 29', TC to LC: same as cable D, above.

Transient Repetition Frequency

High repetition frequency probable.

2.3 Voltage Input to Bailey System

a) Confirm 24v DC, 125v DC and 120v AC tolerance and ranges.

i Input voltages to system

120v AC Regulated - + 1%

120v AC Unregulated - + 10%

125v DC Max - 140V, Min - 105V

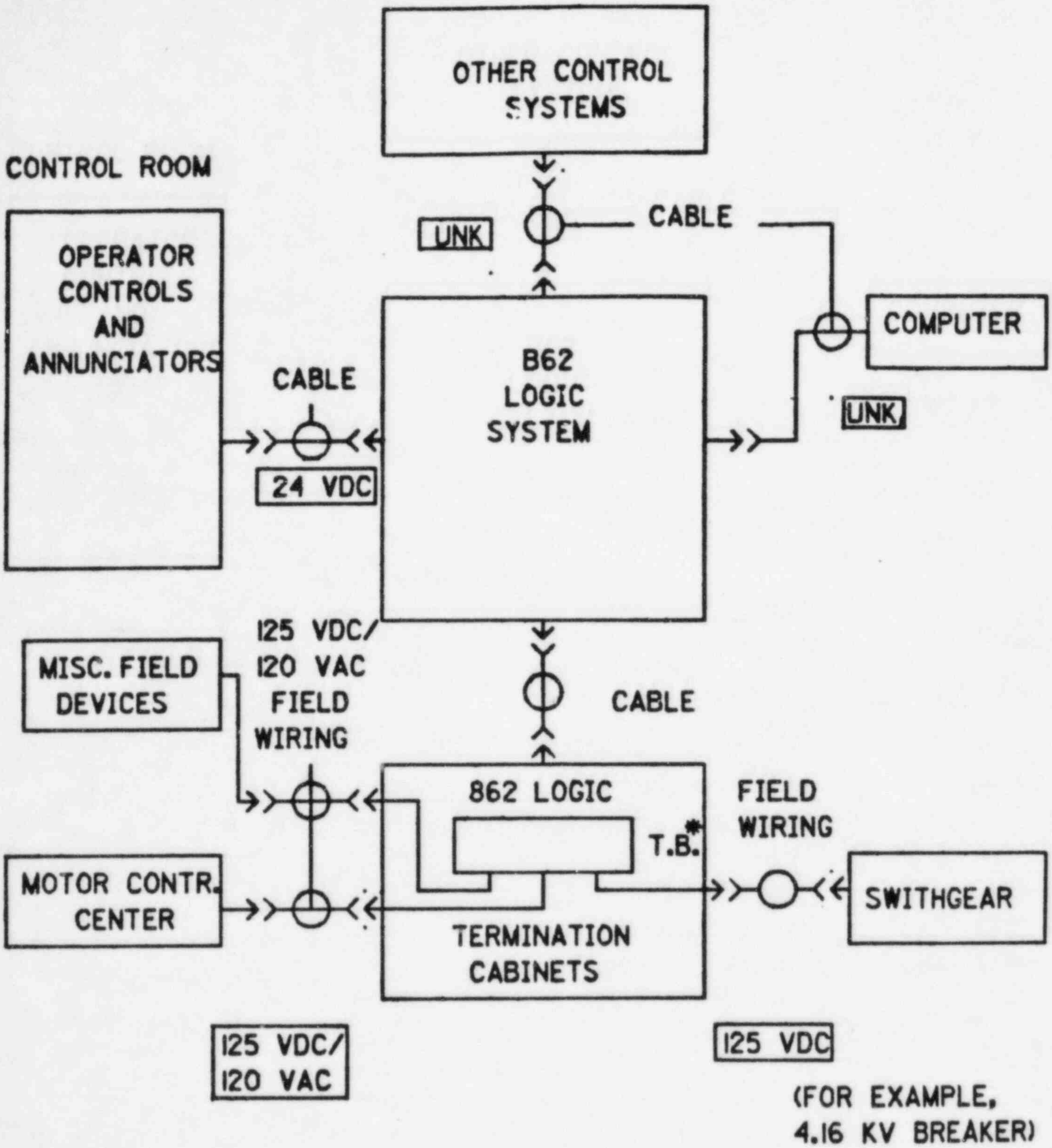
ii Output voltages from Bailey System

120v AC Regulated, Max - 130v, Min - 106v, Frequency variation 3Hz at 25 C.

125v DC, Max - 134v, Min - 121v

24v DC, Max - 26.3v, Min - 23.2v

iii Bailey System cards designed to operate + 20% to - 30% rated voltage.



———— CABLING CONSIDERED IN ANALYSIS

* TERMINAL BOARD

>> INDICATES DIRECTION OF SIGNAL/CONTROL

[24 VDC] INDICATES DOMINANT SIGNAL/CONTROL VOLTAGE LEVEL

SYSTEM-TO-PLANT CONNECTIVITY

FIGURE 2.1

Typical Field Input

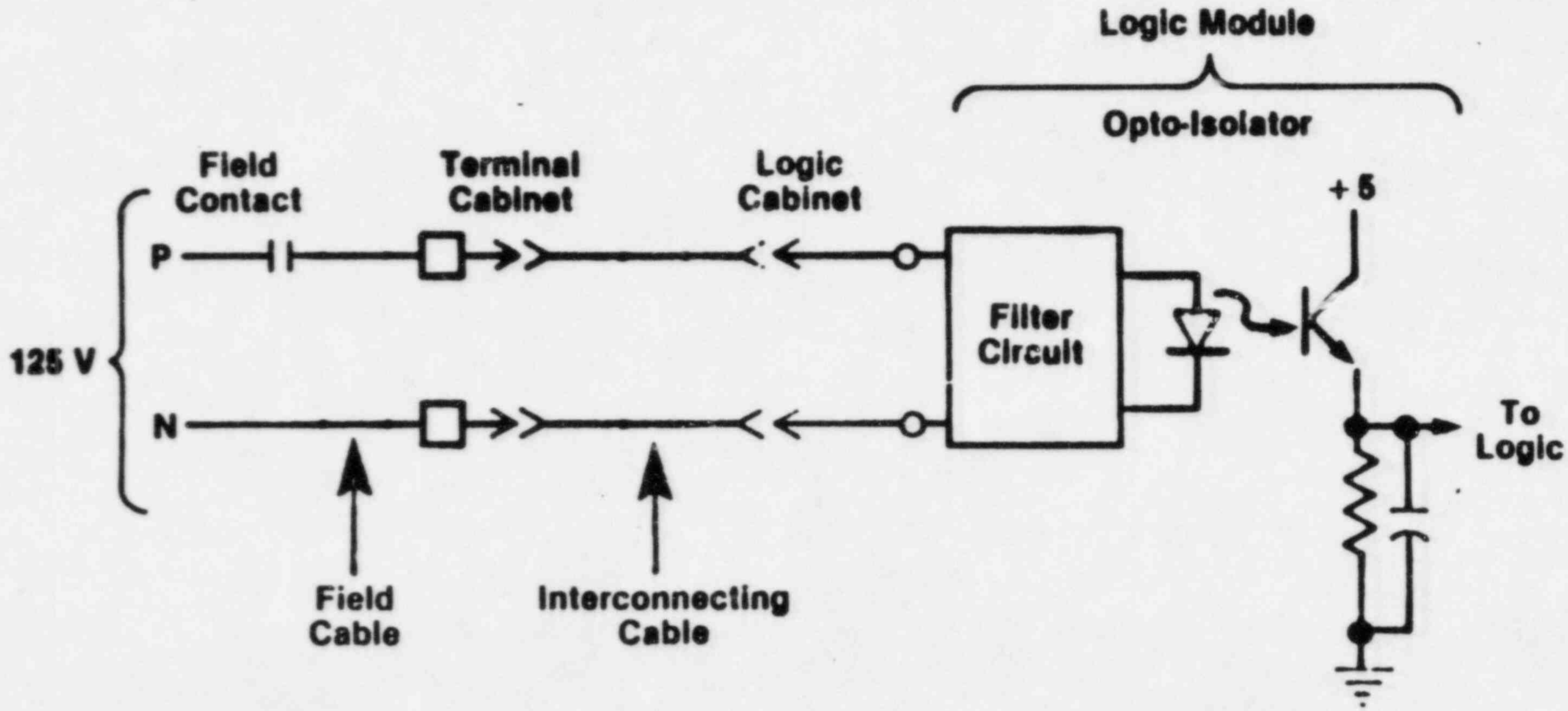


Figure 2.2 Page 17

Typical Field Output

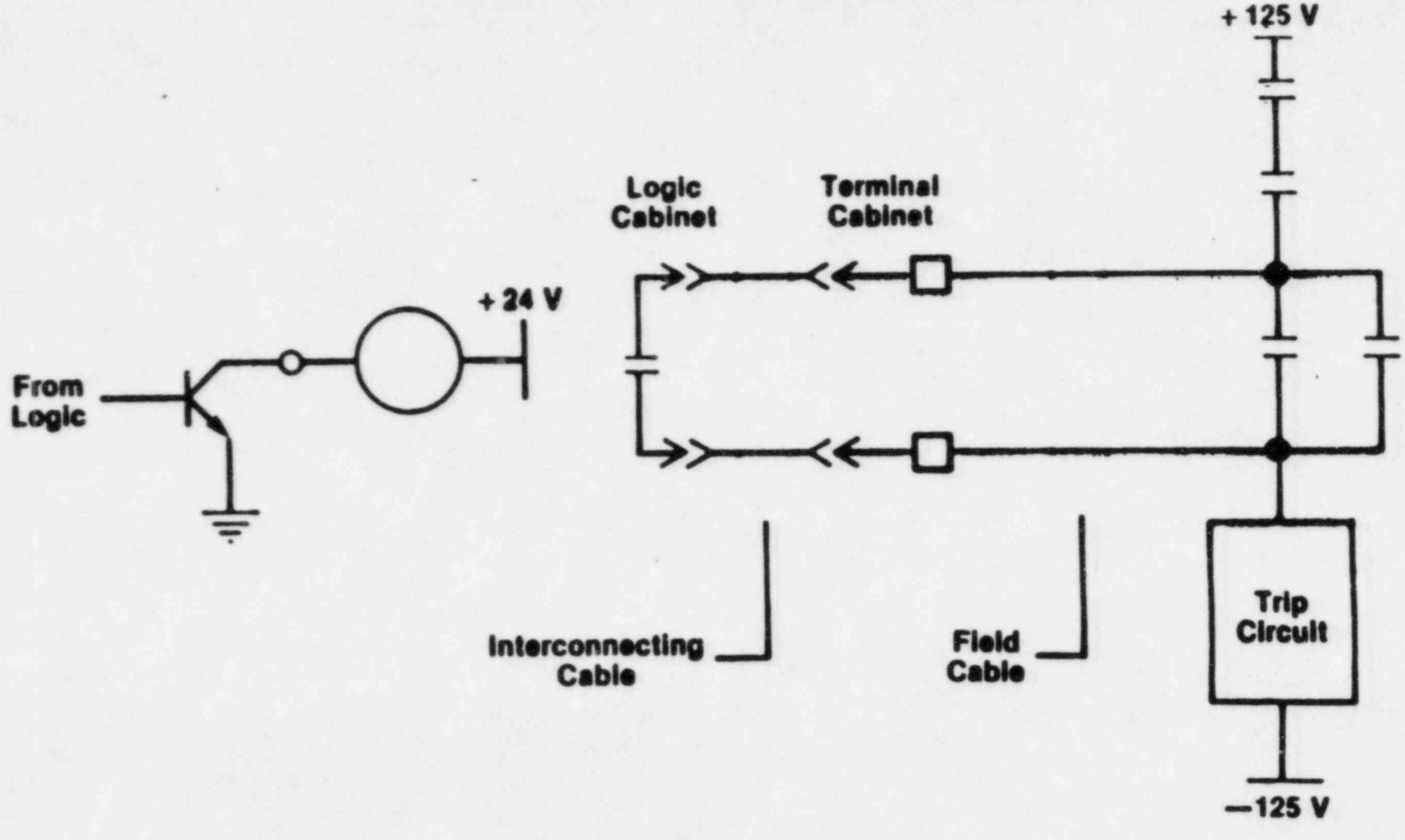
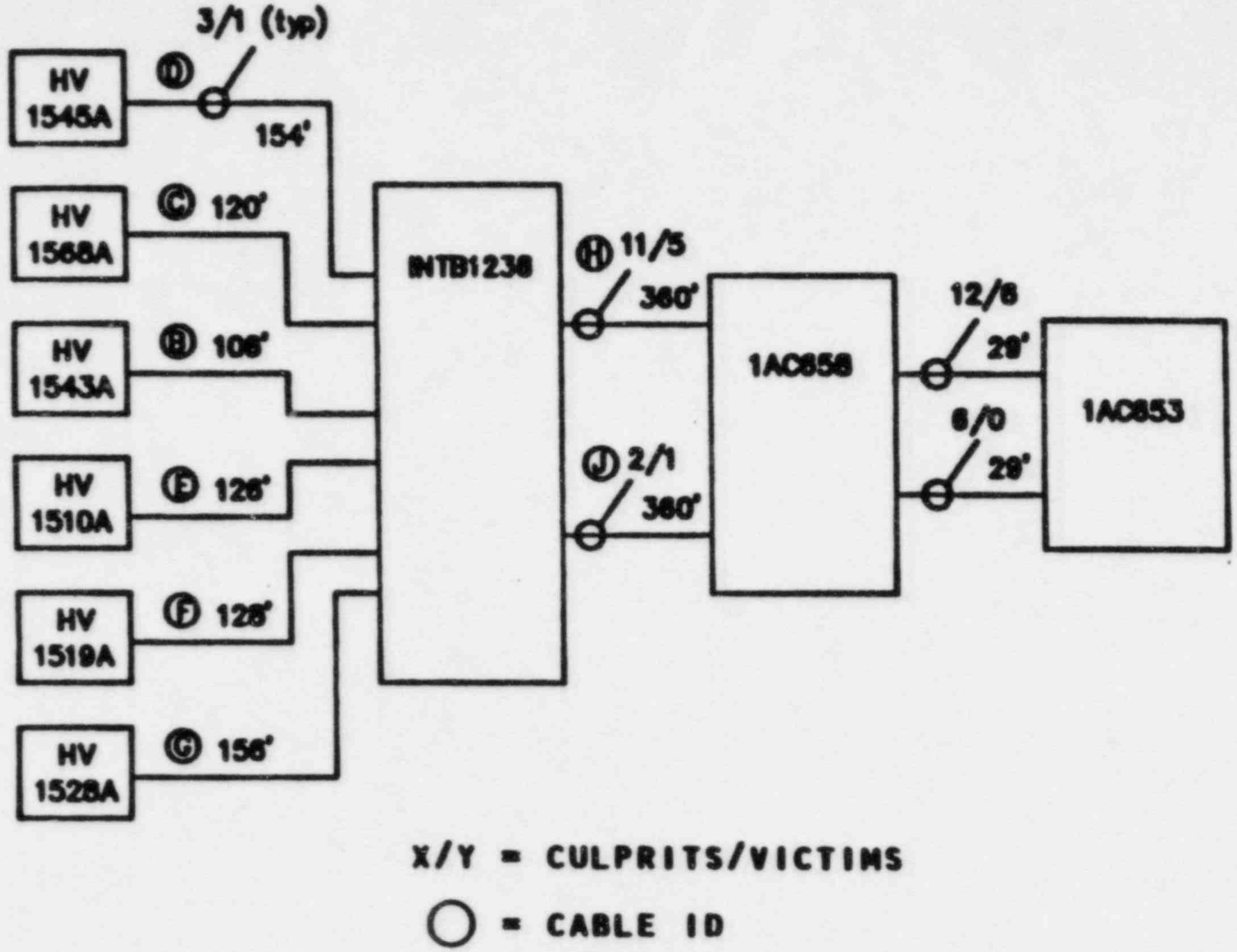
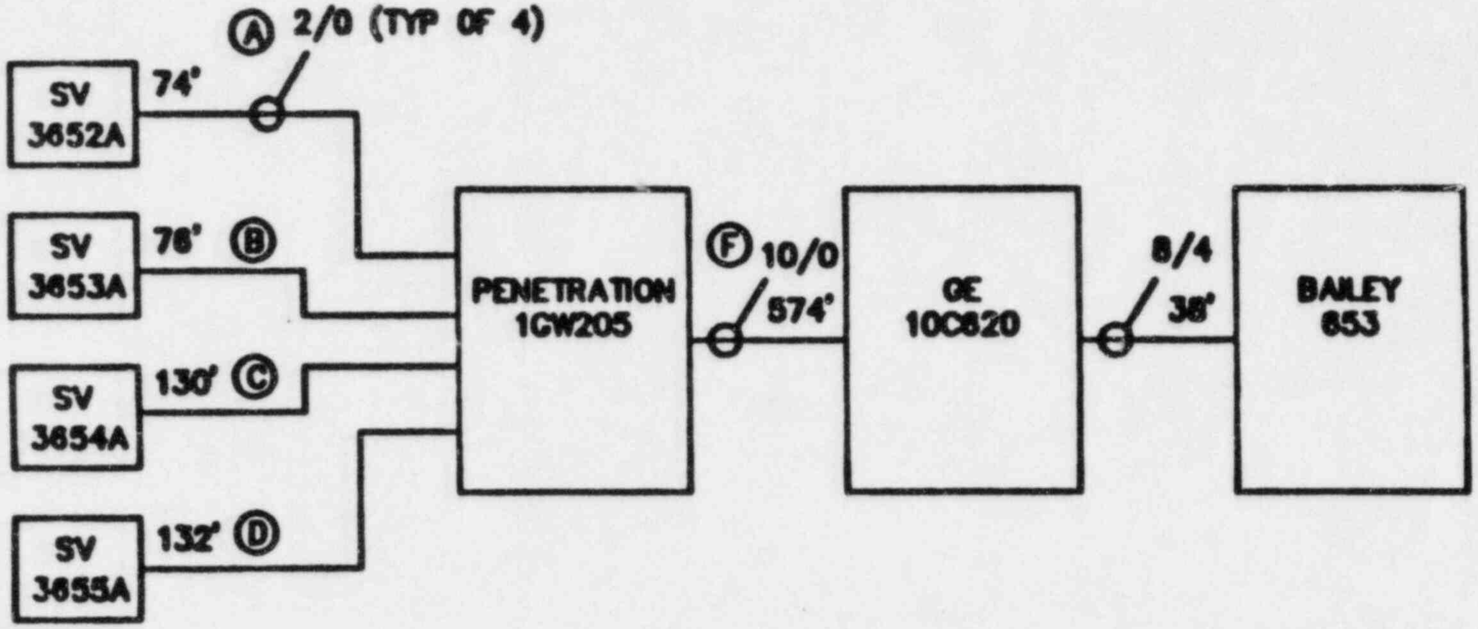


FIGURE 2.3 PAGE 18



FEED WATER HEATER VENT VALVES

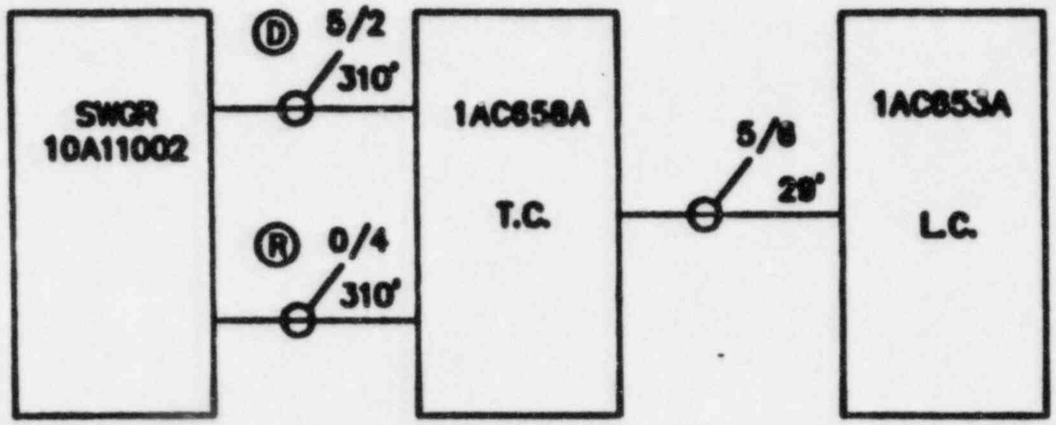
FIGURE 2.4 PAGE 19



X/Y = CULPRITS/VICTIMS

○ = CABLE ID

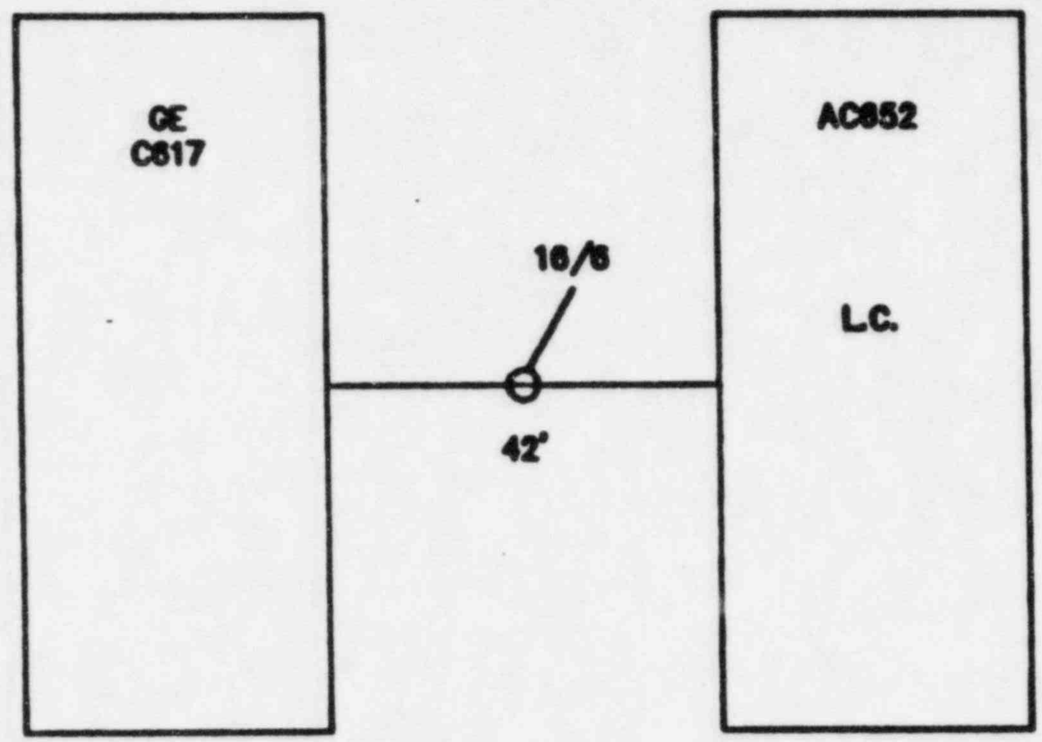
CONTROL AND INDICATION FOR ADS PILOT SOLENOID VALVES



X/Y = CULPRITS/VICTIMS

○ = CABLE ID

7.2 KV SWITCHGEAR TRIP COIL

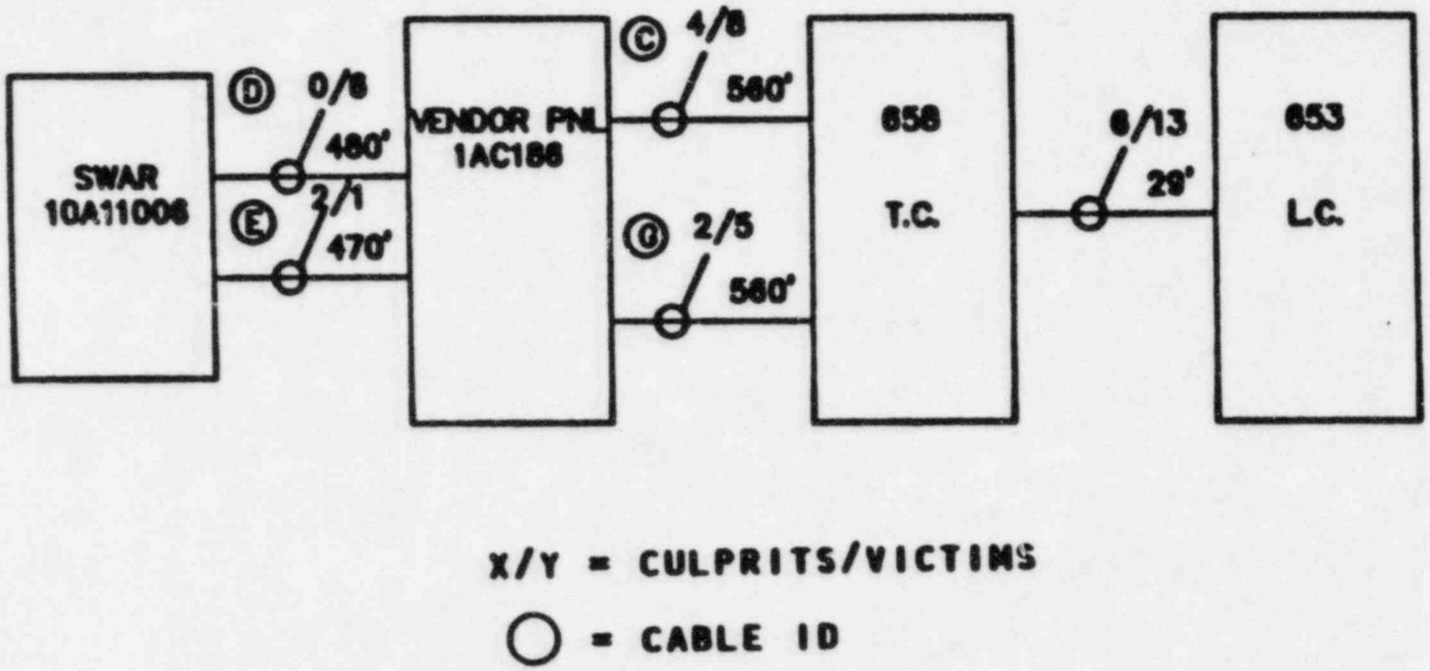


X/Y = CULPRITS/VICTIMS

○ = CABLE ID

BAILEY/GE INTERFACE RELAYS

FIGURE 2.7 PAGE 22



CHILLER COMPRESSOR CONTROL AND INDICATION

3.0 THREAT ANALYSIS: WIRE TO WIRE COUPLING

This section provides an explanation of the dominant threat coupling mechanism. Also, examples of measured transients are provided.

3.1 DOMINANT COUPLING MECHANISM FOR ELECTROMAGNETIC INTERFERENCE

Figure 3.1 (Page 28) typifies the dominant threat coupling mechanism. Only three relevant wires are shown in the figure but other culprit and/or victim wires are in the same multiconductor cable.

In the worst-case situation depicted in Figure 3.1, the return wire for the 125v DC supply and the load are outside of the multiconductor cable. Also, the breaker contact to which the input is connected, is open.

Due to the close spacing of wires in the multiconductor cable, there exists significant

Culprit-Wire-to-Victim-Wire Capacitance = C_{cv}.

Due to the collapse of the magnetic field in the inductive load, a large transient voltage - oftentimes kilovolts in amplitude - occurs on the load (culprit) wire when the System output relay contact is opened.

This is coupled via C_{cv} to the wire connected to the input buffer (victim; see Figure 3.1). Even though the victim wire voltage is less than that appearing on the culprit wire, that voltage can be large enough to cause the input to "think" that a valid input signal is present. This (erroneously) causes the system to perform those operations which <u>should</u> occur when there <u>is</u> a valid input signal, thereby causing a control system error called "falsing".

Falsing is caused by wire-to-wire coupling of electromagnetic interference (EMI). It can also be caused by the presence of a wire carrying 120v AC with or without the occurrence of a contact-opening transient. Without a transient, a lesser steady state AC voltage is induced on the victim wire.

It was wire-to-wire coupled EMI, both transient and steady state AC, that caused the effects described at the beginning of this report.

3.2 WIRE-TO-WIRE-COUPLING VIA INTRA-AND INTER-CABLE MEANS

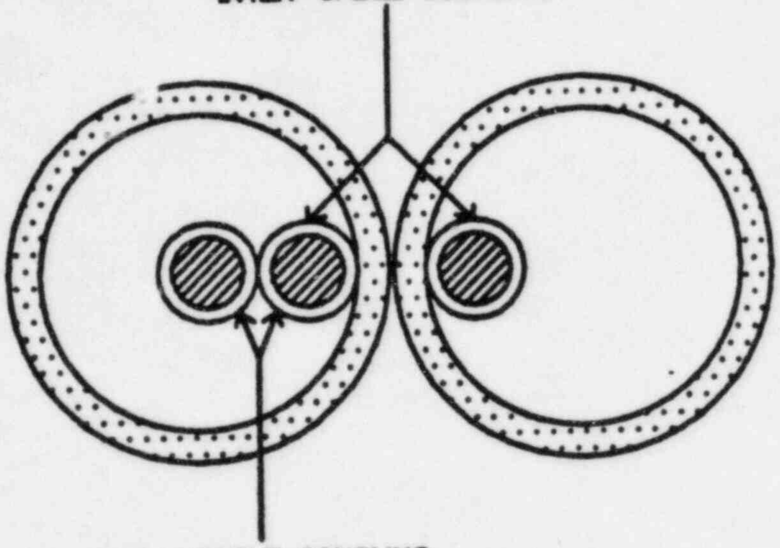


Figure 3.2

The capacitance, C_{cv}, in figure 3.1, is inversely proportional to the spacing of the wires:

$$C_{cv} = \text{Constant} \times \frac{1}{\text{Spacing Between Wires}}$$

Transient voltages can be coupled from a wire in one cable to a wire in another cable (inter-cable wire-to-wire coupling). Plant cabling is such that intra-cable wire-to-wire coupling is dominant because spiraling maintains close spacing between any two wires within that cable over the entire cable run. Spiraling also results in a varying space between wires in adjacent cables which, on the average, is much greater than that between wires within the same cable. Thus, C_{cv} between wires within a cable is much greater than that between wires which are in separate cables.

The focus of this report is on the worst-case: intra-cable wire-to-wire coupling, with C_{cv} measured between wires which are immediately adjacent to one another in a cable.

In practice there are more wires in the cables than are illustrated in Figure 3.2. This complicates theoretical determination of maximum wire-to-wire capacitance: it is more accurate to measure the capacitance.

3.2 WIRE-TO-WIRE-COUPLING VIA INTRA-AND INTER-CABLE MEANS (Cont.)

880 ft. of 12 conductor cable was used in the consultant's laboratory to conduct tests and measurements. The extrapolated value of maximum capacitance between wires measured on the cable is:

C_{cv}, Two-wire = 0.0969 Microfarads (uF)/2500'
(38.8 Picofarads (pF/foot)

C_{cv}, Eleven wire = 0.171 uF/2500' (68,4 pF/foot) (3.1)

(2500 ft represents the worst case)

The latter measurement reflects the total capacitance between a single wire and all other wires in the same 12 - conductor cable. Those data are useful for assessing the upper bounds on victim voltages due to multiple culprit wires.

The presence of non-culprit wires other than a single victim and a single culprit in a cable bundle can have a mitigating effect on victim wire voltage; the capacitance between the victim wire and those other wires reduces the victim wire voltage. The worst case assumption of no mitigating effects is used throughout this analysis. --------------**

3.3 MITIGATION OF EMI

The following program was used to reduce the victim-wire voltage induction and prevent falsing of the system.

(1) Determine worst case loads and cable lengths.

Details of this review have are on pages 7 - 23.

(2) Determine theoretical maxima of amplitudes and durations of transient waveforms as seen by the victim input(s)

See details on Pages 33 - 39

(3) Experimentally measure the transient withstand capability of the revised input buffer circuitry

Work done at consultant's laboratory.

** For bibliography of the above and other aspects of wire-to-wire coupled EMI. See Appendix A 1 & 2.

3.3 MITIGATION OF EMI (Cont.)

(4) Determine that the victim input voltage due to EMI does not cause the system to False.

i.e determine that the transient withstand capability (amplitude and duration) is larger than the amplitudes and durations induced on the input(s). This was carried out initially by experiment at the consultant's laboratory using equipment loaned from Hope Creek jobsite and will be an ongoing program throughout the startup phase.

3.4 EXPERIMENTALLY MEASURED TRANSIENT VOLTAGES

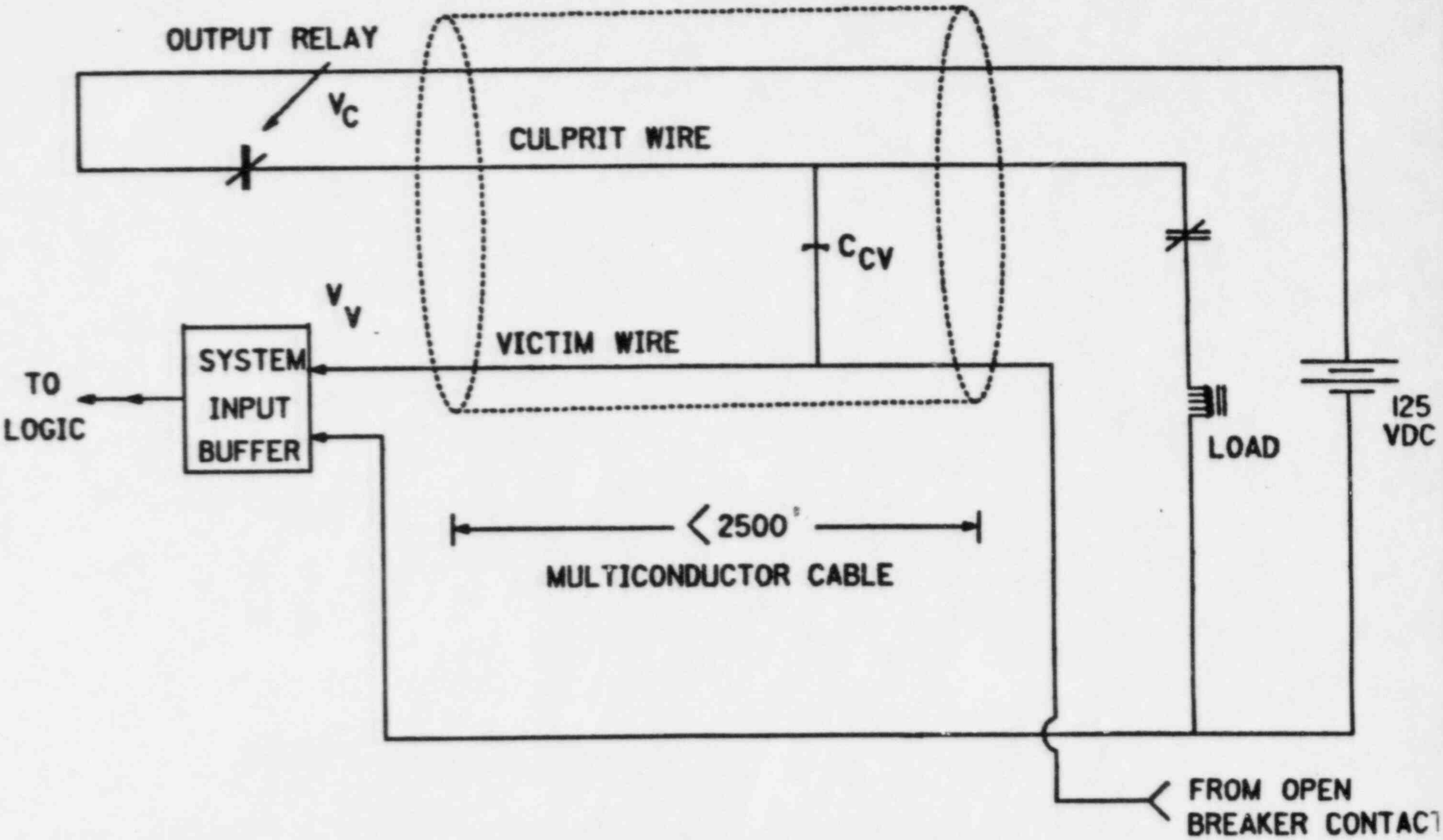
The approach used to insure that the revised input buffer circuit is immune to the worst case transients that can occur at Hope Creek, involves determination of theoretical upper bounds on the amplitudes and durations of transient voltages produced by various worst case Plant loads and then, evolution of an input buffer which is immune to those worst case threats. Thus, the design is based on theoretical worst case threats which are greater in amplitude and duration than those which actually occur in practice (typically, transient amplitudes observed in practice are on the order of 1/4 to 1/3 those predicted by theory).

In interpreting Figure 3.3 (Pages 29 & 30) relevant to the culprit voltages, it should be noted that those voltages are independent of the input impedance of the input buffer, but they do depend on the length of the cable connected across the load. The lesser victim voltages in Figure 3.4 (Page 31) are strongly dependent on the input impedance of the input buffer. The revised buffer has a relatively low input impedance, accounting for the small victim voltages shown in that Figure. Much larger voltages were measured when the original buffer circuitry was employed.

Figure 3.5 (Page 32) is a table of ranking of the worst case threats and the order is dependent on the maximum transient victim voltage (V_v)

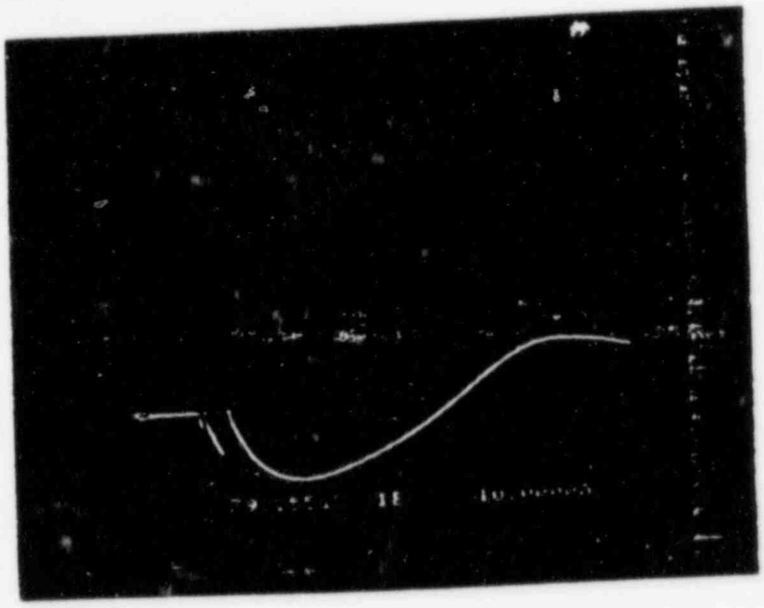
Load data in the table were determined either by actual measurements or by analysis. Calculations were then made by extrapolation of data obtained from measurements and testing carried out on the 880 ft. of Okonite cable at the consultants laboratory. Therefore it will be seen that maximun victim voltage (V_v), is a function of length, the capacitive coupling, the number of conductors, coil voltage and inductance.

FIGURE 3.1



TYPICAL 480 V TRIP CIRCUIT

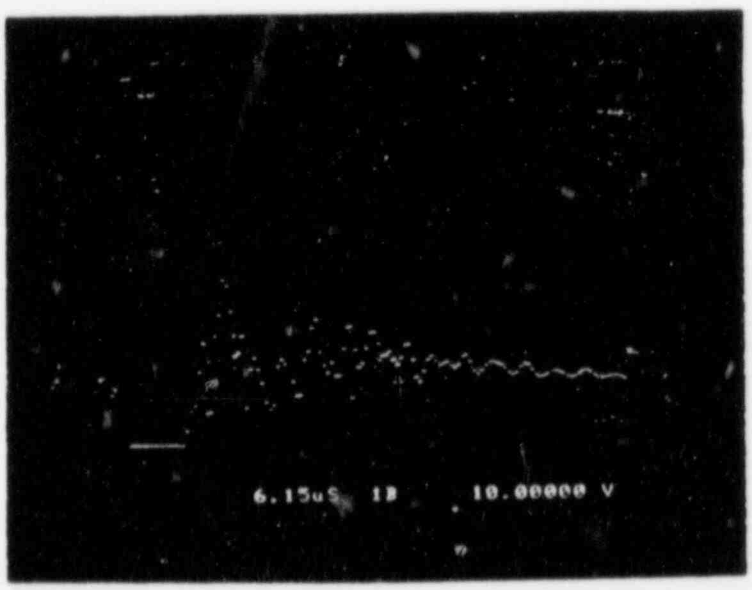
DOMINANT THREAT COUPLING MECHANISM



(A) 4.16 kV Breaker
Closing Coil

Scales:

100 V/Div VERT
793.6 uS/Div HORIZ



(B) Expanded view of
Front end of
Transient in (A)

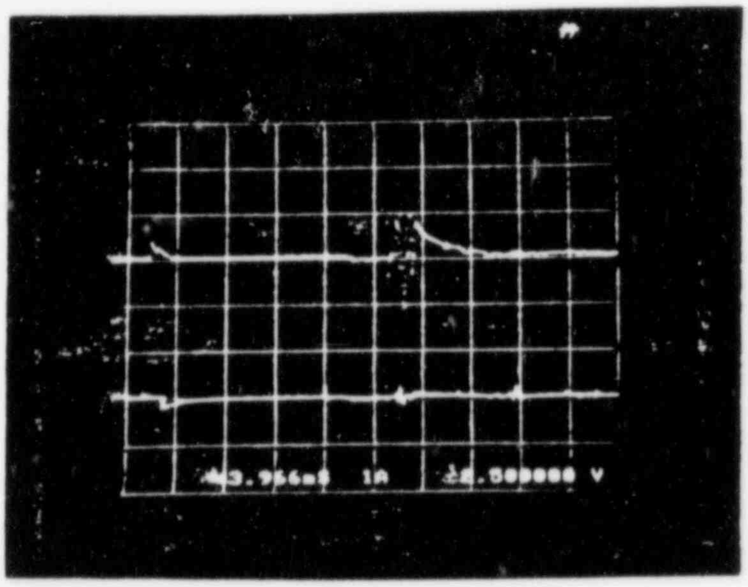
Scales:

100 V/Div VERT
6.15 uS/Div HORIZ

CULPRIT WIRE TRANSIENT VOLTAGES

(From on-site experiments by PSE&G and Bechtel Personnel)

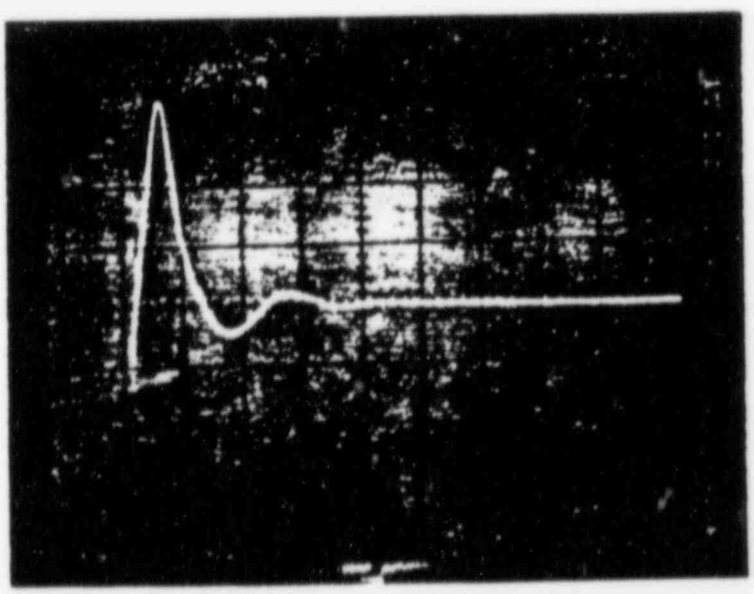
Figure 3.3a & 3.3b



(C) Coils on 4.16 kV Breaker

Scales:

Top: 25 V/Div VERT
3.97 mS/Div HORIZ
Bot: 50V/Div VERT
3.97 mS/Div HORIZ



(D) Agastat Timer Coil with 0.05 uF Cable Capacitance

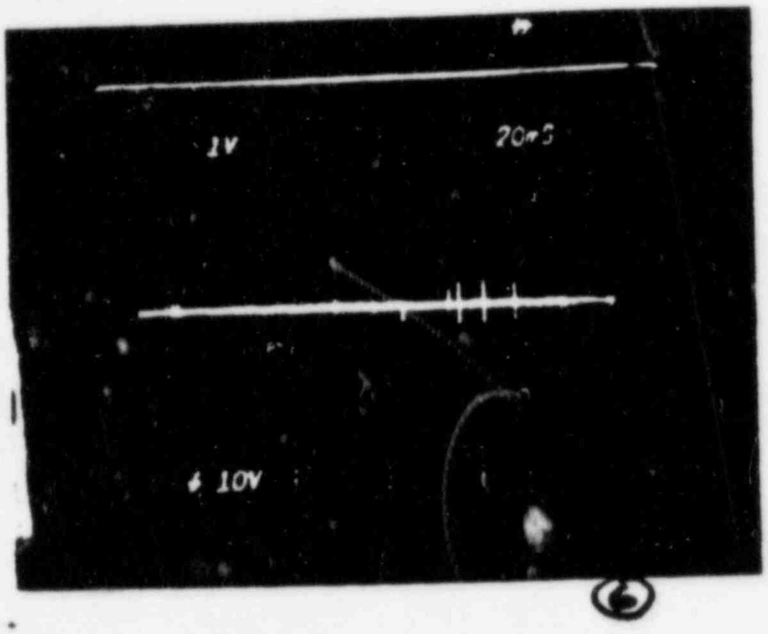
Scales:

229 V/Div VERT
1.0 mS/Div HORIZ

CULPRIT WIRE TRANSIENT VOLTAGES (Cont)

(From on-site experiments by Consultant's personnel)

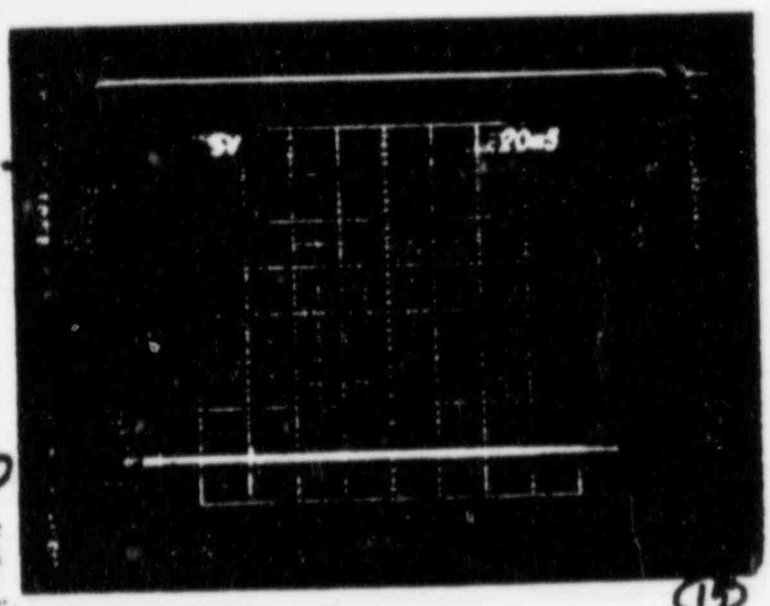
Figure 3.3c & 3.3d



(A) 7.2 kV Breaker

Scales:

10 V/Div VERT
20 mS/Div HORIZ



(D) 4.16 kV Breaker

Scales:

50 V/Div VERT
20 mS/Div HORIZ

VICTIM WIRE TRANSIENT VOLTAGES WITH REVISED INPUT BUFFER

(From on-site experiments by Consultant's personnel)

Figure 3.4

THEORETICALLY DERIVED RANKING OF EMI SUSCEPTIBILITY

BECHTEL REFERENCE	LOAD	CABLE LENGTH		CURRENT		INDUCTANCE		AHL	TRANSIENT MAX Vc	TRANSIENT MAX Vv	t (ms)	Ccv	R	DAMPING FACTOR	CATEGORY CASE	RANK#
7.2KV SWITCHGEAR TRIP COIL	TRIP COIL	1550ft	X	5.1A	X	0.14H	=	1110	6.2kV	281V	0.672	0.0955uF	417 OHMS	244	III 1	1
CHILLER COMPRESSOR CONTROL AND INDICATION	AGASTAT TIMER	1069ft	X	0.625A	X	0.665H	=	444	1.92kV	65.2V	12.7	0.0782uF	105 OHMS	3,437	VI 2	2
RSP INTERFACE	GE HDR RELAY	1903ft	X	0.125A	X	5.1H	=	1258	1.04kV	50.1V	85	0.0738uF	120 OHMS	19,196	VI 5	3
4.16kV ITE BKR TRIP COIL	TRIP COIL	46ft	X	5.0A	X	0.142H	=	32.7	44.6kV	40V	11.4	0.0018uF	25 OHMS	510,000		4
CONTROL AND INDICATION FOR ADS PILOT SOLENOID VALVE	SOLENOID/RELAY	38ft	X	0.4A	X	13.90H	=	212	38.9kV	29V	88.8	0.0015uF	313 OHMS	386,000	II 2	5
TEST BYPASS FOR CONDENSATE STORAGE TANK VALVE	TWO PARALELL GE RELAYS	949ft	X	0.24A	X	1.5H	=	342	1.53kV	28V	5.76	0.0368uF	521 OHMS	601	VI 3	6
FEED WATER HEATER VENT VALVES	SOLENOID VALVES	545ft	X	0.13A	X	2.50H	=	177	1.42 kV	14V	11.4	0.0120uF			II 1	7
BAILEY/GE INTERFACE RELAYS	AGASTAT GP RELAY	42ft	X	0.10A	X	45.0H	=	189	16.6kV	14V	72.0	0.0016uF	1250 OHMS	70,675	VI 1	8
CHILLER COMPRESSOR CONTROL AND INDICATION	P&B RELAYS	1069ft	X	0.12A	X	1.4H	=	180	.07kV	14V	3.3	0.0415uF			VI 2	9
THROTTLING MOV	PILOT RELAY	859ft	X	0.075A	X	1.9H	=	122	0.57kV	9V	2.66	0.0333uF	1430 OHMS	112	VI 4	10
CHILLER COMPRESSOR CONTROL AND INDICATION	480V BREAKER TRIP COIL	1069ft	X	1.83A	X	0.65H	=	1274	7.25kV	147V	19.12	0.0415uF	68 OHMS	13,600	VI 2	N/A

4.0 CIRCUIT DESIGN FOR IMMUNITY TO EMI

Figure 4.1 (Page 39) illustrates the original and revised buffer circuitry for the Bailey 862 Logic System input card. The changes are discussed as follows:

CONSIDERATIONS

The more important aspects of the design considerations that were incorporated are listed below:

1) 60Hz noise level rejection

2) Transient rejection, voltage level

3) Transient rejection, time value

4) Power dissipation in the cabinets

5) Manufacturability, including but not limited to size

6) Reliability

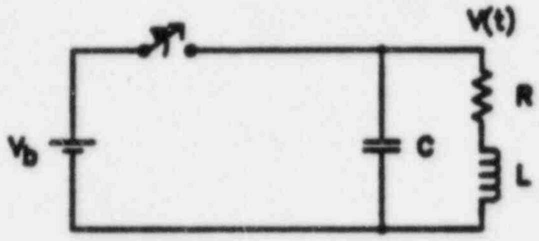
7) System Compatibility

CIRCUIT

The revised circuit; see figure 4.1 (Page 39); provides inrush current protection by inclusion of the 24.9 ohm resistor or the 2K ohm resistor. The staple jumper choice of the values will dedicate the input circuit to either 120v AC or 125v DC and 24v DC service. The 2uF capacitor acts as the discriminator between noise and valid signals. The bridge network and zener diodes limit current and therefore power dissipation. The 2 uF capacitor helps select between a valid signal and a short duration pulse by increasing the turn-on time of the input stage.

4.1 THEORETICAL MAXIMA OF AMPLITUDES AND DURATION OF TRANSIENTS

The initial purpose here is to determine the maximum transient culprit voltage. Towards that end, consider the simple RLC circuit shown below:



This is the culprit circuit with, e.g. V_b = 125v DC: the inductance and resistance are those associated with a Plant load, the capacitance is that due to internally distributed capacitance across the inductive/resistive load plus that due to the Plant cabling :

$$C = \text{Capacitance across load} = C_{distributed} + C_{cable} \cong C_{cable}, \quad (4.1)$$

where approximation arises because for Plant loads, the cable capacitance is much greater than the capacitance distributed across the load.

The capacitance from the load wire in the cable bundle shown in Figure 3.1 to the common wire of the load is at least equal to the culprit-to-victim capacitance, C_{cv}:

$$C \cong \text{Capacitance across load} \geq C_{cv}; \; C = C_{cv}, \text{ worst case.} \quad (4.2)$$

In part, C arises inside the cable bundle between the culprit and 125v DC wire (see Figure 3.1). Also, there is capacitance from the load wire in the bundle to all of the other wires in the cable, at least some of which are returned to common via closed contacts in the field.

Typically there are twelve conductors in the cable. If all of those conductors were returned to common, the larger capacitance given in (3.1) would apply. As will become apparent below, the assumption $C=C_{cv}$ is a conservative one, as the amplitude of the transient decreases for larger values of C.

4.1 (Cont.)

It is assumed that the switch is opened at time $t = 0$. Worst case, the switch is perfect insofar as no arcing occurs on opening (arcing is present in any practical switch; see Section 4.4). Prior to $t = 0$. there is a steady state DC current

$$I_o = \frac{V}{R} \qquad (4.3)$$

The above circuit is said to be underdamped if

$$D = \frac{4L}{R^2C} > 1 \qquad (4.4)$$

All known worst case Plant loads are underdamped. For this underdamped condition, the general character of v(t) is **

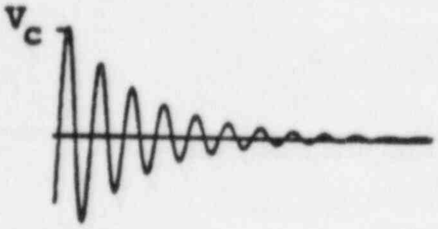
$$v(t) = V_c e^{-Rt/2L} \sin(2\pi f_o t+\phi), \qquad (4.5)$$

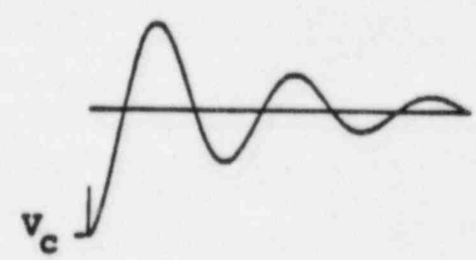
where f_o is the frequency of oscillation and

$V_c = I_o(L/C)^{1/2}$ = Maximum peak amplitude of the transient on the culprit wire and

$I_o = V_b/R$ = Steady-state current prior to opening the switch.

The general oscillatory character of (vt) is shown below.





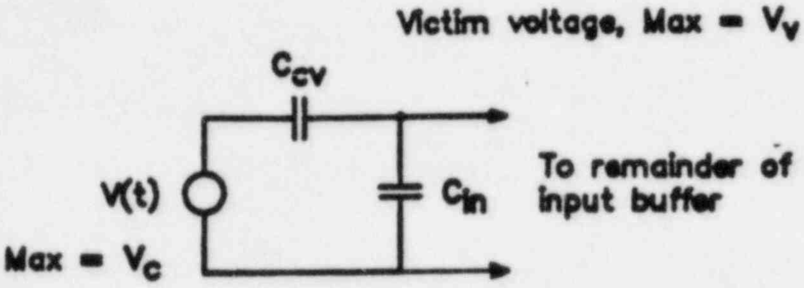
Duration of the transient is defined as the time required for the transient to decay to 1/e (= 36.8%) of its peak value:

$$\tau = \text{Duration of transient} = 2L/R \qquad (4.6)$$

** For bibliography see Appendix A. 3 & 4

4.2 MAXIMUM VICTIM-WIRE VOLTAGE

For transient analysis purposes, each of the input buffers shown in Figure 4.1 can be modeled as a pure capacitance, C_{in}. (The effect of the input resistors in the circuits in Figure 4.1 are to slightly mitigate victim voltages. Worst case, that mitigation is neglected). The equivalent circuit for coupling of the transient from the culprit wire to the victim wire is as shown below:



The voltage generator, v(t) is the same as that in Figure 4.2. The maximum voltage at the input of the circuit is:

$$\text{Maximum victim voltage} = V_v = V_c \frac{C_{cv}}{C_{cv} + C_{in}} \cong V_c \frac{C_{cv}}{C_{in}} \quad ,(4.7)$$

where the approximation is for a well designed input circuit where $C_{in} >> C_{cv}$. For good or poor designs, the approximation is worst case.

But, from (4.5) with the worst case assumption $C = C_{cv}$ of (4.2),

$$V_c = I_o \, (L/C_{cv})^{1/2} \quad (4.8)$$

Substitution of (4.8) into (4.7) leads to:

$$V_v = I_o \, (LC_{cv})^{1/2} = \frac{V_b}{RC_{in}} (LC_{cv})^{1/2} \quad (4.9)$$

From (4.9), it is apparent that:

- o Maximum victim voltage is proportional to the square root of the length of the cable (C_{cv} is directly proportional to the length), and
- o Maximum victim voltage is inversely proportional to the input capacitance of the input buffer.

4.2 MAXIMUM VICTIM-WIRE VOLTAGE (Cont.)

The second observation implies that, due to the input capacitors in Figure 4.1, the revised input buffer will withstand 2.0 uF/0.1 uF = 20 times the transient amplitude that can be withstood by the original input buffer.

It is the increased input capacitance of the revised input buffer which enhances the transient withstand capability.

4.3 MEASURING TRANSIENT WITHSTAND CAPABILITY

The nature of each of the circuits shown in Figure 4.1 is such that response is to the total energy of the input signal - proportional to voltage x time for transient inputs which are of short duration in comparison with the rise time of the circuit. Thus, for example, the victim wire (i.e., the input circuit) can withstand input voltages which endure for less than 10 - 20 milliseconds (ms) which are larger than the steady state level at which the circuit is designed to provide actuation. For the revised input buffer, that steady state level is about 75 - 82 volts for an input configured (via the jumpers shown in the circuits in Figure 4.1) for either 125v DC or 120v AC inputs.

In Figure 4.2, victim wire voltages and durations below the curves do not cause falsing. Above the curves, falsing occurs. The revised circuitry does provide adequate withstand capability.

The data for the curves in Figures 4.2 were measured at the consultant's laboratory for the final production model input buffers.

The duration axes in Figure 4.2 are those of a square wave input signal applied to the input buffer which is "on" for the times given on the horizontal axes, and "open" at other times. In relation to the durations of transients cited in (4.6) the square-wave measurement technique is conservative insofar as the volts x time of square wave of duration T is greater than that for a transient with the duration cited in (4.6).

The two durations would be exactly equal if the transient waveform did not oscillate during the decay period (which due to underdamping, it does;). The net result of this conservatism is that the input circuit will actually withstand longer-duration transients than are indicated in Figure 4.2 without falsing.

4.4 RELATIONSHIP OF THEORY TO OBSERVED TRANSIENTS

The amplitudes of transients observed in practice are substantially less than those predicted by the theory given in section 4.2 (typically, 1/4 to 1/3). The dominant cause of the difference is arcing of the contact or actuator. That arcing dissipates some of the energy stored in the inductive load's magnetic field so the amplitude of the transient is reduced. Arcing is particularly noticeable in Figures 3.3a and 3.3c.

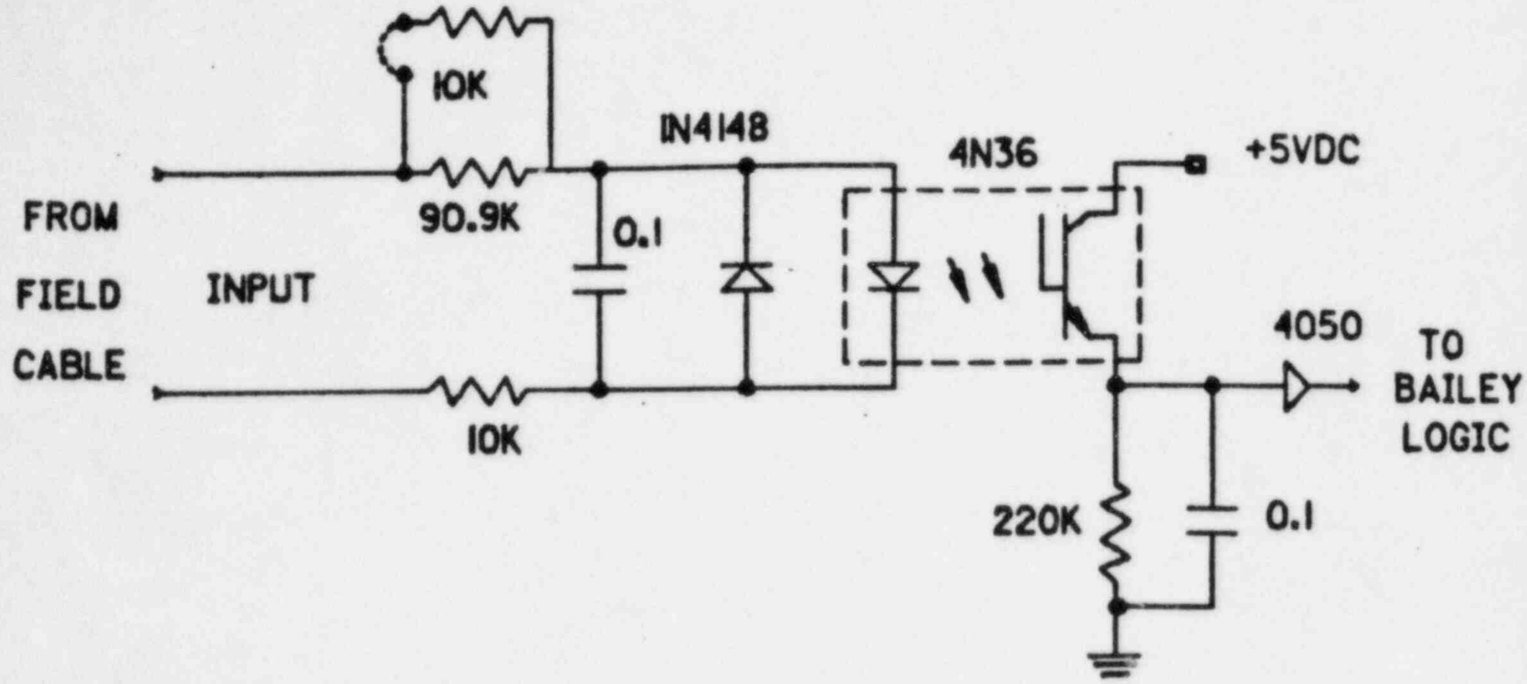
Durations of transients observed in practice are usually in close agreement with those which are theoretically predicted. Measurements of durations of transients induced by opening the trip coil on a Plant 480 volt breaker were within 20% of those predicted by theory.

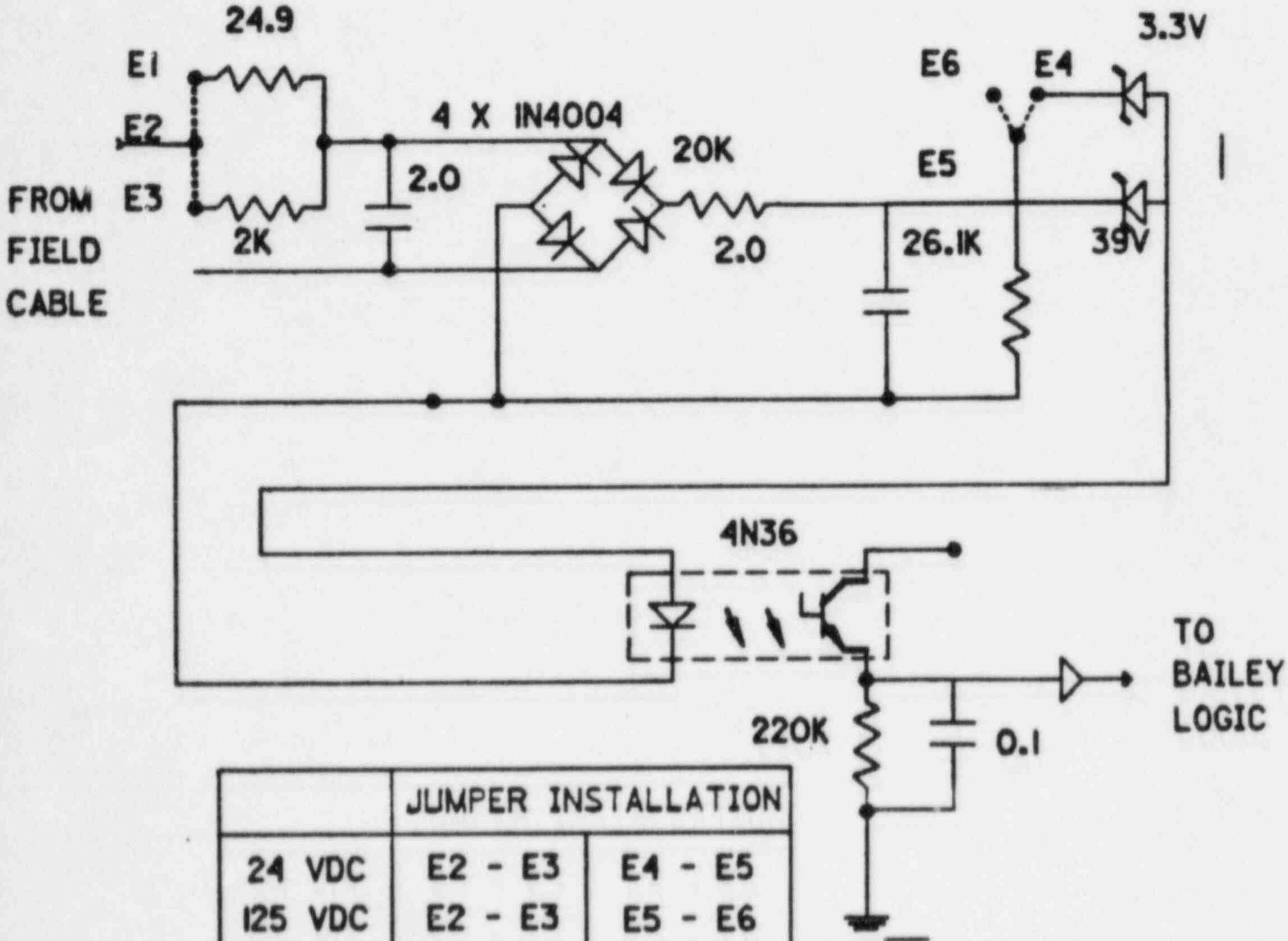
4.5 DETERMINATION OF IMMUNITY TO EMI

Immunity is assured when the amplitudes and durations of victim-wire-transients from inductive loads fall under the curves given in Figure 4.2 (Page 40). The numbers of the plots are the rankings shown in Figure 3.5 (Page 32).

Initially, the 480v breaker appeared to be the most serious threat but by virtue of the timing of contact actuations internal to the breaker it does not pose a threat. Figure 4.3 illustrates the breaker. Both the closing and tripping coils represented potential threats. However, the contact marked "trip" in Figure 4.3, remains closed when the closing coil is actuated, that actuation occurring either at the system or the interrupting contacts at the breaker. The transient generated when the tripping contact in the breaker is opened by the action of the closing coil is, in part, dissipated in the "tripping" of the breaker. That part of the transient which is due to leakage through the tripping contact, "looks" into a low rather than high impedance. Therefore, the transient voltage induced on the culprit wire is, relative to the transient occurring across the tripping coil, very small.

It was confirmed by measurements at the Consultant's laboratory that neither the tripping nor closing coils of the 480v breaker constitute a significant transient threat and is therefore, marked N/A in the table.

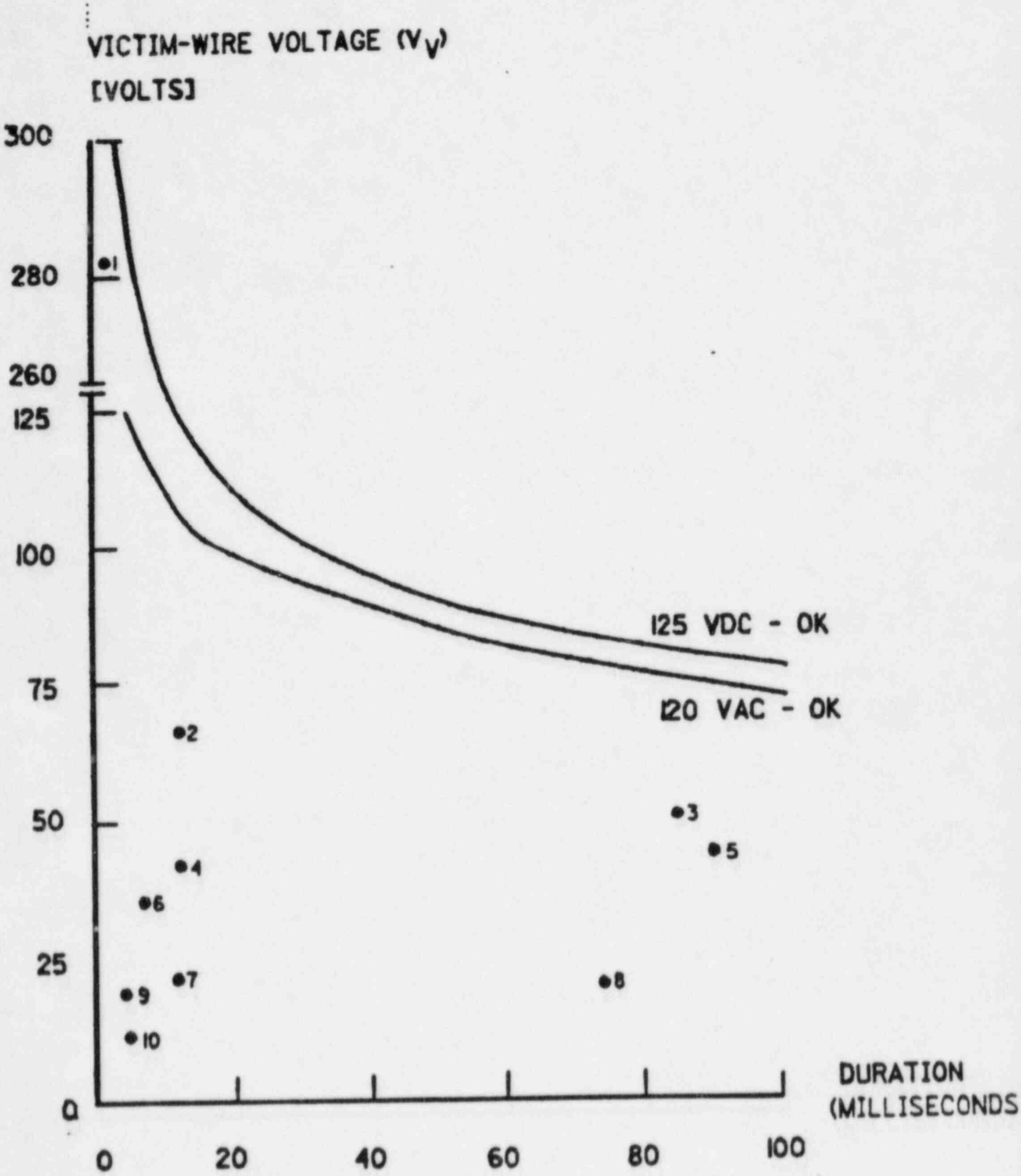




	JUMPER INSTALLATION	
24 VDC	E2 - E3	E4 - E5
125 VDC	E2 - E3	E5 - E6
120 VAC	E1 - E2	E5 - E6

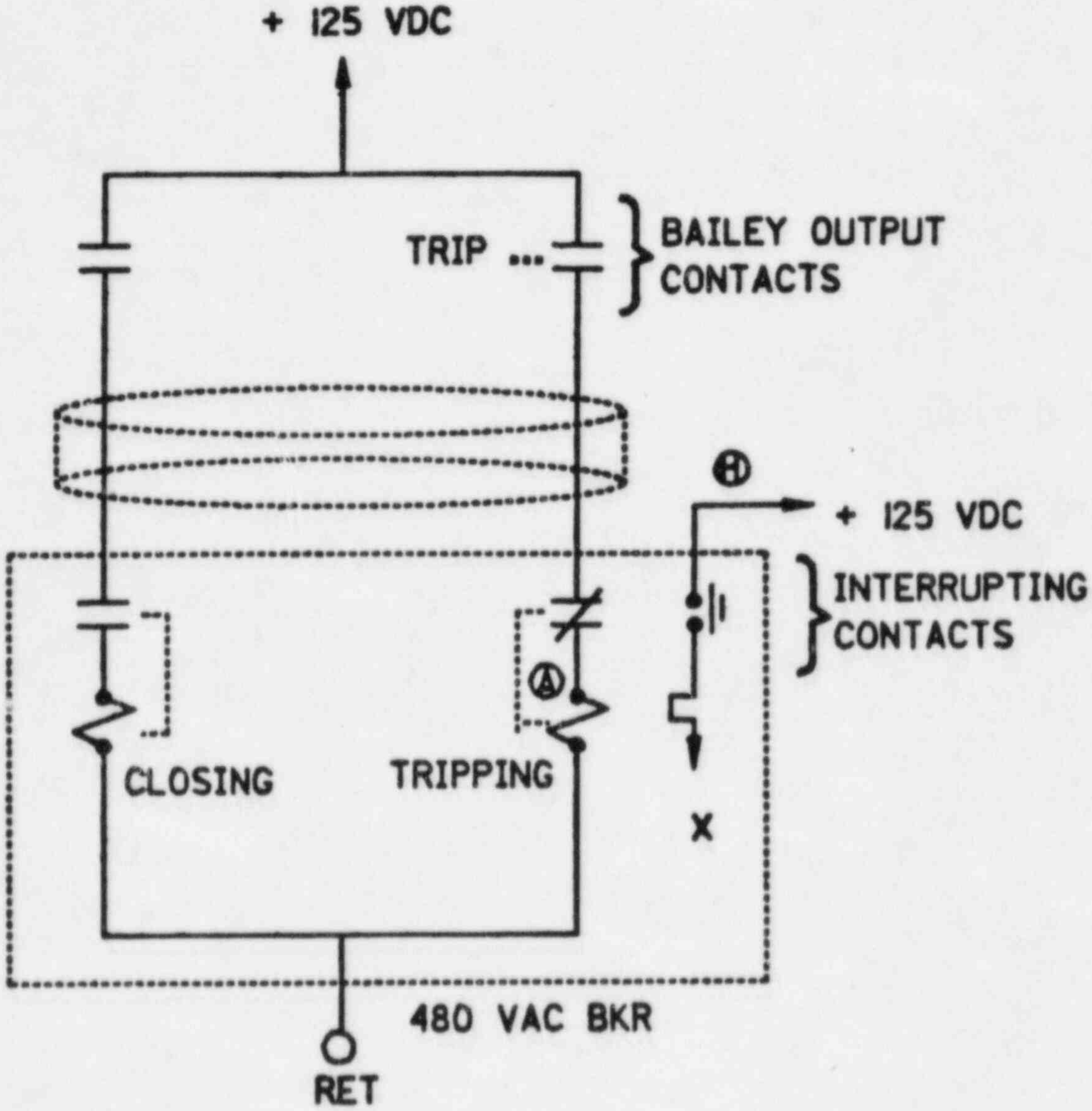
ORIGINAL (TOP) AND REVISED (BOTTOM) INPUT CIRCUITRY

FIGURE 4.1



ANALYTICALLY DETERMINED INPUT BUFFER CONFIGURATION
TRANSIENT THREATS VS.
MEASURED INPUT BUFFER IMMUNITY LEVEL

FIGURE 4.2



480 V BREAKER

FIGURE 4.3   PAGE 41

5.0 OTHER SOLID STATE DIGITAL SYSTEMS EVALUATION

All other 1E solid strte digital systems were evaluated for susceptibility by a review of the results of any testing that may have been carried out by the vendor at the place of manufacture and by a study of the input circuitry.

The results of this evaluation follows:

5.1 Emergency Load Sequencer

This system utilizes a field buffer module that accepts only DC voltage and has been tested for EMI. Review of the circuit design and EMI test report verifies that this system is capable of rejecting induced AC 60 Hz noise and the transient spikes identified by the analysis and testing earlier in this report.

Further verification will be obtained during pre-operational testing which is presently scheduled for December 1985.

5.2 Radiation Monitoring System

All the cables used for this system are twisted shielded pairs which run in the instrument cable tray. This system will be tested to MIL-STD-462 (July 1967). The cable type and specification requirement for EMI immunity will render this system acceptable.

Further verification will be obtained during pre-operational testing which is presently scheduled for December 1985.

5.3 Redundant Reactivity Control System

A review of the input circuitry and inductive loads on the system, indicate that no potential threat exists. There is a mix of 125v DC and 24v DC in some cables. However, these are used only for interrogation purposes and will not generate a spike of any magnitude

Further verification will be obtained during pre-operational testing which is presently scheduled for December 1985.

6.0 EFFECT OF DESIGN CHANGE ON BUFFER INPUT CONTACTS

Due to the modification of the Bailey logic module input (LMI) buffers, increased steady state and inrush currents can be expected at the field side of the input buffers. In some cases field contacts (i.e. control switches, relays, pressure switches, etc.) provide input to more than one buffer. In order to avoid damaging these switches, a survey was conducted to identify those cases where contact ratings may be exceeded by excessive LMI buffer loading.

Using information supplied by Bailey regarding maximum allowable LMI fanout for various switch categories, all logic diagrams were reviewed to identify cases where the number of fanouts allowable for a particular contact type were exceeded.

The review identified all field contacts that fanned out to four or more input buffers at each voltage level of 24v DC, 125v DC and 120v AC.

For each case identified in the review, the inrush and steady state (S.S) currents predicted by Bailey were compared to the contact ratings provided by the switch vendors. In cases where the predicted inrush current exceeded the "make" rating of the contact or when the steady state current exceeded the "break" or "carry" ratings, the case was flagged as having a problem.

6.1 SUMMARY.

Problems identified in the review are:

1. Emergency load sequencer panels 1A - DC428 output relays, Airpax - North American Phillips (NAP) P/N B07D931BD1, may not have sufficient contact clearance to break current at 125v DC.

2. PSL-1389; calculated inrush current is 1.26A. Contact rating @ 125v DC is 0.3A, make, break and carry.

3. PSH-3109 fans out to 11 buffers, the calculated inrush is 47.7A. Contact rating @ 120v AC is 24A, make, break and carry.

4. PSL-3151A2 fans out to 4 buffers, calculated inrush is 21.2A. Contact rating @ 120v AC is 15A.

Figure 6.1 (Page 45) is a table of fanouts in excess of Bailey reccomendations.

6.0 EFFECT OF DESIGN CHANGE ON BUFFER INPUT CONTACTS (Cont.)

5. The interrogation voltage of Bailey output modules and relays in Bailey analog systems is 125v DC. By changing this to 24v DC, the inrush current is within acceptable limits.

6.2 RESOLUTION (See para. 6.1 for related item numbers)

1. The ELS vendor conducted a series of tests to show that in most cases the relay contact rating was adequate. In those cases where it was not, an interposing relay will be fitted with a contact rating suitable for the duty.

2. An interposing relay will be fitted with a contact rating suitable for the duty.

3. An interposing relay will be fitted with a contact rating suitable for the duty.

4. An interposing relay will be fitted with a contact rating suitable for the duty.

5. The interrogating voltage of Bailey output modules and relays has been changed to 24v DC and the wiring changed to suit.

6.3 TURN-ON/TURN-OFF TIME DELAYS

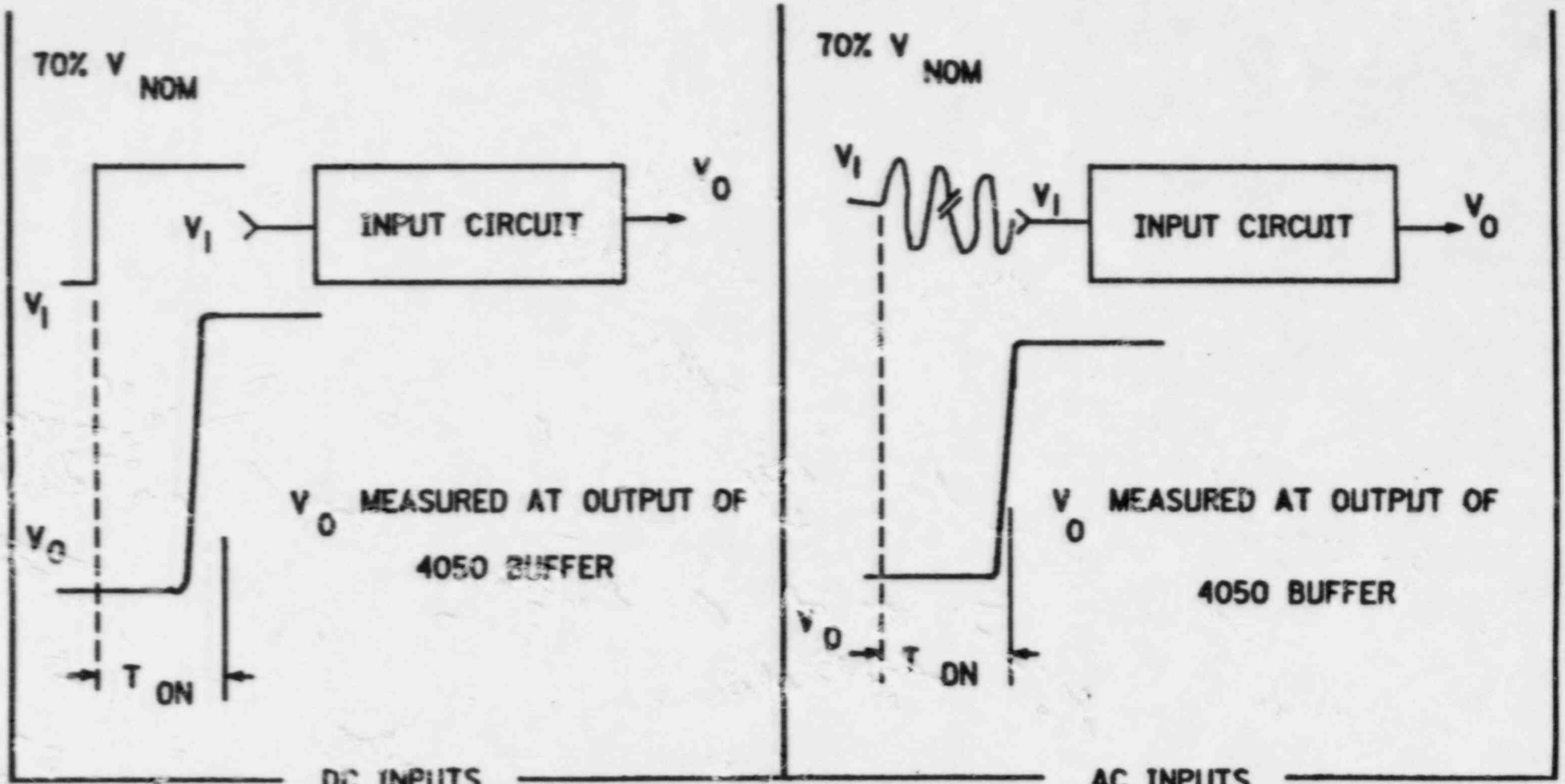
The design criteria for the Bailey 862 logic cards, provides for an input circuit turn-on time of within 100 ms with a similar period for the turn-off time. The modification changed the timing ranges such that problems of a logic racing type were encountered when testing the 4.16kV bus transfer system. This was resolved by reprogramming the FPLA chip on the logic module and carrying out an extensive review of all other circuits.

The curves of the turn-off and turn-on times are shown in Figures 6.2 and 6.3. The original and revised times are as follows:

Turn-off time mS	24v DC	125v DC	120v AC
Original	12	12	12
Revised	104	68	90
Turn-on Time mS			
Original	0.3	0.3	0.3
Revised	17	56	55

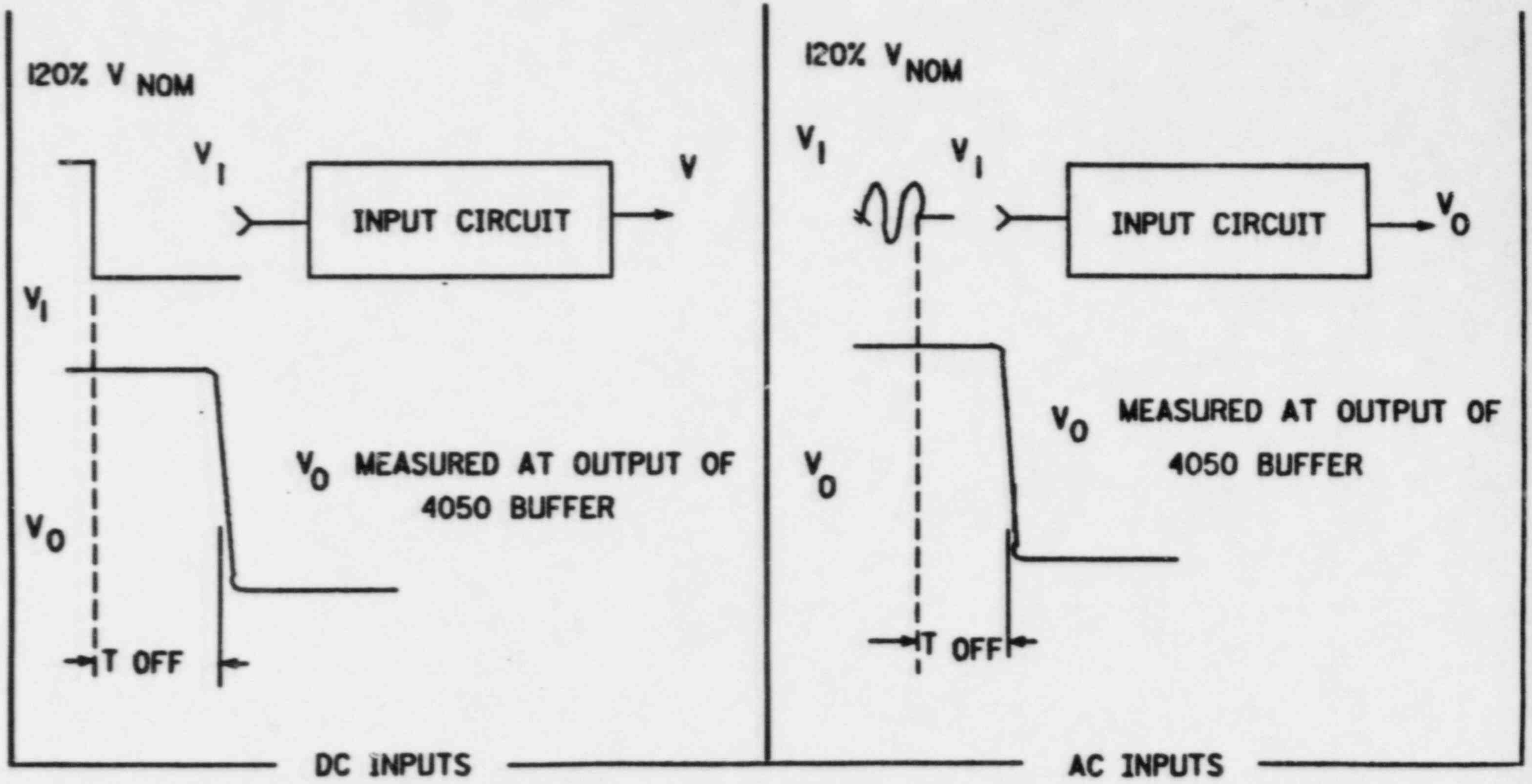
ECONTACTS WITH FANOUTS IN EXCESS OF BAILEY RECCOMENDATIONS

CONTACT REFERENCE: BECHTEL TAG OR EQUIP. NO.	CONTACT REFERENCE: MANUFACTURER	CONTACT REFERENCE: PART NO.	LOGIC DWG. REFERENCE	CONTACT VOLTAGE	NO. OF FANOUT	PREDICTED CURRENT: S.S.	PREDICTED CURRENT: INRUSH	CONTACT RATINGS: MAKE	CONTACT RATINGS: BREAK	CONTACT RATINGS: CARRY	PROBLEM EVIDENT Y? N?	DEVICE P/O	ITEM #	VENDOR PRINT
			X X X X X X	X X X	X X X							X X X	X X	X X X
KWA014 (HSS-4410A,10C399)	Struthers-Dunn	219BBX	J-103-0 (2)	125VDC	16	0.07A	1.12A	30A	0.5A	10A	N	J201(Q)	N/A	N/A
KWB014 (HSS-4410B,10C399)	"	"	"	"	52	0.23	3.64	"	"	"	N	"	"	"
KWD014 (HSS-4410D,10C399)	"	"	J-103-0 (3)	"	24	0.11	1.68	"	"	"	N	"	"	"
Seq. Pnl. AC428 Output	N.Am. Phillips	007931001	J-105-0(2)	125VDC	56	0.25	3.92	10	0	10	Y	JB10(Q)	N/A	N/A
Seq. Pnl. CB428 Output	"	"	"	"	54	0.24	3.78	"	"	"	Y	"	"	"
Seq. Pnl. BC428 output	"	"	"	"	41	0.18	2.27	"	"	"	Y	"	"	"
Seq. Pnl. DC428 output	"	"	"	"	54	0.24	3.78	"	"	"	Y	"	"	"
PSL 1309	United Electric	J302S164A	J-01-0 (2)	125VDC	18	0.08	1.26	0.3	0.3	0.3	Y	J5203	5.1	N/A
PSH 3109	Penn Controls	P72AA-6	J-19-0 (3)	120VAC	9	0.85	47.7	24	24	24	Y	M003	PS-8	TH-3-8
PSH 3109 (2nd. contact)	"	"	"	"	2	0.19	10.6	"	"	"	N	"	"	"
PSLL 3121/3132	"	"	"	"	2	0.19	10.6	"	"	"	N	"	PS-6	"
PSLL 1623A	Mercoid	DAW703300	J-19-0 (15)	120VAC	2	0.19	10.6	15	15	15	N	M007	B	20-B
PSLL 1625A	"	"	"	"	2	0.19	10.6	"	"	"	N	M007	C	N/A
PSL 3151A2	United Electric	J302S164A	J-31-0 (7)	120VAC	4	0.38	21.2	"	"	"	Y	M012	N/A	62
LSHH 1544A/1561A	Pott. & Brum.	PMC17AY24	J-04-0 (3)	120VAC	3	0.28	15.9	20	20	20	N	J300	3.11 3.12	N/A
LSHH1559A/1543A	"	"	J-04-0 (4)	"	2	0.19	10.6	"	"	"	N	"	3.23 3.25	N/A
PSL 7065	Penn Controls	P72CA-8	J100-0 (5)	120VAC	2	0.19	10.6	24	24	24	N	M003	PS103	TH-3-8



TURN-ON TIMES OF THE INPUT BUFFERS

FIGURE 6.3 PAGE 47



TURN-OFF TIME OF THE INPUT BUFFERS

APPENDIX A

7.0

Bibliography

1. Digital Design for Interfe~~nce Specifications.
   Dr. R.K. Keenan, TKC. Pinellas Park, Florida. 1983.

2. A Simple Method of Estimating Crosstalk.
   C.R. Paul. Proceedings, IEEE Symposium on Electromagnetic Compatibility. pp. 430 - 435. August 1983.

3. Electromagnetic Interfarence and Solid State Protective Relays.
   W.C. Kotheimer and L.L. Mankoff, IEEE Transactions on Power Apparatus and Systems. vol. PAS-96 no.4, Jul/Aug 1977.

4. Reference Data for Radio Engineers, Fifth Ed., 1972.
   pp. 6 - 11, 12. H.P. Westman, Editor.