



Successful
Instrumentation
and Control
Systems Design

Second Edition

Michael D. Whitt



Setting the Standard for Automation™

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DEDICATION

I would like to dedicate this book to my wife Mary and son Elliot, who have continually supported me through the travails of writing this book—I'm truly blessed; my parents, who instilled in me a love for reading, and, by extension, writing; and Jesus Christ, who is my inspiration and through whom all things are possible.

TABLE OF CONTENTS

List of Figures	xix
Preface	xxix
List of Acronyms – Part I	xxxvii
List of Figures – Part I	xxxix
Introduction – Part I	1
Part I – Chapter 1: The Project	3
A. Introduction	3
B. Project Planning	4
C. Contracts and their Effects on Project Structure	8
1. Constraints	9
2. Contract Types: The Cost-Plus Contract (CP)	10
3. Contract Types: The Time and Material Contract (T&M)	13
4. Contract Types: The Time and Material/Not-To-Exceed Contract (T&M/NTE)	14
5. Contract Types: Lump Sum (Fixed Price) Contract	14
6. Project Structures: The Turnkey Project	16
7. Project Structures: The EPC Project	16
8. Project Structures: The Retrofit and Green-Field Projects	17
9. Project Structures: The Hybrid Project	17
D. The Customer/Service Provider Relationship	17
E. Project Flow for a Controls Project	18
1. The Owner’s Project	21
a. Owner’s Phase 1 – FEL Stage 1: Business Planning	22
b. Owner’s Phase 1 – FEL Stage 2: Project Definition	24
c. Owner’s Phase 1 – FEL Stage 3: Project Planning	24
d. Owner’s Phase 2 – System Design	25
e. Owner’s Phase 3 – Deployment	26
f. Owner’s Phase 4 – Support	27
g. Owner’s Project Deliverables	27
2. The Control System E/I&C Engineer’s Project	30
a. E/I&C Seller Phase 1 – FEL Stage 1: Business Planning	31
b. E/I&C Seller Phase 1 – FEL Stage 2: Project Definition	32
c. E/I&C Seller Phase 1 – FEL Stage 3: Project Planning	33
d. E/I&C Seller Phase 2 – System Design	33
e. E/I&C Seller Phase 3 – Deployment	34
f. E/I&C Seller Phase 4 – Support	34
g. E/I&C Seller’s Project Deliverables	35
3. The Control Systems Integrator’s Project	40
a. CSI Seller Phase 1 – FEL Stage 1: Business Planning	40
b. CSI Seller Phase 1 – FEL Stage 2: Project Definition	40
c. CSI Seller Phase 1 – FEL Stage 3: Project Planning	42
d. CSI Seller Phase 2 – System Design	42

e. CSI Seller Phase 3 – Deployment	43
f. CSI Seller Phase 4 – Support	44
g. CSI Seller’s Project Deliverables	44
4. The Control Panel Fabricator’s Project	50
a. FAB Seller Phase 1 – FEL Stage 1: Business Planning	51
b. FAB Seller Phase 1 – FEL Stage 2: Project Definition	51
c. FAB Seller Phase 1 – FEL Stage 3: Project Planning	51
d. FAB Seller Phase 2 – System Design	51
e. FAB Seller Phase 3 – Deployment	52
f. FAB Seller Phase 4 – Support	52
g. FAB Seller’s Project Deliverables	52
F. Integrated Control Solutions	52
Part I – Chapter 2: The Project Team	55
A. The Owner (i.e., Buyer, Customer)	57
1. Plant Administration	58
2. Plant Operations	59
3. Plant Engineering/Maintenance	59
4. Plant Purchasing	59
B. The Owner’s Engineer (OE)	60
1. The OE as an Individual	60
2. The OE as an In-House Team	60
3. The OE as a Consulting Management Firm	61
4. The OE as a Prime Contractor	61
C. The Designer	61
1. Project Manager (PM)	62
2. Project Engineer (PE)	63
3. Discipline Lead Engineer (DLE)	63
4. Discipline Engineer(s)	63
5. Discipline Design Supervisor (DDS)	63
6. Discipline Technical Support (Design) Staff	64
a. Lead Designer	64
b. Designer	64
c. CADD Technician	64
d. Engineering Aide (EA)	64
D. The Control Systems Integrator (CSI)	64
1. The Process Control Team	65
a. Process Engineers/Specialists	65
b. PLC/DCS Programmers	66
c. HMI/SCADA Programmers	66
2. The Server Setup Team	66
3. The Network Setup Team	67
4. The Startup & Commissioning Team	67
E. The Constructor (i.e., Builder)	67
1. E&I Construction Superintendent	67
2. E&I Field Engineer & Coordinator	68
3. E&I General Foreman	69
4. Instrument Foreman	69
5. Instrument Fitter/Mechanic	69
6. Pipe Fitter	69
7. Instrument Electrical Foreman	69
8. Electrician	69
9. Instrument Electrician/Technician	70

Part I – Chapter 3: The Managed Project	71
A. Key Project Management Tools	73
1. The Detailed Scope of Work (SOW)	74
2. The Estimate*	76
a. Budgetary	76
b. Bid	76
c. Definitive	77
3. The Schedule*	78
4. The Proposal	79
a. Executive Summary	81
b. General Scope of Work	81
c. Assumptions	82
d. Inclusions	82
e. Exclusions (Exceptions)	82
f. Deliverables	82
g. Milestone Schedule	82
h. Safety	83
i. Price & Payment Schedule	83
j. Bid Award & Contract Negotiation	83
5. The Project Execution Plan (PEP)	84
a. Contact List	85
b. Existing System Description	85
c. Disposition of Existing Equipment	85
d. Addition of New Equipment	85
e. Company and Applicable Industry Standards	85
f. Approved Vendors List	86
g. Vendor-Provided Pre-engineered Subsystems (OEM)	86
h. Instrumentation Data	86
i. Quality Control	86
j. Document Control	86
6. The Status Report	87
B. Project Management Techniques	90
1. Assessing Project Status	90
2. Staff Meetings	91
a. The Meeting Facilitator	92
b. The Facilitator’s Toolbag	93
c. The Meeting Agenda	96
3. Management of Change (MOC)	96
Part I – Summary	101
Part I - References	103
List of Acronyms – Part II	109
List of Figures – Part II	111
Introduction – Part II	115
Part II – Chapter 4: Basic Design Concepts	117
A. Scaling and Unit Conversions	117
1. Definition of Key Terms	118
2. Accuracy and Repeatability	120
3. Resolution Effects on Accuracy	122
4. Instrument Range versus Scale	123

5. Instrument Calibration	123
6. Linearization and Unit Conversions	124
7. Practical Application	127
B. Introduction to Information Management	129
Part II – Chapter 5: Design Practice	147
A. Basic Wiring Practice	148
1. Inter-Cabinet Wiring	148
a. Generating a Cable Schedule	149
2. Intra-Cabinet Wiring	155
a. Generating a Wiring Diagram	156
B. Failsafe Wiring Practice	166
C. Hazardous Area Classification and Effects on Design	170
1. Hazardous Locations	170
a. Class I	172
2. Explosionproofing	174
3. Intrinsic Safety	175
4. Purging	175
a. Class X Purge	175
D. Connecting to the Control System	177
1. Discrete (Digital) Wiring	178
a. Sinking and Sourcing	179
2. Analog Wiring	184
a. Circuit Protection (Fusing)	185
E. Design Practice Summary	192
Part II – Chapter 6: The Control System	193
A. Introduction	193
B. The Cognitive Cycle	194
C. Control System Overview	195
1. A Historical Perspective	195
2. PLC versus DCS	197
a. The Distributed Control System (DCS)	197
3. Major Control System Elements	200
a. The Physical Plant	200
4. Control Modes and Operability	202
a. Local/Remote (L/R) Mode Selector	204
D. The Human-Machine Interface	205
1. The Graphic User Interface (GUI)	205
a. Action Links	207
2. The HMI Database	210
a. Tagnames	210
3. The HMI Alarm Manager Utility	211
4. The Historian	212
5. The Trend Utility	212
6. Reports	213
E. Programmable Logic Controller	214
1. Major PLC Components	214
a. The Rack Power Supply	215
2. The PLC Program	216
a. I/O Map	216
3. The I/O Interface	222

a. Physical (Hardware) Address	223
F. Networking.....	230
1. Optimized/Proprietary Networks	230
2. Optimized/Non-Proprietary Networks.....	232
a. Serial Communications (RS-232)	232
3. Non-Optimized (Open) Local Area Networks	234
4. Wireless Local Area Networks.....	234
a. The “Bluetooth” Standard	234
5. The Ethernet Client/Server Environment	235
a. “Thick” Client Architecture	236
6. The Industrial Enterprise-Wide Network	238
a. The Remote I/O (RIO) LAN.....	239
G. Working with a Control Systems Integrator (CSI).....	241
1. Initial Search.....	241
2. Writing a Control System Specification	242
a. Process Overview.....	242
H. Selecting a Control System	246
References – Part II.....	249
List of Acronyms – Part III	257
List of Figures – Part III.....	259
Introduction – Part III	267
Part III – Chapter 7: Piping and Instrumentation Diagrams (P&IDs)	271
A. General Description	271
B. Purpose.....	272
C. Content.....	272
1. Symbology (ANSI/ISA-5.1-2009)	273
2. Symbol Identification	273
a. Prefix	274
D. Practical Application	276
1. Tank Level: LT-10, LSH-10, LSSL-47.....	276
2. Tank Fill: HV-13, ZSC-13	277
3. Tank Discharge: PP-10	277
4. Pump Discharge Pressure: PIC-48.....	277
E. P&ID Summary	278
Part III – Chapter 8: Links to Mechanical and Civil.....	279
A. General Equipment Arrangement Drawing (Civil and Mechanical)	279
1. Purpose	279
2. Interfaces	279
3. Content	279
4. Practical Application	280
5. Equipment Arrangement Summary	280
B. Piping Drawing (Mechanical)	281
1. Purpose	282
2. Interfaces	282
3. Content (as related to I&C).....	282
C. Pump and Equipment Specifications (Mechanical)	282
D. Links Summary.....	282

Part III – Chapter 9: Preliminary Engineering	283
A. Development of a Detailed Scope of Work.....	284
1. Purpose (Project Overview).....	284
2. Project Scope—I&C.....	284
3. Safety Concerns.....	284
4. Assumptions.....	284
5. Exclusions.....	284
6. Deliverables.....	284
7. Milestone Schedule.....	285
B. Control System Orientation.....	285
C. Project Database Initialization.....	288
1. Initialize Document Control Table.....	289
a. Table.....	290
2. Initialize Instrument and I/O List Table.....	295
a. Instrument Table.....	296
3. Database Summary.....	302
D. Estimate and Schedule Development*.....	302
1. Cover Worksheet.....	303
2. Devices Worksheet.....	303
3. Count Worksheet.....	309
4. Labor Worksheet.....	310
5. Summary Worksheet.....	314
6. Schedule Worksheet.....	316
7. Estimate and Schedule Summary.....	317
E. Preliminary Engineering Summary.....	319
 Part III – Chapter 10: Control Systems Integration (CSI)	 321
A. FEL Stage 1 – Business Planning.....	321
1. Cost/Benefit Analysis.....	322
2. Control System Specification.....	323
3. Functional Description.....	324
a. Tank Level: LT-10, LSH-10, LSSL-47.....	324
4. Project Estimate.....	325
a. Field Device Control Elements.....	325
5. Project Proposal.....	327
B. FEL Stage 2 – Project Definition.....	327
1. Sequential Function Chart (SFC).....	328
2. Continuous Function Chart (CFC).....	328
3. Control Narrative.....	329
4. Sequence Control Detail Sheets (SCDS).....	329
5. Device Control Detail Sheets (DCDS).....	329
6. Functional Logic Diagrams.....	329
C. Control Narrative.....	329
1. Sequential Function Chart (SFC).....	329
2. Continuous Function Chart (CFC).....	333
3. SFC Control Narrative Fragment.....	334
a. Powerup & Initialize.....	335
4. Sequence Step Detail Sheet (SSDS).....	337
a. Step S02 – Fill Tank.....	338
5. Device Control Detail Sheet (DCDS).....	345
a. Pump PP-10 Device Logic.....	346
6. Functional Logic Diagram.....	350
a. Tank TK-10 Control Sequence Step 02.....	353

7. Logic Diagram Standard ISA-5.1	362
8. FEL2 Systems Integration Summary	363
D. Operator Interface Specification Development – The HMI	365
1. Animation Plan	366
a. Colors	366
2. Screen Diagrams	367
a. Graphic Screen	369
3. Tagname Database, Device Driver, and I/O Mapping	374
4. Finished Graphics Screen	375
5. Alarm Manager	377
6. Historian	378
7. HMI Report Generation	378
E. Network Single-Line Diagram Generation	378
F. Other Systems Integration Tasks	379
1. Control System Cabinetry Design and Delivery	379
2. I/O Address Assignment (Partitioning)	379
a. Hardware (HW) Address	380
3. Factory (or Functional) Acceptance Test (FAT)	381
4. Site Acceptance Test (SAT)	384
5. Commissioning	385
6. Operations and Maintenance (O&M) Manual	385
a. Operations	386
7. Onsite Training	386
G. Systems Integration Summary	387
Part III – Chapter 11: Information Management	389
A. Document Control	389
B. Instrument and I/O List	390
1. Instrument and I/O List Table	391
2. Preliminary Design Query	391
3. Plan Drawing Takeoff Query	392
4. Plan Dwg Takeoff Query Report	392
5. X-Ref Document Cross-Reference Query	393
6. X-Ref Document Cross-Reference Report	394
C. Database Summary	394
Part III – Chapter 12: Instrument Specifications	397
A. Purpose	398
1. Mechanical Designers	398
2. Instrument Designers	399
3. Other Users	401
B. Interfaces	401
C. Examples	402
1. LT/LSH-10	402
2. PV-48	405
D. Summary	407
Part III – Chapter 13: Physical Drawings	409
A. Control Room	409
1. Environmental Issues	409
a. Heating, Ventilation and Air Conditioning (HVAC) ⁹	409
2. Physical Arrangement	410
3. Control Room Design Summary	411

B. Termination Room	411
1. Environmental Issues	411
a. Lighting	411
2. Furniture and Equipment Arrangement	413
a. Personnel Clearances.....	413
3. Termination Room Design Summary	413
C. Process Area (Instrument Location Plan)	413
1. Why Produce Instrument Location Plan Drawings?	415
2. Anatomy of an Instrument Location Plan	415
3. Design Considerations	416
4. Drawing Production Technique	417
a. Step One: Initialize Drawing (Generate drawing background)	417
5. Material Takeoff.....	429
D. Instrument Installation Details	433
1. Electrical Installation Details	434
2. Tubing Details	435
3. Mounting Details.....	436
4. Related Database Activities	436
5. Material Takeoff.....	438
E. Summary.....	438
Part III – Chapter 14: Instrument and Control Wiring.....	441
A. Instrument Elementary (Ladder) Diagram.....	444
1. Motor Elementaries	447
2. AC Power Distribution Schematic.....	449
3. DC Power Distribution Schematic.....	451
4. PLC Ladder Diagram (Elementary)	452
a. Discrete (Digital) Inputs	455
B. Loop Sheet (Ref: ISA-5.4-1991)14	458
C. Connection Diagrams.....	462
1. Junction Box JB-TK10-1: Initial Layout.....	463
2. Termination Cabinet TC-2	469
a. DC Circuits (TS-2)	470
D. Wiring Summary.....	479
Part III – Chapter 15: Panel Arrangements.....	485
A. Procedure.....	486
B. Junction Box JB-TK10-01 Arrangement Drawing ARR-002	487
1. Set Up a Scale	488
2. Design the Panel.....	488
3. Generate a Bill of Materials	491
C. Summary	492
Part III – Chapter 16: Procurement	493
A. Typical Purchasing Cycle	494
B. Material Classification	496
C. Bulk Bill of Materials	496
D. Detail Bill of Materials	501
E. Procurement Summary.....	506
Part III – Chapter 17: Quality Control—The Integrated Design Check.....	509
A. Administrative Content – Individual Checks.....	509

B. Technical Content – Squad Check 510

C. Squad-Check Roster 511

D. Design Check Summary 511

Part III – Chapter 18: Phase 3—Deployment 513

A. Construction 513

 1. Kickoff Meeting 513

 2. Construction 514

B. Pre-Commissioning 515

C. Cold-Commissioning (Site Acceptance) 516

 1. Device Tests 516

 2. Subsystem Tests 517

D. Hot-Commissioning (Startup) 517

E. Adjustment of Document Package to Reflect Construction Modifications 517

F. Issue for Record 518

G. Phase 3 Summary 518

Part III – Chapter 19: Phase 4—Support 519

A. Warranty Support 519

B. Continuing Service Support 519

References – Part III 521

Additional Resources 523

Index 525

LIST OF FIGURES

Figure 1-1. Typical bid package content	6
Figure 1-2. Success triangle.	9
Figure 1-3. Risk to reward analysis by project type	11
Figure 1-4. Effects of constraints on project structure	13
Figure 1-5. Typical CSP project lifecycle.	19
Figure 1-6. Control system project flow by involvement level	20
Figure 1-7. Sample Owner’s capital improvement project plan	22
Figure 1-8. Sample E/I&C seller’s project plan	31
Figure 1-9. Sample CSI seller’s project plan	41
Figure 1-10. Sample FAB seller’s project plan	50
Figure 1-11. Typical controls project participants	56
Figure 1-12. Engineering design team	62
Figure 1-13. Control Systems Integration design team	65
Figure 1-14. Construction team	68
Figure 1-15. Simplified contract award overview	72
Figure 1-16. Project Execution Plan template for small tasks	87
Figure 1-17. Project status report – data collection and status calculation fields	89
Figure 1-18. Project status report – analysis fields	91
Figure 1-19. Meeting Status Notes form	94
Figure 1-20. Emerging Issues Notes form	94
Figure 1-21. Needs List form	94
Figure 1-22. Action List form	95
Figure 1-23. Suggestion List form	95
Figure 1-24. Sample project meeting agenda form	97
Figure 1-25. A Management of Change (MOC) process	99
Figure 2-1. Typical error pattern caused by deadband	121
Figure 2-2. Typical error pattern caused by hysteresis.	123
Figure 2-3. Conversion problems	125

Figure 2-4. Data translation process — from field device to HMI	126
Figure 2-5. Signal conversion at PLC input	127
Figure 2-6. Engineering unit calculation at the HMI	127
Figure 2-7. Spreadsheet versus database comparison	130
Figure 2-8. Typical relational database program structure	133
Figure 2-9. ICS-based project flow with database-intensive activities highlighted.....	135
Figure 2-10. The P&ID takeoff query	136
Figure 2-11. The I/O partitioning query	137
Figure 2-12. The software & logic assignment query	137
Figure 2-13. The cable and conduit schedule query (partially shown)	138
Figure 2-14. The instrument specification query (partially shown).....	139
Figure 2-15. The construction checkout query.....	139
Figure 2-16. The Validation & Verification (V&V) test queries.....	140
Figure 2-17. The site acceptance test queries	141
Figure 2-18. Typical document handling process	144
Figure 2-19. Typical cabling scheme	148
Figure 2-20. Defining the cable route (wire W1, route C1/T1/T2/C2/C2a)	149
Figure 2-21. Sample cable schedule.....	150
Figure 2-22. Cable area fill	151
Figure 2-23. Cross-sectional views of cable orientation before, during, and after a conduit bend .	152
Figure 2-24. Conduit facts.....	152
Figure 2-25. Conduit sizing calculator	153
Figure 2-26. Sample conduit schedule	155
Figure 2-27. Sample instrument arrangement	155
Figure 2-28. Interconnection wiring example	157
Figure 2-29. Form A contact set (SPST – NORMALLY OPEN).....	158
Figure 2-30. Form B contact set (SPST – NORMALLY CLOSED).....	159
Figure 2-31. Form-C contact set (SPDT)	159
Figure 2-32. 5-pole relay used as a motor starter (shown in shelf state, with interlocks, overloads, and PLC input)	161
Figure 2-33. Common types of switches and their diagrams	162

Figure 2-34. Types of contacts	162
Figure 2-35. Interval timer timing diagram	163
Figure 2-36. Time delay on de-energize (TDOD) timer timing diagram	163
Figure 2-37. Time delay on energize (TDOE) timer timing diagram	164
Figure 2-38. Sample ladder elementary format	165
Figure 2-39. Failsafe interlock chain (devices shown in shelf state)	169
Figure 2-40. Hazardous boundaries	171
Figure 2-41. Basic discrete (digital) circuit	178
Figure 2-42. Discrete (digital) circuit wiring technique	179
Figure 2-43. Simple switching	180
Figure 2-44. Sinking and sourcing digital input modules	182
Figure 2-45. Isolated digital output module	184
Figure 2-46. Sinking and sourcing digital output modules	185
Figure 2-47. Analog circuit wiring technique	186
Figure 2-48. Analog wiring methods: 2-wire vs. 4-wire	191
Figure 2-49. The cognitive cycle	195
Figure 2-50. Typical control system	203
Figure 2-51. The Human-Machine Interface (HMI)	206
Figure 2-52. Graphical User Interface with pushbutton configuration template	209
Figure 2-53. Trend screen	213
Figure 2-54. Typical PLC rack	215
Figure 2-55. Sequential function chart washing machine sequence control application	220
Figure 2-56. Continuous function chart washing machine temperature control application	221
Figure 2-57. Control detail sheet	223
Figure 2-58. Suggested program flow of control	224
Figure 2-59. I/O tally worksheet	227
Figure 2-60. Revised I/O tally worksheet reflecting new setup	229
Figure 2-61. I/O tally worksheet with split by I/O type	231
Figure 2-62. Remote I/O network	232
Figure 2-63. Industrial network	240
Figure 3-1. Instrumentation and controls engineering tasks (Phases 1 – 3)	269

Figure 3-2. Typical feed tank configuration	270
Figure 3-3. Typical P&ID symbology	274
Figure 3-4. Typical P&ID symbology showing combined automation system functions	275
Figure 3-5. P&ID presentation of the TK-10 subsystem	276
Figure 3-6. Basic P&ID drawing	278
Figure 3-7. TK-10 feed tank with equipment labels	280
Figure 3-8. TK-10 Feed tank area equipment arrangement	281
Figure 3-9. Detailed Scope of Work	283
Figure 3-10. Existing control system	287
Figure 3-11. Revised control system	288
Figure 3-12. List of tables	289
Figure 3-13. Document control table structure	290
Figure 3-14. Document control table, datasheet view	291
Figure 3-15. OrderDrawingsQuery (design view)	292
Figure 3-16. Document control table data	292
Figure 3-17. Transmittal query	293
Figure 3-18. Transmittal query design view (with criteria filter)	294
Figure 3-19. Transmittal query, datasheet view	294
Figure 3-20. Instrument and I/O list table	297
Figure 3-21. Tagname update query, design view	298
Figure 3-22. TagnameUpdateQuery, design view, with criteria filter	298
Figure 3-23. Query tagname display	299
Figure 3-24. Reports	300
Figure 3-25. Report wizard	301
Figure 3-26. P&ID takeoff query report	301
Figure 3-27. P&ID takeoff query report, design view	302
Figure 3-28. Finished database products	303
Figure 3-29. Cover sheet for Estimate workbook	305
Figure 3-30. Devices worksheet	306
Figure 3-31. Devices I/O assignment index table	307
Figure 3-32. Devices I/O assignment index, revised	308

Figure 3-33. Devices I/O calculator. 308

Figure 3-34. Count worksheet 309

Figure 3-35. Background data table. 310

Figure 3-36. I/O configuration worksheet 310

Figure 3-37. Labor worksheet. 311

Figure 3-38. Direct engineering labor, Phase 1 312

Figure 3-39. Direct engineering labor, Phase 2 313

Figure 3-40. Indirect engineering labor, Phase 2. 313

Figure 3-41. Engineering and construction labor, Phase 3. 313

Figure 3-42. Engineering summary worksheet 314

Figure 3-43. Project cost summary table 315

Figure 3-44. Engineering cost summary table 315

Figure 3-45. Phase 1 deliverables summary table 316

Figure 3-46. Phase 2 deliverables summary table 316

Figure 3-47. Instrument and I/O summary table 317

Figure 3-48. Schedule worksheet 318

Figure 3-49. Design schedule and staffing plan 319

Figure 3-50. Project manhour loading chart. 320

Figure 3-51. Systems Integration services checklist 322

Figure 3-52. Existing control system 327

Figure 3-53. New control system 328

Figure 3-54. TK-10 feed tank control sequence overview 330

Figure 3-55. Sequential function chart fragment. 330

Figure 3-56. Sample sequential function chart logic. 331

Figure 3-57. Sequential function chart (SFC) 332

Figure 3-58. Continuous function chart 333

Figure 3-59. Sequence step 2: “fill tank” sequence 340

Figure 3-60. Sequence step 5: “empty tank” sequence 343

Figure 3-61. Pump PP-10 motor controls elementary wiring diagram 347

Figure 3-62. Pump PP-10 device control detail sheet 348

Figure 3-63. HV-13 fill valve device control detail sheet 351

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- <http://cavalldecartro.highlandagency.es/library/Chimera--A-Jim-Chapel-Mission.pdf>
- <http://betsy.wesleychapelcomputerrepair.com/library/Matrix-Computations--3rd-Edition---Johns-Hopkins-Studies-in-Mathematical-Sciences-.pdf>
- <http://www.netc-bd.com/ebooks/Nebula-Awards-Showcase-2012.pdf>