How To Become an Instrument Engineer

The Making of a Prima Donna

by
Gregory K. McMillan
and
Stanley Weiner

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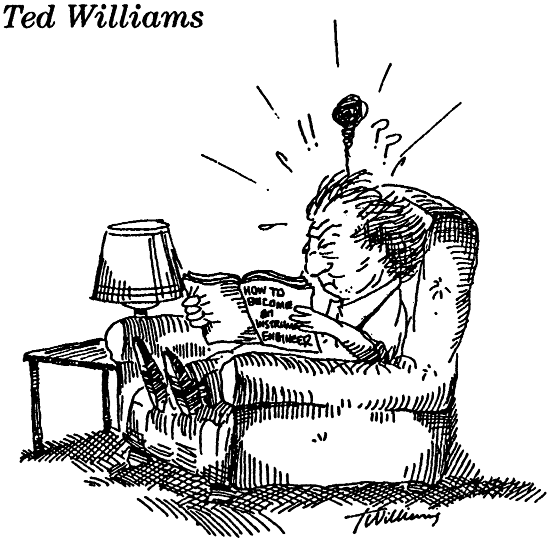
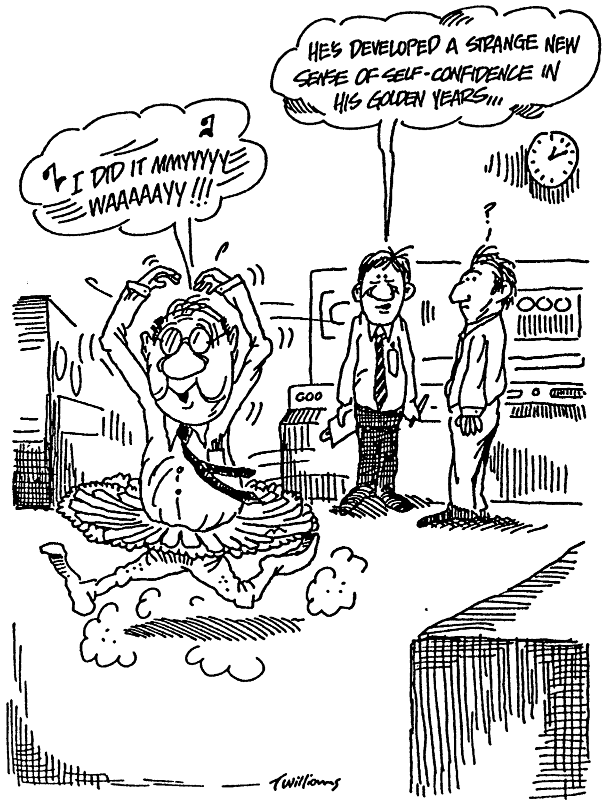
Cartoons by
Ted Williams



INSTRUMENT SOCIETY OF AMERICA



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Amazing Stories

Existential Silliness and Instrument Engineering

Zen and the Art of Instrument Selection

The Unofficial Guidebook to Instrument Engineering

The Last Self-Help Book

P.S., Your Instrument Is Dead

A Fistful of Fuses

How To Thrive on Failure

Cosmic Consciousness and the Ability To Influence Engineers

A Complete Course in Instrument Engineering
(With Some Things Left Out)

Why Control Systems Work When They're Really Not Required

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Any resemblance between the generic corporate engineering departments mentioned in this book and any organization that the authors have worked for is purely coincidental. The opinions expressed in this book should not be construed to reflect the views of the management of ISA or these companies.

Contents

Acknowledgments

The authors would like to thank that venerable and considerable group of professors, practicing engineers, and nonpracticing engineers (managers) who have made us what we are today — extremely strange prima donnas. In particular, we wish to thank the professors who taught us partial differential equations (it has been extremely useful in filling out time sheets), the safety engineers who put water sprinklers in control rooms, the chemical and mechanical engineers who gave us exceptionally innovative pressure drops for control valves, the HVAC engineers who install ten-ton air conditioners in twenty by twenty equipment rooms, the electrical engineers who put electrical heat tracing on uninterruptible power supplies, and the managers who want low cost, high yield, safe, and technologically advanced plants built in less than a year and requiring no intelligent life for operation or maintenance.

Please don't take us seriously.
We certainly don't.

The Authors

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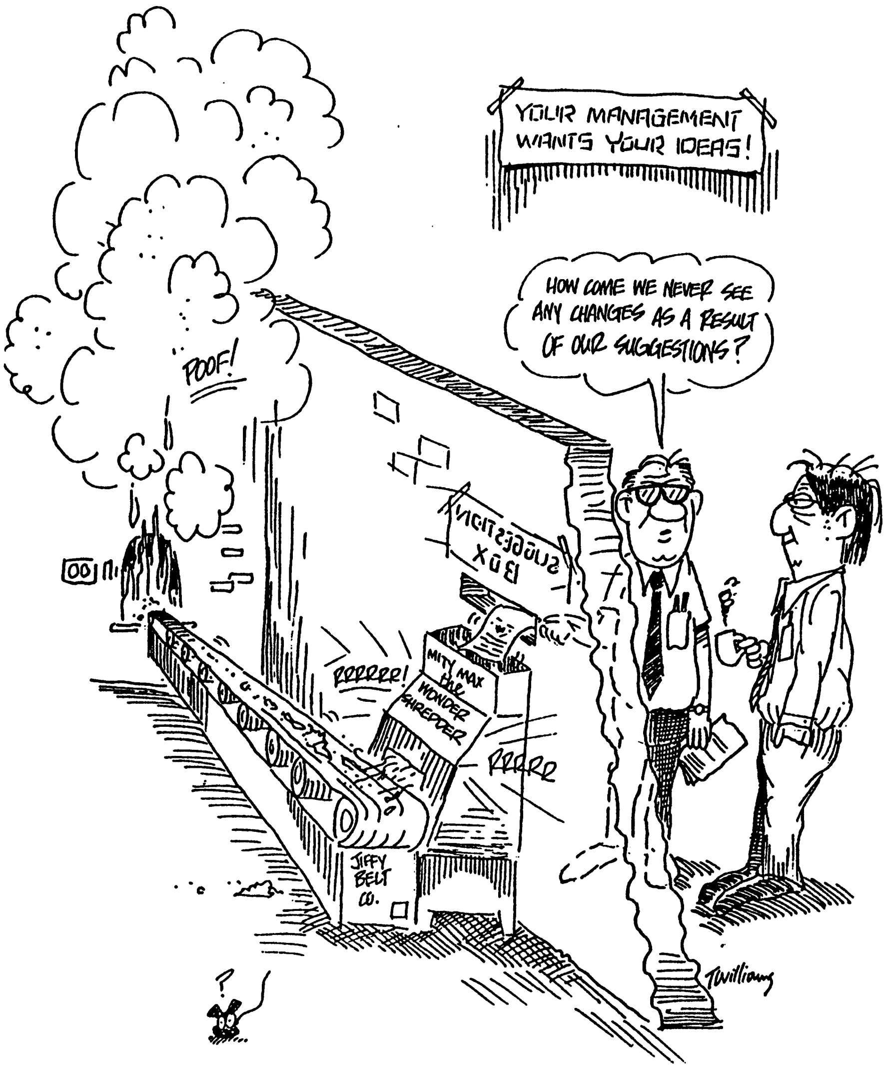
YOUR MANAGEMENT WANTS YOUR IDEAS!
HOW COME WE NEVER SEE ANY CHANGES AS A RESULT OF OUR SUGGESTIONS?
POOF!
SUGGESTION BOX
MITY MAX THE WONDER SHREDDER
RRRRRR!
RRRRR
JIFFY BELT CO.

The Selection, Training, and Survival of an Instrument Engineer

The Chosen Few

We would like to say that a person becomes an instrument engineer after years of diligent study and academic preparation, but this is a nonfiction book. No one plans to become an instrument engineer. The prospective instrument engineer doesn't even know the profession exists until the job offer comes. There are few curricula in universities with even a remotely similar title, no mention of the profession by counselors, and no recognition of the profession in such technical societies as IEEE and AIChe. On top of this, public understanding of the profession is nonexistent. Have you ever tried to explain to a spouse or a friend what an instrument engineer does? Tell them you specify D/Ps, RTDs, PLCs, and PCVs. It leaves them speechless.

One usually becomes an instrument engineer by default or, in other words, because one has found nothing better to do. The lure of gainful employment has attracted chemical, mechanical, and electrical engineers to this technology. (There was once even a civil engineer in instrumentation, but he kept trying to bury his installation mistakes in concrete. He now works for the nuclear industry.)

If you are one of the chosen few who have a job offer in front of you right now and want to know if you've got what it takes to become an instrument engineer, you need to truthfully answer. the following questions: **Do you like to thumb through glossy pages in hundreds of catalogs?** (We personally like to *sniff* the new pages.) **Do you like to keep track of the intricate details of thousands of gadgets that change yearly?** (We never were very good at this, but fortunately our employer expedited standardization by acquiring an instrument company.) **Are you capable of forgetting all the math you learned in college?** (The few cases in which algebra might be needed, such as control valve and orifice sizing, were done first with special-purpose slide rules and then with special-purpose personal computer programs. There is some debate as to whether an instrument engineer even needs to be able to count! This does not mean that the village idiot can become an instrument engineer, although a prefrontal lobotomy can help you maintain your composure during a performance review. You must be able to learn on the job how to specify, install, check out, and start up complicated systems.)

Instrument engineering is basically a lot of fun. It is like being paid to go shopping at your nearest electronics or computer store. Americans love to go shopping. Just look at how crowded your favorite shopping mall is on the weekends. As an instrument engineer, you get to buy thousands of gadgets with someone else's money. You also get to watch these gadgets in action. The visual and audible feedback in a control room is impressive.

The Learning Experience

It is an undeniable truth that instrument engineers learn by making mistakes. In fact, to be a really good instrument engineer, you should leave a trail of disasters in your past as long and incomprehensible as the course of the Amazon. Your goal is to go from being a lowlife engineer on the early shift of winter start-ups to being a consultant after a golden handshake in a plush office complete with stereo and wet bar. If you can't wait that long, you can acquire the same comforts by becoming either a manager or an instrument sales representative, or both.

Some chemical companies have recognized the need for on-the-job training (usually after a new engineer is found wandering aimlessly on a job site with his calculus book) and have tried to establish their own instrument engineering school or have brought in an outside consultant. The schools until recently either have taught process control from the professor's viewpoint (the same one who thinks the universe is described by partial differential equations) or have taught instrumentation from the illegible notes of comatose engineers who mumbled in monotone. What is unfortunate is that experienced engineers typically don't like to speak in public or write. Also, they are usually too busy to extrapolate beyond their experiences or to develop principles to guide their own future actions or those of others. The result is a shortage of good mentors and instructors. Professional societies such as the Instrument Society of America have done an excellent job of seeking out and finding engineers able to communicate their experiences. (This last statement has nothing to do with the Society's decision to publish this book.)

To be really effective, a school should give the student engineer a trial run at a career in instrumentation by condensing years of mistakes into one very intense experience, which should be as close to real life as possible. First, the student should be bombarded with thousands of facts on how instruments work until he or she suffers a mental meltdown. To insure plenty of mistakes will be made, no information should be given on how to determine what instrument is best for a given application. The student should be given a project where the instruments have already been purchased and the design drawings issued for a lump sum bid. Verbal harassment by a real-life project manager about schedules and budgets should be used to add a greater touch of realism. The student should receive a set of process and engineering diagrams drawn with disappearing ink so that process revisions can be made with a clear conscience. The process should be revised hourly. Chemicals and/or concentrations should be chosen that do not appear in handbooks on physical properties or materials of construction. Electrical engineers, mechanical engineers, and chemical engineers should be given solids-handling projects, computer projects, and electrical distribution monitoring projects, respectively. For start-up, each engineer should be reassigned to a completely different project.

A tour of duty with a large engineering department is equivalent to attendance at the school described above. Such organizations create an environment for the maximization of mistakes. They like to play musical chairs with the assignment of engineers to projects so that there is no continuity or foundation of knowledge to build on. You will never be asked to work on a project that is technically related to anything you have worked on previously.

Of course, you must know when you have made mistakes and have a chance to correct them in order to learn from them. Therefore, it is not wise to go to work for a contract engineering firm until you have been exposed to a lot of mistakes or, in other words, until you are experienced. In such firms, you are either in a design or field section with no overlap in function. In the design section you move from one project to another without having to try to make your designs work. In the field section you spend all your time fixing other people's mistakes but don't get to make any design mistakes of your own.

A stint as a plant engineer is necessary to round out your perspective. Only by facing the day-to-day repair problems can you appreciate the impact of instrument selection, documentation, location, and installation on its serviceability. Many of the operational problems don't surface until after start-up. If all your field experience ends after commissioning, your viewpoint is distorted. You may be happy in your ignorance, but the plant engineer who has to live with your design will not be.

As a rule, plant engineers do not think highly of either corporate or contract engineers. These organizations tend to have engineers with average or above average technical capability but below average maintenance experience. Corporate engineers have more start-up experience than contract engineers, but they are less likely to treat the plant engineer as a customer. Nothing infuriates a plant engineer more than a corporate engineer refusing to alter a design for better reliability because it threatens the budget or the schedule. Even though the project money is allocated to and paid by the plant, corporate engineering acts as though it has total responsibility for the money. Therefore, plant engineers feel they have no control over corporate engineers and, for this reason, prefer contract engineers. The lesson to be learned here is to treat whoever uses the installation as a customer and seek to identify the short-term and long-term needs of that customer. While all this seems like common sense, it is not widely practiced. Consequently, corporate departments have recently begun to make their employees sit through several days of sheer excitement called 'Total Quality' programs to explain this fundamental principle. (This comes too late for many corporate departments, based on the present binge of decentralizations.)

The Game

In most large companies, you don't have to worry about your mistakes adversely affecting your potential for raises and promotion. Your performance review is based on a set of goals concerning whether the instruments were purchased on time and within the budget and not on whether they function properly or not. Thus, you can include lots of extra instruments in your estimate, buy the ones with the shortest delivery, have instrument systems fail right and left, and still meet your goals! Even if you mess up the estimate and don't meet your goals, don't worry. Your promotion and raise is based on how well you play the corporate game and not on your performance review. There are many rules to the game, but the foremost one is, "Don't rock the boat." The maintenance of the status quo is of primary importance. The primary goal in the life of a manager is not to upset the next level manager. The sole purpose of each level of management is to sooth the next level by means of numerous reports. Disasterous results are OK as long as everything is done in compliance with corporate procedure and the data is properly reported. Innovative thinking is encouraged figuratively but not literally. Any free thinking or radical methods make managers nervous. If you want to maximize your monetary rewards, smile and say "yes" a lot and attend all the management training programs. You might even become a manager, in which case your raises will automatically be larger and you never have to do anything more technical than to analyze the performance of your investments. You have then reached the ultimate goal of being a non-practicing engineer who gets to set the salary of all the practicing engineers. Even when a technical ladder of promotion equivalent to the management ladder exists, managers at the same level earn more money because they set the raises. Imagine what the raises of the managers would be if they were set by the practicing engineers!

This book is not intended to make you a manager. After all, it *is* a technical book. If you learn everything stated in this book, you will be well on your way to becoming a prima donna who can strike fear into the hearts of at least the first level of management. Any direct influence on upper levels is too high an aspiration and nearly impossible to achieve because these lofty personages do not want to hear and be confused by mundane facts.

Success???

Somewhere along the line, someone may ask if you are a successful instrument engineer. First, you must define "success". Some people like to use the words money, prestige (which can include fancy titles), company or national reputation (which can come from writing books other than ones like this), job security, performance, or even knowledge. For an instrument engineer, all of the above may be wrong. The real source of "success" probably depends on how you are perceived by your management or clients. It doesn't matter whether you work for a large corporation or a small engineering company, a little luck, work on high visibility projects, and being fortunate enough to have agreeable, competent people on your jobs are the real keys to success.

Learn and understand the "Good-Good" and "Bad-Good" theories. "Good-Good" engineers try to do the best job possible while helping other design engineers, operation supervisors, maintenance engineers, and even project managers. "Bad-Good" people are rotten to anyone when it advances their own reputations. If they are very intelligent, they are very dangerous. Everything that goes wrong is someone else's fault. Identify these villans quickly and stay away from them. Most nice guys can't play their game and win.

Rules of Thumb

1-1 Being experienced in instrument engineering means you have made and corrected a lot of mistakes.

1-2 You must check out and start up your own designs; otherwise, you will make the same mistakes again.

1-3 You must treat the user like a customer if you and your organization are to survive.

1-4 Confrontations with management indicate suicidal tendencies.

1-5 If you want a sense of accomplishment, stay technical. If you want to make money, become a manager, sales representative, or outside consultant.

1-6 Attend as few meetings as possible. They accomplish nothing besides wasting time and aggravating you. If you like going to meetings, you will never be a good instrument engineer and you will probably end up in management. I kid you not. People who like meetings are either lawyers, managers, or mental health professionals, and people who should *see* a mental health professional, manager, or lawyer.

1-7 Join every airline's frequent flyer club if you work for a corporate engineering department. You will be doing more than enough travel to make it worthwhile. Besides, learning to deal with all the coupons, stickers, membership cards, bonuses, upgrades, and periodic reports is good training for dealing with the variety of clients and/or customers that make the profession such a challenge.

1-8 Buy and use luggage that doesn't have to be checked. Checked luggage gets lost or destroyed and wastes time. Carrying your clothing in a shopping bag is tacky. Having your dirty socks and underwear fall out of your briefcase at a meeting is also tacky.

1-9 Create the perception that you do wonderful things that produce amazing results.

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YESSIR, A LITTLE SUPER-GLUE ON THE OL' SLIDE RULE OUGHTA KEEP OUR CONTROL VALVE SIZES WHERE WE WANT 'EM!
FRED FUNGELMEYER PROJECT MANAGER
T. Williams

How To Deal with Project Managers

"Mommy, Where Do Project Managers Come From?"

Some things in life are unavoidable — like taxes, death, and project managers. One of the most fundamental laws of engineering is not taught in any college: "All projects must have a project manager". Project managers (PMs) are not created in universities; they are all former engineers. The conversion process is accomplished by management (who may also be ex-engineers who have possibly had some business courses they never understood). The transformation is not done by retraining. The manager just calls into his office the least competent and least liked engineer and informs that person of his promotion into the ranks of project management. (Some companies have a position called "project engineer," which is something like an assistant project manager. It gives the future PM a chance to *gradually* begin antagonizing fellow workers.)

In a chemical company, PMs may have degrees in chemical engineering, chemistry, or mechanical engineering. Every once in a while a PM is an ex-instrument/electrical engineer. Twenty years after he became a PM, he can still tell you how to do your job. He or she still has a drawer full of cardboard slide rules with which to size orifice plates, control valves, and rotameters, select the materials of construction, tell you what date it will be in 24 weeks, convert the dew point in degrees centigrade to pounds of water per pound of dry air, and determine the velocity of 14.5 gpm of 60 degree water in a 2½ inch schedule 40 pipe. Such PMs are virtual warehouses of obscure and useless information, and the contents of their desks are like the relics of some ancient civilization. Visiting their offices is like being in a time warp. Unfortunately, you cannot ask Scotty to beam you up.

Time-Tested Trick

Project managers don't like to buy anything not permanently installed (such as test equipment or engineering tools) no matter how essential it is to the project. A time-tested trick is to include the necessary personal computers for engineering design and calibrators for checkout in a large order for a distributed control system and have it shipped with everything else to the panel fabricator. This scheme avoids the scrutiny of the receiving and accounting department, which is in cahoots with the project manager.

"Will the Last Person Please Turn Out the Lights"

In these days of decaying corporate engineering departments, it is interesting to note that design engineers are considered expendable and project managers are essential. In those departments that retain skeleton organizations, a large proportion of the remaining people are project managers. Project managers are the means through which a corporate structure can exercise leverage to achieve its goals. It is interesting to note that the goals of the project manager, which are fast and cheap installations, are increasingly emphasized, as the organization decays, over the goals of the design engineer, which are functional and reliable installations. In the last death throes of a corporate engineering department, the project managers cut time and money from projects without even consulting the design engineers in a desperate attempt to meet their goals. What they don't realize is that the good design engineers they relied upon to bail them out have left for greener pastures and that project costs are higher because there are too many managers and not enough workers left. Such departments self-destruct, and when such organizations disappear completely, the project managers are the ones left to turn out the lights.

"Who's on First?"

The phrase "how to deal with project managers" does not mean how to *bargain* with project managers. (This would imply that project managers are rational beings.) What the phrase refers to is coping with project managers, especially those who have worked themselves up to manic frenzy and have lost touch with reality. Anyone who has sat in a project meeting during a crisis knows how bizarre the reasoning of the project manager gets from the pressures of trying to meet schedules and budgets. It is not unusual to sit in meetings where, after several hours, you are more confused than ever. The discussions resemble the old joke about "Who's on first, what's on second, and I-don't-know is on third".

The Theory of Money

It has been said many times before the existence of PMs and it will be said many times again that the big things in life are money and schedules. The meaning of the word "money" has evolved in recent years from "what it costs to purchase an instrument" to a series of definitions that must have come from a graduate business school. People understand what it costs to purchase an instrument; it is easy to look at a purchase order and see a number on it. But buying an instrument is just one part of the total job. The instrument must be specified, sometimes programmed, calibrated, tested, installed, checked out, and commissioned. It costs money to do all of these things. Some of this money is easy to identify, such as the purchase price, but more than half of the money is hidden. As an example, if you install a control valve in a pipeline, who pays for the installation? Piping may end up paying for block valves, drain and vent valves, bypass valves, and the actual installation of the control valve in the pipeline. Piping may even pay to run an instrument air header near the valve. The installation costs charged to the instrument account may be only those associated with connecting the two wires to the I/P transducer. The electrical account may pay for the cable tray or the conduit system. Conclusion: things do not always cost what they appear to cost.

Project managers have their own theory about money: "If you can't see it, don't worry about it." In other words, if a cost doesn't appear on a purchase order or as a man-hour charge to the instrument account, it doesn't exist. Thus, to make engineering look more cost-effective, PMs won't allow the instrument engineer to put in the estimate all the hours needed. With fewer hours, the instrument engineer won't have enough time to buy all the instruments. Who cares if the real costs are higher or the installation doesn't work? After all, the cost to fix an application is charged against expense and not against capital. Furthermore, if man-hours were reduced on all projects, upper management could reduce the number of engineers. With a reduction in the number of engineers, the support groups (drafting, computer services, secretaries, purchasing, etc.) could also be cut. Who cares if there is no one left to do the work? The projects can be contracted out and the PM can exercise more control. Contract engineers don't talk back.

The big question is: Who developed this theory of money used by the PMs?

(a) A Ph.D. at Podunk's E. Scrooge School of Business.
(b) An ex-engineer with an MBA from a local college's weekend program.
(c) An ex-engineer who became a director without getting an MBA.
(d) A project manager who wanted to become a director.
(e) A director who wants to retire and needs some incentive money to leave when an engineering department self-destructs.
(f) Some of all of the above.

Notable Quotes

We don't have any stories about project managers because they are too unbelievable, even for this book. Just let your imagination run wild. However, we do offer the following viewpoint on PMs from a very respected instrument engineer who wishes to remain anonymous.

"It is often stated that project managers understand only cost and schedule, not quality. That is a very unbalanced analysis of a fine group of people. They really understand little about cost and schedule. With some individuals, there is a variable ability. It does seem that 'cost' becomes more important and better understood just after the purchasing cycle, as does 'schedule' two weeks before mechanical completion.

"Deal with project managers as little as possible. A worried look, along with vague references to overruns or schedule slippages, keeps them off balance. If the PM suspects you have everything under control and running smoothly, you can expect a cost reduction program or a speedup."

3


DANGER
HIGH
VOLTAGE
THESE SIGNS PLUS A FEW DEAD BIRDS SCATTERED AROUND THE KEYBOARDS SHOULD KEEP THE PESKY PROCESS ENGINEER AWAY!
TWilliams

How To Snow Process Engineers

Smarter Than Your Average Bear

Snowing a process engineer is a difficult task. A process engineer is smarter than your average engineer. They were the kind of people who actually did their homework on time and studied daily in college. They love calculations and still use on the job many of the equations they learned in college. While the math is simpler than that learned in electrical engineering, the terms are strange. While you cannot hope to second guess a process engineer, you can feel less intimidated by buying and reading a basic text such as *Basic Principles and Calculations in Chemical Engineering* by Himmelblau (on sale by the Chemical Engineering Book Club) and "Flow of Fluids through Valves, Fittings, and Pipe," Crane Technical Paper No. 410. They contain all kinds of formulas, steam tables, and pipe data. It's four years of chemical engineering essentials condensed into two books. If we had had these in college, we might never have been on academic probation.

The Threat

Process engineers are encroaching on the work of the instrument engineer. There are very few new products or processes to keep them busy. Most of today's work consists of automating existing processes to improve product quality or reduce operating costs. Most process engineers now have a good programming background. This background, coupled with their practical knowledge of process equations, means that these engineers can make serious inroads into the configuration work of distributed control systems. The potential problem is only going to get worse with the advent of smart transmitters and control valves. If the whole instrument system can be set up, calibrated, and commissioned by programming in the control room, the traditional skills and tools (calibration boxes, jumpers, and screw drivers) of the instrument engineer will no longer be needed. More and more, process engineers go to schools on configuration and casually use terms previously reserved for instrument and control engineers. It is the duty of every instrument engineer to stop this before it gets out of hand! You must learn how to snow process engineers to reduce their level of confidence and make them back off.

The Best Defense Is a Good Offense

First, you need to attack them on their own turf. Process engineers don't remember the really important stuff from college. However, certain expressions activate portions of their brains. You can tell when this happens because they begin to frown and have a dazed look in their eyes. Your goal is to capitalize on this idiosyncrasy (which is an interesting word in that it synthesizes the words "idiot" and "crazy").

Whenever you are talking about flashing or cavitation in control valves, use the term "adiabatic expansion". No practicing engineer understands thermodynamics. Explain inaccurate flow measurement by the phrases "laminar flow," "insufficient Reynolds number," "transition zone," or "Bernouli Principle". Explain improperly sized control valves with the words "system curve," "static and dynamic losses," "sonic velocity," or "choked flow" at the "vena contracta". Learn to draw pump curves and compressor maps. Never say "pressure" when talking about these curves.

Say "head versus flow" and use "gpm" for pumps and "acfm" for compressors. Strike fear into their hearts with casual mentions of "NPSH and cavitation" problems for pumps and "surge and stonewall" problems for compressors. Blame poor vortex meter performance on "unsymmetrical velocity profiles, swirl, and hydrodynamic noise". Of course, none of these are instrument problems. A process engineer can be finished off with the accusation that "counter current two-phase flow in the condensate lines" has caused the temperature control problem.

Scare Tactics

Process engineers are uneasy about anything electrical. This can be used to your advantage. Keep the process engineer off balance by using as many electrical terms as possible. Even simple terms such as "4-20 millamps" and "1-5 volts dc" are effective. Drag out that oscilloscope even if you look at something as simple as an I/P signal. Fiddle with the dials and create impressive displays. Pull out circuit diagrams even if they're for your TV at home and pore over them for hours while muttering resistance and capacitance values. Discuss grounding problems with the process engineer until he or she appears to be getting sick. Use high tech, electrically based primary elements such as the electromagnetic flowmeter instead of simpler ones such as the orifice meter. Use extra wires whenever possible in an installation and, finally, lobby against the standardization of data highways and communication protocol so that it will take an instrument engineer to figure out how to interface all these new computer systems and smart devices.

The Accused

Even if you successfully snowed the process engineer and staved off his encroachment, you still have to defend the integrity of your instruments. Process engineers have a nasty habit of blaming instruments whenever anything goes wrong operationally. Since your measurements provide the only window they have into the process, they accuse these instruments of providing a distorted view if they don't like what they see. More often than not, the cause lies in faulty equipment operation, but it is often difficult to prove. The mechanical engineer responsible for the installation is typically not around (perhaps the company is afraid to turn them loose in the field). It is in your own best interest to learn how the equipment is supposed to operate so that you can avoid ridiculous accusations. A relatively simple item to start with is the common steam trap. These buggers are the source of more headaches than any other piece of equipment. They frequently dump too little or too much condensate, creating disturbances to the pressure, flow, level, and temperature control of exchangers, reboilers, and associated equipment.

The only sure way to establish the integrity of your instruments is to make sure there are three ways of measuring or inferring the value of a critical operating parameter. They will never agree exactly, so two measurements or inferences will generate more questions than one. The process engineer will listen to reasonable explanations only if they are accompanied by an avalanche of data.

War Story

During the checkout of three well-mixed tanks in series, a test was devised to see how long it took to get the acid reagent into each tank. A very large reagent delivery delay was suspected because a two-inch line was used from the discharge of the metering pump, even though the reagent flow was only a few gph to the last tank. After waiting an hour for the pH to drop in the last tank, the process engineer said something must be wrong with the pH measurements. He grabbed an empty beaker and filled it with a sample from the last tank. A freshly standardized laboratory pH meter showed the pH of the sample was two, whereas the displays in the control room indicated the pH was still about seven. Since three separate pH measurements still indicated the contents of the last tank were still neutral, the instrument engineer insisted on three separate samples and laboratory tests. The next two samples indicated the pH was about seven. The beaker for the first test, even though it looked clean, had the dried-up residue of a two-pH buffer solution.

Rules of Thumb

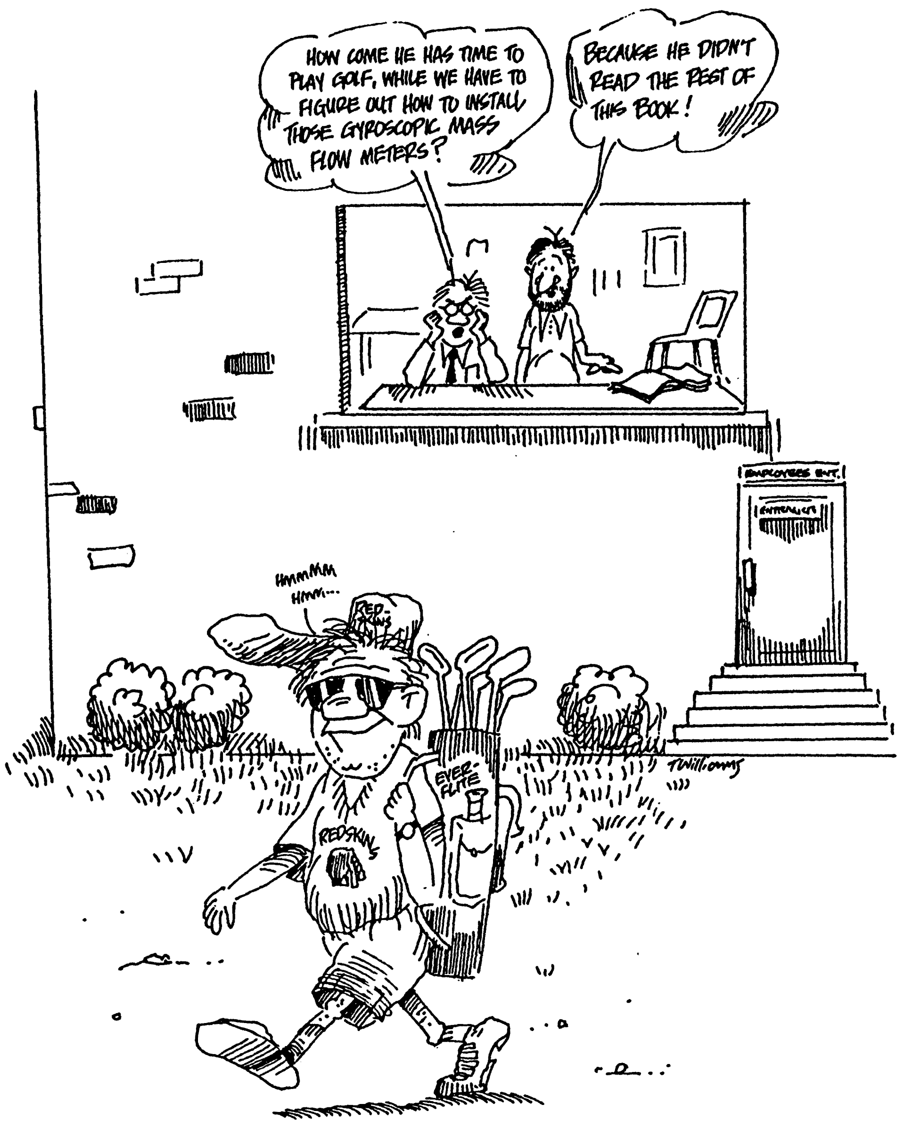
3-1 Blow the process engineer away with as many thermodynamic and fluid mechanic terms as possible.

3-2 Use all the electrical terms, gadgets, and drawings you can find.

3-3 Whenever steam and condensate are directly or indirectly involved, check out the operation of the steam trap before you question the integrity of your instruments.

3-4 Use three or more (never two) measurements for critical process variables so you can defend their integrity.

4



HOW COME HE HAS TIME TO PLAY GOLF, WHILE WE HAVE TO FIGURE OUT HOW TO INSTALL THOSE GYROSCOPIC MASS FLOW METERS?
BECAUSE HE DIDN'T READ THE REST OF THIS BOOK!
EMPLOYEES ENT.
HMMMM HMM...
REDSKINS
EVER-FLITE

How To Avoid Reading the Rest of This Book

If you don't like to read or don't have the time, you can survive as an instrument engineer by using the following.

Rules of Thumb

4-1 Learn effective excuses. Some time-tested ones are:

(a) The schedule is not long enough.
(b) The process is not defined or the information is wrong and late.
(c) The estimator didn't put enough money or man-hours in the project estimate.
(d) Drafting and construction are incompetent.
(e) The PM is wasting my time.
(f) The vendors don't understand the specs and sent the wrong equipment.

4-2 Base your equipment selection on the following:

(a) For controllers, use distributed control systems. Let the vendor spec and do the configuration (nobody understands what they are doing anyway).

(b) For flowmeters, use orifices and d/p transmitters. You will waste some energy and money but at least you can relate to its principle of measurement.
(c) For temperature, use type J thermocouples and isolated transmitters.
(d) For level, use bubblers. They are easier to calibrate than other methods.
(e) For pressure, use anything that turns you on; just pick a range with your pressure in the middle.
(f) For analyzers, think of some way to avoid them. They are expensive, time consuming, and never work.
(g) For control valves, use globe valves one size smaller than the pipeline. This will waste money in large line sizes but will help keep America strong by supporting its steel and alloy industry.
(h) For automated on-off valves, use line-size ball valves with spring return cylinder operators.
(i) For pressure gages, use 4½-inch face with stainless steel movements and bourdon tubes with ½-inch connections.
(j) For temperature gages, use 5-inch bimetal with every angle, ½-inch connections, and a stainless steel well.
(k) For rupture discs, let the process engineer determine their capacity and specify stainless steel and Teflon™ with vacuum support. They may not always burst at the right pressure, but at least they won't corrode. The vacuum support is like an athletic supporter: you may not think you need it until you get a low blow.
(l) For relief valves, let the process engineer do the sizing and let your fingers do the walking through the nearest catalog. They are easy to pick out because the catalogs were also designed to be used by mechanical engineers.
(m) For wire, use individually shielded and twisted pairs routed through dedicated trays, conduit, and drip loops. You may not always need them but it makes pretty pictures to show your boss.

4-3 Don't work on distillation systems. You have better things to do than wait several days to see if a column will line out. If you don't have a chemical engineering degree, the column could be installed upside down and you wouldn't know it.

4-4 Don't work on sequence or interlock systems. They are worse than a jigsaw puzzle with all pieces the same color, and alarms are always going off whenever one of the pieces doesn't fit.

5


WHY DID YOU BUY POPCORN POPPERS INSTEAD OF RELIEF VALVES ?!!
....IT WAS THE LOWEST BID.... WHAT'S THE MATTER, DON'T YOU LIKE POPCORN?
TWilliams

How To Function in a World with Vendors and Buyers

You Can't Tell the Players without a Scorecard

Vendor is a non-sexist fancy name for the salesperson. Once, you were able to tell a vendor from a buyer by the size of their bellies. If the belly was bursting out of a three-piece suit, it was a vendor. If the belly was protruding from a sport jacket (usually plaid), it was a buyer. The habitats of these species were the local posh restaurants between the hours of 11:00 am and 2:00 pm. They were a jolly group, mostly because of the three-martini lunches. The IRS changed all of this. Now you can call and conduct business with a vendor in the office around lunchtime.

Fringe Benefits

Most instrument engineers (the authors are the exception) commute or carpool in seven-year-old Chevys. Vendors drive new Buicks with computerized dashboards. Since the instrument engineers feel intellectually superior yet are paid less than the vendors, a hostile environment is created. To help smooth things over, vendors do the following things:

(1) Take the engineer to lunch at least once a year to the neighborhood Chinese restaurant.
(2) Give the engineer tickets to a local sporting event, provided the team is doing poorly. If the home team is in first place, the tickets go to the manager or buyer.
(3) In places other than the east or west coasts of the United States, vendors provide passes to local social events, such as boating and camping shows. In these cases, the passes are offered at the last minute and are for the entire family.
(4) So as not to insult the engineers, vendors never offer tickets to cultural events such as symphonies or operas.
(5) At Christmas time, the engineer's desk is filled with calendars of fishermen,* pens that leak, coffee mugs with company logos, and coasters with company logos to keep the coffee mugs from staining the desk (as if anyone really cared).

Fun and Money without Guilt

It is fun to be with vendors even when they are sober. They are basically social animals. They were the type of students who stayed out and partied all night before the exam. They may not have got the highest grades, but grade points don't mean much once you get on the job. Besides, the information you learned in school was extraneous anyway, as discussed in Chapter 1. They wanted to make money and still have fun. The potentials for this on the selling end are much greater than on the user end of the instrument engineering game. Maybe they were the smart ones!

*We haven't figured out whether a relationship exists between instrument engineering and fishing. There is a possibility that at some state universities in the Midwest they manage to slip a chapter on camping and fishing into the Electrical Engineering Field Theory course; but since we are not EEs, it's only a rumor.

Vendors have a different outlook on the job. They are not bogged down with worries of whether an instrument will actually work. They live and thrive on the glitter and glamour of the advertisement and marketing information passed on down the line from the manufacturer. They actually believe this stuff. They have a clear conscience because they rarely get out into the field. Since very little data is ever gathered on the actual performance of instruments, any problem relayed from an irate user is usually discounted as being caused by poor installation or maintenance practices. Actually, vendors get very few formal complaints because the user is basically introverted and prefers to correct the problem and bitch privately rather than make a public case.

Welcome to the Real World

Even the user doesn't realize how poorly field instruments perform. It is the authors' experience that the accuracy of these devices after installation is about an order of magnitude worse than advertised. This has to come to light from cross checks made possible with the accuracy and computational capability of distributed control systems. For example, attempts to close material and energy balances has revealed that the advertised accuracy of 0.5% to 1.0% for flowmeters is really more like 5% to 10%. Similar results have been documented for the relatively simple and innocuous pressure transmitter. The accuracy specifications given in the catalogs are based on tests under controlled and ideal conditions. The exposure of the device to the environmental and process conditions commonly found in a chemical plant causes all kinds of problems never even envisioned, especially where mechanical components are involved.

Data from the world's largest user of instruments shows that eighty-five percent of the failures in a control loop occur in the field. You as a user must learn to take the advertised specs and claims with a grain of salt. As summarized by one streetwise immigrant in his own special brand of English: "Beware of the vendor; he will try and fool you around." You can make progress in the fight against the overabundance of misinformation and the dearth of data and provide a great service to the instrument engineering community at large by documenting the results of field cross checks and tests. Don't expect the manufacturer to include this information in the catalog; that won't sell instruments, particularly if the competitors still paint a rosy picture. The best you can hope for is that it will be included in an application note. You as a user must learn to ask for these notes. They are not commonly given out because they make the vendor's products look as though they have problems. They do, but so do the competitors. Given that all instruments have application problems, often, your best bet is to go with the vendor who is up front about them.

Are Vendors Carnivorous?

Because instrument engineers buy so many different items, they must learn to deal with large numbers of vendors. Vendors somehow find out when a project is approved or when money is about to be spent, even before you do. The occasion is marked by vendors circling you like sharks in a feeding frenzy.

Just a Number

The worst thing a local vendor can do is call you up at the last minute, because the regional sales manager just came into town, to demonstrate their newest microprocessor-based junction box. When they arrive late, after taking the buyer out to lunch, the local person has the catalog sheets, which he or she proceeds to read to you. Despite popular belief, most engineers can read the locally accepted language. This doesn't mean that they understand it, but neither does the vendor.

The majority of catalogs are just a collection of pictures and buzz words. They don't give enough information to determine whether the instruments will fit your application. There is also a

32-digit model number that completely describes the standard off-the-shelf version. If you want anything special, you must put an "X" in front of the model number and then describe it in detail. If you really want to know about the instrument, you must read the instruction book. The sales manager keeps one copy, written in Chinese. It seems the Chinese invented the basic principles while they were building the Great Wall and they don't want the rest of the world to understand it. The price depends on the current price of rice in China and cannot be converted to U.S. dollars without first converting into Swiss currency.

Buyers are extremely strange people (based on the way they dress and act). The job is absolutely horrible. What possesses a person to want to become a buyer is beyond comprehension! The paperwork is enormous. The instruments lose their form and functionality and become just a statistic. The whole emphasis of the job is to buy the lowest priced instrument, unless two free tickets to the ball game are at stake. Do not let these people make decisions for you. This can be done by writing the specs so that only the manufacturer of your choice can satisfy them. This also avoids the delays in going out for quotes. Since the buyer doesn't understand the first thing about what you say, it is not that hard to do.

The Paper Mill

Buyers and vendors deserve each other. Most purchasing agents don't know what they are buying, and most vendors don't know what they are selling. However, in order to obtain a price and delivery, a requisition, with nine copies of a specification, is required. What the buyers do with the nine copies is one of the great mysteries of this profession. We do know that the vendor gets two copies. A logical mind might think that one copy is sent to the factory to get the instrument built. WRONG. The vendor interprets the engineer's specification onto a factory order sheet. No more needs to be said about this.

The purchasing paperwork system has many other absurdities. consider what is written on the back of the purchase order form and on the back of the vendor's acknowledgment form. It looks as though a bunch of first-year law students from the "Paper Chase" wrote the one and a group of CPAs wrote the other. Neither group understands what the other has done.

A truly bizarre experience is that of approving and issuing of vendor data by a large contract engineering outfit. One million trees each year are sacrificed so that the dimensional drawings of each I/P transducer used on a valve can be distributed and filed. It doesn't matter that these transducers are all the same and come already mounted on the valve. Since contract engineering firms frequently get paid for each piece of paper issued, they are astute at making sure every device on the job has vendor literature. The few drawings and installation manuals of real interest get lost in the pile of superfluous vendor data. If you really need some information, obtain and distribute it personally. Work with the vendor to eliminate unnecessary vendor data. It is a waste of time and money for everyone concerned.

What do they do with the 14 copies of vendor data that you are supposed to get with each order? There is usually one person who really needs the instruction book, installation book, wiring diagram, spare parts list, and dimensional drawings. This is the person responsible for the calibration and maintenance of the device. He or she doesn't get any of the information, not even the set that comes in the shipping carton! The person in receiving throws that one away. (We would like to accuse the project manager of holding all the other copies for ransom, but then we might be accused of being unfriendly.)

What's It All About

The question often asked in college bars after midnight is, "If winning popularity polls is important in industry, why don't they teach that instead of Advanced Engineering Mathematics?" Psychology professors are easier to find than Ph.D.s in engineering, are not significantly more or less mentally disturbed, and are cheaper.

War Stories

5-1 About twelve years ago in one large firm, a special meeting of all instrument engineers in engineering was held about 2:00 pm to warn instrument engineers not to waste company time by going on business lunches. The meeting didn't get started till 2:30 pm because the manager and buyers were late getting back from a lunch with the vendors.

5-2 Early in his career, a young engineer became the lead engineer for the world's largest plant to produce an important chemical. He was energetic but painfully naive. When notified of a price increase in the analog controllers, he tried to save the company money by buying all the controllers immediately. The manufacturer and the vendor were less than pleased because their profits were reduced accordingly.

During start-up, half of the controllers failed. It seems that all the failures known over the years culminated in this batch of controllers. Problems were experienced with thumb wheels, slide switches, umbilical cords, Zener diodes, capacitors, case clearances, pointer clearances, and case connections. Most of the problems developed when the manufacturer went to alternate, cheaper suppliers of components to reduce the cost of the controller. Many of these problems had been identified prior to the shipment in question. It was almost as if the pile of rejects over the years had been sent in an effort to get the job out the door.

After the project, the instrument engineer went with his manager to the manufacturer for restitution. The engineer and manager were wined and dined, but the manufacturer never admitted there were any real problems because the engineer had no written proof of the repairs made. The manufacturer essentially called him a liar. The engineer took it personally until he realized that it was all part of the game. The game plan for the manufacturer was to sell as many instruments as possible. Publicly admitting a reliability problem was strategically unwise because it opened the door to advertisement of the problem and possible liabilities.

Rules of Thumb

5-1 While a vendor is not quite in the same category as a used car salesperson, don't be gullible enough to believe everything he or she says.

5-2 The actual accuracy and reliability of field instruments after being placed in service is enough to make you upchuck. If this is too upsetting to you, become a programmer so that all the problems you face are well defined and under your control.

5-3 Document the data from actual field results of instrument installations and share the results with the vendor and other users.

5-4 Insist on getting application notes and having access to the person at the factory who designed the instrument.

5-5 Use innovation and imagination in the writing of your specs to insure you get the manufacturer of the best, not the cheapest instrument for your job.

5-6 Turn down all offers to become an instrument buyer.

5-7 If you have clothes that resemble those worn by your buyer, you know it's time to send them to Goodwill Industries.

5-8 Avoid a blanket vendor data system like the plague.

6


HERE, HELEN,,, USE THE NEW COMPUTER-AIDED DESIGN PROGRAM TO MAKE TWENTY P and ID'S OUT OF THE CLIENT'S EFD. PUT FIVE COLUMN TRAYS ON EACH DRAWING...
COMPUTER AUTOMATED RANDOM MESSAGE GENERATOR
100
XYZ CON ENG.

How To Do Engineering Flow Diagrams (EFDs)

"You Can Call Me Ray, or You Can Call Me Jay"

Some people call EFDs "Piping and Instrument Diagrams" (P&IDs). Some people say EFDs and P&IDs are not the same. Some engineering companies take their clients' EFDs and convert them to P&IDs. This is a good way to make money. For $50 per hour, a company can do well changing some symbols and title blocks.

Creative Copying

The best way to get started on EFDs is to find an old set of drawings from a similar project and copy whatever you can. Then find another project and copy parts of that one. The more different jobs you copy, the more creative you look. Let's face it, almost everything has been done before. Just find it.

Appearance is Everything

Putting a lot of instrument and electrical symbols on the EFD clutters up the drawing but makes the control system look impressive and diminishes the importance of the process equipment and piping since there is no room for it. Show all kinds of symbols, such as flow elements and transmitters, transducers, solenoid valves, limit switches, interlocks, software and hardware alarms, manifolds for orifice meters, and drain valves for pressure transmitters and control valves. Analyzer sample systems, along with all the filters, regulators, and fittings, are a great way to fill up a drawing. Irrelevant notes and interlock descriptions are a great way to use up space above the nameplate.

In some contract engineering firms, the only thing instrument engineers are allowed to do on the EFD is assign the instrument numbers. We think this is a serious degradation of an honorable profession. You should refuse to put those numbers on until you get a piece of the main action. Since the EFDs cannot be issued without numbers, you are in the driver's seat, as long as the process engineer does not read the following section.

Numbing Numbering

Every instrument needs a number. It's like a name or identification. Simple? No!

There are probably almost as many ways to number instruments as there are instrument companies. Since people can't agree on what company to use, there is no reason they should agree on a numbering system.

Four main groups seem to be fighting the battle: engineering, manufacturing, maintenance, and purchasing/accounting (they are only trying to keep track of the money) departments.

One group wants the instrument numbers associated with the department and equipment numbers; another group wants to use the same sequence on every project even though they have fifty-five FIC-101-1s in the plant; another group tries to keep the number of digits below eight so they fit on a nameplate or CRT tag; and there is always one group who wants each of six million instruments in a large corporation to have a unique number.

The best game is to have more than one number for the same instrument. There are different ways to play this game.

Version A: Build a plant, number all the instruments, and wait a few years. Now come back and modify the unit while changing the numbering system. All the existing instruments, wires, etc., have the old numbers while all the new stuff has the new numbers. It's fun checking out flow transmitter 01FT-123-1 that goes to controller 23FC634-7 that goes to I/P-132-6, which is tubed to 07FV-316-2. There is no telling how the wires are identified.

Version B: Hire an engineering company that has a standard numbering system. About the time all the instruments are bought, show the numbering system to the operating and maintenance people. Watch them get violent. Agree to have all the nameplates with the plant numbers even though all the drawings have the engineering company numbers. Agree to develop a cross reference system on your personal computer spread sheet program.

Version C: Same as B, except that you refuse to develop a cross reference system unless they give you your own personal computer.

Version D: Same as B, except that you quit.

Test problem 1: Develop your own version of the numbering game.

Test problem 2: Develop your own numbering system. Hint: Use Roman numerals.

Rules of Thumb

(If you think these rules are good ideas, you need more help than this book can offer. On the plus side, you have management potential.)

6-1 Converting EFDs to P&IDs is a good way to make money.

6-2 Refer to drawings from as many old jobs as possible in order to look creative.

6-3 Depict as much obscure detail as possible in order to make your control systems look impressive.

6-4 Use as many inane notes as possible to fill up space. Some time-tested ones are:

- (a) Insulate hot and cold pipe to prevent personal injuries.
- (b) Slope piping to drain.
- (c) Prevent instrumentation from freezing.
- (d) Mount instrument and control valves in accessible locations.
- (e) Provide on-off switches for all motors that must be started or stopped from the location where the switch is mounted.
- (f) Provide freeze protection for safety showers located in areas with dangerous chemicals.
- (g) Connect electronic instruments with wire and pneumatic instruments with tubing.
- (h) Interlock bypass switches must not be operated by unauthorized personnel while the programmable controller is bypassed.

7


VARIABLE SPEED DRIVE PARTS HERE
NEW PARTS
DISTRIBUTED CONTROL SYSTEMS THIS SIDE ONLY
HEY, WAIT A MINUTE, OLD GEEZER... WHAT'S THAT THING?
IT'S A CONTROL VALVE, WISE GUY! THEY WERE USED BEFORE MECHANICAL ENGINEERS BECAME EXTINCT AND WHEN SILICON CHIPS COST MORE PER POUND THAN METAL!

How To Select Control Valves

Do Experts Exist?

There used to be control valve experts in every part of the industrialized world. That was in the days before the microprocessor and the oil embargo. Now, hardly anybody cares about automated valves. Almost all the valve companies are part of some multi-national organization that sells software to Russians for vodka that goes to universities that do research with professors who don't speak the local language, which in turn allows the undergraduates to go for MBAs and law degrees in order to run the corporation. Besides, there is no glamour in control valves like there is in distributed control systems.

Would any new electrical engineer, out of a distinguished university that taught him or her "the Nyquist Criterion for Discrete Time LTI Feedback Systems" be interested in pipe when all those data highways need a parent? Even old EEs like a cable tray better than flanges, gaskets, and packing. Besides, has anyone ever "interfaced" with hardened stainless steel valve trim?

If you have read this far and are still interested, the following list should convince you to make your assistant responsible for the automated valves. He'll probably get "deployed" before he screws up too badly (notice that I said he; female engineers don't get deployed — they quit before things get that bad).

Reasons for Not Using Valves

(1) They leak.
(2) They make noise.
(3) They use energy.
(4) 83.43% of the time they are sized incorrectly. 76.1% are too big. 5.13% are too small. 2.2% are both.
(5) You need to understand about vapor pressure, which makes valves cavitate and flash.
(6) You need to be a metallurgist to understand why 304ss is better than 316ss some of the time.
(7) You need to remember what they tried to teach you in "statics" about unbalanced forces. If you don't understand this, you may actually try to buy an operator with a 3 to 15 psig spring.
(8) If you screw up in sizing or selection and the valve needs to be changed, everybody will know it. It's easy to change wiring or programming at night when the technicians are on coffee break. It is hard to hide a 400 lb valve under your coat.

Reasons for Using Valves

(1) They work.
(2) Variable speed drives may be more expensive and may not work.
(3) You get to use a personal computer to size them.
(4) They come with free Chinese food and tickets to fishing shows (see Chapter 5).
(5) They are great to stand on to reach field-mounted temperature transmitters (see Chapter 8).
(6) You make friends with some nice old timers who tell some great war stories.

How To Select the Proper Valve Company

In the old days, each valve company had its favorite color, such as green, red, blue, etc. Sometimes the only way that you could tell one valve from another was by the color. Now companies use multiple colors. Some companies have valves built in outside shops or in other countries and sell them through still other companies. To further confuse you, they paint them different colors, depending on where and how you bought them. Conclusion: colorblind engineers can now buy automatic valves.

Some users of control valves actually send inspectors to the factory before the valves are shipped. This is a great way to build up frequent flyer mileage, to get some good steak dinners, to get tours of automated machine shops, and to increase your prestige with the project manager.

War Story

A process engineer calls the company control valve expert with a problem. He is charging liquid ammonia at 150 psig pressure to a reactor at zero psig pressure and 35 degrees centigrade. When the liquid ammonia goes through the globe-style control valve into the reactor, it changes from a liquid to a gas. The process engineer would like some kind of control valve that would keep it in the liquid state.

The friendly instrument engineer, who barely passed thermo in college, suggests that the reactor pressure could be raised and/or the temperature lowered to keep the ammonia in the liquid state. The process engineer doesn't like this idea at all because the reactor is not rated for a higher pressure and the chemicals won't react at a lower temperature. So, he hangs up, angry at the instrument engineer. One month later, our friendly instrument engineer gets a phone call from another process engineer with the same problem. His response is, "Didn't I hear this story before?" "Yes, you did," answers the second process engineer, "but seeing as how the first guy couldn't solve the problem, they assigned someone new."

Rules of Thumb

7-1 Split ranging two control valves to increase rangeability works only in the movies. The term itself, as defined by the vendor-written catalogs and standards, is useless.

7-2 If you ever specify a split range, reverse-acting positioner, expect to explain the concept a minimum of seven times.

7-3 Bypasses around automatic valves are a great way to defeat the most sophisticated control and interlock systems.

7-4 Buy control valve bodies the same size as the pipe because:

- (a) It supports your favorite valve company.
- (b) Nobody likes pipe reducers, and there is no such thing as an expander.
- (c) It reduces pipe stresses (this doesn't make sense to a mechanical engineer, but there aren't many of them around).
- (d) You are preparing for future expansions.
- (e) The valve makes less noise and the fluid velocity is lower (this is almost as dumb in most cases as item 7-4c, but it impresses process engineers and project managers).
- (f) The bolts, gaskets, and operators are bigger. This makes the valve easier to stand on and makes a better ground path for magnetic flowmeters.

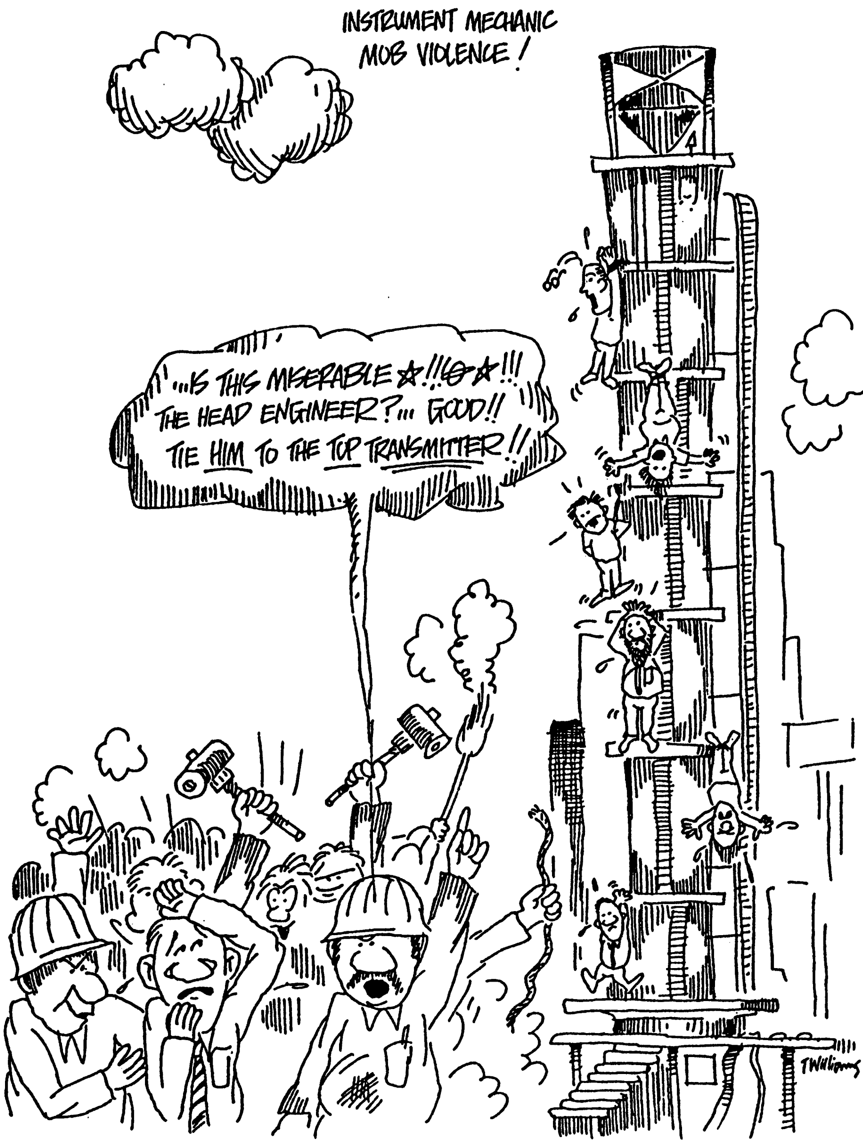
7-5 Noise reduction trims (with small holes) are great places to trap pipe scale and oyster shells.

7-6 Make sure that valve companies never mark the end of the shaft of butterfly valves with the disc position. Not knowing whether the valve is open or closed makes for great arguments.

7-7 Sandblast and paint nameplates so the valve can't be identified; otherwise, it may take years for it to become unreadable.
7-8 Rotary valves are easier to buy than globe bodies because you don't have to specify the trim type (i.e., equal percentage, linear, etc.).

7-9 If you don't know which manufacturer's valves to buy, use the Instrument Society of America's method for calculating the sizing coefficient. That will buy you enough time to get your act together.

8


INSTRUMENT MECHANIC MOB VIOLENCE!
...IS THIS MISERABLE ☆!!@☆!!! THE HEAD ENGINEER?... GOOD!! TIE HIM TO THE TOP TRANSMITTER!!
TWilliams

How To Select Field Instruments

Flowmeters

The selection and sizing of flowmeters requires a basic philosophy or prejudice. One must say something like, "I hate orifice plates and all other differential-type meters," and then go looking for some other way of measuring flow. The opposite approach (use an orifice unless it won't work) has been the most popular method of selection since the Ark. If your company likes differential-type meters and you don't, a case must be made for not using them. You need to know the arguments and counterarguments for their disadvantages.

They are not very accurate. If you're getting ±2% of full scale, consider yourself lucky. Who needs accuracy anyway? Repeatability is what everybody really needs. You can't calibrate them anyway.

They have nonlinear signals. Square root charts, scales, or square root extractors are required. Transmitters can extract square roots for additional cost with a reduction in accuracy. Microprocessor-based recorders and controllers can extract square roots with small loss of accuracy.

They have poor rangeability (about 4:1). If the max flow is 70,000 pph, size for 100,000 pph to get an even number of 70,000 pph at midscale and 50,000 pph on the lower portion of square root chart. Of course, the reading is not much good below 30,000 pph due to a high noise-to-signal ratio, and the meter coefficients are not accurate below 20,000 pph due to low Reynolds number (now your rangeability is only about 2:1).

They really are a pain to install. There is never enough straight pipe to get a good velocity profile, but velocity profiles are only pretty pictures in engineering textbooks between hydraulic differential equations. There must be at least 4000 ways of installing d/p transmitters. You need to know dumb things like those listed in the Rules of Thumb.

Rules of Thumb for d/p-Type Flowmeters

8-1 Mount the d/p above the taps for gases (except steam).

8-2 If you mount the d/p below the taps for steam, the sensing lines will fill up with condensate and freeze in the winter.

8-3 Mount the d/p below the taps for liquids. Most liquids freeze, solidify, plug, or leak.

8-4 If you steam trace the sensing lines, the liquid will boil and solidify.

8-5 If you insulate the sensing lines, the chlorides in the insulation will corrode the stainless steel tubing if it gets wet.

8-6 If construction keeps track of how much it costs to install instruments, never use orifices and d/p transmitters. All the parts and labor are charged to your account. If you buy "in-line" flowmeters, piping pays for installing them.

Rules of Thumb for "In-Line" Flowmeters

8-7 For all waste disposal-type projects (otherwise known as sewer jobs) and for acids and bases, get magnetic flowmeters. Buy platinum electrodes and Teflon™ liners (it never corrodes).

8-8 For all petroleum-type liquids, get turbine meters with upstream strainers. This excludes the tar or crude from the bottom of distillation columns, which isn't worth measuring anyway.

8-9 Use vortex meters for steam in up to 8-inch pipe size. You can't use a 10-inch unless you build it yourself. Once the pipe gets above 8 inches, it's easier to measure boiler feedwater flow and convert it to steam (pph = 500 × gpm × specific gravity).

8-10 For small flows like 5 pph or if you want to do a mass balance, use gyroscopic mass flowmeters. "Mass balances" is a neat thing to say to process engineers (see Chapter 3).

8-11 Every plant needs at least three "sight flow indicators" with spinners located where the vice president and plant manager can watch them. No matter how sophisticated the control system or flowmetering technique, a spinner is something every executive understands. If your safety department is not sympathetic to the needs of upper management and won't allow glass indicators, some mechanical totalizers can be almost as effective. Electronic LED totalizers last longer, but they don't click. Put a clicking totalizer on the plant product so management can walk through the control room and tell how well the plant is operating by the noise level.

Pressure Transmitters

Pressure transmitters are really boring. If you *need* a pressure transmitter, you can't buy anything else. There are all kinds of ways to measure flow, temperature, and level, but pressure transmitters are all basically the same. They all have about the same accuracy and they all work. There are hardly any good war stories about bad pressure transmitters that were incorrectly manufactured and/or installed. In order to help fill up this book, we have scrounged up some rules of thumb.

Rules of Thumb for Pressure Transmitters

8-12 Buy pressure transmitters with ½-inch process connections and 316 stainless steel wetted parts. A ¼-inch connection will break when you stand on it.

8-13 If you need some metal other than 316 stainless steel, buy a transmitter with a chemical seal installed at the factory (not at your local hamburger joint; they have been known to use oil from the french fries to fill the seal).

Temperature Measurement

When in doubt, use type "J" thermocouples to measure temperatures. DON'T use copper wire to connect your thermocouples to transmitters, recorders, or distributed control systems unless the instruments are located in a place that is always the same temperature as the head of the thermocouple. If you want to bias the temperature you are measuring by the difference in temperature between the thermocouple head and the control room instrument, switch the thermocouple polarity at the head and at the control room.

Thermocouples are a hassle to buy; you have to make decisions based on no information. For example, what kind? R, S, T, J?? (Don't know where to get these silly letters.) Do you want stainless steel sheath or bead-type insulators? (If you buy the kind with insulators, you can buy wire and insulators and build them in your spare time.) Single and dual elements? (You can get twice as much for a little more money. It's somewhat like buying peanut butter or jelly.) Grounded or isolated? (Isolated becomes grounded if you wait long enough.) If you use thermocouples, someone may ask you how the cold junction works, and then you are in big trouble. In addition, who really believes that two different kinds of strange wire welded together will generate a voltage?

Be creative and sophisticated. Use resistance temperature elements. Even project managers understand that when the temperature of a metal changes, the resistance changes. Besides, it is neater to buy platinum than iron-constantan. Just remember to specify 3-wire platinum RTDs with the DIN calibration or standard. Everybody in Europe and South America will love you.

If the temperature signal has to go to a controller, you may need a 4 - 20 mA dc convertor or transmitter (same thing — just a different name). OK, folks, where do you mount the transmitter? If you like to torture instrument mechanics, buy "head-mounted" transmitters. That way, the electronics are mounted on the thermocouples or RTDs, which are located in inaccessible, hot, and vibrating pipes. Make sure the transmitters are checked during snowstorms and thunderstorms so the mechanic can carry fancy calibration equipment up ladders under challenging conditions.

Level

If you've read this far, you may be asking, "Why did these two nuts write this book?" Possible answers are:

(1) They hate management and this is a way of getting back.
(2) To become rich and famous when the movie is made.
(3) They hate college professors and this is a way to get even.
(4) To become rich and famous when the show opens on Broadway.

(5) To convince management that instrument engineers are smarter than the average bear and should be paid accordingly.
(6) To become rich and famous when the opera opens at the Met.
(7) All of the above are partially correct.

Now for the real reason. One of us started out in college to be a physicist. The other went to graduate school to become a physicist. We didn't make it. So here in the level portion of this book, we get our chance at immortality. ALWAYS MEASURE LEVEL WITH NUCLEAR DETECTORS. Why? You get to put those neat yellow and black warning signs all over the plant. You can practice duck and cover like in the 1950s. You can blame your hair loss on radiation. You don't have to calculate the calibration of the transmitter. You don't have to ask the process engineer what the temperature, pressure, or specific gravity are and if they will change. Corrosion is not a factor. The nuclear source is a good place to store radioactive waste products from old bombs and defective power plants. Nuclear energy is a truly American industry. Finally, the plant gets to assign someone the title of "Nuclear Safety Engineer" (it's a good job for deployed project managers).

War Story

Several tanks with extremely nasty chemicals had the latest and best in nuclear level detectors. The level spans were long but were kept at less than the diameter of the vessel. The detectors had signal linearizers to compensate for the varying radiation path lengths from the single source. Since it was a batch operation, the level measurement was used to signal when the tank was empty. During water batching, it was found that these devices were giving false readings of up to 50% level when the tank was empty. A real-time trend of tank nitrogen padding pressure and level showed that the false level indication coincided with an increase in pressure. The nuclear device vendor said such pressure effects had been observed only for changes of several hundred psi. Some calculations by a former physics major showed that at very low levels a false signal of several percent could appear at the detector from a gas density increase due to the longer path length and that the 13:1 gain of the linearizer at this point could blow it up into a 50% false level signal.

9


A KLINGON WAR CRUISER JUST ZAPPED OUR DISTILLATION COLUMN!!!
...HEH-HEH... I MERGED A STAR TREK GAME WITH THE CONFIGURATION. THE CONTROLS WERE SO AUTOMATED, THE OPERATORS WEREN'T PAYING ENOUGH ATTENTION TO THE DISPLAYS... HEH-HEH-HEH...
HERB
TWilliams

How To Select Control Room Instruments

Choice Choices

Selecting control room instruments is easy. You look at what is going on at a particular location and make your decision based on your observations. Consider the following alternatives:

(1) The plant is using XYZ brand instruments. They know how to maintain them and have a warehouse full of spare parts. Conclusion: Buy some more.

(2) The plant is using XYZ brand instruments. They know how to maintain them and have a warehouse full of spare parts. Conclusion: Buy another brand. XYZ is probably ripping you off because they think you will always buy their stuff.

(3) Buy some of each brand. It complicates the engineering. Everyone thinks you are a genius. You become indispensable. You get more free lunches and tickets to camping and fishing shows.

(4) Let the vice president decide. He or she sees the big picture and is in a much better position to make decisions than an arrogant instrument engineer.

(5) Buy instruments that are almost obsolete. Then, in a few years when the plant can't get spare parts, you can replace them. This keeps corporate engineering busy.

(6) Buy systems with CRTs. You won't have to design and check out control panels, and the operators can sit in soft chairs instead of standing up and looking at silly dials and lights. You also get to build those cute graphics on CRTs with things that move. It's almost as good as being an illustrator for kid's cartoons.

(7) Only buy instrument systems that can talk to the popular brand of computers with no more than four interposing adaptor boxes. It's like buying VCRs that will allow you to watch one station, listen to the sound in stereo via your receiver, and record a movie. A good engineer can do almost anything with enough splitters, adaptors, convertors, and 400 miles of wire (twisted shielded pairs and coax judiciously intermixed).

(8) Get your company to buy stock in some instrument company. Then you can get a great discount and not have to argue with everybody and their brother about what to use. The problem with this idea is that there aren't enough instrument companies to go around.

(9) Build your own instruments. It's not economical, but it may impress management and you may get patents even though you could do the same or better with off-the-shelf devices. If you become successful, your company may have to start an instrument division or go out and buy an instrument company to market your great development.

For more reasons than we care to enumerate, all of the above ideas are ostentatiously odoriferous or, in other words, they stink. However, the ideas in this book will not become obsolete 1/10 as fast as your current variety of control room instruments.

Copious Capability

If engineers spent as much effort in finding ways of applying their distributed control systems as they spend in trying to select one, they would get more for their money. Almost all distributed control system installations have untapped capability. Most systems have microprocessor controllers with so much computational power that the main limit to what you can do with a bunch of signals is your imagination.

The toughest part of applying a distributed system is learning how to configure it. You usually can't learn it from the catalogs. The best way to learn it is to go to a short course and immediately afterwards sit down at a console and start using what you were taught. The key thing to remember is that you really can't hurt anything, so don't be afraid to experiment. Once you are familiar with a system, it's duck soup. Knowing the ins and outs of a distributed control system gives you an incredible sensation of power. Project managers are like putty in your hands because these black boxes are a complete mystery to them.

We really like working with distributed control systems because we can screw up a control strategy royally, and, as long as we have enough measurements and valves, we can correct our mistakes overnight with a configuration revision. In the days of analog devices, a major change in strategy was embarrassing because it meant you needed new hardware, different wiring, and/or recalibration. It was hard to hide your goofs from the project manager, especially when you needed his or her signature on a purchase order. The implementation of any complex control strategy with analog devices indicates suicidal tendencies.

Why You Need a Distributed Control System for Complex Strategies

(1) Complexity is transparent to the operator.
(2) Parameters are accurate.

(3) Parameters are easily adjusted.
(4) Pure time delays are available.
(5) All the math functions you could possibly think of are available.
(6) Computations are accurate.
(7) Real-time simulation testing can debug displays, strategy, and configuration.
(8) Mistakes can be quickly corrected.
(9) Graphic interfaces make strategies understandable.
(10) Tracking functions can make bumpless transitions between strategies.
(11) The graphic displays impress managers.

Nameplates

There is absolutely no university, technical school, or Short Course that teaches the design and construction of nameplates. All of the following must be determined (Example 2 is much more sophisticated):

(1) Size of nameplate
(2) Color of nameplate
(3) Color of letters and numbers
(4) Number of lines
(5) Number of characters per line
(6) Size of characters
(7) What goes on line 1, 2, 3, etc.

Example 1:

BEER LEVEL
LI-101-1

Example 2:

LI-101-1
PRODUCT INVENTORY
0 TO 100%

There are an infinite variety of possibilities, especially if you are building nameplates on a colored CRT. You could make a career out of it!

War Stories

9-1 In less enlightened times, when distributed control systems didn't exist, an instrument engineer decided to install tracking kits in the outer controller in about thirty cascade loops after watching operators struggle with the commissioning of such loops. It seemed like a brilliant idea. The outer controller's output would track the inner controller's measurement whenever the outer controller was in manual so that the transition from auto to RSP in the inner loop and the transition from manual to auto in the outer loop would be bumpless. A few months later, all the tracking kits were removed. The operators kept trying to operate the manual output of the outer controller. Since it would not move, the controller was sent to the repair shop. Since the mechanics did not understand the function of the tracking kit, they spent days running diagnostics on all thirty controllers. As a postnote, tracking is now used extensively in distributed control systems. Why does it work now? CRT messages and graphic displays tell the operator when and where tracking is enabled. Also, the operator has become accustomed to a greater level of automation.

9-2 In the old days before the revolution, nameplates were black and white laminated plastic. You could engrave a black nameplate so that the letters were white or a white nameplate so that the letters were black. One particular engineer personally liked white plates with black letters because you could wipe them off when they got dirty. If you wiped off a black plate, the dirt got into the white letters and you couldn't clean them. This is the kind of thinking that made this instrument engineer into a consultant.

10


WHERE ARE THE INSTRUMENT PANELS?
DID YOU CHECK THE BROOM CLOSET?
BUTTONS ... WHISTLES
AUTO-SANDWICH FIXER
PRESS HERE
AUTOMATIC THIS
AUTOMATIC THAT
THE LATEST
HIGH-TECH CAFETERIA WE ALREADY KNOW WHAT YOU WANT TO EAT...
AUTOMATIC TURKEY COOKER
AUTOMATIC SPOON DISPENSER
TAKE YOUR PICK
RRRRR
AUTOMATIC COFFEE EVERYTHING
SELF CLEANING TABLE....
T. Williams

How To Do Control Room Layouts

"It Looks Like a Nice Place to Stay, but Does It Have Cable?"

Control room layouts fall into two main categories. Category #1 occurs when you are building a new plant and need a "control building". The only reason we can come up with for why this building is called the "control building" is that it has one room called a "control room". It also has 24 offices for the following people:

(1) Operating Superintendent
(2) Operating Supervisor
(3) General Foreman*
(4) Day Shift Foreman*
(5) Night Shift Foreman*
(6) Technical Service Engineers
(7) Maintenance Foreman*

*Foreperson sounds funny.

There are also the following rooms:

(1) Computer equipment
(2) Instrument equipment
(3) Electrical power equipment
(4) Uninterruptible power supply (UPS) room
(5) Motor control center
(6) Men's bathroom
(7) Women's bathroom
(8) Unisex bathroom
(9) Men's shower and locker room
(10) Women's shower and locker room
(11) Janitor's supply room
(12) Instrument shop
(13) Conference room
(14) Training room
(15) Lunch room and cooking area

Everything is optional except for the lunch room. The place has so many rooms it could be a hotel. The plot thickens. Since this control building is so big and complex and must serve so many different functions, its design and construction is on the critical path. That means the "control building" must be designed before the engineering flow diagrams or even the process flow diagrams are finished. Consequently, the instrument engineers don't know how many cabinets, control panels, consoles, etc., are needed. If you don't know how much equipment is required and how much space each will take up, how do you size and lay out the control room? Two methods are used predominantly. In method A, the project manager has a size in mind. This size may have some relationship to the size of the recreation room in his or her house or the size of the living room that his or her spouse would like to have. Project managers normally plan for a building of "X" square feet with a cost of "Y" dollars. If the sizes of all the offices and other rooms previously listed are added up, that number can be subtracted from the "X" square feet to obtain the size of the control room. Sometimes this is a negative number, in which case the project manager asks if the plant can be operated without controls.

In the old days, the control rooms and the cooking facilities were combined. That allowed the operators to hunt and fish on their off shifts and then prepare exotic meals when they were getting paid. The aroma of the onions and garlic frying in the hot oil was enough to make you pass out. Did you know that the only triple A rated dining in St. Louis is in a "control building" and that most of the gourmet chefs in Missouri were trained in chemical plants?

"Who Said This Wasn't a Technical Book?"

Method B for sizing the control building uses a formula with the following input data:

- D1 = distance of control building to operating structure
- D2 = distance of control building to road
- D3 = length of pickup trucks parked in front of control building
- W4 = width of pickup trucks parked in front of control building
- DT = distance of control building to unit substation
- DMCC = distance of motor control center to unit substation
- WAC1 = watts required to operate main air conditioning unit
- WAC2 = watts required to operate backup air conditioning unit
- DEG = distance to emergency generator
- PFo½ = power factor while operating unit at 50% capacity

(The formula for combining all the above variables should appear here. However, in order to print it, the publisher would have to increase the price of the book by 50 cents or else reduce our royalties by one dollar. Since it is so complex and has no relative significance, we decided to delete it. But if you send a stamped, self-addressed envelope and two dollars to cover the handling cost, we will send you a 5¼-inch, quad density disc that contains a menu-driven program used to configure distributed control systems.)

We now come to Category #2 of control room layout. You have an operating plant with pneumatic panel instruments with oil dripping out of the air pilots, half the controllers in manual, relay cabinets with a variety of jumpers in strategic places, annunciator acknowledge buttons with pennies in them, recorder pens that leak ink all over your hands and the chart paper, and all the other wonderful sights that gave the instrument business its start. Someone, while in the process of getting divorced, decides to either change the process and/or instruments. Since the panels have been modified from the graphic style popular in the fifties by welding ¼-inch steel to the front, and since 75% of the wires and tubes are hanging unsupported, and since there are four different numbering systems on unreadable nametags, it is decided by management and some aggressive young engineers to install a distributed control system. The schedule calls for the replacement of all these wires, tubes, panels, cabinets, etc., during the annual two-week shutdown. If you determine that the room isn't big enough, they will let you put the instrument cabinets in the janitor's closet and put a second story on the building for additional offices and training facilities. Main rule: Don't mess with the lunch room. Secondary rule: Hire co-op students from the local engineering school to tag all the existing instruments, wires, and tubing. Give the co-op a plastic tag machine and a personal computer with a spread sheet program to document where and what they have discovered. It's a lousy job, but it builds character. Plus, those EE students have to learn how to do more than calculate the voltage on a ground wire with zero resistance connecting two resistors with infinite impedance.

War Story

During a unit upgrade, a new control room was to be built (adjacent to the existing lunch room, of course). Demolition work was required to clear the area. After this work was "completed," two feet of a four-inch, 150 psig steam line remained in the new control room.

The first night, a gasket on the blind flange failed, allowing steam to leak into the unheated control room. The next morning, the leak was discovered, along with one inch of condensate that covered the control room floor.

The instrument engineer asked to have two electric heaters brought in to dry out the panels. No damage was apparent, but a checkout of the panels was to start within a week. Construction was asked to get the steam line out of the control room.

The next night, the heaters had warmed the room to about 85 degrees Fahrenheit. Construction had replaced the gasket but left the steam line in place. Sometime during the night, the four-inch block valve split and steam poured into the control room until the next morning. The control room temperature zoomed to over 200 degrees Fahrenheit. (The operators had asked for a steam bath, but the engineer would have preferred separate facilities.)

Since the control panels were not designed to be steam cleaned, conduits warped, causing wires to fall loose, controller and annunciator cases to warp, and some nameplates to twist 180 to 360 degrees. It looked like one of those mirrored carnival houses that distorts images.

11


...OH YES, THOSE SWITCHES, TEE-HEE-HEE... I'M AFRAID WE GOT A LITTLE CARRIED AWAY WITH INTERLOCKS. ONE HAS TO ACTUALLY FLUSH THE TOILET TWICE BEFORE ONE CAN START UP ONE'S PLANT.
HIGH TECH TOILET
HITECH
Twilliams

How To Do Sequencing and Interlocks

Let's Interlock the World

Interlocks are like alarms: they multiply like rabbits. Just the mention of the word starts those wheels turning in people's minds and out crank more interlocks than you can possibly install, most of which are extraneous and/or illogical. They are a waste of time and money and divert attention from the critical ones. To see how *not* to design an interlock system, you need to look at how interlocks have been implemented to date.

How Interlocks Are Presently Implemented

(1) Personnel protection (safety) interlocks are grouped with property protection interlocks and sometimes even operational interlocks. This maximizes confusion about an interlock's justification.

(2) A large room is selected and then filled to capacity with everyone associated with the project. This maximizes the diversity of opinions and approaches to the problem.

(3) The participants look at all the possible things that can go wrong and put interlocks on all of them. They don't adequately explore the interrelationship and sequence of events that lead up to catastrophic release or failure, the prevention of which should be their primary objective. This makes it difficult to key on the critical interlocks.

(4) The engineer gets preoccupied with the study of the failure modes and the security of software devices. This minimizes the attention given to the design of the weakest links in the system — the field instruments.

(5) All systems are filled to capacity with interlocks. The important interlocks get lost in the crowd. They are now more susceptible to inadvertent changes, bypasses, and failures.

(6) The design engineer doesn't have time to write a checkout and test procedure for any of the interlocks. Subsequently, the design and maintenance engineers do what is easiest. They carefully check out the instruments in the cozy environment of the control room with simulated signals and ignore the weakest links in the system — the field instruments.

How do you steer clear of this mess? At one time, if you worked only on distributed control systems and stayed away from programmable controllers, you were safe. Now interlocks are being put in distributed systems, and control loops are being put in programmable controllers. Each is going after the other's market.

This doesn't mean to suggest you revert back to analog devices and relays. While such systems are simpler, the potential for monitoring the integrity of field and control components and for generating diagnostics can be used to make a software system more reliable than a hardware system.

Who Do You Trust?

The security problem with software is blown out of proportion. If you consider that there are typically several hundred people in a plant who know how to use a jumper or a screwdriver, but there are only one or two professionals who know how to get inside a program, the potential for defeating a hardware system is much greater. Have you ever looked inside a cabinet filled with voltage/current switches and timers and seen all those readily recognizable screwdriver adjustments or knobs? Have you ever looked inside a relay cabinet and wondered where all those jumpers came from? Have you ever tried to trace out the wiring maze of a relay system that has been in service for many years? Any resemblance between what you see and what is on the original drawings is purely coincidental.

The best way to avoid the implementation of interlocks is to tell your boss you are a continuous type of guy or gal and cannot think discretely. If this doesn't work, some photos of your boss fondling a pneumatic instrument may help twist the hands of fate.

If you get stuck doing an interlock system, use the following rules of thumb to minimize your grief.

Rules of Thumb

11-1 Insist on a standardization of classes that separates economic issues from safety issues. In other words, break out the operational and property protection interlocks from those designed to protect human life.

11-2 Work backwards from the catastrophic failure or release and identify the most direct and distinct causes. Make sure you have interlocks that measure the initiator of these causes and manipulate all the final elements necessary to prevent the occurrence of these causes.

11-3 Use complete system redundancy from the sensor to the final element with as much diversity of components and connections as possible to eliminate common mode failures for your most critical interlocks.

11-4 Write and enforce a software verification and system test procedure for all important interlocks. If some are not important, see if you can delete them.

11-5 Use software diagnostics and functional tests of all the system devices (from the sensor to the final element) to help maintain the long-term integrity of the system.

War Story

An operator affectionately called "Top Gun" asked what the big red button was for in the control room. When his fellow operators said it shut down the boilers if you pressed, he said, "like this?" and actually pushed the button and tripped the boilers. When the foreman found out, he became furious. The next day he asked "Top Gun" to show him exactly what he did. "Well," "Top Gun" said, "I did this," and actually pushed the button and tripped the boilers again!

12


IT IS A DIVINING ROD, AND I AM LOOKING FOR A GOOD EARTH GROUND... ANYTHING ELSE?
CONTROL BUILDING NO.2
PLEASE CLOSE DOOR
rwilliams

How To Do Electrical Power and Grounding for Instruments

Those Electrons Are Cagey Little Fellows

Writing this Chapter is one of the funniest things we have ever done. One of us is a chemical engineer and the other is indeterminate (something to do with engineering physics). We get confused buying VCR connectors at the local electronics store. We usually offer to buy an EE lunch if he or she will go with us. About five years after we graduated from college, we thought that we understood voltage, current, frequency, and power. Then the EEs changed everything. The confusion started slowly. First they changed cycles to hertz. Then they told us that inverters put out ac power that wasn't a sine wave, but don't worry because it doesn't bother the power supplies that supply the 65, 45, or 24 volts to the transmitters. Everything seemed OK until they started messing with the power supplies. In the beginning of the electronic era, no one could decide if we should use 0.4 to 2.0 mA dc, 1 to 5 mA dc, 4 to 20 mA dc, 10 to 50 mA dc, 1 to 5 V dc, 0 to 1 V dc, or 0 to 10 V dc. The other major problem was whether to wire an instrument loop in series or in parallel. People would sit and add up the impedances of the controllers, switches, recorders, etc., to make sure the sum didn't exceed 750 or 800 ohms. There are even a lot of countries where 115-volt 60-hertz power is hard to find.

Then there were isolated and nonisolated transmitters. There were two- and four-wire transmitters and two-, three-, or four-wire resistance temperature elements. There were 16-gage twisted, shielded pairs and triads or you could buy 20-gage twisted pairs and triads with individual or overall shields on the multiconductor cables. Why did the wire diameter get bigger as the number got smaller? (The EE who thought of this scheme must have been standing on his head at the time.) Why did the electrical power guys use 14-gage wire for ¼-inch solenoid valves that drew 15 watts while the instrument people used 20-gage wire to transducers on 24-inch control valves? Now you know why we went around saying, "Some people don't do windows — we don't do electrical work." But now one of the authors has it all figured out. He divides the world into four groups of people:

(1) There are those who know and know that they know (there are very few of these people).

(2) There are those who know, but don't know that they know (there are very few of these people).

(3) There are those who don't know and know that they don't know (there are more of these people, but they are usually OK).

(4) There are those who don't know but think they know (this is the biggest group and the most dangerous).

Most people who say that they understand electrical grounding, radio frequency interference (rfi), twisting and shielding of wires, electrical noise, and isolation transformers belong to group 4. The best thing to say is, "I really don't understand it, but it works." That's a lot better than "I did it just like the textbook says, but it doesn't work."

Rosana Dana Discusses Grounding

What is all this talk about grounded process computers? Aren't all chemical plants on the ground? You don't see them flying around in the air, do you? Do you think you are in a space station or something? What? This is about electrical grounding? Never mind!

An Unearthly Mess

There is so much confusion and concern about the electrical grounding of computer systems that they become a ripe candidate for complex schemes that do more harm than good. A common mistake encouraged by the computer manufacturers is to try and keep the computer system ground isolated from the power system ground by methods concocted to keep the computer equipment from touching any metal. Power supply conduits have been insulated from computer cabinets through the use of plastic conduit fittings, plastic plumbing fittings, and drip loops (even though there are no drips in the computer room unless your safety department thinks a sprinkler system can put out an electrical fire, but that's another story).

The silliness does not stop here. An extensive search is conducted for a location with just the right soil to drive in a magic combination of ground rods. It is a dirty business. Even if you, by some stroke of luck, get a low resistance ground, corrosion will soon render it ineffective. Additionally, an elaborate system of connecting everything to this ground is devised, the worst of which daisy-chains connections so that a single break in a ground connection can completely isolate multiple pieces of equipment from ground. These practices violate the National Electrical Code (NEC) and are unsafe because there is no path for ground fault current and a potential can exist between the computer and its surroundings.

NEC 1, Computer Manufacturers 0

As usual, the best method is the simplest. The metallic enclosures should be bonded together back to the power ground system. This can be done by tying the cabinet steel to the ground conductor of the power supply circuit. The path resistance is lowered by a larger wire size, and the ground for electromagnetic interference (emi) and radio frequency interference (rfi) is improved by a greater number of strands. The result is a system that is safer and less susceptible to ground loops and noise because other connections to ground via fittings have a much higher resistance. The computer enclosures should also be connected along with the dc power supply ground and signal common to a signal ground close to the cabinets to minimize noise pickup. The nearest building steel or underfloor concrete rebar should be used for the signal ground.

To Fail or Not To Fail

There is an interesting tradeoff in the design of electrical distribution systems for instrumentation. You would like to have separate fuses and maybe even separate circuits for each device in an instrument system so that a loss of electrical power can be localized. It is obvious that the fuse for transmitter power should be separate from the fuses for a direct-acting controller and I/P transducer power so that the operator can still manually operate the valve after a blown transmitter fuse, and that paralleled trains of equipment should have separate power systems as far back to the utility source as possible. However, sometimes a tradeoff exists between the desire to localize failures and the need for fail-safe action. For example, a transmitter failure to a reverse-acting controller will drive the I/P transducer signal full scale. Since the valve action was chosen to go to the fail-safe position on electrical signal failure, the full scale position is probably unsafe. What do you do now? Well, if you are fortunate enough to have a distributed system controller, you can cause the controller output to track the last valid output for a loss of measurement signal on automatic. The operator is notified via an alarm so that the controller can be manipulated in manual. Also, consider systems that trip on high signals (high pressure, high temperature, or high level). If a fuse blows to these transmitters, it should also cut the power to the solenoid valves (deenergize to trip) for the system to be fail-safe. The solenoid valves should share the same fused circuit, or a trip on loss of transmitter signal should be added.

Rules of Thumb

12-1 If the control room is more than a couple of hundred feet from the transmitters and valves or if there are a lot of wires, use field junction boxes. Use multiconductor, individually twisted shielded pairs. Make sure there are spares to cover additions, changes, and screw-ups.

12-2 Purchase at least 50% more wire than you could possibly use. (We've been told that construction superintendents trade about 1/3 of the wire they receive for cowboy boots.)

12-3 Don't run motor control circuits in the same conduit or tray as low voltage dc circuits (4 to 20 mA dc, thermocouples, or RTDs). If you know what you are doing, it may work some of the time. When it doesn't, you are in big trouble.

12-4 A really great way to upset a plant's management and maintenance people is to install a distributed control system with multiple computers and programmable controllers in a location that has frequent electrical power interruptions. If you do this and then don't put in an uninterruptible power supply (UPS) because it is expensive, complex, and puts out strange wave forms, it indicates that either you are mean, stupid, trying to get fired, looking for a lot of work, or some of each.

12-5 Design all ac power ground systems per the NEC.

12-6 Design the dc signal ground system to use parallel connections from enclosures, dc power supply, and dc signal commons to a single signal ground to the nearest building steel or floor rebar.

12-7 Transmitters, controllers, and control valves should be separately fused to localize failures.

12-8 Parallel trains of equipment should have separate power systems as far back to the utility source as possible.

12-9 If a measurement failure to a reverse-acting controller can cause an unsafe condition from a high I/P transducer output, a loss of measurement signal override should be used to freeze the controller output at the last valid output in the automatic mode until the operator can take over in manual.

12-10 High trip systems that use transmitters should use the same fused circuit as the solenoid valves, unless a loss-of-signal trip has been added to maintain fail-safe action on electrical failure.

War Story

Engineer X took over a start-up from engineer Y (don't worry, this is not an algebra problem). The unit was operating but some process interlocks had to be added with the unit running. It was vital to keep the unit running because a shutdown would allow the material in the elevator (a process, not a passenger one) to cool off and solidify. The operators had an understandable tendency to get angry with anyone who caused them to have to shovel and axe-pick out the elevator. This was engineer X's first day on the site with a brand new inexperienced electrician (this fact was unknown to engineer X). Engineer X told the electrician to pull some wires off an existing switch but did not instruct him to check if they were hot first. They were hot, the electrician shorted the circuit to ground, the fuse blew, and the unit went down.

They rushed to the power panel. One circuit was tripped, but it was the wrong one according to the schematics! After agonizing for ten seconds and realizing there was little to lose, they threw the switch. Things went back on line.

This was very puzzling to engineer X because the schematics were not right. As the engineer investigated further, it became apparent that nothing was powered per the schematics. When the electricians were consulted, the explanation was that engineer Y had not balanced the loads in design. On checkout, it was clear that the loads would have to be switched around. Engineer Y had ordered them to move things around until the load was balanced but had not documented the moves. Realizing that this was bound to be a nightmare of significant magnitude, engineer X decided it was better to dig his (generic) head in the sand, do the required work, and leave as fast as possible.

13

...TELL YA WHAT I'LL DO, PAL. I'LL GIVE YA $10.00 A POUND FOR IT IF I CAN PICK IT UP TODAY. WE JUST WON THE BID FOR A PACKAGED PRODUCTION UNIT FOR YOUR PLANT!
NO ADMITTANCE - THIS AREA FOR SURPLUS PACKAGED EQUIPMENT PARTS ONLY!
IF IT AIN'T CHEAP... WE AIN'T GOT IT
ACME PACKAGED EQUIPMENT CO.
KEEP OUT
ACME PACKAGED EQUIP. CO.

How Not To Do Packaged Equipment

Junkyard Blues

It is easy to see how not to do packaged equipment. Just look at the instrumentation on most any piece of packaged equipment. Air compressors, refrigeration units, centrifuges, HVAC units, bagging machines, conveyors, dryers, rotary feeders, and filters are particularly fertile areas for discovering examples of cost consciousness gone amok. The instrument systems look like something left over from a garage sale. The stuff is interesting in a strange sort of way. Nowhere else can you find such a complete collection of junk. It brings back childhood memories of visits to the five and ten cent store. Unfortunately, this nickel and dime hardware is protecting process equipment ranging in price from thousand to millions of dollars. For example, a $30 thermostat may be responsible for insuring a $5-million distributed control system does not overheat, a $200 bimetallic temperature switch may be protecting a million-dollar refrigeration unit from high temperatures, and a $100 microswitch pressure switch may be protecting a $10-million compressor from low lube oil pressure. Like most absurd situations, this is the result of a series of honest mistakes.

Just a Job

As strange as it may sound, the packaged equipment manufacturer doesn't realize he is selling junk. The manufacturer doesn't know a good instrument from a bad one. The company is usually too small to employ an experienced instrument engineer and no one understands the severity of the plant environment or the difficulty of the process application. The user is not blameless. The user's purchasing department suffers from the same lack of knowledge as the manufacturer.

Purchasing insists on quotes and going with the lowest bid. The manufacturer quickly realizes the ground rules of the game and goes to the local sales representative for the type of instruments needed and asks for the least expensive set for the application. Once the manufacturer has found a set that is cheap enough, large numbers are procured to get a quantity discount. Fittings are designed for mounting the instruments and the system documentation is revised.

Even if all the existing instruments in the warehouse are used up, newer models are typically more expensive. There is considerable inertia to change. The manufacturer thinks the user is getting what he or she needs based on communication with the buyer. The project manager thinks he or she is saving the project money by preassembly. The buyer, in turn, thinks he or she is saving money with the lowest bid. Everyone is doing his job as best he knows how, but the end result is obsolete junk.

The Experience Factor

You can tell the level of experience of an instrument engineer by how he or she handles the situation. The engineer just out of school is unaware of the problem and is liable to be caught completely by surprise. The engineer who has gone through a few start-ups will mount a crusade to convince the supplier to change the instrumentation. The engineer who has spent more time on the start-ups than he did in school will buy whatever is necessary to replace, in the field, the instrumentation supplied with the equipment. The engineer about ready to take the golden handshake knows that wholesale replacement can void the equipment warranty and can be physically impossible.

Since the supplier does not understand instrument engineering and rarely gets documented feedback on the field problems, he or she may be under the false allusion that the user may do more harm than good by replacement. Also, if the request for replacement is made after the contract is awarded, there is little incentive to make a change. Consequently, the supplier will often threaten to void the equipment warranty.

The instrumentation used in packaged equipment is often commercial grade with different thread sizes and types than that used in industrial plants. Also, some sensor fittings are difficult to add after the equipment is built (such as speed and vibration probes for rotating equipment). Thus, a complete "swap out" of the instrumentation may be physically impossible.

The experienced engineer attaches an acceptable list of instruments with manufacturers and model numbers detailed for each category of instrumentation to the request for bids. The supplier is required to note and explain any exceptions to the list in the bid. Altered fittings are incorporated before shipment of the equipment. Any field modification that still has to be done is selective and preferably supplemental so as not to void any warranties.

Sometimes the engineer is forced to choose between a warranty and the right instrument and be willing to stick his neck out and take personal responsibility for a waiver of the warranty if the change is essential to the protection of the equipment. While it may be satisfying to say "I told you so," your company would prefer to keep the equipment intact more than your reputation.

Dubious Documentation

Just getting the right instrumentation is only half the battle. You still have to get it installed and documented properly. Most vendor-supplied documentation requires a lot of imagination on the part of the user with regard to what the actual installation will look like. The smart engineer works with the vendor enough to do the documentation within the user's drafting section. While this may seem like a duplication of effort, the drawings from the supplier will only have a fraction of the really pertinent information. It is amazing how much can say so little when it comes to vendor drawings. Most of the documentation by the supplier is window dressing and a distraction from the real installation requirements.

War Story

On the first job as a lead instrument engineer, a young engineer was caught completely by surprise by the inferior quality of the solenoid valves and pressure switches supplied with some packaged air-handling equipment and the lack of information on the electrical wiring required. He knew he was in trouble when the project manager said that they found a bunch of things to wire up that were not on any drawings just a few weeks before start-up. The engineer spent two frantic weeks personally tracking down each electrical connection. The as-built drawings looked like someone had bled on them (figuratively, he had). The experience was brutal to say the least. Shortly thereafter, he made a career decision to get out of detailed instrument design and into control system technology. Now he studies control systems and makes suggestions to instrument engineers, one of which is "Don't use packaged equipment."

Rules of Thumb

13-1 In order to avoid the junkyard blues on packaged equipment start-ups, specify your instrument requirements in great detail in the request for bids and make any fitting changes prior to shipment.

13-2 A warranty on packaged equipment is only as good as the quality of the instrumentation protecting it.

13-3 If you like crossword puzzles, you will like vendor drawings for packaged equipment. Both leave a lot to the imagination. Your best bet is to make your own set of drawings.

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Things That Shouldn't Be Instruments

Level gages are not instruments; they are piping items that should be specified and purchased by mechanical engineers. They have threaded (screwed) connections, and instrument engineers don't know how to determine the length of the nipples required to install the gages. Pipefitters install gage glasses.

Relief valves and rupture discs should be sized by the process engineer when designing vessels on a computer. Once the capacity of the relief valve is determined, a mechanical engineer can pick the proper size from a chart in the catalog that gives him the connection sizes. Pipefitters install them and the plant mechanical maintenance department is usually responsible for their testing.

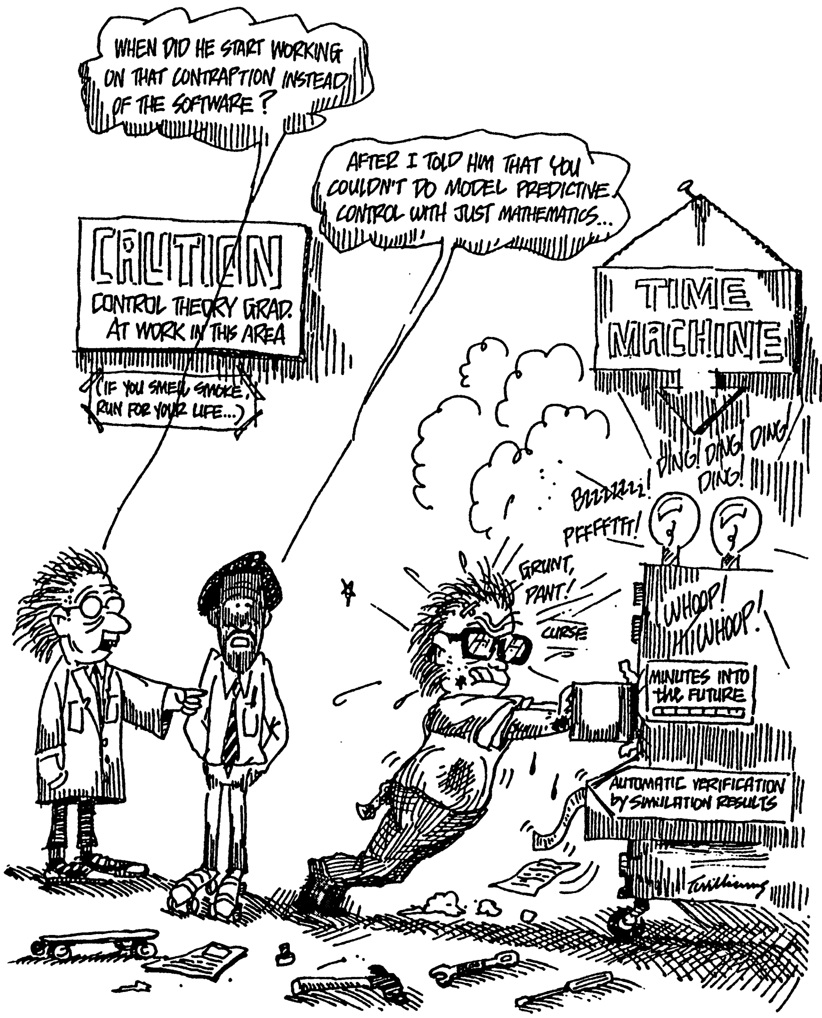
Pressure gages should not be the responsibility of the instrument engineer. Piping should provide them. After all, mechanical engineers need work.

Thermometers are similar to pressure gages. The best part about a thermometer is that it is one of the few industrial instruments that can be used around the construction office, home, or car. It's really neat to have a big dial thermometer mounted outside your bedroom window.

We don't know what restricting orifices are. They may be things that compensate for screwups in the sizing of pumps and line sizing. Whatever they are, we want no part of them. We hear the best way to size them is to buy line-sized stainless steel plates ⅛-inch thick with a ¼-inch hole drilled in them. If, during start-up, the ¼-inch hole is too small, look for a drill with a ⅜-inch bit. If no drill is available, make the hole bigger with a torch. Every pipefitter knows how to use a torch.

If anyone gives you trouble about whether any of the above are really instruments, tell them you read it in a book.

15


WHEN DID HE START WORKING ON THAT CONTRAPTION INSTEAD OF THE SOFTWARE?
AFTER I TOLD HIM THAT YOU COULDN'T DO MODEL PREDICTIVE CONTROL WITH JUST MATHEMATICS...
CAUTION
CONTROL THEORY GRAD. AT WORK IN THIS AREA
(IF YOU SMELL SMOKE, RUN FOR YOUR LIFE...)
TIME MACHINE
DING! DING! DING! DING!
BZZZZZZ!
PFFFFTTT!
GRUNT, PANT!
CURSE
WHOOP! WHOOP!
MINUTES INTO THE FUTURE
AUTOMATIC VERIFICATION BY SIMULATION RESULTS

How To Avoid a Control Problem

Requiem for Reality

The more control theory courses you take in college the more apt you are to have a control problem. The severity of the problem is an exponential function of the depth of your theoretical background. If you had graduate courses in control theory, you are in big trouble. Your company will think you can solve almost any control problem and, what's worse, you may think you can, too. Each year, hundreds of new doctorial graduates armed with Bode plots, Laplace transforms, Nyquist plots, Z-transforms, state space plots, Lipaunov diagrams, matrix algebra, and tensor analysis start out optimistically to tackle the practical process control problems. Few succeed. They may be able to fake out their management and themselves for a couple of years by utilizing skills of slanted simulation tests honed in graduate school. But sooner or later they have to face the scourge of REAL data, something they were able to scrupulously avoid during their academic careers. Many are unable to deal with the facts of life and therefore return to the safety of the university cocoon.

It's Not a Pretty Sight

Real control problems are not very glamorous. Most are related to performance problems with sensors, control valves, and process equipment — the last place a new graduate in control theory would look. Solving these problems requires an understanding of three terms: dead time, time constant, and gain. It also involves getting your hands dirty. While these terms may seem strange to you at first, they are in the time domain your brain is accustomed to. You don't have to translate your trend recordings to a frequency, "S", or "Z" domain. You can relate to these terms on a physical rather than a mathematical basis. This book cannot get into a detailed explanation of how to use them. All this Chapter offers is a perspective of the situation. Besides, one of the authors wants you to buy his first book, *Tuning and Control Loop Performance.* The author warns you it is rather long and tiring. He realized this when he fell asleep proofreading it.

Control problems are not solved by the application of higher mathematics. Control loops perform poorly because they are either not tuned correctly, have insufficient measurement accuracy or valve stroke resolution, or have a dynamics problem caused by too small a process time constant, too large loop dead time or process gain, noise, interaction, or changes in these characteristics.

If dead time could be eliminated, it wouldn't matter what the process time constant or gain was because there is no limit to the allowable controller gain for zero dead time systems. Noise by definition wouldn't exist because no process disturbance frequency is too fast for the controller. But in real life there is always dead time. Just the virtue of the fact that you have installed a measurement device and control valve has created dead time. Students who have been brainwashed by excessive exposure to advanced control theory frequently think they can cancel out the effect of dead time in the loop by the use of a special complex algorithm. The basic principles of physics fix space and time relationships on our scale unless the speed of light is approached. Since we don't have warp drives on our control systems, we are relegated to locating and eliminating the sources of dead time or adding measurements in feedforward and cascade loop configurations to short circuit some of the dead time. While these techniques may be mentioned in graduate study, they are passed over in favor of the esoteric and intellectual pursuit of the one control algorithm that will solve all control problems. The first step to being able to avoid making a control problem worse is the realization that such an algorithm doesn't exist and never will exist.

There is so much misinformation and so little understanding of how to decipher control problems that a ripe condition exists for the evolution of consultants who know all the buzz words and can talk their way out of almost any situation. No one knows enough to refute the explanations they offer when their recommendations fail. Big money can be made by a "silver-tongued devil".

How To Avoid a Mental Meltdown

You can avoid the more severe dynamic control problems by refusing to work on distillation column control (characterized by high dead time, high expectations, and considerable confusion as to the proper pairing and location of the controlled and manipulated variables); pH control (characterized by high process gain and insufficient measurement accuracy and reliability); and compressor surge control (characterized by too small a process time constant, unstable operation, and insufficient valve speed). You are probably wondering why reactor temperature control was not mentioned. Well, there is usually no dynamic problem with a well designed reactor system. The main limitation to this loop's performance is the accuracy of the measurement and the resolution of the valve stroke since the loop dead time is small compared to the process time constant. Of course, poor equipment designs and operational practices can cause a problem in almost any loop. The best way to avoid the hassle of a control problem is to work on flow loops because they are easily tuned and no one seems to care how tight they control.

You Have the Power

If your control specialist returns to the university or a control problem sneaks up on you, it pays to know what tools are at your disposal. Given that you cannot change the equipment, piping, or process, what is left are the instruments in the loop. You can add or change the transmitters, controllers, valves, and variable speed drives, and you can use the computational capability of the more powerful distributed system controllers to your advantage. Distributed control systems make it easy to implement special control strategies because the complexity is transparent to the user, graphic displays make the system more understandable, the parameters are accurate and easily adjusted, pure time delays and all the time and math functions you could imagine are available, tracking is possible, and real-time simulation tests can be used to debug the strategy and train the operator.

Rules of Thumb

15-1 The elimination of loop dead time by complex algorithms is a fantasy. Loop dead time can only be reduced by the addition, subtraction, or modification of loop instruments or process equipment and piping.

15-2 Avoid working on distillation, pH, or surge control problems.

15-3 If you are stuck with a control problem, you can amaze friends and relatives alike by doing some of the following:

(a) Use a faster controller (smaller cycle time) to improve surge, flow, level, or pressure loops that already have variable speed drives.

(b) Use a faster measurement to improve surge, flow, level, or pressure loops that already have variable speed drives and faster controllers. Also, use a faster measurement to improve composition loops and temperature loops with direct mixing of hot and cold fluids.
(c) Use a faster valve to improve surge, flow, level, or pressure loops.
(d) Use a more precise (less hysteresis) valve to improve nearly all loops but especially those with a high process gain (such as pH loops) and those with nonself-regulating processes such as level and exothermic temperature loops.
(e) Use a variable speed drive for the same reasons you would want to use a faster or more precise valve.
(f) Use self-tuning if you don't want to learn how to tune controllers, if you like control theory jive talk, or there are unpredictable changes in the process dynamics.
(g) Use adaptive gain or notch gain if you want your level control to float between high and low limits and not upset processes upstream or downstream.
(h) Use a dead time compensator such as the Smith Predictor, if the loop dead time is fixed and large, to improve loops where either there are more set point changes than load changes or the loop dead time is significantly greater than the process time constant.
(i) Use model algorithmic control or model predictive control for the same conditions and reasons you use dead time compensators or where there is too much interaction between loops.
(j) Use signal characterization on the measurement to improve pH loops with relatively fixed titration curves, on the controller output to improve temperature loops with relatively fixed installed valve characteristics, and on the controller set point to improve surge loops with predictable surge curves.

(k) Use cascade control to improve loops where an inner loop can enclose major disturbances and can be faster than the outer loop.
(l) Use a bypass of the cascade so the outer loop can directly manipulate the control valve whenever the rangeability of the inner loop measurement is insufficient (i.e., the low flow start-up of a three-element boiler drum level to feedwater flow cascade).
(m) Use feedforward control to improve the performance of any loop with a medium to large dead time.
(n) Use a feedforward multiplier for slope changes and a feedforward summer for intercept changes in a plot of the measured load disturbance versus required controller output. Use a lag or delay if the disturbance arrives after the corrective action and a lead if the disturbance arrives before the corrective action in the process.
(o) Use feedforward on the controller output for slow loops and on the controller set point for fast loops.
(p) Use ratio control for blending or wherever you need flow feedforward multiplication.
(q) Use selective control to choose between multiple measurements or control valves for shifting optimum points (i.e., reactor hot spot control), for safety reasons (i.e., high pressure override of flow control), or for shifting load allocations (i.e., multiple steam header letdown stations).
(r) Use override control to implement selective control or to do an automated start-up or shutdown.
(s) Use velocity limiters to reduce noise and avoid introducing an additional lag in loops where the normal rate change for the controlled variable is slow (i.e., level loops on large tanks).
(t) (Use a signal filter to reduce noise where the addition of a small lag does less harm than noise (i.e., flow loops).
(u) Use measurement degradation or failure protection

schemes wherever possible. For example, if the measurement pegs upscale or downscale, force the distributed system controller to track an output saved from before the failure and notify the operator.

(v) Use control valve degradation and failure protection on surge loops.

(w) Use an automated start-up and shutdown wherever possible to reduce operator workload and improve system safety.

(x) Use pressure and temperature compensation for all critical gas flow loops and surge loops with multiple recycle steams or discharge flow measurements.

(y) Call ISA and order the books *Tuning and Control Loop Performance* and *pH Control* if you don't understand items (a) through (x).

Note that distributed control systems reduce the task of implementing items (f) through (x). All of the items, with the possible exception of item (i), are used in conjunction with a PID controller.

War Stories

15-1 A control systems engineer got an urgent phone call requesting some troubleshooting assistance on a distillation column control scheme he had designed. The plant engineer described the "control problem" by stating the column pressure control was poor. He related this poor performance to the fact that the reboiler steam valve seemed to operate fully open or fully closed. Time for a model predictive algorithm that includes valve movement minimization? Right? Wrong!

Knowing that the column base level controller provided a set point for the reboiler, the systems engineer inquired about the level loop performance. While examining the process data, the plant engineer became quiet, then sheepishly confessed discovering that the steam flow transmitter had obviously failed since there was no indication of flow even when the steam valve was wide open.

The base level loop was adjusting the steam flow set point above and below zero, thus achieving tight level control with on/off steam flow. The amazing part of the story is that the column had operated for several days in this manner and that the main concern arose from degraded pressure control.

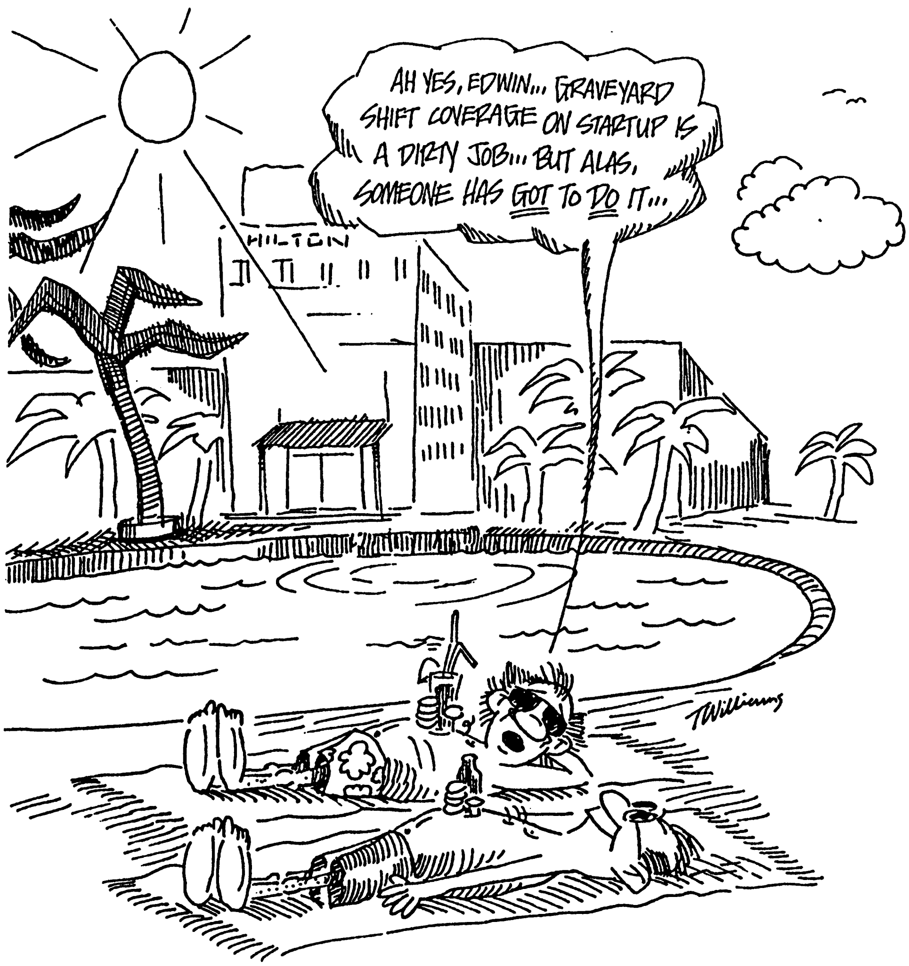
(The following three stories show how a large measurement time constant has fooled a control systems engineer, a biochemical engineer, and the management of a large plastics plant.)

15-2 A control systems engineer made a presentation at a control conference on how the addition of a measurement filter had enabled him to improve the control of a rather fast but noise-free process, according to simulation results. He said his company almost didn't approve his paper because the idea had such great potential. The simulation program plotted only the measured variable and not the actual process variable. He only looked at the filtered variable and didn't realize the control of the real variable of interest had actually gotten an order of magnitude worse.

15-3 A biochemical engineer proudly showed two systems engineers how the strip charts were now showing fewer wiggles for the fermentor temperature. The systems engineers were impressed until they noticed the temperature element was now inserted only halfway into the thermowell. The air gap acted as a nice filter.

15-4 When the management of a large plastics manufacturing facility saw that the addition of a massive block of metal at the tip of the temperature sensor smoothed out the trend of extruder temperature, they proclaimed that such blocks of metal should be installed on all such sensors. They didn't realize until a decline in quality control that the block added a large time constant that filtered the real temperature excursions.

16


AH YES, EDWIN... GRAVEYARD SHIFT COVERAGE ON STARTUP IS A DIRTY JOB... BUT ALAS, SOMEONE HAS GOT TO DO IT...
HILTON
TWilliams

How To Check Out and Start Up Systems

"If this is Sunday, it must be Brazil"

We're writing this while flying over Brazil at 7:30 in the morning. After the plane lands and some custom agents growl at us, we will be ready to assist in solving all the instrument problems known to modern man. How can we fail? We've been traveling for 18 hours, so we must be the experts!

"What is in a word?"

"Checkout" is a nice short word that describes the activities of finding and fixing the screw-ups of everyone associated with the project. It's easier to fix your own mistakes or omissions because you know why you did them. It's harder to guess what, if anything, was going on in someone else's head.

A Plan and Pitfalls

First, you need a plan. Get copies of the instrument index, specification sheets, and loop schematics. Try to get some reasonably intelligent plant instrument mechanics to check each instrument against the specification sheets. It's always helpful if the vendor sends you the proper item, already calibrated, but don't depend on it. If the instrument or valve has been correctly installed in the proper location with all the tubes and wires connected, you are halfway home. To actually get home, you need a plan for functionally checking the instruments as close to actual operating conditions as possible and for being one step ahead of the operators when commissioning instrument systems (even if the instrument is functionally OK, it doesn't work too well if the power or air supply is turned off, it is valved out, or critical parts like electrodes were removed for pressure testing or flushing of the lines). The most important thing to remember is "Never underestimate the potential for mistakes." Some things to consider:

(1) Pressure transmitters work better when the block valve between the instrument and the process is open (this is also true for manifolds in d/p transmitters).

(2) There is almost no relationship between the valve output indicator on a controller and the actual position of the valve due to bench settings or incorrectly calibrated positioners (especially in split range applications).

(3) When someone tells you that an instrument is not working properly, don't run off to check it. Ask the person why he or she thinks there is a problem. Process engineers and operators usually have no way of knowing if a flowmeter is giving an incorrect signal. Random testing is a waste of time and sets a bad example.

(4) Two-wire transmitters frequently have four connections. Two connections (marked + and -) are for signal wires, and the other two connections are to check

calibration. Sometimes the signal wires get connected to the calibration terminals. Sometimes you can't tell which terminals are which.

(5) Pour all the water out of the electronics housings on field instruments. Most manufacturers don't build electronics that work while submerged in water.

(6) Control valves with dirt, rust, rags, and lunch boxes in them may seem undersized and perform erratically.

(7) Convince the manufacturing people that when they learn to operate the plant properly, at least 1/3 of the instruments will not be required. This speeds up checkout and allows you to go home to your kids, who are more logical than the people in charge of the start-up.

(8) Always volunteer to work the midnight shift. You avoid all the stupid meetings they have in the daytime and you can do whatever you want without the interference from management, construction, and maintenance. If you are lucky enough to work in a warm climate, you can spend the days at the pool. (That's where we are now).

(9) A good way to avoid checkouts is to work for a large engineering company. They usually have a special crew that does field work. There is usually very little communication between the design engineers and the construction/checkout people. In this way, the design engineers keep doing things the same way (which reduces manhours) and the field gets good at fixing screw-ups.

(10) When you find something that doesn't work and you fix it, there is a sense of accomplishment that is hard to get while sitting in meetings.

War Stories

16-1 During a start-up, a flow measurement indicated the flow had stopped right after the shop had started to wash down the piping. Fortunately, the instrument engineer quickly ran through the possibilities and concluded that since the flowmeter was a turbine meter with an RF coil and water absorbs RF, the RF signal had been attenuated by water entering the pickup coil. He ran to the instrument with a Q-tip, stopped the washdown, opened the pickup coil, swabbed it out, replaced the coil, and started back up.

16-2 In a strategy meeting it was concluded that failure of a new natural draft system would be the worst thing that could happen. It was also decided that instrument checkout should start immediately since the time to fill and drain the tank to check the load cells would not leave enough time for the other instruments.

The total instrument portion of this project consisted of three temperature loops, one weight loop, an agitator current indicator, and three new solenoid valves. How much can go wrong with such a small system? A lot.

Two controllers had standard scales instead of the special ones ordered on the spec sheets, so new ones were made and carried back to be installed and the loop recalibrated.

A computer arrived with an operator interface pot mounted on the instrument instead of on a six-foot cord for panel mounting. The cable was added in the field.

The 0 to 5 V dc meter to measure agitator current from a transducer came in with a 0 to 15 V dc movement. It was sent back to the factory and corrected.

The existing controller case where a relocated controller was to be installed had one slight flaw: the slot would allow an indicator to function properly, but if a controller were plugged into the slot, it wouldn't work. Eventually the slot was swapped with an indicator.

The plant had recalibrated a temperature indicator to match the incorrect scale on the temperature controller so that the transmitters could be interchanged. They had to be recalibrated.

The field-mounted RTD transmitters would calibrate in the shop but would not function when installed. They were mounted by clamps to an epoxy-coated column and connected with PVC conduit. After verifying the wiring, supply voltage, and bench testing, the engineer ran a ground wire to the units and solved the problem.

The RTDs (nine feet long) had extension leads made of high resistance wire instead of copper wire. A value of nine ohms was measured between the two common wires, which shifted the zero on the transmitters when connected. New RTDs were installed.

The load cell system was confirmed by the vendor as being capable of measuring 3500 pounds in five-pound increments. However, after the engineer figured out the available voltage and divided this by the counts, the resulting voltage was below the threshold. The system had to be switched to ten-pound increments.

The computer mentioned earlier received a binary coded decimal (BCD) signal from the load cell system. There is a five-step calibration procedure to align the unit. Four of the steps worked perfectly but one (the span) did not. After many attempts and conversations with the designer of the unit, it was returned. The vendor could find nothing wrong, so he recalibrated it and sent it back to the job site. It was installed as received and checked out again. Still the span would not function. The engineer asked the designer of the unit how he calibrated it and found that the designer shorted out the inputs. With a BCD input, this gives a hexadecimal value of 999 instead of a decimal value of 999. The designer said, "Oh darn," and then informed the field engineer how to change the amplifier for the correct gain.

During the subsequent checkout and start-up, no wiring mistakes were found. The troubleshooting by the plant maintenance people was excellent. The four loops were checked out in the record time of six days.

17


...YEAH, BUT ARE YOU SURE THIS WILL WORK BETTER THAN THE OTHER METHODS?
HERMAN, WILL YOU PLEASE SHUT UP? I ALREADY TOLD YOU. SHIRLEY MACLAINE THINKS SO!!!
MIGHTY MAX CONTROL PANEL
51
RUBBER BAND TIGHTENER
ESP INC.

How To Tune Controllers

You Can Tune a Controller But You Can't Tune-a-Fish

How come you can tune a piano but not a controller? The tuning of a piano requires significantly more knowledge and expertise. The tuning of a controller requires a procedure so simple that even a manager — no, wait — even a *director* could learn it in five minutes, yet more than half of the loops in service are not tuned properly. Part of the problem is that the best procedure was lost over the decades. To fill the gap, procedures were periodically published by professors who had not faced the harsh realities of the industrial installation. These procedures used dynamic terms or graphical methods that were either inappropriate or too difficult for industrial conditions. But, that's not the whole problem. Even if you use the right method, it still requires guts and patience, things modern engineers seem to be deficient in. Don't feel bad, though. There are several good reasons why you shouldn't learn how to tune controllers.

Reasons Why You Shouldn't Learn to Tune Controllers

(1) It keeps graduate students in universities busy and out of trouble inventing complex algorithms to substitute for poorly tuned controllers.
(2) You get to justify the use of fancy new self-tuning controllers. They have more adjustments than your plain old PID controller, but you feel like a control engineer when you're done.
(3) It promotes the job security of the maintenance technician, who seems to be the only one with enough of the right stuff to tune controllers.
(4) You don't have to worry about being called out at three a.m. to tune a controller.

Self What?

The whole issue of self-tuning controllers is kind of interesting. The real purpose of these devices was to retune loops whose tuning requirements continually changed. Instead they are being bought primarily because people do not know how to tune. Some of these devices have twenty or more adjustments. Many of these adjustments are not required, but you still need to know when they might be. Fortunately, these adjustments use terms you might have heard of in a college course in control theory. Also, the use of them is well documented by thick instruction booklets. You can sound just like a real control engineer when you explain it to your boss.

Vintage Vindication

The best tuning method is the oldest. It was first documented by Ziegler and Nichols back in 1943. It is nearly foolproof (not that there are any fools out there). We call it "the closed-loop ultimate oscillation method" so that it sounds technologically advanced (you can call it the Ziegler-Nichols method). The mentor of one of the authors said many years ago that it was the best, but the author naturally had to find out for himself. So to set the record straight, here are the advantages of the ultimate oscillation method:

(1) It includes the effect of the controller characteristics and dynamics.
(2) It includes the effect of all nonlinearities in the loop.
(3) It doesn't require graphical procedures or estimates of gains, dead times, time constants, or obsequious terms.
(4) It allows the controller to stay in automatic. This is essential for some loops (like exothermic reactors) and/or electrical furnace pressure loops that either go unstable or deteriorate too quickly if placed in manual.
(5) It is the only method suitable for tuning the outer loop of a cascade controller due to the oscillatory response of the inner loop.
(6) Nearly all other published methods are not suitable for integrating or runaway processes.
(7) It is faster than open-loop methods for processes with time constants much larger than the dead time. An open-loop method requires about five time constants plus one dead time for the response to line out. Tests in opposite directions are needed. The ultimate oscillation method requires two oscillations for each test whose period is two to four times the dead time. About four tests are required.
(8) It forces you to find the maximum gain — a key factor in maximizing loop performance. Most controllers don't have enough gain. Too much reset is then added in an attempt to make the loop more responsive.
(9) It is less affected by unknown intermittent disturbances.

(10) It is the only tuning method in a book with cartoons.

No Guts — No Glory

While the method is simple, it does require determination. We are not accustomed to forcing a loop to oscillate. All our efforts are directed to preventing excessive oscillations. Once you realize you can kill any oscillations that are getting too large within one dead time by lowering the gain, you realize you are in complete control of the situation.

Closed-Loop Ultimate Oscillation Method of Tuning (Ziegler-Nichols Method)

(1) Make sure the controller is in automatic at its normal set point.
(2) Turn the rate off and set the reset to its minimum if it is in repeats per minute and to its maximum if it is in minutes per repeat (there should be as little rate and reset action as possible).
(3) Double the controller gain.
(4) Change the set point enough to get the loop to oscillate. If the oscillations start to get too large or the controller output hits either 100% or 0%, decrease the gain.
(5) Repeat steps (3) and (4) until there are nearly equal amplitude oscillations.
(6) Note the last gain setting and time the period of the sustained oscillations (a stop watch can be used to time the peaks of a measurement on an indicator if the recorder is too slow).
(7) For a PID controller, the proper gain setting is about one half the last gain setting that caused the sustained oscillations; the reset setting is about twice the

period of the sustained oscillations if in minutes per repeat (invert for repeats per minute); and the rate setting is about one tenth of the period.

You also need to make sure the loop should be tuned "hot". Tight control of a loop may bang around the control valve a lot if it is hit by frequent disturbances. If this flow is a recycle or feed stream, the upsets to other equipment may be unacceptable. This often happens with level loops. The gain of those loops that are the source of oscillations in other loops should be decreased. The culprit loop can usually be found by successively placing loops in manual until the oscillations stop. If all the loops are in manual and there are still oscillations, the disturbances can be considered to be uncontrollable noise. A word of caution here. Some level loops, such as those on overhead receivers of distillation columns, require tight control so that changes in overheads flow immediately translate to changes in reflux flow (important for material balance and internal reflux control).

Rules of Thumb

17-1 If you don't know how to tune a controller, don't feel left out; no one else does either.

17-2 Most controllers have too much reset action and not enough gain action.

17-3 The real value of self-tuning controllers is for critical loops that require frequent retuning.

17-4 Self-tuning controllers have more adjustments than the PID they are designed to replace.

17-5 The best tuning method was invented before you were born. It is the ultimate oscillation method.

17-6 The best self-tuning controller is the one that looks at closed-loop oscillations rather than open-loop tests.

War Stories

17-1 An analog controller for level control of a distillate receiver that had a proportional band of 100% was replaced with a digital controller to test a new distributed control system. The tuning settings were duplicated. The control of the receiver level was so much better, the whole column performance dramatically improved. The plant thought the new system was fantastic. Later, they found out the digital controller used gain instead of proportional band. A gain of 100 had been used. They could have gotten the same results from their old analog controller if the proportional band had been set to 1%.

17-2 The start-up of a new distributed system showed that several reactor loops were oscillating. The source of the oscillations was traced via tests and real-time trends to a loop that was doing exceptionally tight control of a stripper's receiver level. The manipulated recycle flow to the reactor was periodically banged nearly full scale by the level loop.

18


THE GREAT PUPPETEER... the CORPORATE GAME
AND NOW.... THE FINAL CUTTING OF THE "TIES"....
Twiining

The Final Resting Grounds of Instrument Engineers

Running On Empty

By the time you are eligible for a company's early retirement plan, you have probably estimated one hundred thousand, specified fifty thousand, and commissioned twenty thousand instruments. You have no doubt gone on a hundred start-ups and worked ten thousand hours of uncompensated overtime. Worst of all, you have had to scrupulously tailor one hundred and seventy-five goals so that you can survive thirty-five performance reviews. It's amazing how these tired old veterans get themselves up for another start-up.

Opulent Options

If you last 3.3 years as a real instrument engineer, your prospects for the future are greatly diminished. The probability of going into any of the following careers is about zero.

(1) Marital relations law
(2) Mental health professional
(3) Elementary school teacher or principal

(4) Pediatrician or OB-GYN
(5) Sociologist or anthropologist
(6) Retail food or clothing clerk
(7) Laborer
(8) Professional terrorist
(9) Politician
(10) Film actor, producer, or director
(11) TV actor, producer, or director
(12) Sports announcer
(13) Used car salesperson
(14) Cook in a fast food restaurant
(15) Life guard
(16) Professional sports player
(17) Smuggler (engineers look nervous)

Possible Alternative Careers

(1) General handyman
(2) Writer of children's books with nice pictures
(3) Hardware store owner or salesperson
(4) Writer of TV soap operas
(5) TV weather person
(6) Cook in an Italian, Jewish, or Greek restaurant
(7) Water polo player
(8) Farmer
(9) Fisherman/hunter
(10) Motorcycle repairman

(There is a story behind all of the above but the book is getting too long and we are getting tired. Also, perhaps you will hire us to come and lecture so we can explain this book to you in person.)

Whatever you do, please don't try to teach in a university. The students might learn something of practical value, which would contradict the purpose and direction established for the last 300 years. Besides, they won't be prepared for their next course.

We once knew a person who was almost an instrument engineer (he did analyzer work) who threatened to go to law school for the following reasons:

(1) To sue the company that he had worked at for forty years in order to recover $37 a month in additional pension benefits.
(2) To screw up the legal profession if that was not already the case.

Many instrument engineers have a perceived goal of becoming a consultant sometime in the future. They feel they have gained a vast storehouse of knowledge that could be of value to a variety of companies and to themselves. Many of these very talented, experienced engineers spend most of their time doing trivial jobs for organizations unwilling to make use of their expertise.

There Is a Better Place for You and Me

Once you take the golden handshake (or silver handshake, depending on the amount of money involved), you are "home free" literally and figuratively. You can choose to be on a permanent paid vacation and experience life, liberty, and happiness. You may decide to work part-time for a small contract engineering firm where you can enjoy the challenge of the job without being overtaxed or having to play the corporate game. It is a tribute to the profession that so many of these engineers decide to dabble in the art of instrument design.


EARLY INSTRUMENT ENGINEERS...
(an insight into some of their problems)
ME TELL YOU ONCE, ME TELL YOU 100 TIMES... CONTROL LOOP WORK BETTER THAN YOUR WAY!
WHY YOU NO HERE DURING START-UP?
SQUISH!
TWilliams

Believe It or Don't

(1) A young engineer told the president of a chemical company there were too many managers for the number of workers in the corporate engineering department. The president thanked him profusely and immediately transferred half of the managers to the plants to learn how to become practicing engineers again.

(2) A project manager found a major design flaw in the control system after carefully reviewing all the drawings. He quickly authorized the purchase of the additional instruments required to correct the problem.

(3) After major problems in meeting product quality specs, a process engineer said, "The instruments are right, it must be the process that's screwed up."

(4) A person read this whole book.

(5) A vendor refused a purchase order and recommended the purchase of transmitters from a competitor because the vendor's transmitters have an excessively high failure rate.

(6) An EFD was drawn with control strategies that didn't resemble anything ever done before.

(7) A control valve for low viscous flow was sized according to the laminar flow equations.

(8) A vortex shedding flowmeter actually achieved the stated 15:1 rangeability.

(9) A distributed control system's computational power was fully utilized to do advanced control strategies.

(10) An air conditioner was installed that was quiet and exactly the right size for the control room.

(11) An interlock was periodically functionally tested from sensor to final element at actual operating conditions.

(12) A book was published that clearly explained how to design the grounding systems for instrumentation.

(13) A plant standardized on the type of instruments supplied with a piece of packaged equipment because the quality was superior.

(14) A banana milkshake appeared on an instrument purchase order.

(15) A control theory specialist invented a model predictive controller that correctly picked the winner of the last Miss Universe contest.

(16) A chemical plant was designed, checked out, and started up without any changes.

(17) An engineer used a book from college to correctly tune a loop.

(18) An engineer was given raises and promotions throughout his career based on the performance of his designs.

(19) Banana milkshakes are the missing link in the unified force theory.

(20) The authors of this book are sane.

Self-Test

If you get more than 33 percent of the following questions right, you could have written the book.

(1) An instrument engineer is:

(a) Born every five minutes.
(b) Made on the job.
(c) Found in an alley.

(2) You hear a project manager say that he doesn't care how much the installation costs, just as long as it works. This is possibly due to the fact that:

(a) The project manager finally realizes what is best for the company.
(b) The project manager is anti-matter from a parallel universe where everything is the opposite.
(c) You are suffering from a mind disorienting fever.

(3) A process engineer does the software configuration for you. This happens because:

(a) He knows how to implement control strategies better than you.
(b) You are a wimp.
(c) You went on a Caribbean vacation and never came back.

(4) You only looked at the cartoons in this book. This indicates:

(a) You think a picture is worth a thousand words.
(b) You heard the book was a graphic exposé.
(c) You don't know how to read.

(5) A vendor offers you tickets to a fishing show because:

(a) He or she genuinely likes you and prefers to spend his or her free time with you.
(b) He or she knows you are from the East Coast and that you think a tackle box is something you sit in at a football game.
(c) No one else wanted to go.

(6) A project has ninety-nine EFDs because:

(a) It is a very large job.
(b) It is a time and material job by a contract engineering firm.
(c) The computerized drawing numbering system only allows two digits.

(7) An engineer calculated the dynamic unbalanced forces on a control valve trim to the third decimal place because:

(a) It was critical to the correct sizing of the actuator.
(b) He or she got a new personal computer and software package.
(c) He or she suffered a time warp back to college and calculus homework assignments.

(8) Which requires more maintenance?

(a) A magnetic flowmeter.
(b) An orifice flowmeter.
(c) Joan Collins.

(9) How do you decide what distributed control system to use?

(a) You choose the lowest bidder.
(b) You choose the one that you know best how to use.
(c) You choose the one whose displays most impress your upper management.

(10) How do you size a control room?

(a) You dimensionally layout all the panels specified to date.
(b) You do (a) and double it.
(c) You choose the largest size you can get away with.

(11) How do you do sequencing and interlocks?

(a) However your distributed control system vendor tells you to.
(b) Very carefully.
(c) How do you do, yourself, but my name is not sequencing and interlocks.

(12) What is best?

(a) A grounding system where everything is grounded at least once.
(b) A grounding system with separate and parallel instrument ground conductors tied to one good earth ground.
(c) A banana milkshake.

(13) You are asked to start up a piece of packaged equipment. Your best bet is to become:

(a) A friend of the vendor and find out everything he or she knows about the equipment.
(b) A friend of a shrink who will get you excused with an insanity plea.
(c) An ex-employee.

(14) Which of the following shouldn't be an instrument?

- (a) A distributed control system.
- (b) A ruptured disc.
- (c) A broken level gage glass.

(15) Which of the following can be used to solve a control problem?

- (a) Control theory.
- (b) A seer.
- (c) Scotty and warp drive.

(16) What excites instrument engineers the most?

- (a) The opportunity to buy "Savings Bonds".
- (b) The end of around-the-clock coverage.
- (c) The Flintstones.

(17) If a graduate student invents a new algorithm that always outperforms a PID controller, it must be the result of:

- (a) Years of diligent study.
- (b) Divine revelation.
- (c) A freak break in the space and time continuum of the academic world.

(18) The Instrument Engineer's Hall of Fame is located in:

- (a) Springfield, Massachusetts.
- (b) The author's imagination.
- (c) 128th Street in the Bronx.

(19) If you selected (a) as the answer to each of these questions, it indicates:

- (a) You are "one righteous dude" (or dudess).
- (c) You have management potential.
- (c) You are suffering from exposure to Kryptonite.

(20) If this book has no socially redeeming value, is it pornographic?

- (a) Yes.
- (b) No.
- (c) Let me look at the cartoons again.

About the Authors

Gregory K. McMillan is a Consultant with Don H. Munger and Company, Inc., St. Louis, MO. He brings to this position extensive prior experience in the design, construction, check-out, and start-up of instrumentation systems as lead engineer on major projects. During his tenure as Fellow at Monsanto Company, St. Louis, he was the recipient of five Monsanto Achievement Awards for innovative designs.

Mr. McMillan has distinguished himself as Education Chairman for the St. Louis Section of the Instrument Society of America. Well known among the readers of *InTech* magazine for his enlightening as well as interesting articles, he received the Division Best Paper Award for 1981-82. His other ISA publications include *Centrifugal and Axial Compressor Control*, *pH Control*, and *Tuning and Control Loop Performance.*

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After obtaining a B.S. in Chemical Engineering from Drexel University and doing graduate work in Philadelphia, he worked as an instrument engineer for Day & Zimmerman, Inc., Engineers, and Rohm & Haas Chemical Co. He has been with Monsanto since 1966 and has written numerous articles and technical papers.

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